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Development Document for Effluent Limitations Guidelines and Standards for Battery Manufacturing

Final

Point Source Category
Volume I

Subcategories:

Cadmium
Calcium
Leclanche
Lithium
Magnesium
Zinc

VOLUME I

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

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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, 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 I) of the development document specifically addresses the cadmium, calcium, Leclanche, lithium, magnesium, nuclear, and zinc subcategories. Volume II addresses the lead subcategory of 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 includes the following seven subcategories which are included in this volume:

- Cadmium
- Calcium
- Leclanche
- Lithium
- Magnesium
- Nuclear
- Zinc

The nuclear subcategory was considered in the data base, but was not considered for regulation because production had ceased and was not expected to resume.

Within each 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. The pnp was, in general, the weight of anode or cathode material, or weight of cells produced.

Data

The data base for these seven subcategories of the battery manufacturing category includes 69 subcategory specific plants which employed over 12,000 people. Of the 69 plants in the subcategories in this volume, 10 discharge wastewater directly to surface waters, 33 discharge wastewater to publicly owned treatment works (POTW), and 26 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 100 percent of the companies in these seven subcategories. The data base includes some data for 1977 and 1978.

Water is used throughout battery manufacturing to clean battery components and to transport wastes. Water is used in the chemical systems to make most electrodes and special electrode chemicals; water is also a major component of most electrolytes and formation baths. A total of 31 plants from the seven subcategories covered in this volume were visited prior to proposal for engineering analysis, and wastewater sampling was conducted at 19 of these plants. These visits enabled the Agency to characterize about 30 specific wastewater generating processes for the seven subcategories, select the pollutants for regulation, and evaluate wastewater treatment performance in this category. Since proposal one additional battery manufacturing site was visited in order to collect additional information for the Leclanche subcategory.

The most important pollutants or pollutant parameters generated in battery manufacturing wastewaters are (1) toxic metals -- arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc; (2) nonconventional pollutants -- aluminum, cobalt, iron, manganese, and COD; and (3) conventional pollutants -- oil and grease, TSS, and pH. Toxic organic pollutants generally were not found in large quantities although some cyanide was found in a few subcategories. 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 69 plants covered in this document, 33 percent of the plants have no treatment and do not discharge, 9 percent have no treatment and discharge, 10 percent have only pH adjust systems, 12 percent have only sedimentation or clarification devices, 17 percent have equipment for chemical precipitation and settling, 9 percent have equipment for chemical precipitation, settling and filtration, and 10 percent have other treatment systems. Even though treatment systems are in place at many plants, however, the category is uniformly inadequate in wastewater treatment practices. 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 used as the basis for the 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 forming (charging) systems. End-of-pipe treatment includes: hexavalent chromium reduction; chemical precipitation of metals using hydroxides, carbonates, or sulfides; and removal of precipitated metals and other materials using settling or sedimentation; filtration; and combinations of these technologies. While developing the regulation, EPA 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 was 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 multicategory 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 battery manufacturing production normalized 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 and standards 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 discharges in the cadmium and zinc subcategories. These limitations are based on model end-of-pipe treatment consisting of oil skimming when required and chemical precipitation and settling. The pollutant parameters selected for limitation at BPT for the cadmium subcategory are: cadmium, nickel, zinc, cobalt, oil and grease, total suspended solids (TSS), and pH. The pollutant parameters selected for limitation at BPT for the zinc subcategory include: chromium, mercury, silver, zinc, manganese, oil and grease, TSS and pH.

Eight cadmium and zinc battery plants in the data base are direct dischargers. Implementation of BPT limitations will remove

140,470 kilograms (309,000 pounds) per year of toxic metals and 203,500 kilograms (447,700 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 $0.161 million ($1983) and total annual costs will be $0.061 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 battery products in these subcategories. 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.

No BPT limitations are promulgated for the calcium, Leclanche, lithium, and magnesium subcategories. There are no direct dischargers in the calcium and Leclanche subcategories, and low flows and toxic pollutant loads do not justify national limitations for the lithium and magnesium subcategories.

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 general, in process technologies causing an average 87 percent reduction in wastewater flow are the basis for BAT limitations.

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 the 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 the BAT limitations from existing treatment because the flow reduction used to meet BAT limitations would allow the use of smaller -- and less expensive -- chemical precipitation and settling equipment than would be used to meet BPT limitations without any flow reduction. The pollutant parameters selected for limitation at BAT for the cadmium subcategory include: cadmium, nickel, zinc and cobalt. The pollutant parameters selected for limitation at BAT for the zinc subcategory include: chromium, mercury, silver, zinc and manganese.

Implementation of the BAT limitations will remove annually an estimated 141,000 kilograms (310,100 pounds) of toxic metals and 212,150 kilogram (466,700 pounds) per year of other pollutants from estimated raw waste generation at a capital cost above equipment in place of $0.31 million and a total annual cost of $0.09 million in 1983 dollars. The Agency projects no plant closures, employment impacts, or foreign trade effects and has determined that the BAT limitations are economically achievable.

No BAT limitations are promulgated for the calcium, Leclanche, lithium and magnesium subcategories for reasons discussed under BPT.

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

For new source direct dischargers, NSPS are promulgated for the cadmium, calcium, Leclanche, lithium, magnesium, and zinc subcategories. No discharge of process wastewater is promulgated for the calcium, and Leclanche (all processes but foliar battery miscellaneous wash) subcategories based on treatment using the end-of-pipe control technology and water reuse. Standards based on flow reduction and end-of-pipe treatment are promulgated for the cadmium, Leclanche (foliar battery miscellaneous wash), lithium, magnesium, and zinc subcategories. EPA does not believe that NSPS will pose a barrier to entry for new direct sources.

<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 publicly owned treatment works (POTW). Pretreatment standards are technology-based and analogous to the best available technology for removal of toxic pollutants.

For existing indirect dischargers, PSES are promulgated for the cadmium, Leclanche, magnesium and zinc subcategories. The standards promulgated are mass based and for the cadmium and zinc subcategories are equivalent to the BAT limitations. A standard based on flow reduction and the treatment effectiveness of lime, settle, and filter technology as end-of-pipe treatment is promulgated for the foliar battery miscellaneous wash element of the Leclanche subcategory. A standard based primarily on the treatment effectiveness of lime and settle technology as end-of-pipe treatment is promulgated for the magnesium subcategory. No discharge of process wastewater achieved by treatment using the end-of-pipe control technology and water reuse is promulgated for the other processes in the Leclanche subcategory.

No PSES standards are promulgated for the calcium and lithium subcategories because low flows and toxic pollutant loads do not justify developing national standards.

Implementation of the PSES will remove annually an estimated 54,450 kilograms (119,800 pounds) of toxic pollutants and 133,450 kilograms (293,600 pounds) of other pollutants at a capital cost above equipment in place of $1.075 million and an annual cost of $0.354 million in 1983 dollars. 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.

For PSNS the promulgated standards are mass based and equivalent to the NSPS technology. EPA does not believe that PSNS will pose a barrier to entry for new indirect sources.

BCT - BCT effluent limitations for the cadmium and zinc subcategories are deferred pending adoption of the BCT cost test.

Energy and 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 nonhazardous 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 cadmium and zinc subcategories will result in a net increase in electrical energy consumption of approximately 0.02 million kilowatt-hours per year. The BAT effluent technology are projected to increase electrical energy consumption by 0.04 million kilowatt hours per year. 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:

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

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. The nuclear subcategory is excluded from regulation since there are no currently operating plants and there are no known plans to resume production. The lead subcategory (Subcategory C) is the subject of Volume II and is not considered here.

3. The following effluent limitations are promulgated for existing sources.

A. Subcategory A - Cadmium

(a) <u>BPT Limitations</u>

(1) Subpart A - Pasted and Pressed Powder Anodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	0.92	0.41
Nickel	5.18	3.43
Zinc	3.94	1.65
Cobalt	0.57	0.24
Oil and Grease	54.0	32.4
TSS	111.0	52.65
pH	Within the range of 7.5 - 10.0 at all times	

(2) Subpart A - Electrodeposited Anodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	237.0	104.6
Nickel	1338.2	885.2
Zinc	1017.6	425.2
Cobalt	146.4	62.7
Oil and Grease	13940.0	8364.0
TSS	28577.0	13592.0
pH	Within the range of 7.5 - 10.0 at all times	

(3) Subpart A - Impregnated Anodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	339.3	149.7
Nickel	1916.2	1267.5
Zinc	1457.1	608.8
Cobalt	209.6	89.8
Oil and Grease	19960.0	11976.0
TSS	40918.0	19461.0
pH	Within the range of 7.5 - 10.0 at all times	

(4) Subpart A - Nickel Electrodeposited Cathodes BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	193.5	85.4
Nickel	1092.5	722.6
Zinc	830.7	347.1
Cobalt	119.5	51.2
Oil and Grease	11380.0	6828.0
TSS	23329.0	11095.5
pH	Within the range of 7.5 - 10.0 at all times	

(5) Subpart A - Nickel Impregnated Cathodes BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	557.6	246.0
Nickel	3148.8	2082.8
Zinc	2394.4	1000.4
Cobalt	344.4	147.6
Oil and grease	32800.0	19680.0
TSS	67240.0	31980.0
pH	Within the range of 7.5 - 10.0 at all times	

(6) Subpart A - Miscellaneous Wastewater Streams BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Cadmium	6.29	2.77
Nickel	35.54	23.50
Zinc	27.02	11.29
Cobalt	3.89	1.66
Oil and Grease	370.20	222.12
TSS	758.91	360.94
pH	Within the range of 7.5 - 10.0 at all times	

(7) Subpart A - Cadmium Powder Production BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
Cadmium	22.34	9.86
Nickel	126.14	83.44
Zinc	95.92	40.08
Cobalt	13.80	5.91
Oil and Grease	1314.0	788.4
TSS	2693.0	1281.2
pH	Within the range of 7.5 - 10.0 at all times	

(8) Subpart A - Silver Powder Production BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Cadmium	7.21	3.18
Nickel	40.70	26.92
Silver	8.69	3.61
Zinc	30.95	12.93
Cobalt	4.45	1.91
Oil and Grease	424.0	254.4
TSS	869.2	413.4
pH	Within the range of 7.5 - 10.0 at all times	

(9) Subpart A - Cadmium Hydroxide Production BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
Cadmium	0.31	0.14
Nickel	1.73	1.14
Zinc	1.31	0.55
Cobalt	0.19	0.08
Oil and Grease	18.0	10.8
TSS	36.9	17.6
pH	Within the range of 7.5 - 10.0 at all times	

(10) Subpart A - Nickel Hydroxide Production BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used English Units - lb/1,000,000 lb of nickel used		
Cadmium	37.4	16.5
Nickel	211.2	139.7
Zinc	160.6	67.1
Cobalt	23.1	9.9
Oil and Grease	2200.0	1320.0
TSS	4510.0	2145.0
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 A - Electrodeposited Anodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	11.95	5.27
Nickel	67.49	44.64
Zinc	51.32	21.44
Cobalt	7.38	3.16

(2) Subpart A - Impregnated Anodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	68.0	30.0
Nickel	384.0	254.0
Zinc	292.0	122.0
Cobalt	42.0	18.0

(3) Subpart A - Nickel Electrodeposited Cathodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	11.22	4.95
Nickel	63.36	41.91
Zinc	48.18	20.13
Cobalt	6.93	2.97

(4) Subpart A - Nickel Impregnated Cathodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	68.0	30.0
Nickel	384.0	254.0
Zinc	292.0	122.0
Cobalt	42.0	18.0

(5) Subpart A - Miscellaneous Wastewater Streams BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Cadmium	0.79	0.35
Nickel	4.47	2.96
Zinc	3.40	1.42
Cobalt	0.49	0.21

(6) Subpart A - Cadmium Powder Production BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
Cadmium	2.23	0.99
Nickel	12.61	8.34
Zinc	9.59	4.01
Cobalt	1.38	0.59

(7) Subpart A - Silver Powder Production BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Cadmium	1.09	0.48
Nickel	6.16	4.08
Silver	1.32	0.55
Zinc	4.69	1.96
Cobalt	0.67	0.29

(8) Subpart A - Cadmium Hydroxide Production BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
Cadmium	0.05	0.02
Nickel	0.27	0.18
Zinc	0.20	0.09
Cobalt	0.03	0.01

(9) Subpart A - Nickel Hydroxide Production BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used English Units - lb/1,000,000 lb of nickel used		
Cadmium	5.61	2.48
Nickel	31.68	20.96
Zinc	24.09	10.07
Cobalt	3.47	1.49

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

B. Subcategory B - Calcium

(a) BPT Limitations
[Reserved]

(b) BAT Limitations
[Reserved]

C. Subcategory C - Lead
(See Battery Manufacturing Document - Volume II)

D. Subcategory D - Leclanche

(a) BPT Limitations
[Reserved]

(b) BAT Limitations
[Reserved]

E. Subcategory E - Lithium

(a) BPT Limitations
[Reserved]

(b) BAT Limitations
[Reserved]

F. Subcategory F - Magnesium

(a) BPT Limitations
[Reserved]

(b) BAT Limitations
[Reserved]

G. Subcategory G - Zinc

(a) BPT Limitations

(1) Subpart G - Wet Amalgamated Powder Anodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Chromium	1.67	0.68
Mercury	0.95	0.38
Silver	1.56	0.65
Zinc	5.55	2.32
Manganese	2.58	1.10
Oil and Grease	76.0	45.6
TSS	155.8	74.1
pH	Within the range of 7.5 - 10.0 at all times	

(2) Subpart G - Gelled Amalgam Anodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Chromium	0.30	0.12
Mercury	0.17	0.07
Silver	0.28	0.12
Zinc	0.99	0.42
Manganese	0.46	0.20
Oil and Grease	13.6	8.16
TSS	27.9	13.26
pH	Within the range of 7.5 - 10.0 at all times	

(3) Subpart G - Zinc Oxide, Formed Anodes BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Chromium	62.9	25.7
Mercury	35.8	14.3
Silver	58.7	24.3
Zinc	208.8	87.2
Manganese	97.2	41.5
Oil and Grease	2860.0	1716.0
TSS	5863.0	2789.0
pH	Within the range 7.5 - 10.0 at all times	

(4) Subpart G - Electrodeposited Anodes BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Chromium	1404.0	574.0
Mercury	798.0	319.0
Silver	1308.0	543.0
Zinc	4657.0	1946.0
Manganese	2169.0	925.0
Oil and Grease	63800.0	38280.0
TSS	130700.0	62210.0
pH	Within the range of 7.5 - 10.0 at all times	

(5) Subpart G - Silver Powder, Formed Cathodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	86.2	35.3
Mercury	49.0	19.6
Silver	80.4	33.3
Zinc	286.2	119.6
Manganese	133.3	56.8
Oil and Grease	3920.0	2350.0
TSS	8036.0	3822.0
pH	Within the range of 7.5 - 10.0 at all times	

(6) Subpart G - Silver Oxide Powder, Formed Cathodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	57.7	23.6
Mercury	32.8	13.1
Silver	53.7	22.3
Zinc	191.3	79.9
Manganese	89.1	38.0
Oil and Grease	2620.0	1570.0
TSS	5370.0	2554.0
pH	Within the range of 7.5 - 10.0 at all times	

(7) Subpart G - Silver Peroxide Cathodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	13.8	5.65
Mercury	7.85	3.14
Silver	12.9	5.34
Zinc	45.8	19.2
Manganese	21.4	9.11
Oil and Grease	628.0	377.0
TSS	1287.0	612.0
pH	Within the range of 7.5 - 10.0 at all times	

(8) Subpart G - Nickel Impregnated Cathodes
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Chromium	721.6	295.2
Mercury	410.0	164.0
Nickel	3149.0	2083.0
Silver	672.4	279.0
Zinc	2394.4	1000.4
Manganese	1115.2	475.6
Oil and Grease	32800.0	19680.0
TSS	67240.0	31980.0
pH	Within the range of 7.5 - 10.0 at all times	

(9) Subpart G - Miscellaneous Wastewater Streams
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	3.85	1.58
Cyanide	2.54	1.05
Mercury	2.19	0.88
Nickel	16.82	11.12
Silver	3.59	1.49
Zinc	12.79	5.34
Manganese	5.96	2.54
Oil and Grease	175.20	105.12
TSS	359.16	170.82
pH	Within the limits of 7.5 - 10.0 at all times	

(10) Subpart G - Silver Etch
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	21.6	8.84
Mercury	12.3	4.91
Silver	20.2	8.35
Zinc	71.7	30.0
Manganese	33.4	14.3
Oil and Grease	982.0	589.2
TSS	2013.1	957.5
pH	Within the range of 7.5 - 10.0 at all times	

(11) Subpart G - Silver Peroxide Production
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Chromium	23.0	9.40
Mercury	13.1	5.22
Silver	21.4	8.88
Zinc	76.2	31.8
Manganese	35.5	15.1
Oil and Grease	1044.0	627.0
TSS	2140.0	1018.0
pH	Within the range of 7.5 - 10.0 at all times	

(12) Subpart G - Silver Powder Production
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Chromium	9.33	3.82
Mercury	5.30	2.12
Silver	8.69	3.61
Zinc	30.95	12.93
Manganese	14.42	6.15
Oil and grease	424.0	254.4
TSS	869.0	413.4
pH	Within the range 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 G - Wet Amalgamated Powder Anodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lbs/1,000,000 lbs of zinc		
Chromium	0.24	0.099
Mercury	0.14	0.055
Silver	0.23	0.093
Zinc	0.80	0.34
Manganese	0.37	0.16

(2) Subpart G - Gelled Amalgam Anodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Chromium	0.030	0.012
Mercury	0.017	0.007
Silver	0.028	0.012
Zinc	0.099	0.042
Manganese	0.046	0.020

(3) Subpart G - Zinc Oxide Formed Anodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Chromium	9.53	3.90
Mercury	5.42	2.17
Silver	8.89	3.68
Zinc	31.64	13.22
Manganese	14.74	6.28

(4) Subpart G - Electrodeposited Anodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Chromium	94.47	38.65
Mercury	53.68	21.47
Silver	88.03	36.50
Zinc	313.46	130.97
Manganese	146.00	62.26

(5) Subpart G - Silver Powder Formed Cathodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	13.07	5.35
Mercury	7.43	2.97
Silver	12.18	5.05
Zinc	43.36	18.12
Manganese	20.20	8.61

(6) Subpart G - Silver Oxide Powder Formed Cathodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	8.73	3.57
Mercury	4.96	1.99
Silver	8.14	3.37
Zinc	28.98	12.11
Manganese	13.50	5.76

(7) Subpart G - Silver Peroxide Cathodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	2.09	0.87
Mercury	1.19	0.48
Silver	1.95	0.81
Zinc	6.95	2.90
Manganese	3.24	1.38

(8) Subpart G - Nickel Impregnated Cathodes BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Chromium	88.0	36.0
Mercury	50.0	20.0
Nickel	384.0	254.0
Silver	82.0	34.0
Zinc	292.0	122.0
Manganese	136.0	58.0

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

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.57	0.23
Cyanide	0.38	0.16
Mercury	0.32	0.13
Nickel	2.48	1.64
Silver	0.53	0.22
Zinc	1.88	0.79
Manganese	0.88	0.37

(10) Subpart G - Silver Etch BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	3.27	1.34
Mercury	1.86	0.74
Silver	3.05	1.26
Zinc	10.86	4.54
Manganese	5.06	2.16

(11) Subpart G - Silver Peroxide Production BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Chromium	3.48	1.42
Mercury	1.98	0.79
Silver	3.24	1.34
Zinc	11.55	4.83
Manganese	5.38	2.29

(12) Subpart G - Silver Powder Production BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Chromium	1.41	0.58
Mercury	0.80	0.32
Silver	1.32	0.55
Zinc	4.69	1.96
Manganese	2.18	0.93

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 A - Cadmium

(1) Subpart A - Electrodeposited Anodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	7.03	2.81
Nickel	19.33	13.01
Zinc	35.85	14.76
Cobalt	4.92	2.46
Oil and Grease	351.5	351.5
TSS	527.3	421.8
pH	Within the range of 7.5 - 10.0 at all times	

(2) Subpart A - Impregnated Anodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	40.0	16.0
Nickel	110.0	74.0
Zinc	204.0	84.0
Cobalt	28.0	14.0
Oil and Grease	2000.0	2000.0
TSS	3000.0	2400.0
pH	Within the range of 7.5 - 10.0 at all times	

(3) Subpart A - Nickel Electrodeposited Cathodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	6.60	2.64
Nickel	18.15	12.21
Zinc	33.66	13.86
Cobalt	4.62	2.31
Oil and Grease	330.0	330.0
TSS	495.0	396.0
pH	Within the range of 7.5 - 10.0 at all times	

(4) Subpart A - Nickel Impregnated Cathodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	40.0	16.0
Nickel	110.0	74.0
Zinc	204.0	84.0
Cobalt	28.0	14.0
Oil and grease	2000.0	2000.0
TSS	3000.0	2400.0
pH	Within the range of 7.5 - 10.0 at all times	

(5) Subpart A - Miscellaneous Wastewater Streams - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Cadmium	0.47	0.19
Nickel	1.28	0.86
Zinc	2.38	0.98
Cobalt	0.33	0.16
Oil and Grease	23.3	23.3
TSS	35.0	28.0
pH	Within the range of 7.5 - 10.0 at all times	

(6) Subpart A - Cadmium Powder Production - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
Cadmium	1.31	0.53
Nickel	3.61	2.43
Zinc	6.70	2.76
Cobalt	0.92	0.46
Oil and Grease	65.70	65.70
TSS	98.55	78.84
pH	Within the range of 7.5 - 10.0 at all times	

(7) Subpart A - Silver Powder Production - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Cadmium	0.64	0.26
Nickel	1.77	1.19
Silver	0.93	0.39
Zinc	3.27	1.35
Cobalt	0.45	0.22
Oil and Grease	32.10	32.10
TSS	48.15	38.52
pH	Within the range of 7.5 - 10.0 at all times	

(8) Subpart A - Cadmium Hydroxide Production - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
Cadmium	0.028	0.011
Nickel	0.077	0.051
Zinc	0.142	0.058
Cobalt	0.019	0.009
Oil and Grease	1.40	1.40
TSS	2.10	1.68
pH	Within the range of 7.5 - 10.0 at all times	

(9) Subpart A - Nickel Hydroxide Production - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used English Units - lb/1,000,000 lb of nickel used		
Cadmium	3.30	1.32
Nickel	9.08	6.11
Zinc	16.83	6.93
Cobalt	2.31	1.16
Oil and Grease	165.0	165.0
TSS	247.5	198.0
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. Subcategory B - Calcium

There shall be no discharge of wastewater pollutants from any battery manufacturing operations.

C. Subcategory C - Lead
(See Battery Manufacturing Document - Volume II)

D. Subcategory D - Leclanche

(1) Subpart D - Foliar Battery Miscellaneous Wash - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Mercury	0.010	0.004
Zinc	0.067	0.030
Manganese	0.019	0.015
Oil and Grease	0.66	0.66
TSS	0.99	0.79
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.

E. Subcategory E - Lithium

(1) Subpart E - Lead Iodide Cathodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead English Units - lb/1,000,000 lb of lead		
Chromium	23.34	9.46
Lead	17.66	8.20
Iron	75.70	38.48
TSS	946.2	756.96
pH	Within the range of 7.5 - 10.0 at all times	

(2) Subpart E - Iron Disulfide Cathodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of iron disulfide English Units - lb/1,000,000 lb of iron disulfide		
Chromium	2.79	1.13
Lead	2.11	0.98
Iron	9.05	4.60
TSS	113.1	90.5
pH	Within the range of 7.5 - 10.0 at all times	

(3) Subpart E - Miscellaneous Wastewater Streams - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.039	0.016
Lead	0.030	0.014
Iron	0.129	0.066
TSS	1.62	1.30
pH	Within the range of 7.5 - 10.0 at all times	

(4) Subpart E - Air Scrubbers NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
TSS	434.0	207.0
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.

F. Subcategory F - Magnesium

(1) Subpart F - Silver Chloride Cathodes - Chemically Reduced - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Lead	22.93	10.65
Silver	23.75	9.83
Iron	98.28	49.96
TSS	1228.5	982.8
COD	4095.0	1999.0
pH	Within the range of 7.5 - 10.0 at all times	

(2) Subpart F - Silver Chloride Cathodes - Electrolytic - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Lead	40.6	18.9
Silver	42.1	17.4
Iron	174.0	88.5
TSS	2175.0	1740.0
COD	7250.0	3540.0
pH	Within the range of 7.5 - 10.0 at all times	

(3) Subpart F - Cell Testing - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Lead	19.5	7.89
Silver	15.3	6.31
Iron	63.1	32.1
TSS	789.0	631.2
COD	2630.0	1290.0
pH	Within the range of 7.5 - 10.0 at all times	

(4) Subpart F - Floor and Equipment Wash - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Lead	0.026	0.012
Silver	0.027	0.011
Iron	0.112	0.057
COD	4.70	2.30
TSS	1.41	1.13
pH	Within the range of 7.5 - 10.0 at all times	

(5) Subpart F - Air Scrubber - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
TSS	8467.0	4030.0
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.

G. Subcategory G - Zinc

(1) Subpart G - Zinc Oxide Formed Anodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Chromium	4.55	1.97
Mercury	2.82	1.19
Silver	4.55	1.97
Zinc	0.87	0.39
Manganese	6.50	4.98
Oil and Grease	216.7	216.7
TSS	325.0	260.0
pH	Within the limits of 7.5 - 10.0 at all times	

(2) Subpart G - Electrodeposited Anodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Chromium	45.09	19.54
Mercury	27.91	11.81
Silver	45.09	19.54
Zinc	8.59	3.86
Manganese	64.41	49.38
Oil and Grease	2147.00	2147.00
TSS	3220.50	2576.40
pH	Within the limits of 7.5 - 10.0 at all times	

(3) Subpart G - Silver Powder Formed Cathodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	6.24	2.70
Mercury	3.86	1.63
Silver	6.24	2.70
Zinc	1.19	0.53
Manganese	8.91	6.83
Oil & Grease	297.00	297.00
TSS	445.5	356.40
pH	Within the limits of 7.5 - 10.0 at all times	

(4) Subpart G - Silver Oxide Powder Formed Cathodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	4.17	1.81
Mercury	2.58	1.09
Silver	4.17	1.81
Zinc	0.79	0.36
Manganese	5.96	4.57
Oil & Grease	198.5	198.5
TSS	297.8	238.2
pH	Within the limits of 7.5 - 10.0 at all times	

(5) Subpart G - Silver Peroxide Cathodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	1.00	0.43
Mercury	0.62	0.26
Silver	1.00	0.43
Zinc	0.19	0.09
Manganese	1.43	1.09
Oil & Grease	47.6	47.6
TSS	71.4	57.1
pH	Within the limits of 7.5 - 10.0 at all times	

(6) Subpart G - Nickel Impregnated Cathodes - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Chromium	42.0	18.2
Mercury	26.0	11.0
Nickel	42.0	18.2
Silver	42.0	18.2
Zinc	8.0	3.6
Manganese	60.0	46.0
Oil & Grease	2000.0	2000.0
TSS	3000.0	2400.00
pH	Within the limits of 7.5 - 10.0 at all times	

(7) Subpart G - Miscellaneous Wastewater Streams - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.27	0.12
Cyanide	0.039	0.016
Mercury	0.17	0.07
Nickel	0.27	0.12
Silver	0.27	0.12
Zinc	0.05	0.02
Manganese	0.39	0.30
Oil & Grease	12.90	12.90
TSS	19.35	15.48
pH	Within the limits of 7.5 - 10.0 at all times	

(8) Subpart G - Silver Etch - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	1.56	0.68
Mercury	0.97	0.41
Silver	1.56	0.68
Zinc	0.30	0.13
Manganese	2.23	1.71
Oil & Grease	74.40	74.40
TSS	111.60	89.28
pH	Within the limits of 7.5 - 10.0 at all times	

(9) Subpart G - Silver Peroxide Production - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Chromium	1.66	0.72
Mercury	1.03	0.44
Silver	1.66	0.72
Zinc	0.32	0.14
Manganese	2.37	1.82
Oil & Grease	79.10	79.10
TSS	118.65	94.92
pH	Within the limits of 7.5 - 10.0 at all times	

(10) Subpart G - Silver Powder Production - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Chromium	0.67	0.29
Mercury	0.42	0.18
Silver	0.67	0.29
Zinc	0.13	0.06
Manganese	0.96	0.74
Oil & Grease	32.10	32.10
TSS	48.15	38.52
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 A - Cadmium

(1) Subpart A - Electrodeposited Anodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	11.95	5.27
Nickel	67.49	44.64
Zinc	51.32	21.44
Cobalt	7.38	3.16

(2) Subpart A - Impregnated Anodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	68.0	30.0
Nickel	384.0	254.0
Zinc	292.0	122.0
Cobalt	42.0	18.0

(3) Subpart A - Nickel Electrodeposited Cathodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	11.22	4.95
Nickel	63.36	41.91
Zinc	48.18	20.13
Cobalt	6.93	2.97

(4) Subpart A - Nickel Impregnated Cathodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	68.0	30.0
Nickel	384.0	254.0
Zinc	292.0	122.0
Cobalt	42.0	18.0

(5) Subpart A - Miscellaneous Wastewater Streams - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Cadmium	0.79	0.35
Nickel	4.47	2.96
Zinc	3.40	1.42
Cobalt	0.49	0.21

(6) Subpart A - Cadmium Powder Production - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
Cadmium	2.23	0.99
Nickel	12.61	8.34
Zinc	9.59	4.01
Cobalt	1.38	0.59

(7) Subpart A - Silver Powder Production - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Cadmium	1.09	0.48
Nickel	6.16	4.08
Silver	1.32	0.55
Zinc	4.69	1.96
Cobalt	0.67	0.29

(8) Subpart A - Cadmium Hydroxide Production - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
Cadmium	0.05	0.02
Nickel	0.27	0.18
Zinc	0.20	0.09
Cobalt	0.03	0.012

(9) Subpart A - Nickel Hydroxide Production - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used English Units - lb/1,000,000 lb of nickel used		
Cadmium	5.61	2.48
Nickel	31.68	20.96
Zinc	24.09	10.07
Cobalt	3.47	1.49

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

B. Subcategory B - Calcium
[Reserved]

C. Subcategory C - Lead
(See Battery Manufacturing Document-Volume II)

D. Subcategory D - Leclanche

(1) Subpart D - Foliar Battery Miscellaneous Wash - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Mercury	0.01	0.004
Zinc	0.067	0.030
Manganese	0.019	0.015

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

E. Subcategory E - Lithium

[Reserved]

F. Subcategory F - Magnesium

(1) Subpart F - Silver Chloride Cathodes - Chemically Reduced - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lbs/1,000,000 lbs of silver processed		
Lead	1032.36	491.60
Silver	1007.78	417.86

(2) Subpart F - Silver Chloride Cathodes - Electrolytic - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Lead	60.9	29.0
Silver	59.5	24.7

(3) Subpart F - Cell Testing - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Lead	22.1	10.5
Silver	21.6	8.9

(4) Subpart F - Floor and Equipment Wash - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Lead	0.039	0.018
Silver	0.038	0.015

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

G. Subcategory G - Zinc

(1) Subpart G - Wet Amalgamated Powder Anode - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Chromium	0.24	0.099
Mercury	0.14	0.055
Silver	0.23	0.093
Zinc	0.80	0.34
Manganese	0.37	0.16

(2) Subpart G - Gelled Amalgam Anodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lbs/1,000,000 lbs of zinc		
Chromium	0.030	0.12
Mercury	0.017	0.006
Silver	0.028	0.012
Zinc	0.099	0.042
Manganese	0.046	0.020

(3) Subpart G - Zinc Oxide Formed Anodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc	
Chromium	9.53	3.90
Mercury	5.42	2.17
Silver	8.89	3.68
Zinc	31.64	13.22
Manganese	14.74	6.28

(4) Subpart G - Electrodeposited Anodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Chromium	94.47	38.65
Mercury	53.68	21.47
Silver	88.03	36.50
Zinc	313.46	130.97
Manganese	146.00	62.26

(5) Subpart G - Silver Powder Formed Cathodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	13.07	5.35
Mercury	7.43	2.97
Silver	12.18	5.05
Zinc	43.36	18.12
Manganese	20.20	8.61

(6) Subpart G - Silver Oxide Powder Formed Cathodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	8.73	3.57
Mercury	4.96	1.99
Silver	8.14	3.37
Zinc	28.98	12.11
Manganese	13.50	5.76

(7) Subpart G - Silver Peroxide Cathodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	2.09	0.87
Mercury	1.19	0.48
Silver	1.95	0.81
Zinc	6.95	2.90
Manganese	3.24	1.38

(8) Subpart G - Nickel Impregnated Cathodes - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Chromium	88.0	36.0
Mercury	50.0	20.0
Nickel	384.0	254.0
Silver	82.0	34.0
Zinc	292.0	122.0
Manganese	136.0	58.0

(9) Subpart G - Miscellaneous Wastewater Streams - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.57	0.23
Cyanide	0.38	0.16
Mercury	0.32	0.13
Nickel	2.48	1.64
Silver	0.53	0.22
Zinc	1.88	0.79
Manganese	0.88	0.37

(10) Subpart G - Silver Etch - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	3.27	1.34
Mercury	1.86	0.74
Silver	3.05	1.26
Zinc	10.86	4.54
Manganese	5.06	2.16

(11) Subpart G - Silver Peroxide Production - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Chromium	3.48	1.42
Mercury	1.98	0.79
Silver	3.24	1.34
Zinc	11.55	4.83
Manganese	5.38	2.29

(12) Subpart G - Silver Powder Production - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Chromium	1.41	0.58
Mercury	0.80	0.32
Silver	1.32	0.55
Zinc	4.69	1.96
Manganese	2.18	0.93

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 A - Cadmium

(1) Subpart A - Electrodeposited Anodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	7.03	2.81
Nickel	19.33	13.01
Zinc	35.85	14.76
Cobalt	4.92	2.46

(2) Subpart A - Impregnated Anodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
Cadmium	40.0	16.0
Nickel	110.0	74.0
Zinc	204.0	84.0
Cobalt	28.0	14.0

(3) Subpart A - Nickel Electrodeposited Cathodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	6.60	2.64
Nickel	18.15	12.21
Zinc	33.66	13.86
Cobalt	4.62	2.31

(4) Subpart A - Nickel Impregnated Cathodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Cadmium	40.0	16.0
Nickel	110.0	74.0
Zinc	204.0	84.0
Cobalt	28.0	14.0

(5) Subpart A - Miscellaneous Wastewater Streams - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Cadmium	0.47	0.19
Nickel	1.28	0.86
Zinc	2.38	0.98
Cobalt	0.33	0.16

(6) Subpart A - Cadmium Powder Production - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
Cadmium	1.31	0.53
Nickel	3.61	2.43
Zinc	6.70	2.76
Cobalt	0.92	0.46

(7) Subpart A - Silver Powder Production - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Cadmium	0.64	0.26
Nickel	1.77	1.19
Silver	0.93	0.39
Zinc	3.27	1.35
Cobalt	0.45	0.22

(8) Subpart A - Cadmium Hydroxide Production - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
Cadmium	0.028	0.011
Nickel	0.077	0.051
Zinc	0.142	0.058
Cobalt	0.019	0.009

(9) Subpart A - Nickel Hydroxide Production - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used English Units - lb/1,000,000 lb of nickel used		
Cadmium	3.30	1.32
Nickel	9.08	6.11
Zinc	16.83	6.93
Cobalt	2.31	1.16

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

B. Subcategory B - Calcium

There shall be no discharge of wastewater pollutant from any battery manufacturing operations.

C. Subcategory C - Lead
(See Battery Manufacturing Document-Volume II)

D. Subcategory D - Leclanche

(1) Subpart D - Foliar Battery Miscellaneous Wash - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Mercury	0.010	0.004
Zinc	0.067	0.030
Manganese	0.019	0.015

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

E. Subcategory E - Lithium

(1) Subpart E - Lead Iodide Cathodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead English Units - lb/1,000,000 lb of lead		
Chromium	23.34	9.46
Lead	17.66	8.20

(2) Subpart E - Iron Disulfide Cathodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of iron disulfide English Units - lb/1,000,000 lb of iron disulfide		
Chromium	2.79	1.13
Lead	2.11	0.98

(3) Subpart E - Miscellaneous Wastewater Streams - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.039	0.016
Lead	0.030	0.014

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

F. Subcategory F - Magnesium

(1) Subpart F - Silver Chloride Cathodes - Chemically Reduced - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Lead	22.93	10.65
Silver	23.75	9.83

(2) Subpart F - Silver Chloride Cathode - Electrolytic - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Lead	40.6	18.9
Silver	42.1	17.4

(3) Subpart F - Cell Testing - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Lead	19.5	7.89
Silver	15.3	6.31

(4) Subpart F - Floor and Equipment Wash - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Lead	0.026	0.012
Silver	0.027	0.011

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

G. Subcategory G - Zinc

(1) Subpart G - Zinc Oxide Formed Anodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Chromium	4.55	1.97
Mercury	2.82	1.19
Silver	4.55	1.97
Zinc	0.87	0.39
Manganese	6.50	4.98

(2) Subpart G - Electrodeposited Anodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Chromium	45.09	19.54
Mercury	27.91	11.81
Silver	45.09	19.54
Zinc	8.59	3.86
Manganese	64.41	49.38

(3) Subpart G - Silver Powder Formed Cathodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	6.24	2.70
Mercury	3.86	1.63
Silver	6.24	2.70
Zinc	1.19	0.53
Manganese	8.91	6.83

(4) Subpart G - Silver Oxide Powder Formed Cathodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	4.17	1.81
Mercury	2.58	1.09
Silver	4.17	1.81
Zinc	0.79	0.36
Manganese	5.96	4.57

(5) Subpart G - Silver Peroxide Cathodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Chromium	1.00	0.43
Mercury	0.62	0.26
Silver	1.00	0.43
Zinc	0.19	0.09
Manganese	1.43	1.09

(6) Subpart G - Nickel Impregnated Cathodes - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Chromium	42.0	18.2
Mercury	26.0	11.0
Nickel	42.0	18.2
Silver	42.0	18.2
Zinc	8.0	3.6
Manganese	60.0	46.0

(7) Subpart G - Miscellaneous Wastewater Streams - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.27	0.12
Cyanide	0.039	0.016
Mercury	0.17	0.07
Nickel	0.27	0.12
Silver	0.27	0.12
Zinc	0.05	0.02
Manganese	0.39	0.30

(8) Subpart G - Silver Etch - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	1.56	0.68
Mercury	0.97	0.41
Silver	1.56	0.68
Zinc	0.30	0.13
Manganese	2.23	1.71

(9) Subpart G - Silver Peroxide Production - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Chromium	1.66	0.72
Mercury	1.03	0.44
Silver	1.66	0.72
Zinc	0.32	0.14
Manganese	2.37	1.82

(10) Subpart G - Silver Powder Production - PSNS

Pollutant or Pollutant Property	Maximum for	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Chromium	0.67	0.29
Mercury	0.42	0.18
Silver	0.67	0.29
Zinc	0.13	0.06
Manganese	0.96	0.74

There shall be no discharge allowance for process wastewater pollutants from any bettery 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 nontoxic 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 nontoxic, 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 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 are not otherwise considered in 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 provides 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.

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 108) 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 48 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).

<u>Waste Treatment Equipment Manufacturers</u> - 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 114), 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 anode, sometimes called the negative plate, a cathode, also called the positive plate, and electrolyte. The anode and cathode are referred to by the general term electrodes. One or both electrodes consist of a support or grid which serves as a mechancial support and current collector, and the active material which actually undergoes electrochemical reaction to produce the current and voltage characteristics of the cell. Sometimes the active material is the electrode structure itself. The combination of an inert current collecting support and active material is an electrode system. For convenience, in this document as well as in many publications, the terms cathode or anode are used to designate the cathode system or the anode system.

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

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

Battery power is the instantaneous product of current and voltage. Specific power is the power per unit weight of battery; power density is the power per unit volume. Watts per pound and watts per cubic foot, 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 115) 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 110).

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 110) 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 depleated of ions required for electrode reaction. For instance, at the negative plate of a lead-acid battery, sulfate ions are required for the reaction:

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

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 116-125) are drawings or cutaway views of these 10 batteries. Figures III-13 through III-20 (pages 126-133) 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 134) 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 135) 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 111). 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 112) summarizes the characteristics of plants manufacturing batteries in each of the groups discussed in the battery documents based on anode and electrolyte. The cadmium, calcium, Leclanche, lithium, magnesium and zinc subcategories are discussed below.

Cadmium Subcategory

Cadmium anode cells presently manufactured are based on nickel-cadmium, silver-cadmium, and mercury-cadmium couples. Nickel-cadmium batteries are among the most widely used rechargeable cells finding applications in calculators, radios and numerous other portable electronic devices in addition to a variety of industrial applications. Total annual shipments of nickel-cadmium batteries were valued at over $100 million in 1977. Silver-cadmium battery manufacture is limited in terms of product weight amounting to less than one percent of the amount of nickel-cadmium batteries manufactured. Small quantities of mercury-cadmium batteries are manufactured for military and industrial applications. Presently 10 plants are manufacturing batteries in the cadmium subcategory. Total annual production is estimated to be 5251 metric tons (5790 tons) of batteries with three plants producing over 453.5 metric tons (500 tons) of batteries, and one producing less than 0.907 metric ton (1 ton) of batteries. Plants vary in size and in number of employees. Total subcategory employment is estimated to be 2500.

Process wastewater flows from this subcategory are variable and total 114,000 l/hr (30,100 gal/hr). Most plants have flows of <18,925 l/hr (<5,000 gal/hr) while two plants have no process wastewater flows. Normalized process wastewater flows based on the total weight of cadmium anode cells produced vary from 0 to 782 l/kg (94 gal/lb) and averages 148 l/kg (18 gal/lb), with the subcategory having a median flow of 49 l/kg (6 gal/lb). The substantial variations shown in wastewater discharges from these plants reflect major manufacturing process variations, especially between batteries using pressed or pasted electrodes and sintered electrodes. These are addressed in detail in Section V. The most significant use of process water in cadmium anode battery manufacture is in the deposition of electrode active materials on supporting substrates and in subsequent electrode formation (charging) prior to assembly into cells. These operations are also major sources of process wastewater. Additional points of process water use and discharge include wet scrubbers, electrolyte preparation, cell wash, floor wash, and employee showers and hand wash intended to remove process chemicals. The most significant pollutants carried by these waste streams are the toxic metals, cadmium, nickel, and silver. The waste streams are predominantly alkaline and frequently contain high levels of suspended solids including metal hydroxide precipitates.

Treatment commonly used included settling or filtration for the removal of solids at 8 of 9 plants which indicated process wastewater discharge; two plants also indicated the use of coagulants, and seven plants use pH adjustment. Two plants indicated the use of material recovery, five plants have sludges hauled by a contractor and one plant has its sludge landfilled. On-site observations at several plants indicate that the treatment provided is often rudimentary and of limited effectiveness. Battery process wastewater discharges from five cadmium anode battery manufacturing plants in the data base flow directly to surface waters, and four plants discharge to municipal sewers. Recently, one direct discharge plant in the data base has added additional treatment including 100 percent recycle and has no discharge of wastewater. Currently there are three plants which moved their operations to other plants, three plants with no discharge to navigable waters of the United States and four plants which discharge wastewater to surface waters. Wastewater treatment provided was not related to the discharge destination.

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

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

- <u>Calcium Subcategory</u>

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

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

Leclanche Subcategory

Plants included in this subcategory manufacture the conventional carbon-zinc Leclanche cell and some silver chloride-zinc and carbon-zinc air cells as well. All of the battery types included have in common an acidic (chloride) electrolyte and a zinc anode. Among carbon-zinc air batteries, only "dry" cells which use ammonium chloride in the electrolyte are included in this subcategory. Carbon-zinc air depolarized batteries which use alkaline electrolytes are included in the zinc subcategory. The Leclanche subcategory also includes the production of pasted paper separator material containing mercury for use in battery manufacture.

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

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

Major raw materials used in the manufacture of batteries in this subcategory include zinc, mercury, carbon, manganese dioxide, ammonium chloride, zinc chloride, silver chloride, paper, starch, flour, and pitch or similar materials for sealing cells.

Plastics are also used in producing flat cells for photographic use. The zinc is most often obtained as sheet zinc pre-formed into cans which serve as both cell anode and container although some plants form and clean the cans on site. For one type of battery, zinc powder is used. The mercury, used to amalgamate the zinc and reduce internal corrosion in the battery, is generally added with the cell electrolyte or separator. It amounts to approximately 1.7 percent by weight of the zinc contained in these cells.

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

Estimated total process wastewater flow rates reported by plants in this subcategory range from 0 to 2,158 l/hr (570 gal/hr) with an average of 208 l/hr (55 gal/hr). Twelve plants reported zero discharge of process wastewater. The maximum reported volume of process wastewater per unit of production (weight of cells produced) in this subcategory is 6.4 l/kg (0.76 gal/lb) and the average value is 0.45 l/kg (0.054 gal/lb). All plants reporting process wastewater discharge in this subcategory discharge to municipal treatment systems. Significant flow rate variations among plants in this subcategory are attributable to manufacturing process differences, to variations in equipment cleanup procedures employed, and the degree of water conservation practiced at each plant.

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

Lithium Subcategory

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

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

Because of lithium's high reactivity with water, anode processing and most cell assembly operations are performed without the use of process water. In fact they are usually accomplished in areas of controlled low humidity. Process water is used, however, in producing some cell cathodes, either for washing reactive materials or for air pollution control and area cleanup. One plant also reports process water use in manufacturing reactive materials for activating thermal batteries, as discussed in conjunction with calcium anode batteries. Three of seven plants manufacturing lithium anode batteries reported process wastewater discharges which ranged from 3.9 l/hr (1.0 gal/hr) to 150 l/hr (39 gal/hr). The maximum reported flow rate includes 60 l/hr (16 gal/hr) resulting from the manufacture of heating elements.

Wastewater streams from plants in this subcategory may be expected to vary considerably in their chemical composition because of the widely varying raw materials and processes used. Raw materials reported to be used in lithium anode battery manufacture are shown in Table III-7 (page 113).

Pollutants reported to be present include lead, chromium and cadmium. In addition, asbestos, iron, lithium, sodium sulfite and suspended solids may be anticipated in waste streams from specific operations. Cadmium results from electroplating cell uses and is therefore not attributable to operations included for regulation under this subcategory. Chromium and asbestos originate in the manufacture of thermal activators for high temperature military batteries as discussed for calcium anode cells. Wastewater treatment and control practices at the plants in this subcategory are limited to settling and pH adjustment. Three plants report pH adjustment of process wastewater while one plant reports only filtration. Two plants report no discharge of wastewater, four plants discharge to a municipal sewer, and one plant discharges to surface waters.

Magnesium Subcategory

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

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

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

Significant pollutants in wastewater streams resulting from magnesium anode battery manufacture include hexavalent chromium, silver, lead, fluorides, oil and grease, ammonia, and suspended solids. Treatment practices presently applied to these wastes include pH adjustment, settling, and filtration, which is practiced at two plants. One plant utilizes pH adjustment and filtration, and one plant uses filtration only.

Zinc Subcategory

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

In 1976, 17 plants produced approximately 23,000 metric tons (25,000 tons) of batteries in this subcategory. Individual plant production of zinc anode alkaline electrolyte batteries ranged from 0.36 metric tons (0.40 tons) to 7,000 metric tons (7,700 tons).

Of the 16 plants currently producing these batteries, 5 manufacture more than one type of battery in this subcategory. Employment for this subcategory is estimated to be 4,680.

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

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

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

The pollutants found in waste streams from plants producing batteries in this subcategory are primarily metals. Zinc and mercury are encountered in most wastewater streams. Silver, mercury, and nickel are found in waste streams resulting from the manufacture of specific cell types, and hexavalent chromium is found in some waste streams as a result of the use of chromates in cell wash operations. Wastewater discharges in this subcategory are predominantly alkaline and may contain significant concentrations of suspended solids. Oil and grease and organic pollutants are also encountered. Wastewater treatment provided is also variable, but commonly includes solids removal by settling or filtration (12 plants). Sulfide precipitation is practiced at two sites, oil skimming is practiced at one plant, and carbon adsorption is practiced at two plants. One plant has upgraded its system to include ion exchange and metals recovery. Several plants employ amalgamation with zinc for the removal of mercury from process waste streams from this subcategory. Most treatment is performed as pretreatment for discharge to POTW since 11 plants discharge to municipal sewers. Three plants discharge to surface waters and two of the active plants have no wastewater discharge.

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

DCP EFFORT 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).

TABLE III-7
RAW MATERIALS USED IN LITHIUM ANODE BATTERY MANUFACTURE

Acetonitrile
Aluminum
Aluminum Chloride

Barium Chromate
Carbon
Dioxolane

Glass Fiber
Hydrochloric Acid
Iodine

Iron
Iron Disulfide
Isopropyl Alcohol

Lead
Lead Iodide
Lithium

Lithium Bromide
Lithium Chloride
Lithium Fluoborate

Lithium Perchlorate
Methyl Acetate
Methyl Formate

Nickel
Oil
Paper

Poly-2-Vinyl Pyridine
Potassium Chloride
Potassium Perchlorate

Steel
Sulfur
Sulfur Dioxide

Teflon
Tetraphenyl Boron
Thionyl Chloride

Titanium Disulfide
Vanadium Pentoxide
Zirconium

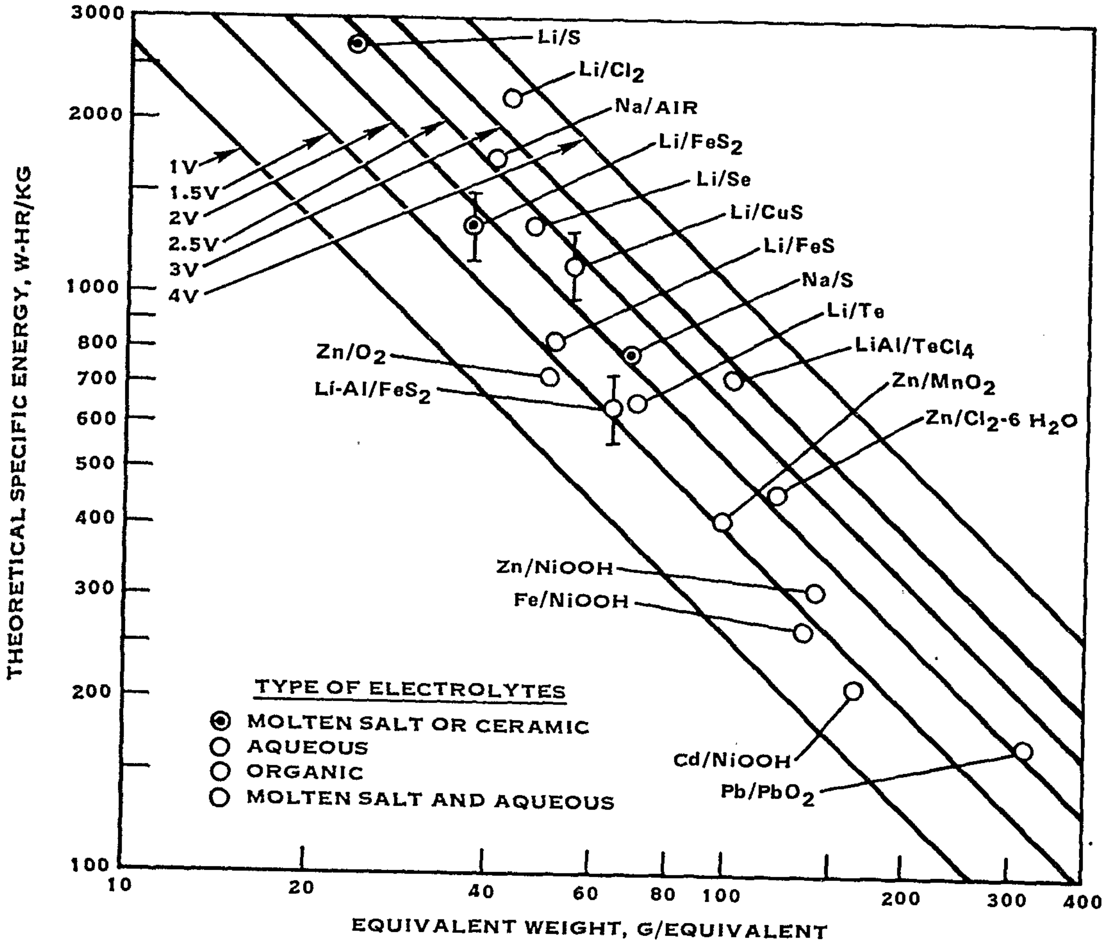


FIGURE III-1
THEORETICAL SPECIFIC ENERGY AS A FUNCTION OF EQUIVALENT WEIGHT AND CELL VOLTAGE FOR VARIOUS ELECTROLYTIC COUPLES

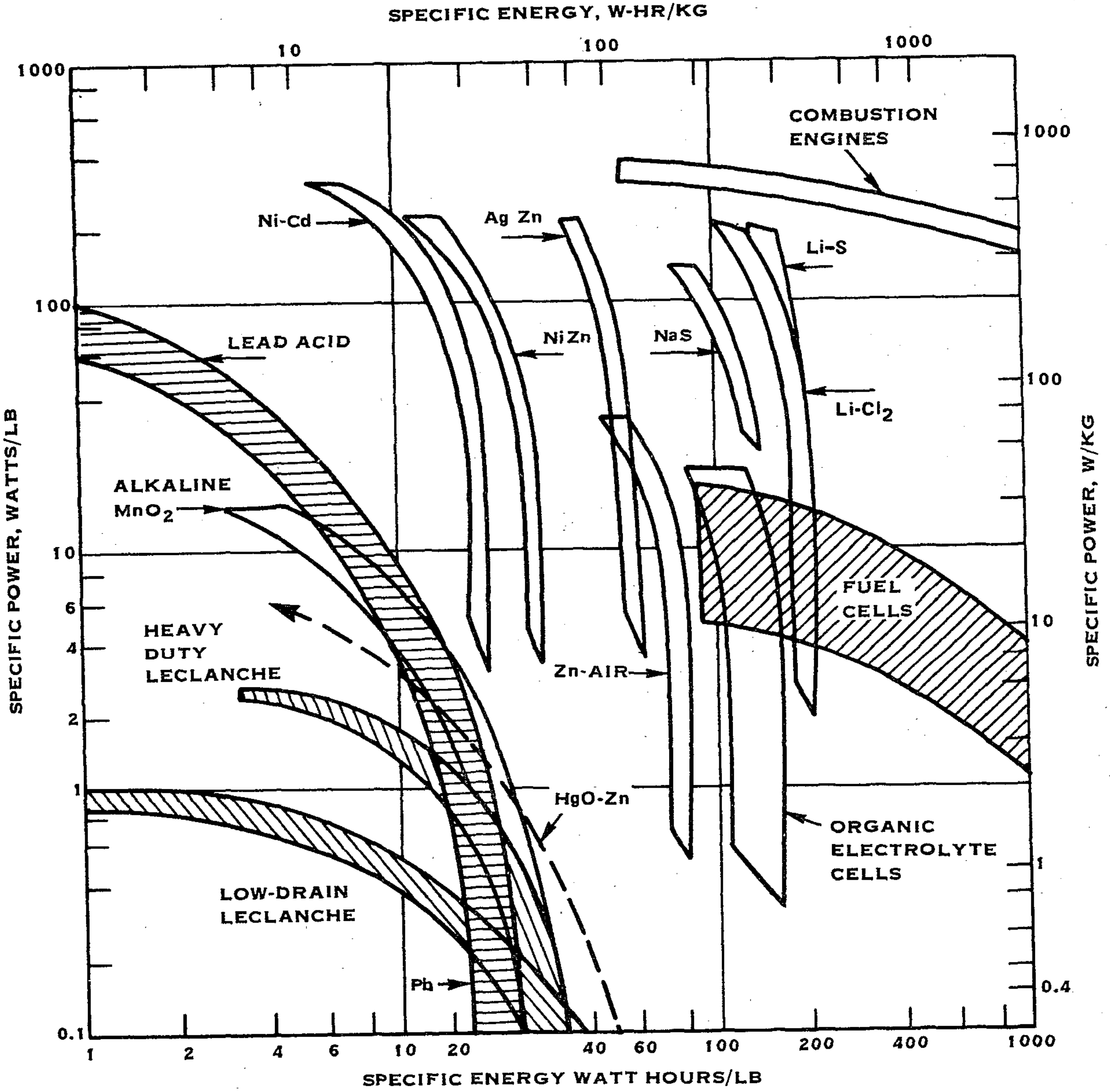


FIGURE III-2
PERFORMANCE CAPABILITY OF VARIOUS BATTERY SYSTEMS

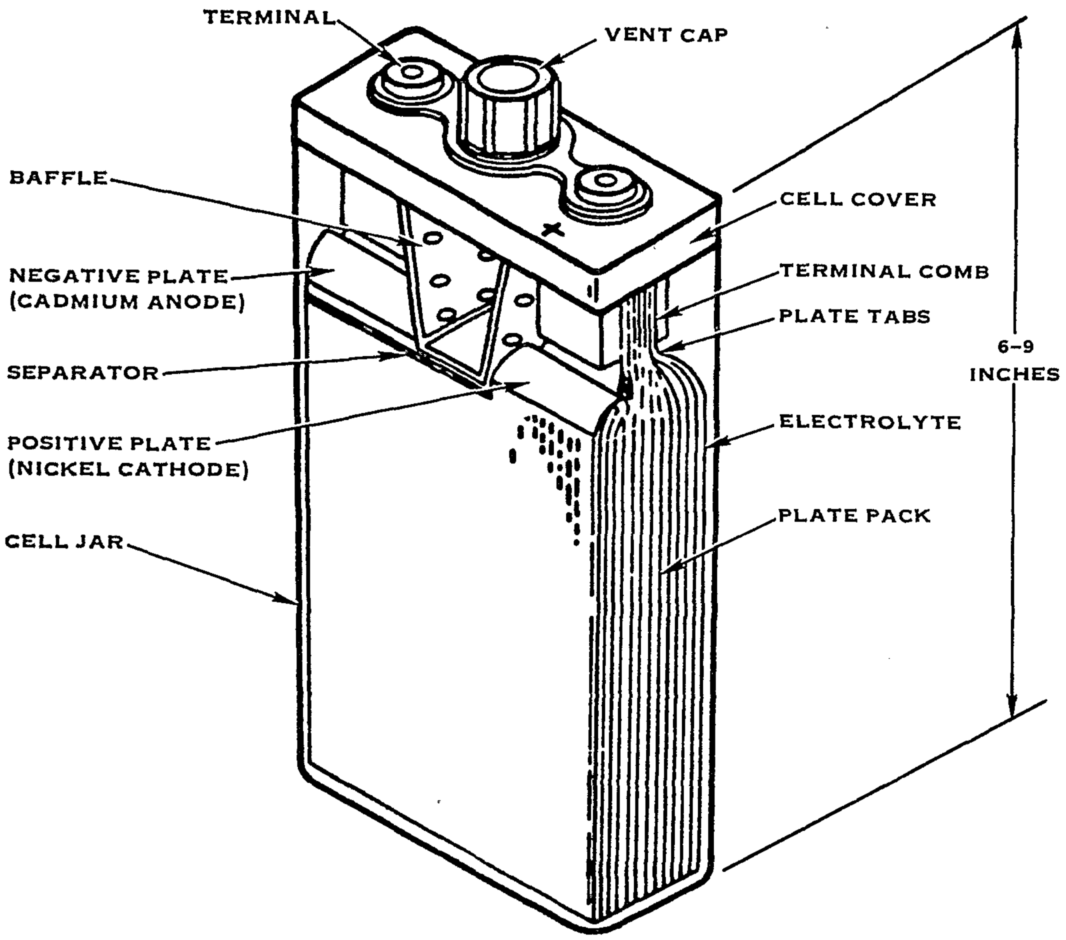


FIGURE III-3
CUTAWAY VIEW OF AN IMPREGNATED SINTERED PLATE NICKEL-CADMIUM CELL
(SIMILAR IN PHYSICAL STRUCTURE TO SOME
SILVER OXIDE-ZINC AND NICKEL-ZINC CELLS)

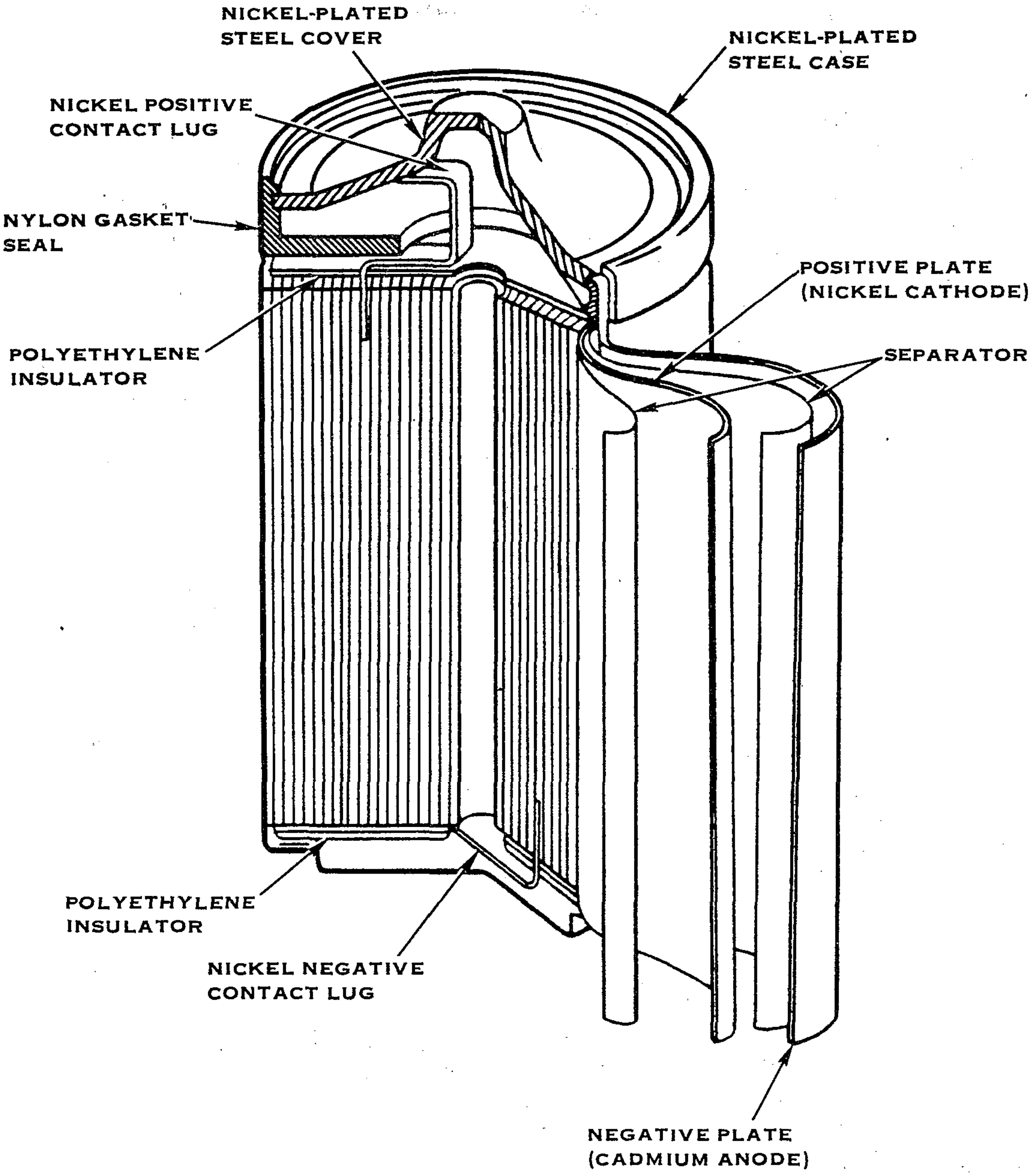


FIGURE III-4
CUTAWAY VIEW OF A CYLINDRICAL NICKEL-CADMIUM BATTERY (SIMILAR IN PHYSICAL STRUCTURE TO CYLINDRICAL LEAD ACID BATTERIES)

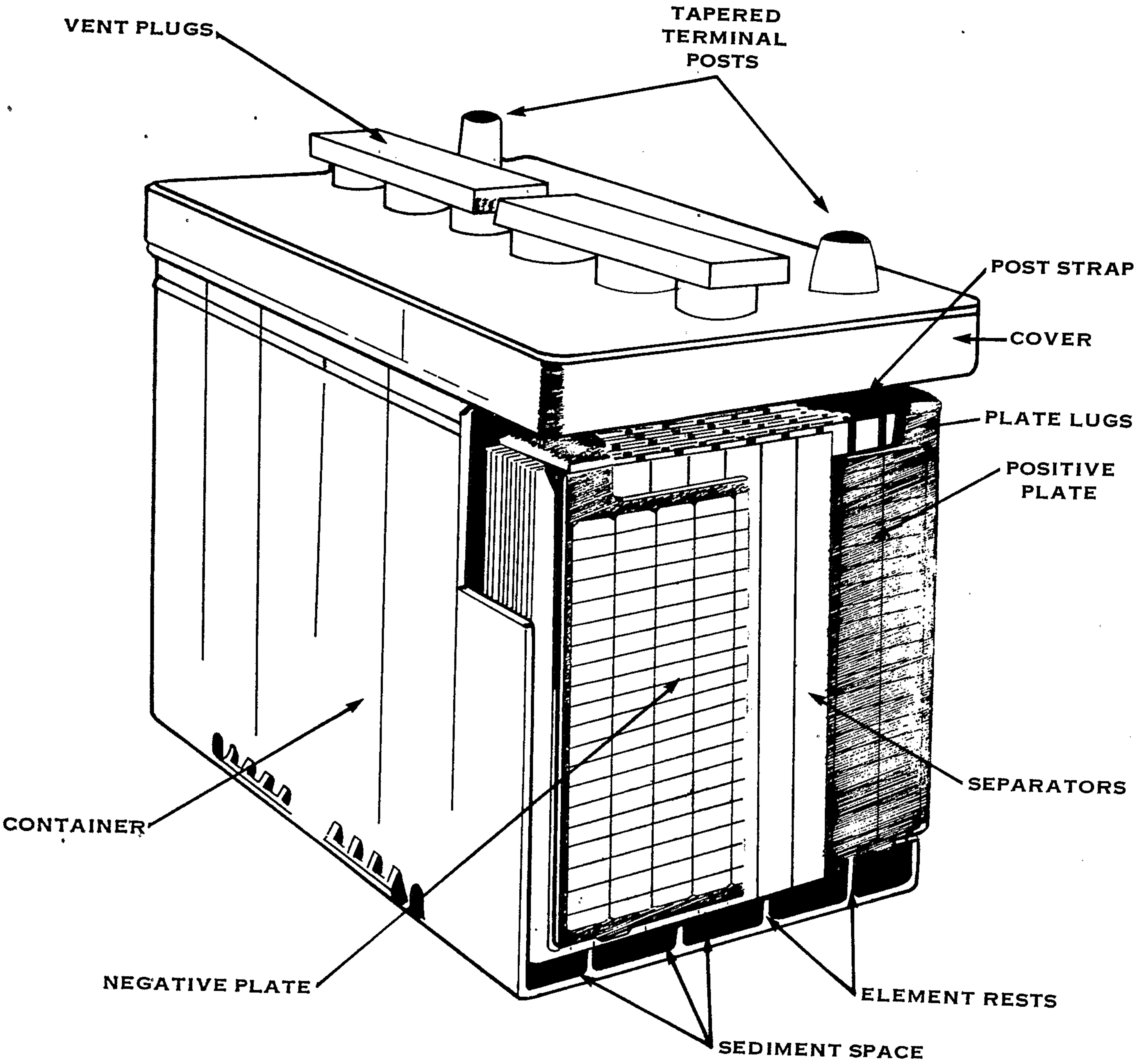


FIGURE III-5
CUTAWAY VIEW OF LEAD ACID STORAGE BATTERY

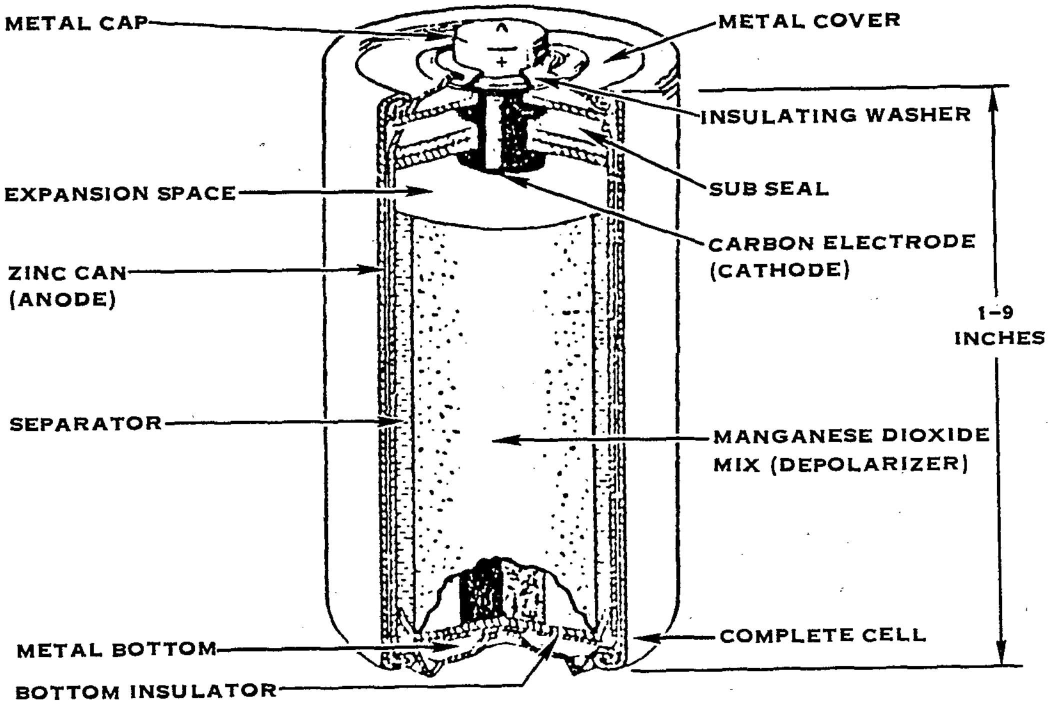


FIGURE III-6
CUTAWAY VIEW OF A CYLINDRICAL LECLANCHE CELL (SIMILAR IN PHYSICAL STRUCTURE TO SOME CARBON-ZINC-AIR AND SILVER CHLORIDE-ZINC DRY CELLS)

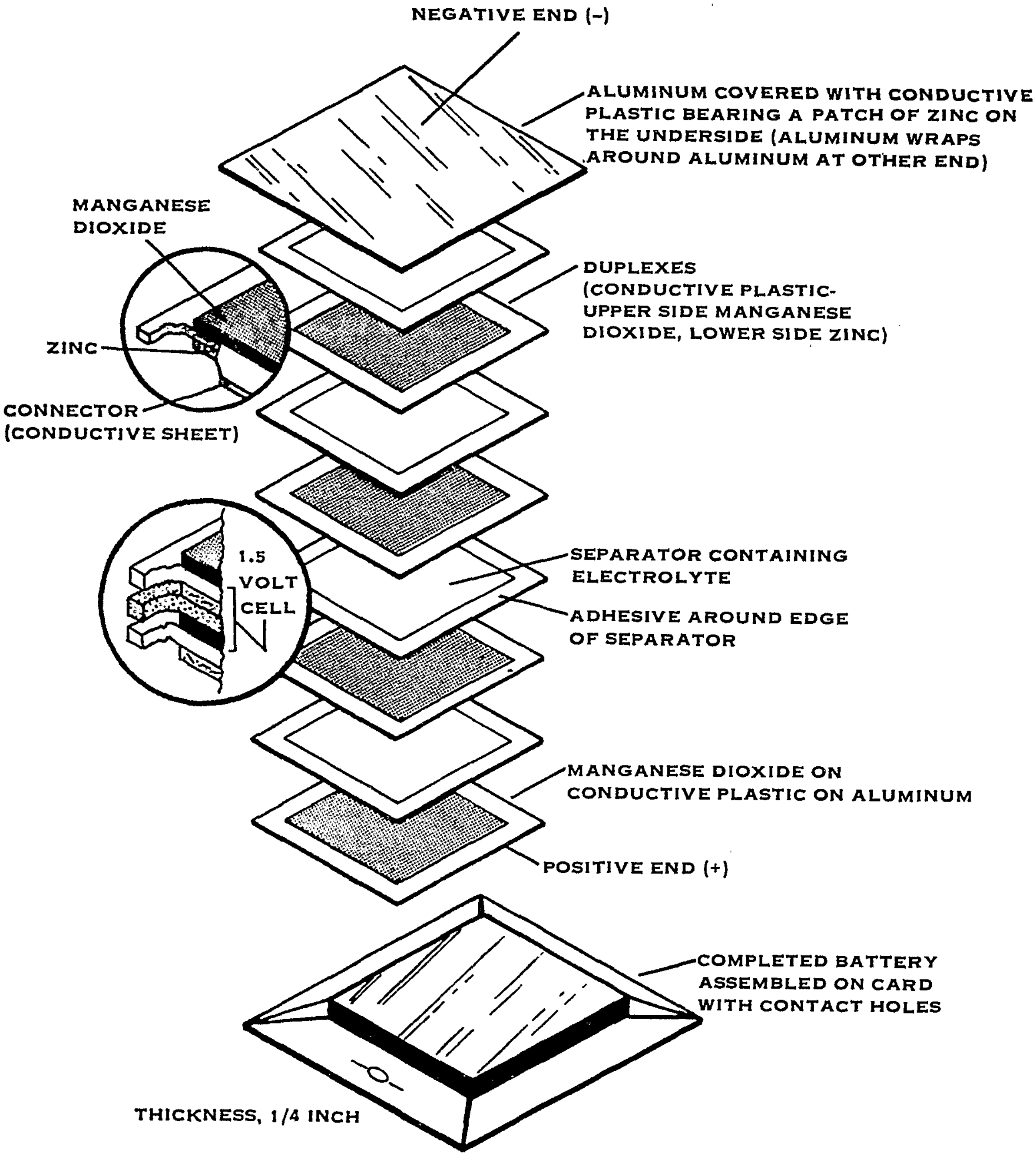
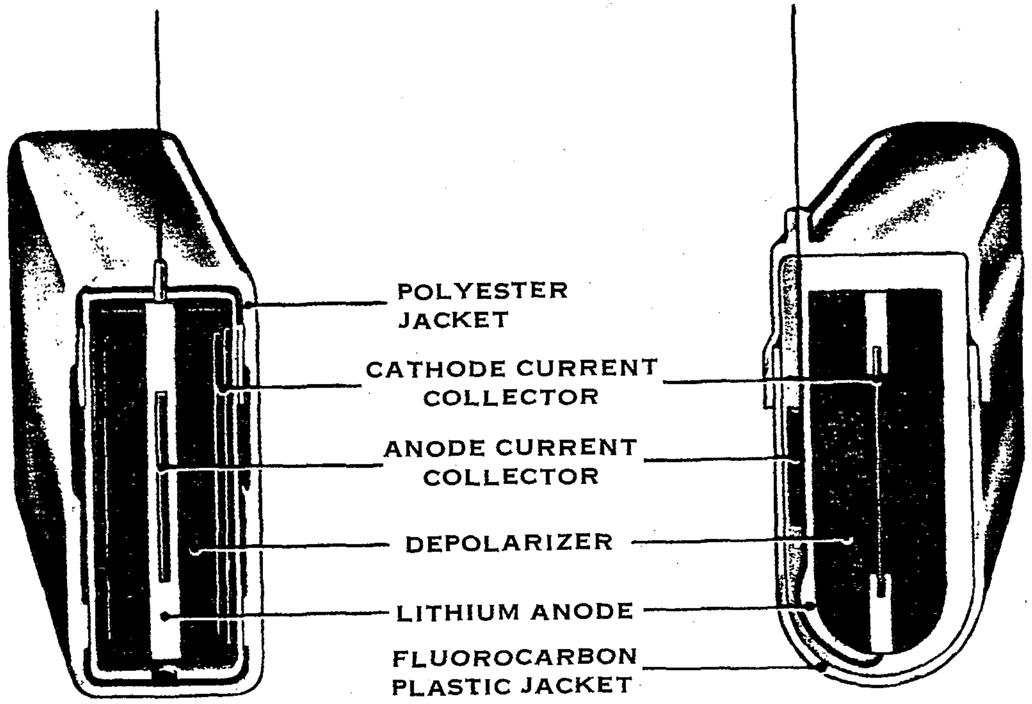


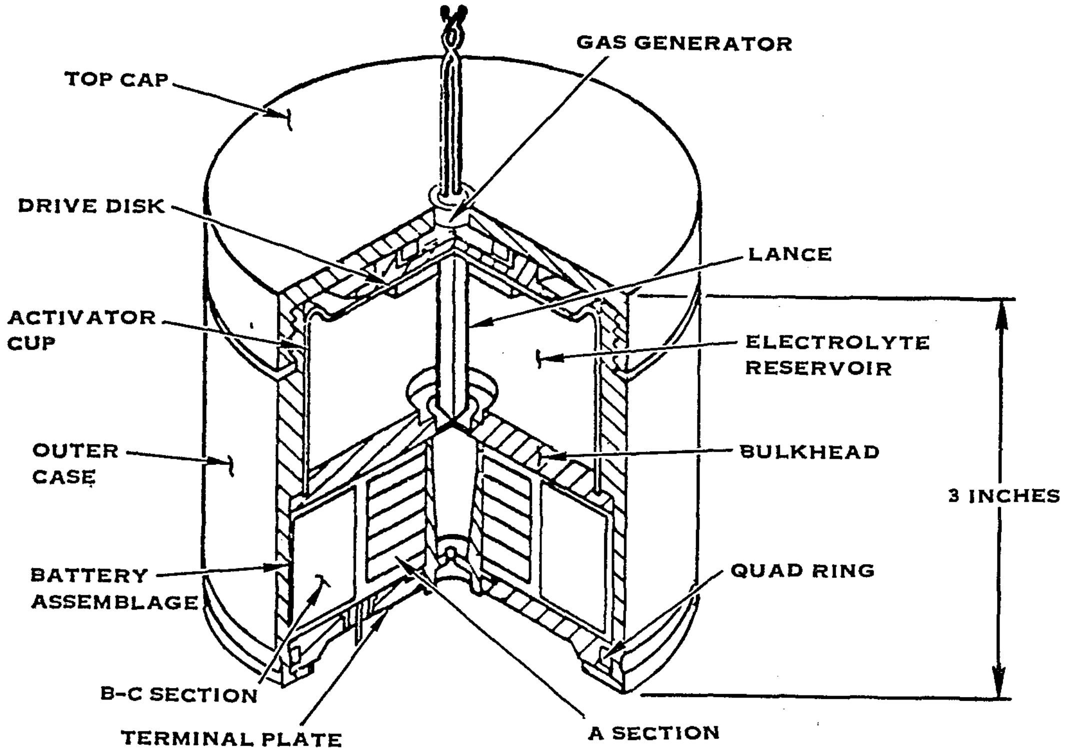
FIGURE III-7
EXPLODED VIEW OF A FOLIAR LECLANCHE BATTERY USED IN FILM PACK



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)

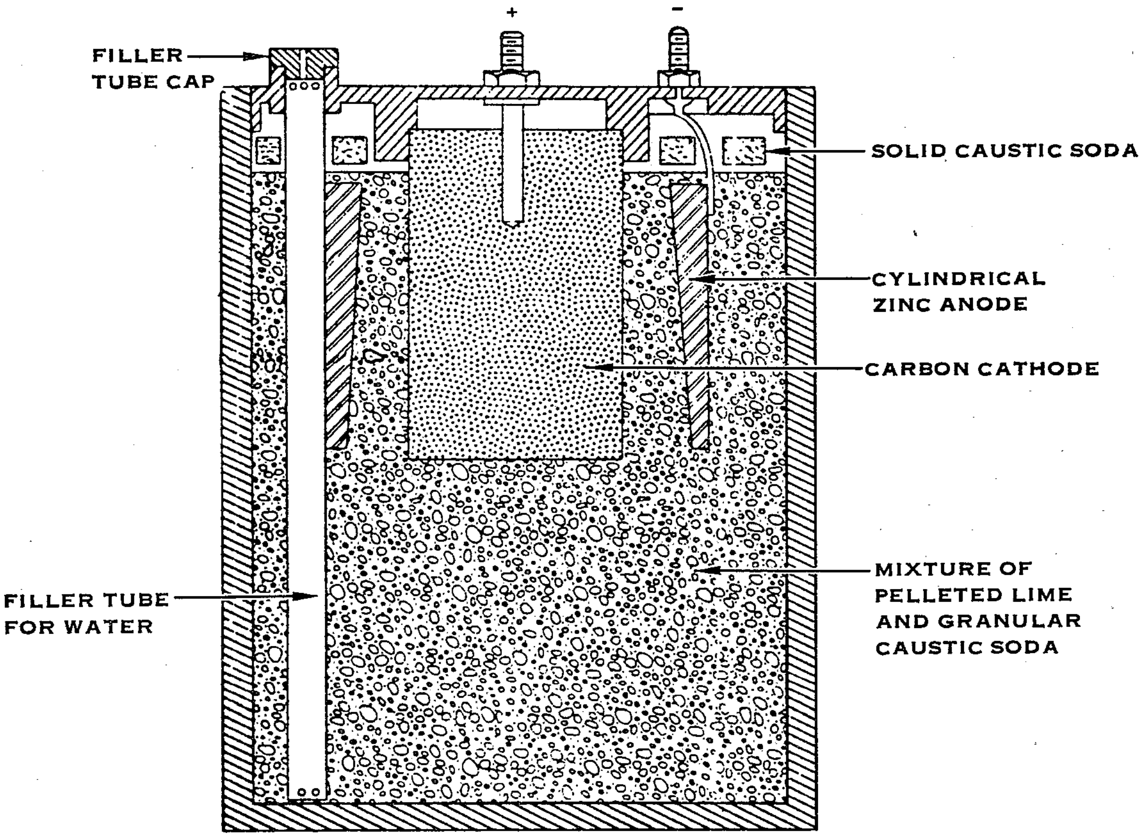


FIGURE III-10
CUTAWAY VIEW OF A CARBON-ZINC-AIR CELL

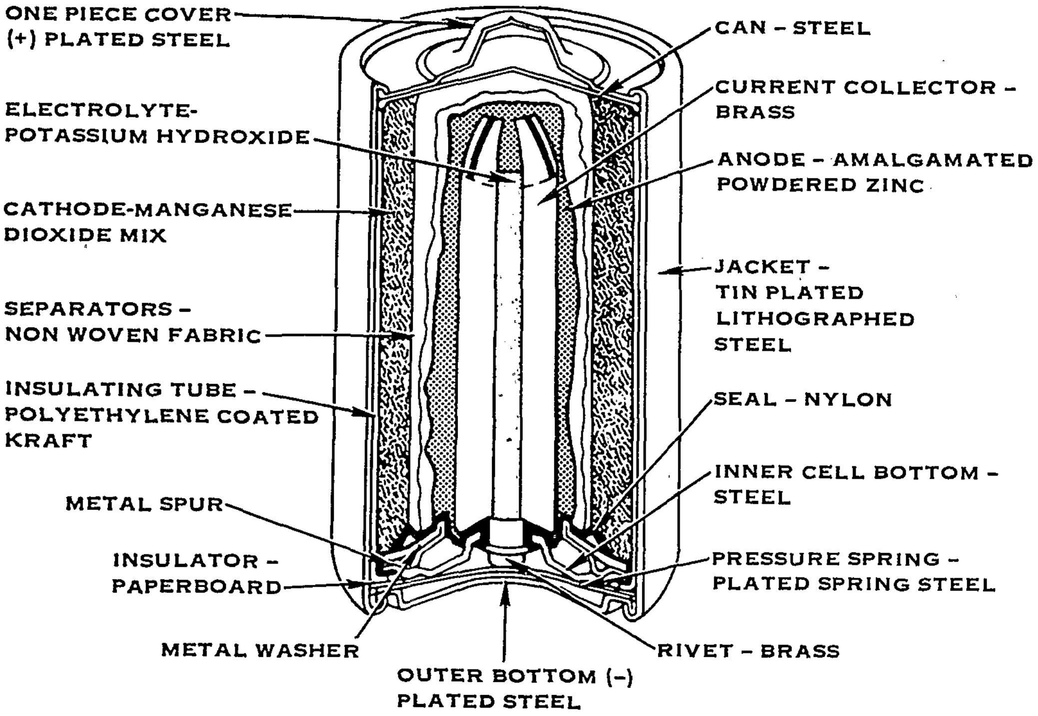


FIGURE III-11
CUTAWAY VIEW OF AN ALKALINE-MANGANESE BATTERY
(SIMILAR IN PHYSICAL STRUCTURE TO CYLINDRICAL
MERCURY-ZINC BATTERIES)

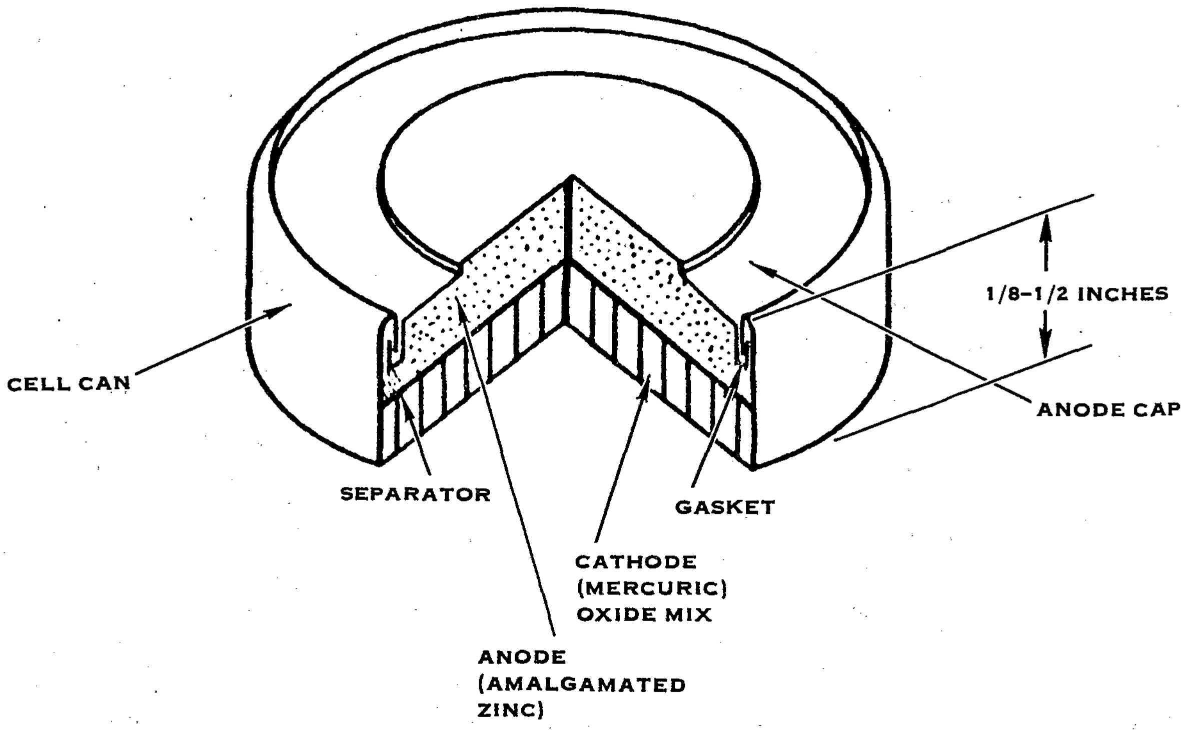


FIGURE III-12
CUTAWAY VIEW OF A MERCURY-ZINC (RUBEN) CELL (SIMILAR IN PHYSICAL STRUCTURE TO ALKALINE-MANGANESE AND SILVER OXIDE-ZINC BUTTON CELLS)

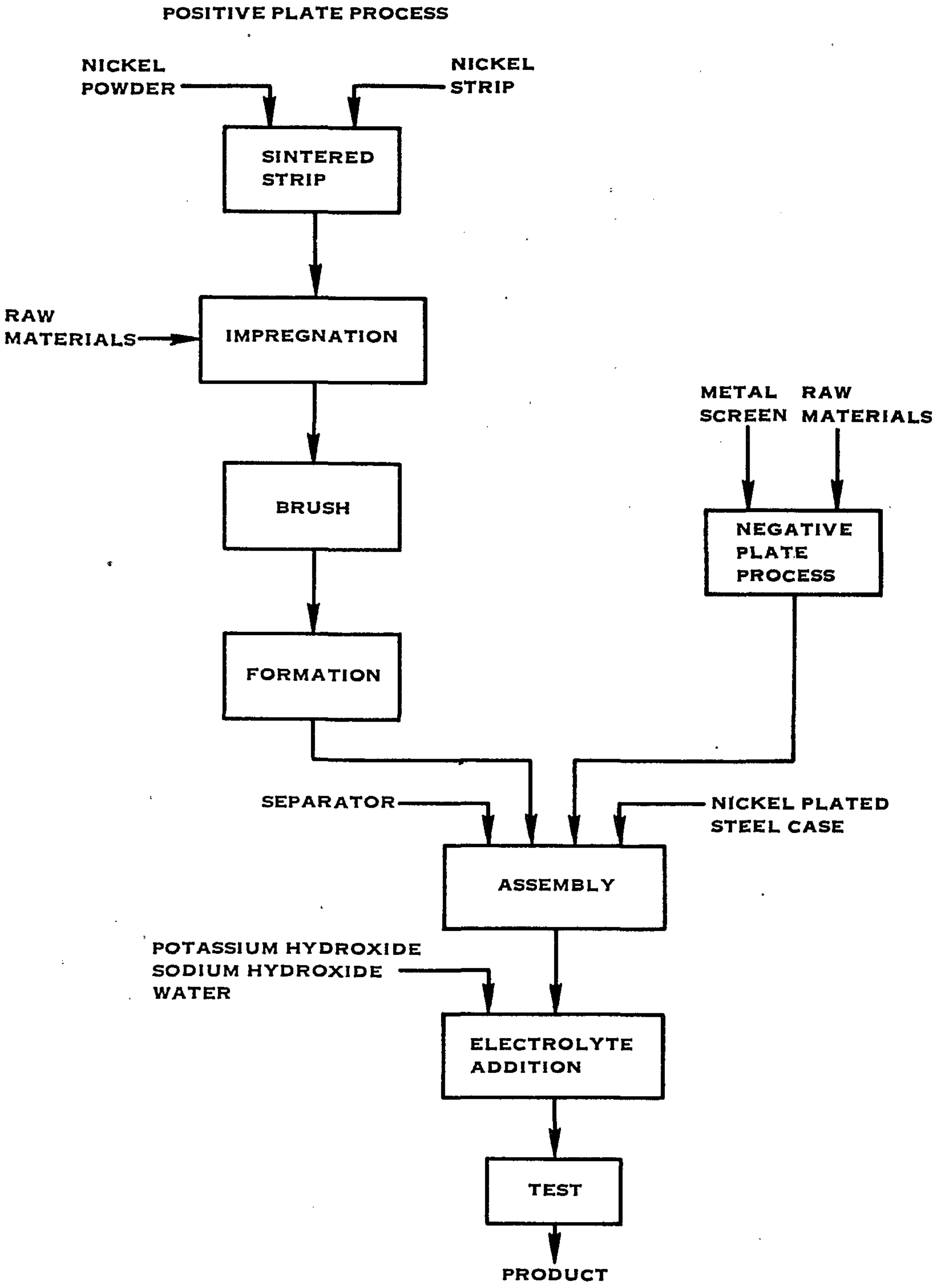


FIGURE III-13
MAJOR PRODUCTION OPERATIONS IN NICKEL-CADMIUM BATTERY MANUFACTURE

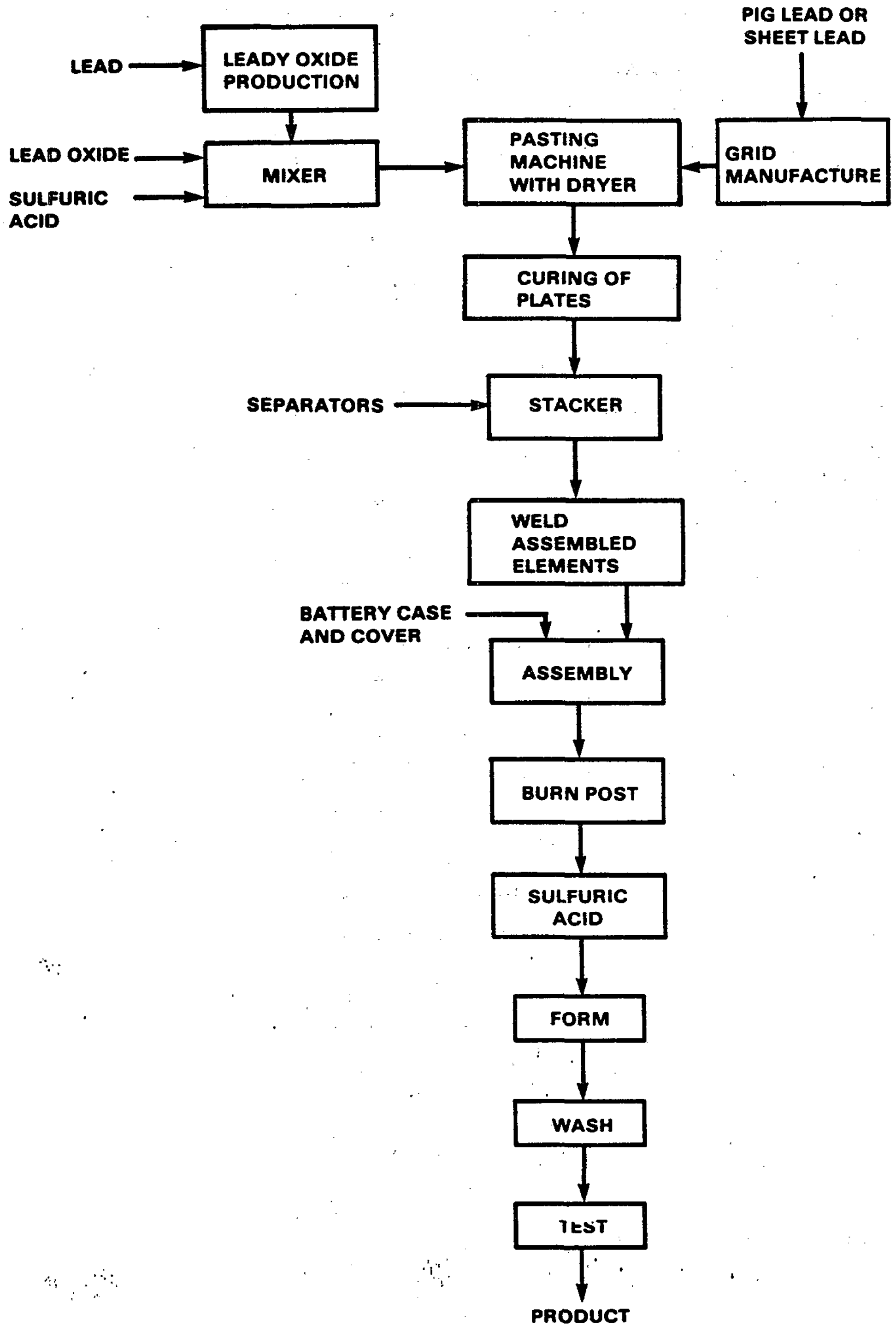


FIGURE III-14
SIMPLIFIED DIAGRAM OF MAJOR PRODUCTION OPERATIONS IN LEAD ACID BATTERY MANUFACTURE

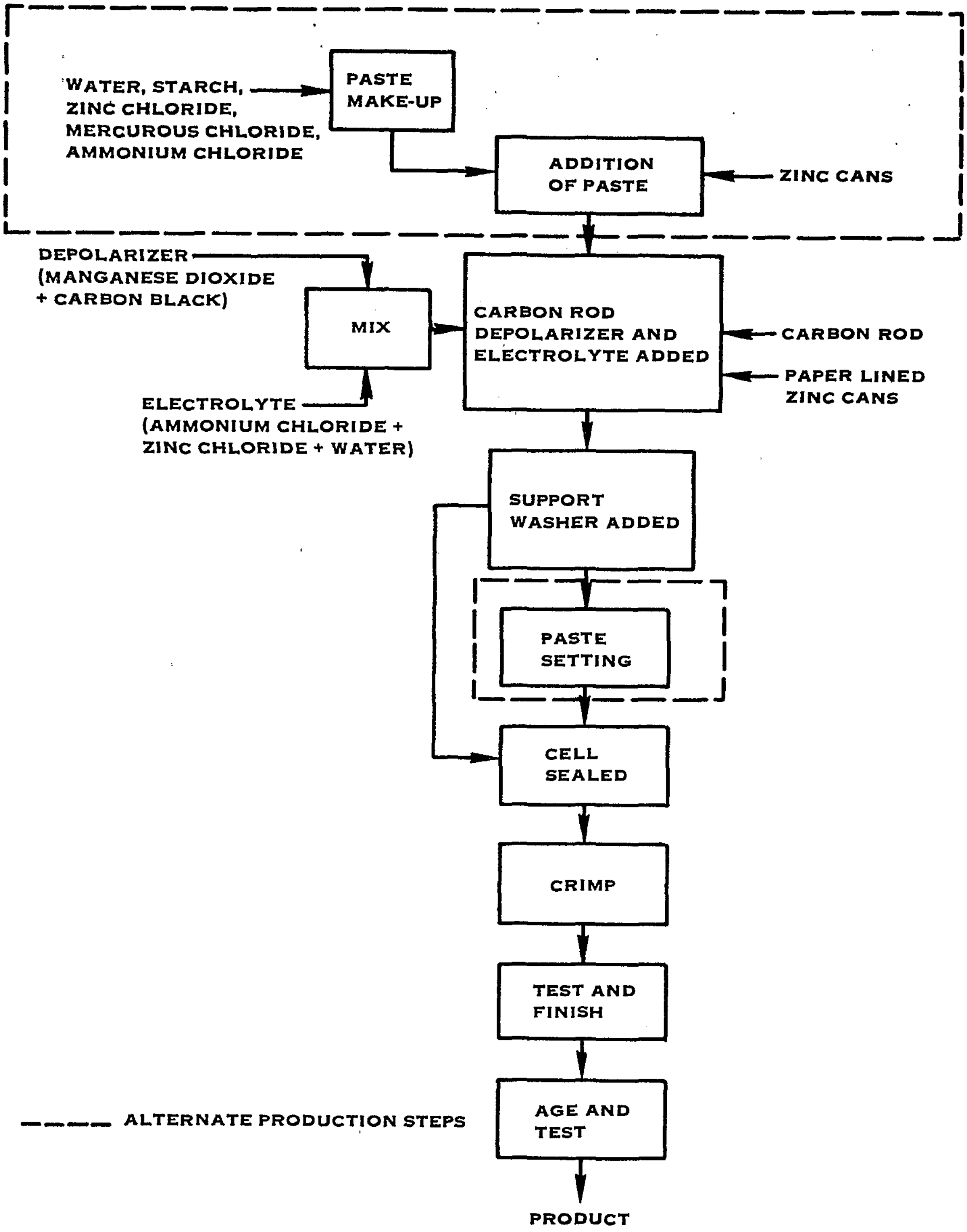


FIGURE III-15
MAJOR PRODUCTION OPERATIONS IN LECLANCHE BATTERY MANUFACTURE

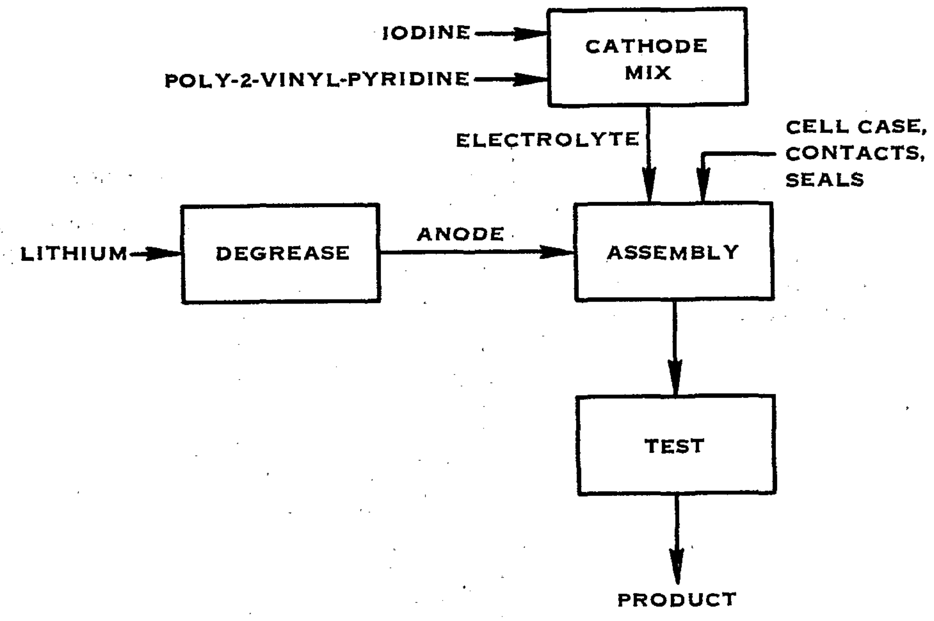


FIGURE III-16
MAJOR PRODUCTION OPERATIONS IN
LITHIUM-IODINE BATTERY MANUFACTURE

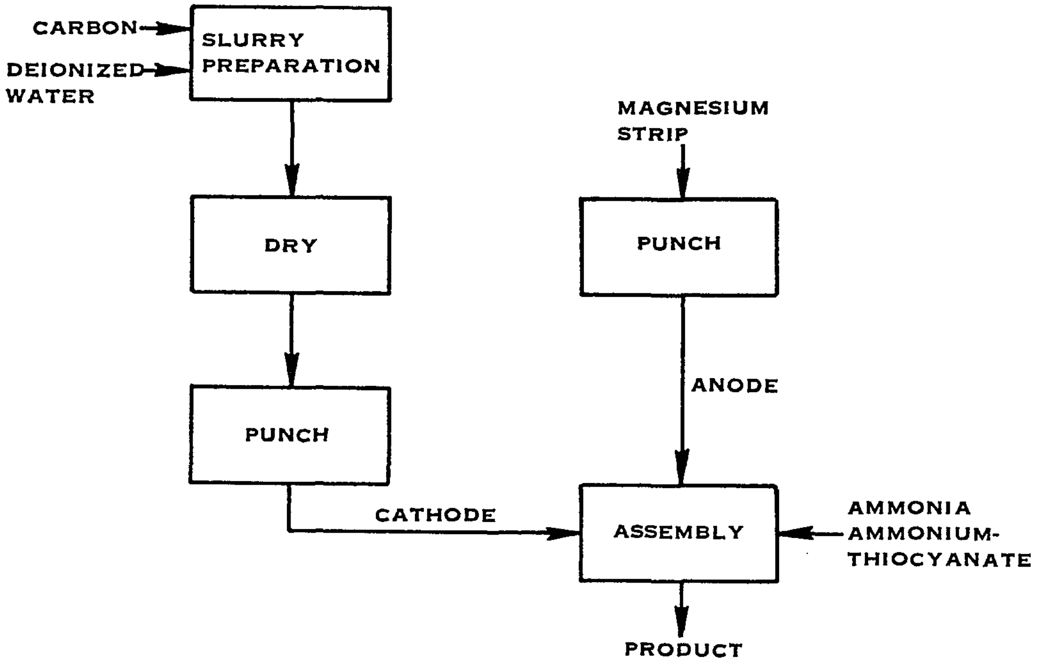


FIGURE III-17
MAJOR PRODUCTION OPERATIONS IN AMMONIA-ACTIVATED MAGNESIUM RESERVE CELL MANUFACTURE

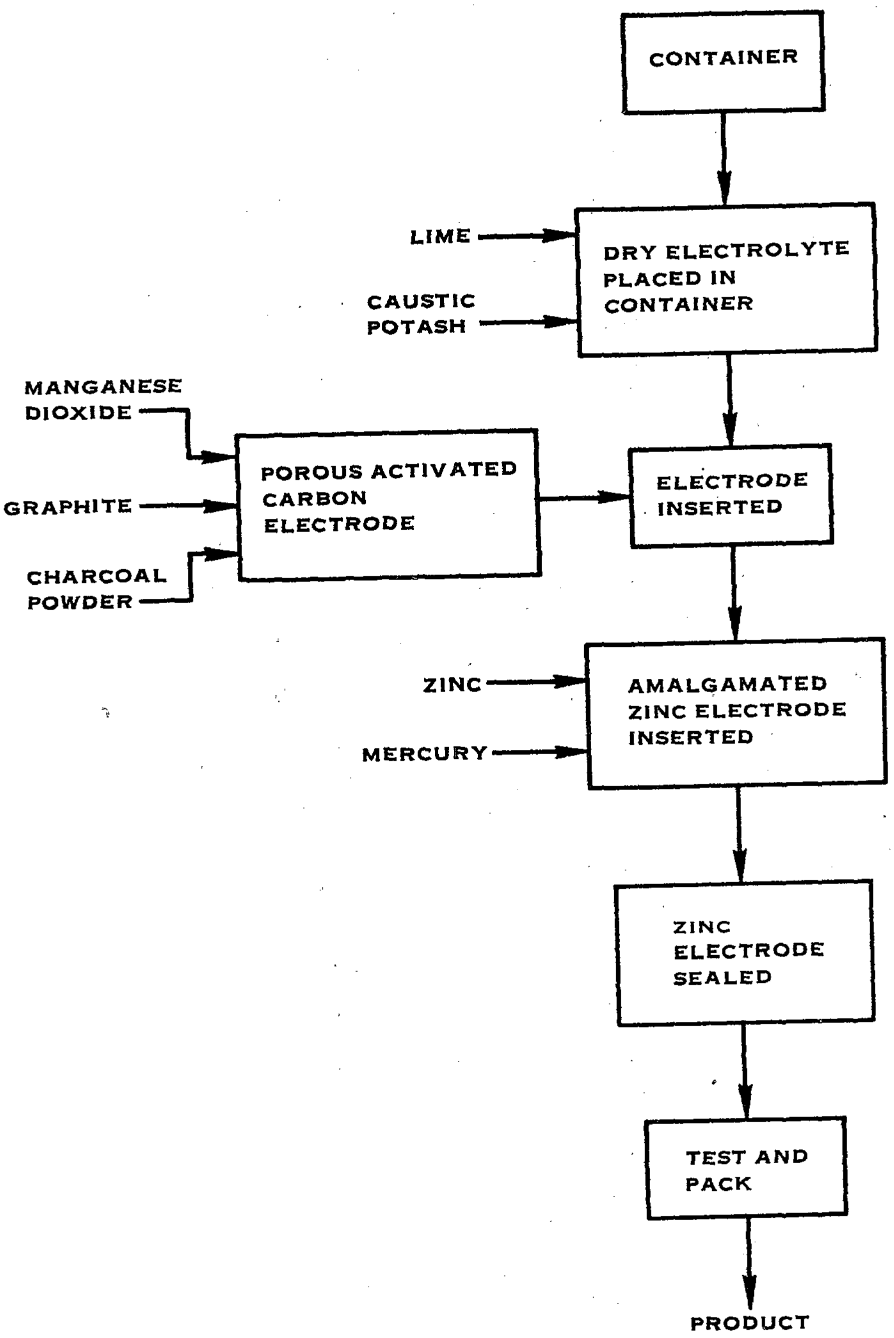


FIGURE III-18
MAJOR PRODUCTION OPERATIONS IN WATER ACTIVATED CARBON-ZINC-AIR CELL MANUFACTURE

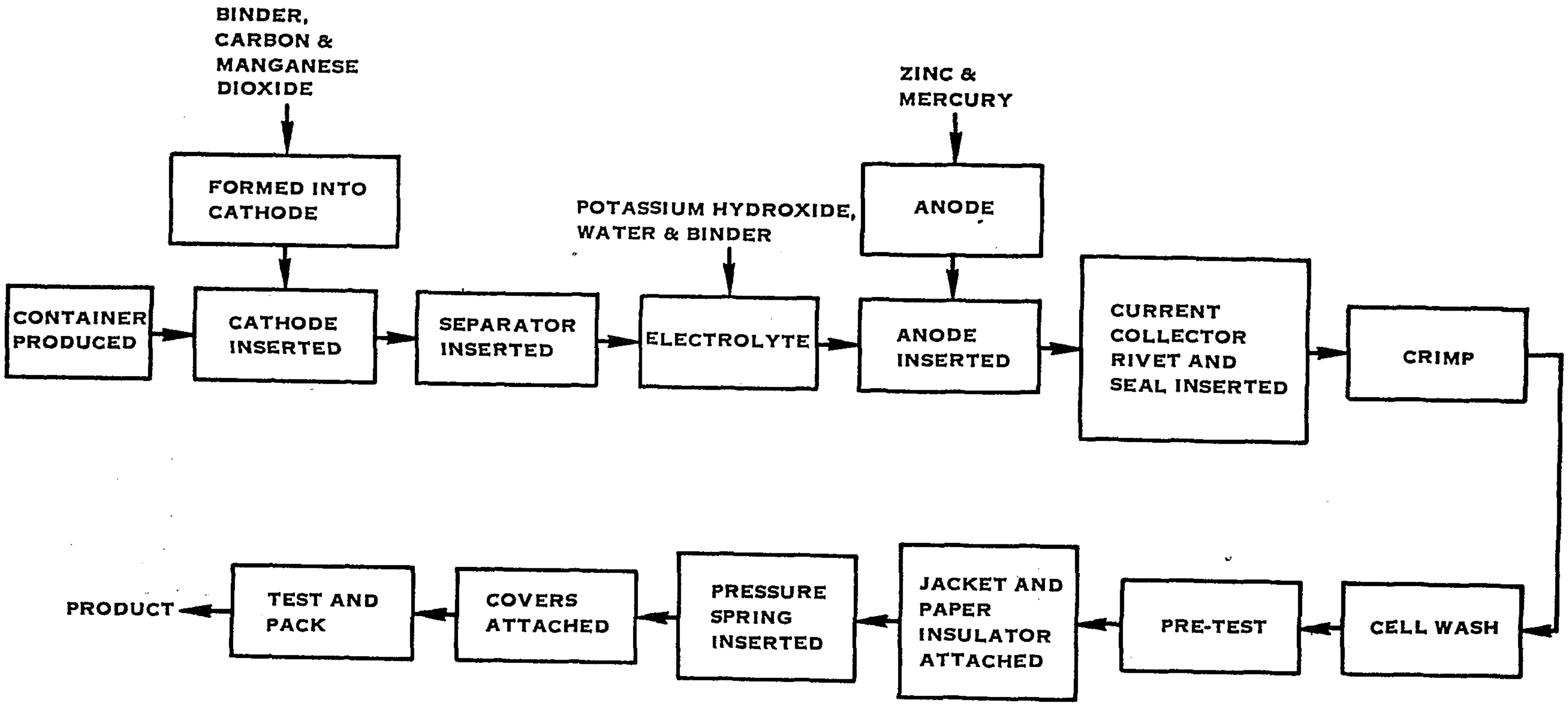


FIGURE III-19
MAJOR PRODUCTION OPERATIONS IN ALKALINE-MANGANESE DIOXIDE BATTERY MANUFACTURE

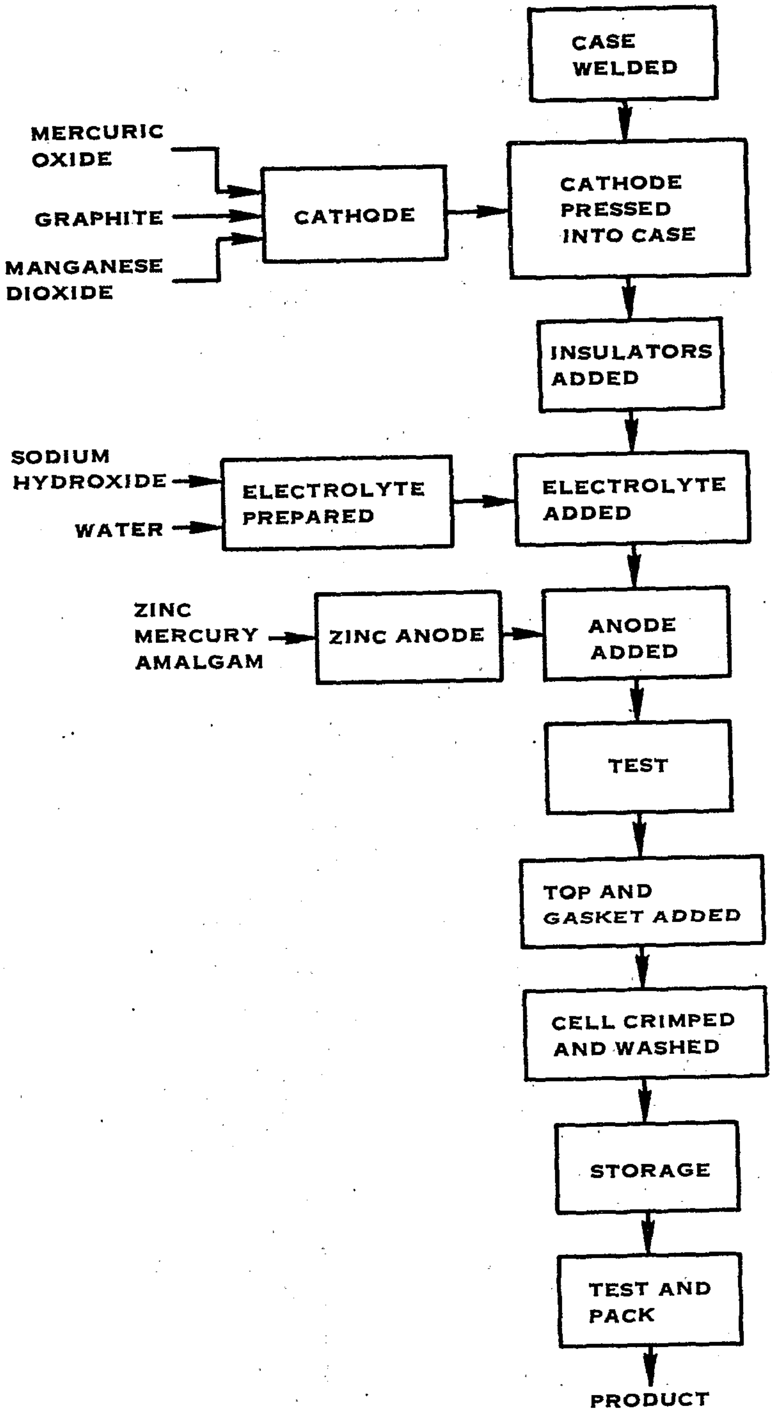
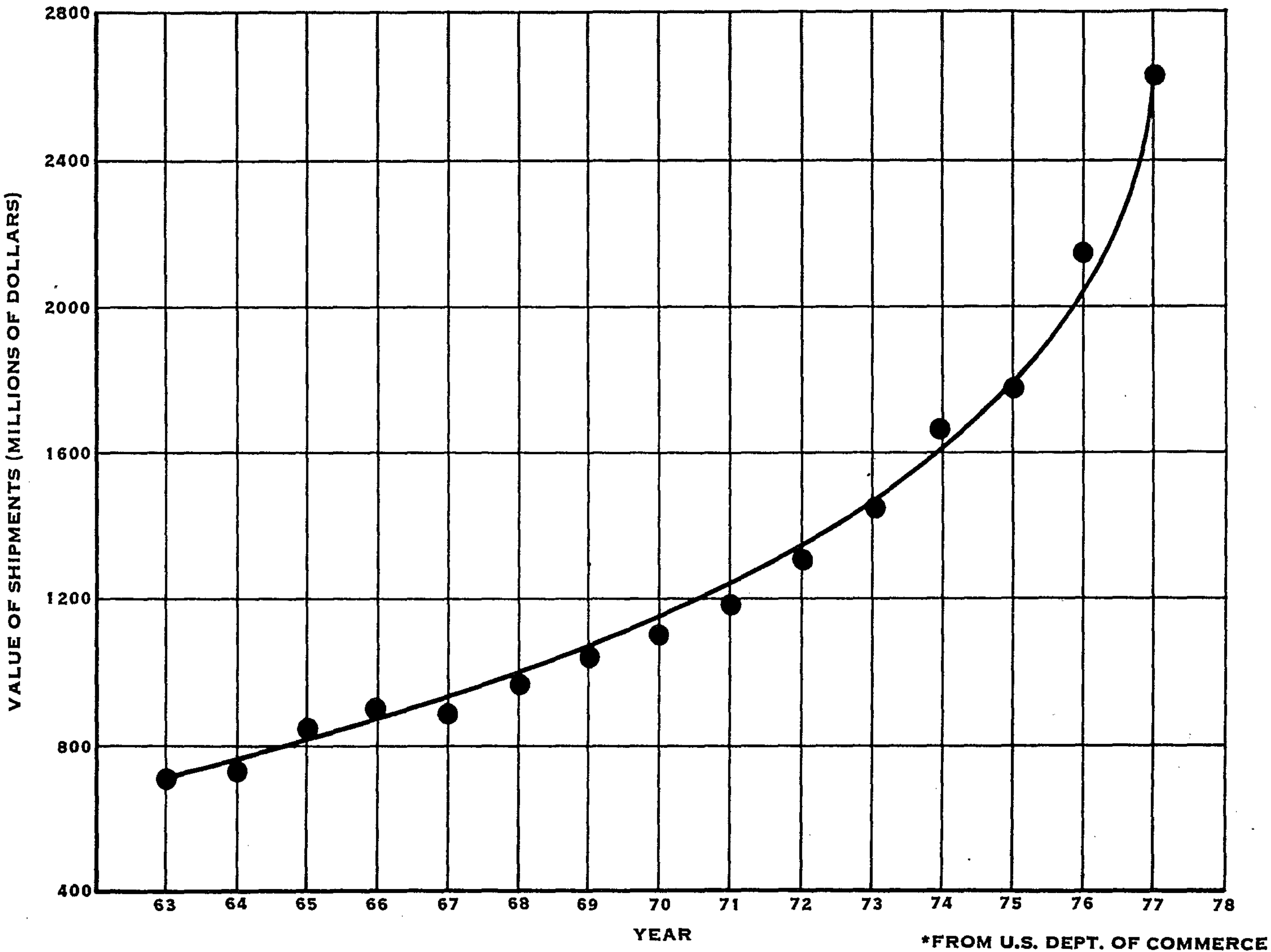


FIGURE III-20
SIMPLIFIED DIAGRAM OF MAJOR OPERATIONS IN MERCURY-ZINC (RUBEN) BATTERY MANUFACTURE



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

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

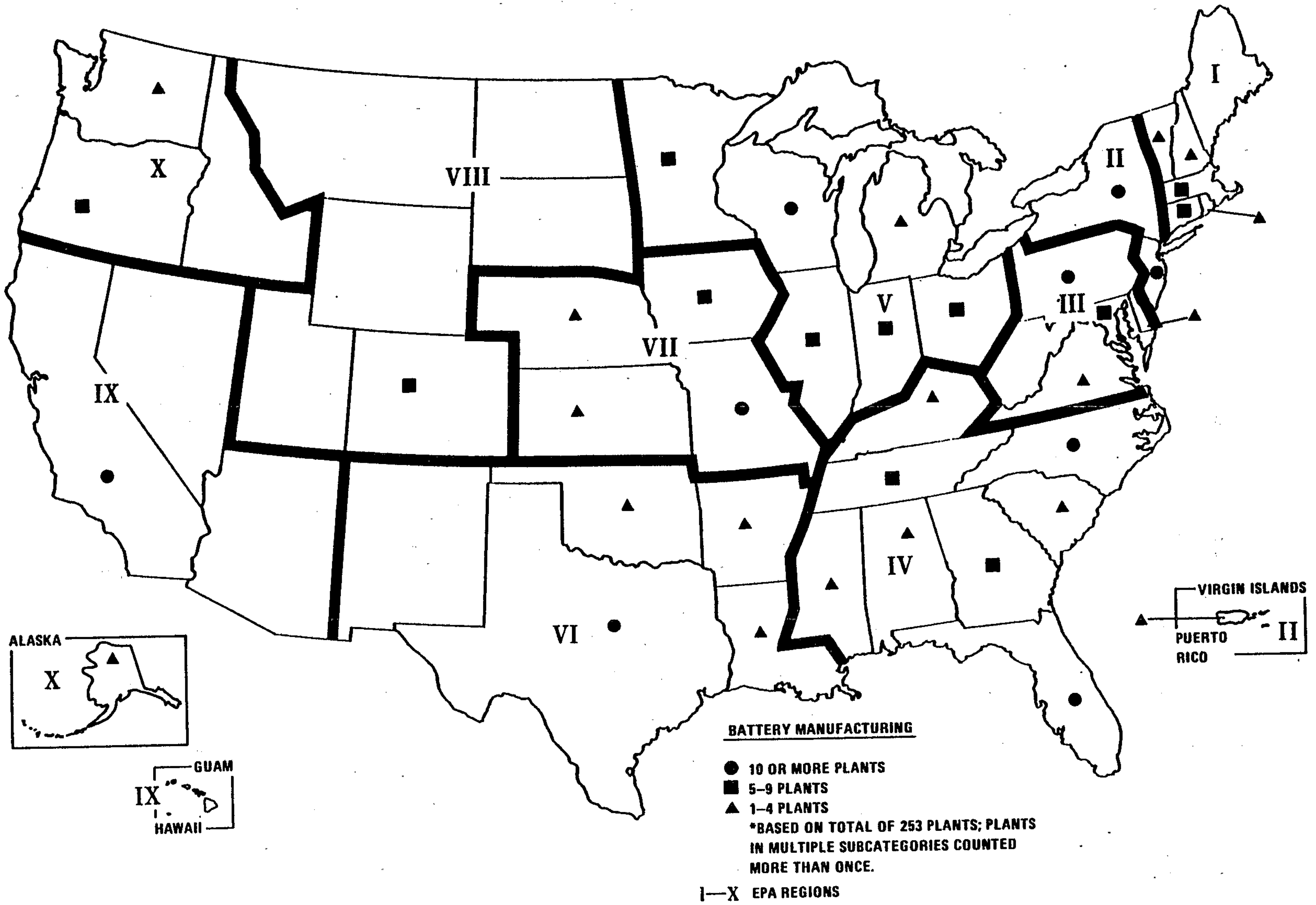


FIGURE III – 22
GEOGRAPHICAL REGIONAL DISTRIBUTION OF BATTERY MANUFACTURING PLANTS

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. 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. Nonwater Quality Environmental Aspects
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 and standards 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.

Nonwater Quality Environmental Aspects - Nonwater quality environmental 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. The determination was made that further breakdown of the original battery type subcategories would be required to encompass existing and possible manufacturing 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 limitations 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. The lead subcategory is discussed specifically in Volume II of the Development Document for Effluent Limitations Guidelines and Standards for the Battery Manufacturing Point Source Category.

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 157). 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 will be discussed in Section V. Each significant battery manufacturing process or production function is called an element in this document. For example, in the cadmium subcategory, a nickel cathode can be produced 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 led to the adoption of the above subcategorization approach is presented in the discussion of process wastewater sources and characteristics in Section V of this document.

FINAL SUBCATEGORIES AND PRODUCTION NORMALIZING PARAMETERS

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

- Cadmium
- Calcium
- Leclanche
- Lithium
- Magnesium
- Nuclear
- Zinc

Specific elements within each subcategory and corresponding production normalizing parameters are summarized in Table IV-1 (page 154). Selection of each production normalizing parameter is discussed within each subcategory discussion.

Cadmium Subcategory

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

Characteristics of each of the process elements discussed above resulted in the selection of production normalizing parameters. It was necessary to select specific production normalizing parameters for each process element because production activity areas in different elements was not found to be reliably related on a day-to-day basis at some plants. The selected parameters, cadmium in the anode, active metal in the cathode, and total cell weight for ancillary operations (except for chemical powder production which is weight of metal in the powder produced or weight of metal used) correspond with the available production data and water use in the process operations addressed.

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

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

1. the use of battery weight for all operations
2. electrode surface area
3. total electrode weight
4. battery electrical capacity
5. number of employees

Total battery weight was found to be readily available from most manufacturers, and was initially considered a logical choice for the production normalizing parameter for these plants. This parameter would have allowed the use of a single parameter for all waste sources in a plant, potentially simplifying the application and enforcement of effluent limitations. Following plant visits, it became evident, however, that production patterns at some plants would render this production normalizing parameter inapplicable, and that production variations resulted in significant variability between production activity in the major wastewater producing operations and the weight of batteries ultimately shipped. Some plants were identified which produced cell electrodes but did not produce finished batteries, and others indicated the production of finished batteries from electrodes processed at other locations. For such plants the battery weight production normalizing parameter is clearly inapplicable to the determination of wastewater discharges from electrode manufacturing operations. Batteries are produced in this subcategory for a wide range of applications and in many different configurations. As a result, the ratio of battery weight to the weight of reactive materials contained by the battery varies significantly. Since the most significant water use and wastewater discharge is associated with the reactive materials, the use of battery weight as a production normalizing parameter for all operations would not result in uniform application of effluent limitations and standards to plants in this subcategory.

Since most of the wastewater discharge volume associated with electrode production results from depositing materials on or removing impurities from electrode surfaces, electrode surface area was considered a possible choice as the production normalizing parameter for these operations. Significant difficulty is encountered in defining the surface area, however, and data were not 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.

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

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 materials is the major source of process wastewater for most cell types. It was not, however, considered a viable production normalizing parameter for use in this study because electrical capacity data were not obtained.

Because the degree of process automation at battery manufacturing plants was observed to vary, the number of production employees was not found to be generally suitable as a production normalizing parameter. Although the number of employees would be a suitable basis for limiting discharges from employee showers and hand washes, battery weight was chosen instead to achieve uniformity with other ancillary wastewater sources and to minimize the number of production normalizing parameters to be applied.

Calcium Subcategory

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

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

Leclanche Subcategory

The Leclanche dry cell uses an amalgamated zinc anode, a carbon cathode with manganese dioxide depolarizer, and ammonium chloride and zinc chloride electrolyte. Batteries manufactured in this subcategory use zinc anodes and acid chloride electrolytes. Most also use manganese dioxide as the cell depolarizer although cells using atmospheric oxygen and silver chloride depolarizers are also included in this subcategory. All of these cells are produced in manufacturing processes in which water use is limited, and the volume of process wastewater produced is small.

In addition to equipment wash and cleaning operations, significant product and process variations within the subcategory include:

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

- Cathode Material
  - Manganese-dioxide and carbon
  - Silver chloride

- Cell Separator

- Paste
    - Cooked
    - Uncooked
- Pasted Paper
    - With Mercury
    - Without Mercury

Amalgamation
- Mercury in electrolyte
- Mercury in separator

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

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

Lithium Subcategory

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

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

Magnesium Subcategory

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

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

Nuclear Subcategory

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

Zinc Subcategory

Batteries produced in this subcategory have an amalgamated zinc anode and a sodium or potassium hydroxide electrolyte. Cells using ten different depolarizer combinations are presently produced within the subcategory in a wide variety of cell configurations and sizes. Zinc anodes for these cells are produced in seven distinct processes, but anodes produced by each process are typically combined with several different types of cathodes, and anodes produced by two or more different processes are commonly used with a given depolarizer.

The weight of reactive material contained in the electrode was found to be the best production normalizing parameter for anode and cathode manufacturing processes. For most ancillary operations, which are usually associated with cell assemblies or with general plant production activity, the production normalizing parameter is the total weight of batteries produced.

For one ancillary operation where the etching of silver foil is used as a substrate for zinc anodes, the weight of silver foil used for etching is chosen as the production normalizing parameter. The use of this parameter rather than total battery weight is necessary because not all batteries at any given plant are produced using etched foil. The volume of wastewater from this operation will therefore not be directly related to the total product weight. For silver powder production, the weight of silver powder produced is used as the production normalizing parameter, and for silver peroxide powder production, the weight of silver powder used is the production normalizing parameter.

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

OPERATIONS COVERED UNDER OTHER CATEGORIES

Many battery plants perform processes on-site which are not unique to battery manufacturing and which are addressed in effluent limitations and standards for other industrial categories. These have been identified in Table IV-2 (page 156). Below, they are generally discussed in reference to all the subcategories. Specific operations are discussed in Section V.

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

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

TABLE IV-1 SUBCATEGORY ELEMENTS AND PRODUCTION NORMALIZING PARAMETERS (PNP)

SUBCATEGORY		ELEMENT	PNP
Cadmium	Anodes	Pasted and Pressed Powder Electrodeposited Impregnated	Weight of Cadmium in Anode
	Cathodes	Silver Powder Pressed	Weight of Silver in Cathode
		Mercuric Oxide Powder Pressed	Weight of Mercury in Cathode
		Nickel Pressed Powder Nickel Electrodeposited Nickel Impregnated	Weight of Nickel Applied
	Ancillary	Cell Wash Electrolyte Preparation Floor and Equipment Wash Employee Wash	Weight of Cells Produced
		Cadmium Powder Production	Weight of Cadmium Powder Produced
		Silver Powder Production	Weight of Silver Powder Produced
		Cadmium Hydroxide Production	Weight of Cadmium Used
		Nickel Hydroxide Production	Weight of Nickel Used
Calcium	Anodes	Vapor Deposited Fabricated	Weight of Calcium Used
	Cathodes	Calcium Chromate Tungstic Oxide Potassium Dichromate	Weight of Reactive Material
	Ancillary	Heating Component Production Heat Paper Heat Pellet	Total Weight of Reactants
		Cell Testing	Weight of Cells Produced
		Plating	NA
Leclanche	Anodes	Zinc Powder	Weight of Cells Produced
		Sheet zinc stamped drawn fabricated	NA
	Cathodes	Manganese Dioxide-Pressed -electrolyte without mercury -electrolyte with mercury -gelled electrolyte with mercury Pasted Manganese Dioxide Carbon (Porous) Silver Chloride	Weight of Cells Produced
	Ancillary	Separator Cooked Paste Separator Uncooked Paste	Weight of Cells Produced
		Separator Pasted Paper with mercury	Weight of Dry Pasted Material
		Separator Pasted Paper w/o mercury	NA
		Equipment and Area Cleanup Foliar Battery Miscellaneous Wash	Weight of Cells Produced

TABLE IV-1 SUBCATEGORY ELEMENTS AND PRODUCTION NORMALIZING PARAMETERS (PNP)

SUBCATEGORY		ELEMENT	PNP
Lithium	Anodes	Formed and Stamped	Weight of Lithium
	Cathodes	Sulfur Dioxide Iodine Iron Disulfide Lithium Perchlorate Titanium Disulfide Thionyl Chloride Lead Iodide	Weight of Reactive Material
	Ancillary	Heating Component Production Heat Paper Heat Pellets	Weight of Reactants
		Lithium Scrap Disposal Cell Testing Cell Wash Floor and Equipment Wash Air Scrubbers	Weight of Cells Produced
Magnesium	Anodes	Sheet Magnesium stamped formed fabricated	NA
		Magnesium Powder	Weight of Magnesium Used
	Cathodes	Silver Chloride – Chemically Reduced Silver Chloride – *Electrolytic* Copper Chloride Copper Iodide Lead Chloride Silver Chloride Vanadium Pentoxide Carbon M-Dinitrobenzene	Weight of Depolarizer Material
	Ancillary	Heating Component Production Heat Paper Heat Pellets	Weight of Reactants
		Cell Testing Separator Processing Floor and Equipment Wash Air Scrubbers	Weight of Cells Produced
Zinc	Anodes	Cast or Fabricated Zinc Powder – Wet Amalgamated Zinc Powder – Gelled Amalgam Zinc Powder – Dry Amalgamated Zinc Oxide Powder – Pasted or Pressed Zinc Oxide Powder – Pasted or Pressed, Reduced	Weight of Zinc Used
		Zinc Electrodeposited	Weight of Zinc Deposited
	Cathodes	Porous Carbon	Weight of Carbon
		Manganese Dioxide – Carbon	Weight of Manganese Dioxide
		Mercuric Oxide (and mercuric oxide – manganese dioxide carbon)	Weight of Mercury
		Mercuric Oxide – Cadmium Oxide	Weight of Mercury and Cadmium
		Silver Powder Pressed Silver Powder Pressed and Electrolytically Oxidized (Formed) *Silver Oxide* Powder – Thermally Reduced or Sintered, Electrolytically Formed Silver Oxide Powder Silver Peroxide Powder	Weight of Silver Applied
		Nickel Impregnated and Formed	Weight of Nickel Applied
	Ancillary	Cell Wash Electrolyte Preparation Mandatory Employee Wash Reject Cell Handling Floor and Equipment Wash	Weight of Cells Produced
		Silver Etch	Weight of Silver Processed
		Silver Peroxide Production	Weight of Silver in Silver Peroxide Produced
		Silver Powder Production	Weight of Silver Powder Produced

NA – Not Applicable to Battery Manufacturing Category

TABLE IV-2

OPERATIONS AT BATTERY PLANTS INCLUDED IN OTHER INDUSTRIAL CATEGORIES

(Partial Listing)

- Plastic and Rubber Case Manufacture
- Cell Containers and Components:
  - A. Forming
  - B. Cleaning and Deburring
  - C. Metal Surface Treatment (e.g., Plating, Chromating, etc.)
- Retorting, Smelting and Alloying Metals
- Inorganic Chemical Production (Not Specific to Battery Manufacturing)
- Pasted Paper Manufacture (Without Mercury)

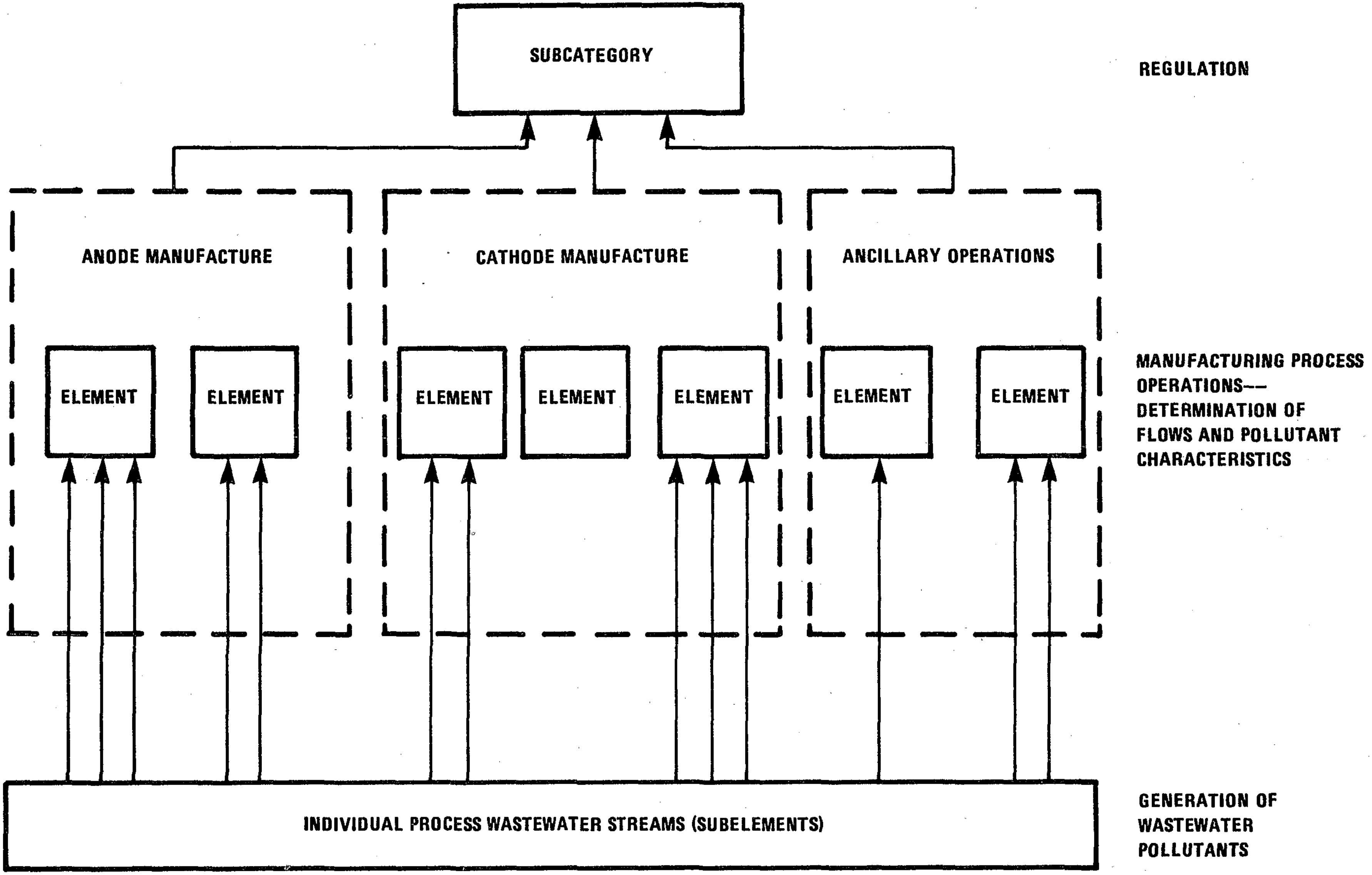


FIGURE IV–1 SUMMARY OF CATEGORY ANALYSIS

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 battery manufacturing category, 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, 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 battery category. This analysis was the basis for subcategorization and selection of production normalizing parameters (pnp) discussed in detail in Section IV. Further analysis included collecting wastewater samples and characterizing wastewater streams within each subcategory.

DATA COLLECTION AND ANALYSIS

The sources of data used in this study have been discussed in detail in Section III. Published literature and previous studies of the 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 subcategory data summaries and were the primary basis for the selection of plants for on-site sampling and data collection. Data from plant visits were used to characterize raw and treated wastewater streams within the category and provide an in-depth evaluation of the impact of product and process variations on wastewater characteristics and treatability.

Data analysis proceeded concurrently with data collection and provided guidance for the data collection effort. Initially, a review and 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 initial 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.

Data Collection Portfolio

The data collection portfolios (dcp) were 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.

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 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, 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, 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. For the subcategories which are the subject of this volume, responses were received from about 50 sites. Because of the dynamic nature of battery manufacturing these numbers may vary since some sites have consolidated operations, some have closed, and new sites may have opened.

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 are commonly produced in a variety of sizes, shapes, and electrical capacities. Available data also indicated that processes could vary significantly in wastewater discharge characterisitcs.

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 (lb/yr) and production rate (lb/hr). 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 69 confirmed battery manufacturing plants which are the subject of this volume, all 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.

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 approximately 40 percent of the 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 each subcategory. These data were augmented by data from plant visits and, where appropriate, by information gained in follow-up telephone and written contacts with selected 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 manufacturing process element in each subcategory. The data base was also used to identify and evaluate wastewater treatment technologies and in-process control techniques used.

Plant Visits and Sampling

Thirty-two battery manufacturing plants were visited as part of the data collection effort for the subcategories in this volume, including one following 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 19 plants.

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.

Sampling and Analysis Procedures

Sampling procedures were applied for screening and verification sampling programs. For screening, plants identified as being representative of the subcategory in terms of manufacturing processes, raw materials, products, and wastewater generation were selected for sampling. Where possible, plants with multiple products or processes were chosen for screening. The screening program was designed to cover battery types under the initial subcategorization.

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 selected plants as part of a separate screening effort using self-sampling kits supplied to each 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 a subcategory that demonstrated effective pollutant reductions were specifically identified for sampling in order to evaluate wastewater treatment and control practices within the industry. For the subcategories containing a relatively small number of plants and relatively few types of wastewater treatment and control practices, the selection of plants for sampling was based primarily on production, manufacturing processes, and wastewater generation.

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 then visited for one day to determine specific sampling locations and collect additional information. In some cases, it was determined during this preliminary visit that existing wastewater plumbing at the plant would not permit meaningful characterization of battery manufacturing process wastewater. 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 sampling visits approximately 200 raw waste samples were obtained characterizing wastewater sources associated with over 30 different battery manufacturing process elements for the subcategories in this volume. 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 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, cyanide, ammonia, 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. 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. All sample analyses were performed in accordance with the EPA protocol listed in Table V-1 (page 238).

The sampling data provided wastewater chemical characteristics as well as flow information for the manufacturing process elements within each 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.

All data was 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 each subcategory are presented in Tables V-2 through V-7 (pages 244-266). Pollutants reported in the dcp as known or believed to be present in process wastewater from plants in the subcategory are also indicated on these tables. In the tables, 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 polllutants 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 could not be 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. Nonvolatile organic pollutants were not analyzed for one zinc subcategory screening sample due to loss of the sample in shipment. Two sets of screening data are presented for the zinc subcategory. Two plants in this subcategory were screened because screening was initially performed on the basis of the initial product type subcategories.

Selection Of Verification Parameters

Verification parameters for each subcategory 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 each 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 were used for the final selection of all verification parameters, which included both toxic and conventional pollutant parameters. An examination was made of all nonconventional pollutants detected at screening and several were also selected as verification parameters. Specific discussion of the selection of verification parameters for each subcategory is presented in the following paragraphs. Table V-8 (page 271) is a summary of the verification parameters selected for all the subcategories.

Cadmium Subcategory. The following 16 pollutant parameters were selected for further analysis in this subcategory:

44. methylene chloride
87. trichloroethylene
118. cadmium
119. chromium
121. cyanide
122. lead
123. mercury
124. nickel
126. silver (for silver cathodes only)
128. zinc

ammonia
cobalt
phenols (4AAP)
oil and grease
TSS
pH

The organic pollutants dichlorobromomethane and bis(2-ethylhexyl)phthalate were all detected in screening raw waste samples at concentrations below the quantifiable limit and were not selected for verification because there was no clear relationship between these pollutants and manufacturing processes in this subcategory. Chloroform was detected in screening but was not selected for verification sampling because the presence of chloroform was attributed to the influent water. Toluene was detected at 0.025 mg/l in the effluent but was not chosen for verification because this pollutant was not related to any manufacturing process. All other organic priority pollutants detected in screening analysis for this subcategory were included in verification analysis.

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

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

Calcium Subcategory. The following 18 pollutant parameters were selected for further analysis in this subcategory:

14. 1,1,2-trichloroethane
23. chloroform
44. methylene chloride
66. bis(2-ethylhexyl)ogtgakate
116. asbestos
118. cadmium
119. chromium
120. copper
122. lead
124. nickel
126. silver
128. zinc
cobalt
iron
manganese
oil and grease
TSS
pH

Three organic priority pollutants, pentachlorophenol, di-n-butyl phthalate, and toluene were detected in screening samples at concentrations below the analytical quantification limit of 0.01 mg/l and were not selected for verification because there was no reason why these pollutants should be present as a result of the manufacturing processes in this subcategory. All other organic priority pollutants detected in screening analysis for this subcategory were selected for verification.

The metal priority pollutants, antimony, arsenic, beryllium, mercury, selenium, and thallium, were not quantifiable in screening analysis and are not known to result from any manufacturing process in this subcategory. Consequently, they were not selected for verification. All other metal priority pollutants were detected in screening and were selected for verification. In addition, asbestos, reported as a raw material in this subcategory and detected in screening samples, was included for verification.

A number of nonconventional pollutants were detected in screening, but not included in verification analysis. Cobalt, iron, and manganese were detected during screening and were included as verification parameters. In addition, the conventional pollutants total suspended solids, oil and grease, and pH were included in verification analysis.

Leclanche Subcategory. The following 16 pollutant parameters were selected for further analysis in this subcategory:

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

Twelve organic priority pollutants were detected at concentrations less than the quantification levels in screening samples for this subcategory. Nine of these pollutants, 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, dichlorobromomethane, chlorodibromomethane, phenol, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, butyl benzyl phthalate, and dimethyl phthalate, were neither reported to be present in process wastewater by plants in this subcategory nor known to be used in the manufacturing process. The remaining three pollutants, methylene chloride, di-n-octyl phthalate, and toluene, were reported as known or believed to be present in process wastewater in the dcp data. Methylene chloride was reported as known to be present and was used in the manufacturing process by one plant. This plant also reported, however, that use of this material had been discontinued. Di-n-octyl phthalate was reported as believed to be present in process wastewater by one plant. Toluene was reported as believed to be present in process wastewater by two plants. Their presence cannot be traced to any use in battery manufacturing processes, and is believed to be due to on-site plastics processing and vapor degreasing operations which are not regulated as part of the battery manufacturing category. On the basis of these considerations, none of these 12 pollutants were included in verification analyses. Chloroform was detected in screening at the quantifiable limit in the raw waste but was not selected for verification because the influent sample concentration of this pollutant was greater than the raw waste concentration. Diethyl phthalate was the only organic priority pollutant detected in screening which was selected for verification analysis.

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

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

Lithium Subcategory. The following 18 pollutant parameters were selected for further analysis in this subcategory:

14. 1,1,2-trichloroethane
23. chloroform
44. methylene chloride
66. bis(2-ethylhexyl)phthalate
116. asbestos
118. cadmium
119. chromium
120. copper
122. lead
124. nickel
126. silver
128. zinc
- cobalt
- iron
- manganese
- oil and grease
- TSS
- pH

Screening analysis for this subcategory encompassed waste streams resulting from the manufacture of cathodes and heating elements for thermal batteries. The selection of verification parameters for this subcategory is based on the screening results as well as a review of raw materials and dcp information for all process elements.

Wet scrubbers used in sulfur dioxide and thionyl chloride cathode manufacture serve to control emissions of vapors of these materials. The resultant wastewater consequently will contain sulfurous and hydrochloric acids, but no priority pollutants. Neutralization and recycle of the scrubber wastes will result in the presence of sodium sulfite and sodium chloride as well as sodium sulfate resulting from oxidation of the sulfite. Lithium scrap disposal is expected to produce a waste containing lithium and iron, but no significant concentrations of priority pollutants. On the basis of these considerations, screening results for this subcategory are believed to identify all of the priority pollutants appropriate for verification sampling and control in this subcategory.

Three organic priority pollutants, toluene, 1,1,1-trichloroethane and butyl benzyl phthalate were detected in screening samples at concentrations less than the quantifiable limit of 0.01 mg/l and were not selected for verification analysis. All other organic priority pollutants detected in screening analysis for this subcategory were selected for verification analysis.

The metal priority pollutants, antimony, arsenic, beryllium, mercury, selenium, and thallium were not quantifiable in screening analysis and are not known to result from any manufacturing process in this subcategory. Consequently, they were not selected for verification. All other metal priority pollutants were detected in screening and were selected for verification. In addition, asbestos is reported as a raw material and was detected in screening samples. It was therefore selected for verification.

A number of nonconventional pollutants were detected in screening but were not selected for verification analysis. Cobalt, iron, and manganese were detected at significant concentrations and were selected for verification. In addition, the conventional pollutants, oil and grease, total suspended solids and pH were selected for verification analysis.

Magnesium Subcategory. The magnesium subcategory is unique in the sense that manufacturing process elements and types of pollutants generated vary from plant to plant. Consequently, one set of parameters cannot be used to represent total screening for the subcategory. All manufacturing processes, production quantities and raw materials used, as well as priority pollutant segments of dcp from all plants in this subcategory were examined. On this basis, three process elements were selected for wastewater screening analysis. For the heat paper production process element, eighteen pollutant parameters were selected for verification as discussed under the calcium subcategory (pages 189-193). Each of the silver chloride cathode processes was sampled separately. Screening analysis results will be used for verification because at present, production in this process element is limited.

Zinc Subcategory. The following 33 pollutant parameters were selected for further analysis for this subcategory:

11. 1,1,1-trichloroethane
13. 1,1-dichloroethane*
29. 1,1-dichloroethylene*
30. 1,2-trans-dichloroethylene*
38. ethylbenzene*
44. methylene chloride
55. naphthalene*
120. copper
121. cyanide
122. lead
123. mercury
124. nickel
125. selenium*
126. silver

64. pentachlorophenol*
66. bis(2-ethylhexyl)phthalate*
70. diethyl phthalate*
85. tetrachloroethylene*
86. toluene*
87. trichloroethylene
114. antimony
115. arsenic
118. cadmium
119. chromium
128. zinc
aluminum
ammonia*
iron
manganese
phenols (total)
oil and grease
TSS
pH

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

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

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

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

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

Verification Data. Under the discussions and analysis for each subcategory, verification parameter analytical results are discussed and tabulated. Pollutant concentration (mg/l) and mass loading (mg/kg) tables are shown for each sampled process. In the tables 0.00 indicates no detection for all organic pollutants except cyanide. 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 the metals and cyanide, total phenols, 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.

CADMIUM SUBCATEGORY

This subcategory includes the manufacture of all batteries employing a cadmium anode. Three battery types, mercury-cadmium, silver-cadmium, and nickel-cadmium batteries, are included. Nickel-cadmium batteries, however, account for over 99 percent of the total mass of cadmium anode batteries produced. Manufacturing plants in the subcategory vary significantly in production volume and in raw materials, production technology, wastewater generation, and in wastewater treatment practices and effluent quality.

There are 13 plants in the data base for the subcategory. Three of the 13 plants have closed, but moved the production to existing plants. Nine of the remaining ten plants manufacture cells based on the nickel-cadmium electrolytic couple. One of these nine plants also produces silver-cadmium batteries. The tenth plant manufactures mercury-cadmium cells, although production at that plant is reported to be sporadic and quite small in volume.

Annual production reported in the subcategory totaled 4800 metric tons of batteries in 1976. Using the latest available data at the first writing of this document (1976-1979), estimated annual production for each battery type was:

Battery Type	Estimated Annual Production	
	kkg	tons
nickel-cadmium	5242	5780
silver-cadmium	8.6	9.5
mercury-cadmium	0.045	0.05

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

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

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

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

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

Manufacturing processes differ widely within the subcategory. This results in corresponding differences in process water use and wastewater discharge. A total of 16 distinct manufacturing process operations or process elements were identified. These operations are combined in various ways by manufacturers in this subcategory and they provide a rational basis for effluent limitations. Following a discussion of manufacturing processes used in the subcategory each of these process elements is discussed in detail to establish wastewater sources, flow rates, and chemical characteristics.

Manufacturing Processes

As shown in the generalized process flow diagram of Figure V-1, (page 391), the manufacture of batteries in this subcategory comprises the preparation and formation of the anode and cathode, assembly of these components into cells and batteries, and ancillary operations performed in support of these basic manufacturing steps. Three distinct process elements for the production of anodes, five for the manufacture of cathodes, and eight different wastewater generating ancillary operations are practiced within the subcategory. They are combined in a variety of ways in existing plants to produce batteries exhibiting a range of physical and electrical characteristics. Additional combinations are possible in future manufacturing.

The observed variations in anode and cathode manufacture, and the combinations of these processes at existing plants are shown in Table V-9 (page 273). This table also lists the eight ancillary operations that have been observed to involve water use and wastewater discharge. The X's entered in the table under each anode type and after each cathode type and ancillary operation identify reported use of the designated manufacturing operations. Data from these operations are used in detailed discussions of each of these process elements.

The process operations and functions shown in Table V-9 provided the framework for analysis of wastewater generation and control in this subcategory. Several operations involve two or more distinct process wastewater sources which must be considered in evaluating wastewater characteristics. The relationship between the process elements and discrete wastewater sources observed at cadmium subcategory plants is illustrated in Figure V-2 (page 392).

Anode Operations

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

Pasted and Pressed Powder - To make cadmium pasted and pressed anodes, cadmium hydroxide is physically applied to the perforated surface of a supporting grid (usually nickel-plated steel) in either a powdered form or compressed powder form. Other anodes included in this grouping are those in which cadmium oxide is blended with appropriate additives prior to either (a) pressing to form a button or pellet, or (b) pasting on a supporting grid.

The charged state for these anodes is achieved in present practice by formation after cell assembly.

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

Formation of these anodes outside the battery case is not presently practiced in the United States but is anticipated in the near future by one manufacturer.

Electrodeposited - Electrodeposited anodes are produced by electrochemically precipitating cadmium hydroxide from nitrate solution onto the support material. (Neither in this discussion nor subsequent discussion of electrodeposited nickel cathodes does the term "electrodeposit" mean deposition of metal as the term is used in electroplating practice. "Electrodeposited" as used in the application of active material to anode or cathode supports actually means "electrochemically precipitated." The material deposited is a hydroxide.) When the appropriate weight of cadmium hydroxide has been deposited, the deposited material is subjected to charge and discharge cycles while submerged in caustic solution and subsequently rinsed. After drying, the formed material is cut to size for assembly into cells.

The cadmium nitrate solutions used in electrodeposition may be partially derived from excess cadmium hydroxide washed off anodes during processing and recovered from the process rinse water. Dissolution of this material in nitric acid generates acid fumes which must be controlled with a scrubber. Figure V-3 (page 394) is a process flow diagram of anode production by cadmium electrodeposition.

Impregnated - A third method of cadmium anode manufacture involves submerging porous sintered nickel stock in an aqueous solution of cadmium salts and precipitating cadmium hydroxide on the sintered material by chemical, electrochemical, or thermal processing. Generally the impregnated material is immersed in a caustic bath to precipitate cadmium as the hydroxide and is then rinsed. The entire impregnation cycle is repeated several times to achieve the desired active material (cadmium) weight gain. After cleaning the anode material by brushing or washing to remove excess deposited material, the anode material is submerged in a caustic solution and an electric current is applied to repeatedly charge and discharge the anode material. Formation is generally followed by rinsing. Figure V-4 (page 395) is a process flow diagram of anode production by cadmium impregnation.

Cathode Operations

Three of the five cathode manufacturing process elements are for producing nickel cathodes. The other two are for producing silver cathodes and mercury cathodes.

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

Nickel Electrodeposited - Sintered nickel grids prepared by either the slurry or dry methods are used as the substrate upon which nickel hydroxide is electrodeposited. (See discussion of the use of "electrodeposited" under Anode Operations.) Nickel powder in either a slurry or dry form is layered on nickel-plated steel which passes through a furnace for sintering. Afterwards, the sintered material is positioned in the electrodeposition tank and the tank is filled with a nitric acid solution of dissolved nickel and cobalt salts. An electrical current is applied to the tank causing nickel and cobalt hydroxides to precipitate on the sintered material. The presence of cobalt in the nickel active material aids in the charge efficiency. After deposition of the desired amount of nickel hydroxide, the material is submerged in potassium hydroxide and electrochemically formed. After formation is completed, the cathodes are removed from the tank for subsequent rinsing and the spent formation caustic is dumped. Figure V-5, (page 396) is a process flow diagram of cathode production by electrodeposition.

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

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

Preparation of the sintered stock required for impregnation using nickel powder is also considered part of this process function. Figure V-6 (page 397) is a flow diagram of the process for producing impregnated nickel cathodes. Nickel hydroxide washed off the impregnated stock during process rinses and in post impregnation cleaning may be recovered and redissolved in nitric acid to produce some of the nickel nitrate solution used in impregnation.

Silver Powder Pressed - The production of silver cathodes begins with preparing a silver powder which is then sintered. The metallic silver cathodes which result are assembled into cells and batteries with unformed cadmium anodes. The resulting batteries are shipped in the unformed state.

Mercury Oxide Powder Pressed - Mercury cathodes are produced by physical compaction of mercuric oxide.

Assembly

Specific assembly techniques differ for different cell types manufactured in this subcategory. For example, anodes and cathodes for large rectangular cells are interleaved with separators which may be plastic or hard rubber rods, while for sealed cylindrical cells, the anodes and cathodes are spirally wound with flexible sheet separators. Assembly of all cells, however, involves the assembly of one or more anodes with cathodes and separators to produce an active cell element. One or more of these elements is then inserted in a battery case, electrical connections made, (as required), and electrolyte added, after which the case is covered and (if appropriate) sealed.

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

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

Ancillary Operations - In addition to the basic electrode manufacture and assembly steps, a number of wastewater generating process operations or supporting functions are required for the production of cadmium subcategory batteries. These wastewater generating ancillary operations discussed under "Process Water Use" includes: (1) washing assembled cells; (2) preparing electrolyte solutions; (3) cleaning process floor areas and equipment; (4) employee hand washing to remove process chemicals; (5) the production of cadmium powder; (6) the production of silver powder; (7) the production of nickel hydroxide; and (8) the production of cadmium hydroxide. Ancillary operations such as welding and drilling or punching which do not generate wastewater are not discussed in this section.

Water Use, Wastewater Characteristics, and Wastewater Discharge

Process Water Use

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

Mean and median normalized discharge flows from both dcp and visit data for each of the wastewater producing process elements included in this subcategory are summarized in Table V-10 (page 274). This table also presents the production normalizing parameters upon which the reported flows are based and which were discussed in Section IV, and the annual raw waste volume for each process. The water use and wastewater discharge from these process operations varies from 1 liter per kilogram of cadmium used for the manufacture of cadmium hydroxide production to 1640 liters per kg of impregnated nickel for sintered impregnated electrodes.

Process Wastewater Characteristics

Anode Operations - Cadmium Pasted and Pressed Powder Anodes - Preparation of the solid active materials is not included in this process group.

Only limited discharge of process water is associated with production of pasted and pressed cadmium powder anodes. The only wastewater discharge from anode production is process area maintenance. Two plants (A and B) use water to clean floors and equipment. The wastewater was sampled at Plant A. The analyses are presented in Table V-11 (page 275). Table V-12 (page 276) shows the pollutant mass loadings in the clean-up wastewater stream on three successive days.

Formation of anodes in this group does not presently produce a process wastewater discharge at any plant in the U.S. However, anticipated production changes by at least one manufacturer to include formation of anodes outside the cell could introduce an additional wastewater source for this process element.

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

Characteristics of the total electrodeposition process wastewater discharge were determined by combining analysis results of the wastewater streams discussed above. Table V-13 and V-14 (pages 277 and 278) show the pollutant concentrations and mass loadings for this process sequence.

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

Analytical results from the second and third sampling days are presented in Table V-15 (page 279) to characterize the raw wastewater from the cadmium impregnation process. Sampling results from the first day are excluded because the impregnation process did not operate on that day. All wastewater streams were sampled except sintered stock preparation clean-up and the formation caustic dump on the third day. The spent formation caustic wastewater stream is not included in the combined stream analysis for that day; however, the spent caustic would not contribute significantly to the pollutant concentrations since the flow is 0.5 percent of the total flow. Wastewaters from anode cleaning, which are included in the analyses shown, were not observed at all sites producing impregnated cadmium anodes. In evaluating the data in Table V-15 it should be noted that the wastewater characteristics for the impregnation rinse on day 3 are not considered representative of the normal process discharge. The data for day 2 (columns 1 and 3) are considered to provide the best available characterization of the total raw waste from this process operation.

<u>Cathode Operations</u> - Nickel Pressed Powder Cathodes - No wastewater discharge was reported from manufacturing cathodes in

this group except for effluent from the production of nickel hydroxide by chemical precipitation at one plant. The precipitation process is addressed as a separate ancillary operation in this subcategory.

Nickel Electrodeposited Cathodes - Wastewater streams resulting from this process are: (1) spent formation caustic removal; and (2) post-formation rinse discharge. Wastewater from this operation was characterized by sampling. Table V-16 (page 280) presents the verification analysis results of the post-formation rinse discharge (on a daily basis). Table V-17 (page 281) presents the daily pollutant mass loadings based on the weight of active nickel applied to produce the cathode.

Nickel Impregnated Cathode - A total of eleven different sources of process wastewater are associated with this variation of nickel cathode manufacture. These wastewater sources include: (1) nickel paste clean-up; (2) spent impregnation caustic; (3) impregnation rinses; (4) impregnation scrubbers (used for nitric acid fume control); (5) impregnated stock brushing; (6) pre-formation soak water; (7) spent formation caustic; (8) post-formation rinses; (9) impregnation equipment wash; (10) nickel recovery filter wash; and (11) nickel recovery scrubber. Any wastewater generated as a result of nickel hydroxide recovery is also attributable to this process element.

Seven plants reported the manufacture of impregnated nickel cathodes. One of these subsequently moved their production. Of the remaining six plants, four plants, A, B, C, and D, were visited for on-site data collection and wastewater sampling. These plants collectively produced all of the wastewater streams identified. Total wastewater discharges from nickel cathode production were characterized for each day of sampling at each plant by summing the discrete wastewater streams characterized above. This approach was required because wastewater streams from individual process steps are frequently treated separately (and directed to different destinations) or combined with wastewater from other process functions. As a result, a single total process raw wastewater stream was not generally available for sampling. The calculated total wastewater characteristics for the production of impregnated nickel cathodes are presented in Table V-18 (page 282). Table V-19 (page 283) presents corresponding pollutant mass loadings. Statistical analyses of these data are presented in Table V-20 and V-21 (pages 284 and 285).

Silver Powder Pressed Cathode - No process wastewater is generated in producing silver powder pressed cathodes. Wastewater does result from the production of silver powder used in these electrodes. This discharge source is discussed separately as an ancillary operation under the zinc subcategory.

Mercuric Oxide Cathode - No process wastewater discharge is reported from production of mercuric oxide cathodes in the cadmium subcategory.

Ancillary Wastewater Generating Operations - Cell Wash - This process operation addresses washing either assembled cells or batteries following electrolyte addition. The caustic electrolyte consisting primarily of potassium hydroxide may be spilled on the cell case during filling. The cells are washed to remove the excess electrolyte and other contaminants. Three plants (A, B, and C) in the subcategory reported cell wash operations. Other plants produce comparable products without the need for cell washing. The quantity of water used to wash cells ranges from 3,032 to 15,746 liters per day (7521 l/day mean). The normalized discharge flows based on the weight of finished cells range from 1.24 to 10.3 liters per kilogram (4.93 l/kg mean). The discharge flow rate reported by plant B, however, reflects the combined wastewater from cell washing and floor area clean-up.

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

Characteristics of cell wash wastewater streams resulting from the manufacture of alkaline electrolyte batteries are expected to vary little among different battery types. Sampling data from cell wash operations in the zinc subcategory, Tables V-93 and V-94 (pages 359 and 360), are considered indicative of cadmium subcategory cell wash effluent characteristics. Cadmium subcategory cell wash discharges, however, are expected to contain nickel and cadmium rather than mercury, manganese, and zinc.

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

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

The floor wash water for maintaining both impregnation and electrodeposition process areas as well as the assembly area was sampled at one plant. The analysis results in units of mg/l are presented in Table V-22 (page 286). In addition, Table V-23 (page 287) shows the pollutant mass loadings in units of mg/kg of cells produced. Pollutants in the floor wash discharge include nickel, cobalt, cadmium, and zinc. Both nickel and cobalt are present due to cleaning the nickel cathode process floor areas. Floor maintenance in the vicinity of the cadmium anode production is the primary contributor of cadmium in the wastewater. The source of zinc is not readily determined.

Employee Wash - For purposes of health and safety, some plants require employees to wash hands prior to lunch and at the end of the work shift to remove process chemicals. Hand-wash water was sampled at one plant. These samples primarily reflect wash water that was used to clean the hands of employees assembling nickel-cadmium batteries as opposed to wash water used by process operators who handle the active material. The analysis results presented in Table V-24 (page 288) show that the wastewater contains primarily oil and grease and TSS which are present due to the nature of the assembly operations. On the first sampling day, all pollutant levels are low since the sample was taken during the second shift when there were only a few employees assembling batteries. The other two samples were taken during the first shift when the number of employees washing their hands was approximately fifteen times greater. Table V-25 (page 289) presents the pollutant mass loadings based on weight of finished cells produced for each sample day.

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

Wastewater discharge from cadmium powder production results from product rinsing and from air scrubbers used to control fumes from process solutions. Wastewater from product rinsing was characterized by sampling. The resulting concentrations together with corresponding pollutant mass loadings based on the total discharge flow are shown in Table V-26 (page 290).

Silver Powder Production - Silver powder used specifically for battery cathodes is produced primarily for silver oxide-zinc batteries, but also for silver-cadmium batteries. Discussion of this operation is under ancillary operations in the zinc subcategory, on page 234. Results of analysis of wastewater samples collected on three successive days are presented in Table V-113 (page 379). Production normalized discharge volumes and corresponding pollutant mass loading for each sampling day are shown in Table V-114 (page 380).

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

This operation was observed during data collection for this study, but the resultant wastewater discharge was not characterized by sampling. However, characteristics of the resultant effluent as supplied by the plant are presented in Table V-32 (page 296). Pollutant wastewater characteristics from this process are similar to nickel impregnated cathodes.

Cadmium Hydroxide Production - Cadmium hydroxide for battery manufacture is produced by thermal oxidation of cadmium to cadmium oxide, addition of nickel sulfate, hydration of cadmium oxide to the hydroxide, and drying of the product. Process wastewater results only from the contamination of seal cooling.

As discussed for nickel hydroxide production, this operation was observed but its wastewater was not characterized by sampling. Wastewater from cadmium hydroxide production is combined with other process wastewater streams prior to treatment. Reported characteristics of the resultant effluent are presented in Table V-32 (page 296). Pollutant wastewater characteristics from this process are similar to impregnated anodes.

Total Process Wastewater Discharge and Characteristics

Water use and wastewater discharge are observed to vary widely among cadmium subcategory plants with process wastewater flow rates ranging from 0 to 450,000 l/day. Individual plant effluent flow rates are shown in Table V-27 (page 291). Most of the observed wastewater flow variation may be understood on the basis of manufacturing process variations. Plants with different process sequences produce different volumes of process wastewater. In some cases, however, large differences in process water use and discharge are observed among different plants using the same process operations. As discussed later in this section, on-site observations and data collection at a number of plants in the subcategory revealed differences in plant operating practices which result in the observed flow variations. In general, these differences are observed to result primarily from differing degrees of awareness of water conservation.

Total process wastewater flow and characteristics were determined for four plants in the cadmium subcategory which were sampled. These characteristics, reflecting the combined raw wastewater streams from all cadmium subcategory process operations at each site on each of three days of sampling, are summarized statistically in Table V-28 (page 292). Prevailing discharge and treatment patterns in this subcategory generally preclude directly sampling a total raw wastewater stream because wastewaters from individual process operations are often treated or discharged separately. In other cases, individual process wastewaters are mixed with other wastewater streams such as non-contact cooling wastewater and electroplating wastewater prior to combination with other cadmium subcategory wastewater streams. Consequently, the total process wastewater characteristics shown in Table V-28 were determined for each plant by mass balance calculations from analyses of wastewater samples from individual process operations.

As Table V-28 shows, concentrations of some pollutants were observed to vary over a wide range. These variations may generally be related to variations in manufacturing processes discussed in the preceding pages. Despite the observed variations, it may be seen that the most significant pollutants are generally consistent from plant to plant and that waste treatment requirements of all of the sampled plants are quite similar.

Wastewater Treatment Practices and Effluent Data Analysis

Reported treatment applied to cadmium subcategory process wastewater (Table V-29, page 293) shows that all but one of the plants which produce process wastewater provide settling for the removal of suspended solids and metal precipitates. Filtration for further pollutant removal was provided at four sites. Despite this apparently high level of treatment, on-site observations at visited plants revealed that the treatment nominally employed was often marginal in its design and operation. An analysis of the treatment in place was done for both active and inactive plants which submitted process information. Some of these plants were visited and sampled, others provided effluent data, and others just reported what treatment was in place.

At one plant which was visited, "settling" was found to occur in sumps in process areas which were observed to provide only limited retention time at average flow rates. The effectiveness of these sumps was further reduced by the fact that they were subject to very high surge flows during which essentially no settling occurred. Finally, several of these sumps were almost completely filled with accumulated solids so that essentially no further settling out could occur. The results of sampling and analysis at this site (Table V-2, page 244) confirmed the extremely high (41 and 46 mg/l) effluent concentrations of cadmium and nickel shown in this plant's dcp (Table V-32, page 296).

At another plant which was visited for sampling and on-site data collection, segregated cadmium subcategory process wastewater streams were treated in batch systems providing pH adjustment, settling, and filtration. Although the obvious deficiencies in treatment at the first plant were not noted at this site, the general level of control maintained over treatment system operation was inadequate as shown by the highly variable effluent performance observed by sampling. Analysis results shown for this plant in Table V-30, Treatment System I and II (page 294), indicate a number of irregularities characteristic of inadequate treatment plant performance. For example, effluent metals sometimes exceeded raw wastewater values even though TSS values were low. This indicates that the metals were not precipitated. Similarly, finding treated TSS levels above raw TSS levels may indicate poor treatment operation.

A third cadmium subcategory plant was visited for sampling treated process wastewater in a settling lagoon after separate treatment of some wastewater streams in settling tanks. At this plant, however, neither pH adjustment nor the use of settling aids (coagulants or flocculants) was practiced. As the analysis of data from this plant (Table V-31, page 295) shows, the effluent pH was consistently outside the optimum range for treatment of these wastes.

Effluent concentration data provided in dcp from cadmium subcategory plants which are presented in Table V-32 (page 296) were evaluated in the light of the on-site observations and sampling results discussed above. Plants D and A (Table V-32) were visited for sampling, and are discussed. Plants E and F (no longer active), and H (Table V-32) did not provide sufficient information to allow a definitive evaluation of treatment system operating parameters. Plants E and H used the equivalent of chemical precipitation and settling technology. Plant F used precipitation and settling followed by ion exchange.

Plant B (Table V-32) which was visited, but not sampled, practices combined treatment of cadmium subcategory process wastewater and of other similar wastewaters. The treatment provided included pH adjustment, settling in a lagoon, sand filtration and final pH adjustment. At this site a large volume of noncontact cooling water from cadmium subcategory processes was also discharged to treatment, increasing the mass of pollutants in the effluent attributable to cadmium anode battery manufacture by a factor of nearly two. Since the initial collection of data, this plant has upgraded its wastewater treatment and control plants to provide additional treatment and complete recycle of all process wastewater. As a result, this plant is presently achieving zero discharge of process wastewater pollutants.

Plant C (Table V-32) has chemical precipitation, settling and filter technology in place; however, from the data submitted, proper pH control was not maintained.

The two remaining active cadmium subcategory plants and one inactive plant achieved zero discharge of process wastewater by in-process control techniques or process variations which eliminated the generation of process wastewater.

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 these systems are generally inadequate for treating cadmium subcategory pollutants.

CALCIUM SUBCATEGORY

This subcategory covers the manufacture of calcium anode thermal batteries for military applications. These batteries are designed for long term inactive storage followed by rapid activation and delivery of relatively high currents for short periods of time. These characteristics are achieved by the use of solid electrolytes which at the moment of use are heated to above their melting point to activate the cell. Heat is supplied by chemical reactants incorporated as a pyrotechnic device in the cell. Because calcium, the cell anode material, reacts vigorously with water, water use is avoided as much as possible in manufacturing these batteries. Production volumes are generally small and manufacturing specifications depend upon military specifications for particular batteries. The most significant pollutants found in the limited volumes of wastewater generated in this subcategory are asbestos and chromium.

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

Specific raw materials used in manufacturing these batteries differ somewhat from plant to plant although the use of calcium, iron, lithium and potassium chlorides, calcium chromate, zirconium, barium chromate, and asbestos is common to all manufacturers of these batteries. Other raw materials used are: silica, kaolin, glass fiber, and potassium dichromate. Present trends are to eliminate the use of calcium chromate and barium chromate in new designs by substituting alternative depolarizers and heat sources. Military specifications for existing designs, however, make it unlikely that use of these materials in manufacturing will be discontinued altogether.

Manufacturing Processes

To manufacture calcium anode thermal batteries cell anodes, depolarizers, electrolytes, and the cell activators (heating elements) are prepared. These elements are assembled with current collectors, insulators, initiators, and containers into cells and multicell batteries. A generalized process flow diagram is shown in Figure V-7 (page 398). The relationship between the process elements and discrete wastewater sources reported at battery plants is illustrated in Figure V-8 (page 399).

Anode Operations

Calcium anode material is generally produced by vapor deposition of calcium on a substrate of metal such as nickel or iron which serves both as a current collector and support for the calcium during cell operation.

Cathode Operations

Cathodic depolarizers for calcium anode cells include calcium chromate, tungstic oxide, and potassium dichromate. They are incorporated into the cells in one of several ways including impregnation of fibrous media, pelletization of powders, and glazing. Electrolyte is incorporated into cells similarly - some cell designs even combine the depolarizer and electrolyte. Almost all cells in production at the time of the survey used a lithium chloride-potassium chloride eutectic mixture as the electrolyte.

One form of cell uses a fibrous medium to immobilize the electrolyte. The fibrous medium, such as glass tape, is impregnated by dipping it in a fused bath of electrolyte, depolarizer, or a mixture of electrolyte and depolarizer. The impregnated material is allowed to cool and then is cut to shape for the specific cell design. Alternatively, the depolarizer or electrolyte may be ground to powder, mixed with a binder such as kaolin or silica, and pressed to form a pellet of suitable size and shape. In general, pellets containing the depolarizer contain electrolyte as well to ensure adequate conductivity, and multilayer pellets containing both depolarizer and electrolyte layers are produced. Pellets are also produced which are a homogeneous mixture of electrolyte and depolarizer throughout.

Ancillary Operations

Heating Component Operations. The heating component containing highly reactive materials is an essential part of a thermal cell. Two basic types of heating components are reported to be in use: heat paper containing zirconium powder and barium chromate; and heat pellets containing iron powder and potassium perchlorate. To produce heat paper, zirconium powder, barium chromate (which is only sparingly soluble), and asbestos or other inorganic fibers are mixed as an aqueous slurry. The slurry is passed through a filter screen to produce a damp paper containing the zirconium and barium chromate as well as the asbestos fiber. The filtrate is generally treated by settling and then is discharged. Heat pellets are prepared by mixing potassium perchlorate and iron powders and pressing the mixture to form a pellet. Heat paper is nonconductive during cell operation and must be used in cells designed to accommodate this insulating layer. Heat pellets become conductive during operation and may be used as part of the cathode current collector as well as the source of heat to activate the cell.

Battery Assembly - Assembly of batteries from these components frequently involves the creation of stacked multicell structures to provide voltages considerably above the single cell output (generally 2.5-3 volts). Assembly is under rigid quality control specifications and is accomplished primarily by hand with frequent intermediate tests and inspections.

Cell Testing - After assembly the cells are hermetically sealed, and may be immersed in a water bath to test for leakage.

Water Use, Wastewater Characteristics, and Wastewater Discharge

Process Water Use

The manufacturing of calcium anode batteries produces little wastewater since most of the production processes involved are dry. As mentioned earlier, the limited use of water is due to the vigorous reaction of calcium with water and the safety problems inherent to this reaction.

Mean and median normalized discharge flows from both dcp and visit data for each of the wastewater producing process elements included in this subcategory are shown in Table V-33 (page 297). This table also presents the production normalizing parameters upon which the reported flows are based, and the annual raw waste volume for each process. Heat paper production in the calcium subcategory as well as the lithium and magnesium subcategory is similar. For this reason data for developing the normalized flow was combined. Annual raw waste volumes from heat paper production are separate for each subcategory.

Process Wastewater Characteristics

Anode and Cathode Operations - No process wastewater discharge is reported from the production of anodes and cathodes in the calcium subcategory.

Ancillary Operations - Heating Component Production - (Heat Pellet Production) No process wastewater discharge is reported from the production of heat pellets. (Heat Paper Production) This process is the major wastewater generating operation in this subcategory. The production normalizing parameter for this process is the weight of reactants used (barium chromate and zirconium). Sampling data from plants A and B characterizing this wastewater stream are presented in Table V-34 (page 298). As shown in the table, the major pollutants are chromium (from the barium chromate) and total suspended solids. The pollutants mass loadings for this waste stream are shown in Table V-35 (page 299). The two plants have similar wastewaters, but plant B has much higher concentrations of the pollutants as well as a substantially higher production normalized wastewater discharge. The latter fact indicates less efficient deposition of the reactants on the heat paper filter substrate at plant B than at plant A.

Cell Testing - At plant A, cell testing produces about 50 gallons of wastewater per year and water use for washing containers is equally small. These operations are considered to contribute no significant amounts of priority pollutants to the wastewater discharge and were not specifically sampled.

Wastewater Treatment Practices and Effluent Data Analysis

Present treatment practice at calcium subcategory plants is limited to settling as is shown in Table V-36 (page 300). Process wastewater is either contract removed or discharged to a POTW. One plant reports no process wastewater from the manufacture of calcium subcategory batteries.

Effluent characteristics reported by one plant in this subcategory are presented in Table V-37 (page 301). Data reported by this plant are specifically for the effluent from heat paper production.

LECLANCHE SUBCATEGORY

This subcategory covers the manufacture of all batteries employing both a zinc anode and a zinc chloride or zinc chloride-ammonium chloride electrolyte. Presently, there are 19 active plants in the subcategory, 17 of which manufacture cells with zinc anode, carbon-manganese dioxide (MnO_2) cathode, and zinc chloride or zinc chloride-ammonium chloride electrolyte. The remaining two plants use a silver cathode. Cells with silver chloride cathodes, however, comprise less than 0.01 percent of the total production in the subcategory.

There are several distinct variations both in form and in manufacturing process for the Leclanche cell, with corresponding differences in process water use and wastewater discharge. Most of the production is in the form of standard, round "dry cells," but other shapes are produced for special purposes, flat cell batteries, foliar film pack batteries, and air-depolarized batteries.

Wastewater discharge results only from separator production and from cleanup of miscellaneous equipment. After a discussion of the manufacturing processes employed in the subcategory, the process elements that produce wastewater are discussed in greater detail. The available data regarding specific wastewater sources, flow rates, and chemical characteristics is presented followed by a discussion of treatment in place and effluent characteristics.

Annual production reported in the subcategory totaled 96,260 kkg (106,108 tons). This total includes all except two plants (making carbon cathode and silver cathode cells, respectively) for which production is judged to be far below average for the subcategory. The total production also includes one high production plant which has discontinued operation (the production is believed to have been shifted to another plant owned by the company). Reported production is based on 1976 annual production rates, except for one plant which was not in production until 1977. Annual production at individual plants in the subcategory ranges from 1.4 kkg (1.5 tons) to 24,000 kkg (26,000 tons) with a median value of 2,700 kkg (3,000 tons). Annual production for 1982 was received on one plant which had not changed significantly from the data submitted earlier.

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

Manufacturing Processes

As shown in the generalized process flow diagram of Figure V-9 (page 400), the manufacture of batteries in this subcategory comprises the preparation of the anode and cathode, the preparation or application of the separator, assembly of these components into cells and batteries, and ancillary operations performed in support of these basic manufacturing steps.

The observed variations in anode, cathode and separator manufacture and the combinations of these processes carried out at existing plants together with ancillary operations that were observed to generate wastewater are shown in Table V-38 (page 302). These variations provide the framework for analysis of process wastewater generation in the Leclanche subcategory as indicated in Figure V-10 (page 401). These tables and figures have been revised following an evaluation of comments received and a plant visit made after proposal concerning foliar battery production. Specific changes are detailed below. Of thirteen identified process elements in this subcategory, only five generate process wastewater. Three of these were characterized by wastewater sampling at two plants in the subcategory. Wastewater discharge from the fourth element is believed to be similar in character, and is eliminated by recycle in present practices. Wastewater discharge from the fifth element is believed to be similar in character to the sampled wastewaters for equipment and area cleanup.

Raw materials common to many of the plants in the Leclanche subcategory are zinc for anodes, MnO_2 and carbon for the cathode mix, carbon for the cathode current carrier, ammonium chloride and zinc chloride for the electrolyte, paper for the separator and paperboard washers, mercuric chloride for anode amalgamation, and asphalt for sealing. Other reported raw materials are zinc oxide, titanium, ammonium hydroxide, phenolics, manganese, adhesives, ammonia, polystyrene, steel, brass, ethyl cellulose, polyvinyl chloride, toluene, polycyclopentadiene, monochlorobenzene, cyclohexanone, silica, starch, solder, wax, grease, magnesium perchlorate, barium chromate, lithium chromate, latex, vinyl film, aluminum, magnesium oxide, and others.

Anode Operations

The Leclanche anode is produced either from zinc sheet or powdered zinc. The zinc sheet is most often formed into a can, which contains the other components of the cell. This can is either purchased, or formed at the battery plant. The other form of zinc sheet metal anode is a flat zinc plate.

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

Cathode Operations

Four distinct types of cathodes are produced in the Leclanche subcategory; cathodes molded from mixed manganese dioxide and carbon with several variations in electrolyte form; porous carbon cathodes (which also contain manganese dioxide); silver chloride cathodes; and cathodes in which manganese dioxide is pasted on a conductive substrate. These cathode types are combined with zinc anodes and electrolyte to make cells with a variety of configurations and performance characteristics.

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

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

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

Pasted Manganese Dioxide - For the pasted MnO_2 cathode a paste consisting of manganese dioxide, carbon, and latex is applied to a conducting film. The steps used to prepare this film are similar to the steps described above for the zinc powder anode. The cathode paste material is applied on the film in rectangular spots, directly opposite the anode spots.

Ancillary Operations

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

Cooked Paste Separator. In cells using cooked paste, the temperature is elevated to set the paste. The raw materials for producing the paste include starch, zinc chloride, mercuric chloride, and ammonium chloride and water. After the paste and cathode are inserted into the zinc can, the can is passed through a hot water bath with the water level approximately one inch above the bottom of the can, heating the can and causing the paste to gel. After the paste is set, the can is removed from the hot water bath and final assembly operations are conducted. One plant reported producing "cooked" paste separator cells.

Uncooked Paste Separator. Some paste formulations are used which set at room temperature. The paste formulation includes zinc chloride, ammonium chloride, mercuric chloride, cornstarch, and flour. The paste is held in cold storage until it is injected into the zinc anode cans. After the insertion of the compressed cathode, the paste is allowed to set. Then final assembly operations are performed to prepare the cells for shipping.

One plant manufactures carbon-zinc cells with an uncooked paste separator. Two plants produce uncooked paste separator material for use in silver chloride-zinc cells. Flour, zinc chloride and ammonium chloride are used in formulating the separator paste.

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

The manufacture of pasted paper separator material containing mercury is specific to battery manufacturing and is included under battery manufacturing. When pre-pasted paper is purchased by the cell assembler, the separator material is inserted, as purchased, directly into the zinc can, followed by cathode mix.

Pasted Paper (Without Mercury) Separator - Some of the Leclanche cell manufacturers use pre-pasted paper separator material which does not contain mercury. Manufacture of the paper separator material which does not contain mercury is not specific to the battery industry because the product has other industrial uses in addition to Leclanche cell manufacturing.

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

In paste cell production, the paste mixture is poured into a zinc can. The depolarizer-electrolyte mix, molded around a central carbon rod, is pushed into the paste. After the paste sets into a gel, the cell is sealed. The cell then goes through testing, finishing, aging, and retesting before being packed and shipped.

Flat cell production includes the manufacture of the duplex electrodes and depolarizer-electrolyte mix cake, cell assembly, and battery assembly. The duplex electrode is made by coating one side of a zinc sheet with conductive carbon. Manganese dioxide, carbon, ammonium chloride, zinc chloride, and water are mixed and pressed into a cake which serves as a depolarizer and electrolyte.

Duplex electrodes and depolarizer-electrolyte cakes are stacked with a paper separator in between and a plastic sleeve around the four sides and overlapping the top and bottom of the cell. The cells undergo a quality control inspection and are assembled into stacks with a final flat zinc electrode and tin-plated steel end boards. The stacks are inspected, dipped in wax, aged, and inspected again for quality assurance. Stacks are then assembled into finished batteries.

To assemble porous carbon cathode cells, the porous carbon "agglo" cathode is inserted into the zinc anode container. An electrolyte-separator paste is then added, and the cells are sealed and interconnected to form batteries.

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

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

Equipment and Area Cleanup - In the Leclanche subcategory, some equipment cleanup practices cannot be associated with production of only one of the major cell components, anode, cathode, or separator operations. They include the clean-up of equipment used in assembling cells, employee handwash in the production area, as well as the preparation and delivery of electrolyte.

Foliar Battery Miscellaneous Wash - Foliar battery production equipment and cleanup practices are separated out from the other Leclanche subcategory equipment and area cleanup practices. Although these practices are similar, unique physical dimensions of the foliar battery and product quality requirements make the water use requirements different from the other batteries produced in this subcategory.

Water Use, Wastewater Characteristics, and Wastewater Discharge

Process Water Use

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

Mean and median normalized discharge flows from both dcp and visit data for each of the wastewater producing elements included in this subcategory are summarized in Table V-39 (page 303). This table also presents the production normalizing parameters upon which the reported flows are based and which were discussed in Section IV, and the annual raw waste volume for each process.

Process Wastewater Characteristics

Anode and Cathode Operations - There is no process wastewater associated specifically with Leclanche anode or cathode manufacture.

Ancillary Operations - Cooked Paste Separator - The source of direct process wastewater discharge from making cooked paste separators is the hot bath used for setting the separator paste which becomes contaminated from contact with the outside of the can, from an occasional spill of one or more cans into the bath, and waste from the operating machinery. Wastewater from the paste separator manufacture was sampled at the only plant reporting the use of this process. The only source of direct process discharge is from the hot bath paste setting. At this plant, no wastewater was discharged from either the paste preparation or paste clean-up operations, due to in-process controls. The paste preparation water supply tank held water previously used for cleaning. The sources of water reused in mixing the paste included floor wash water from the paste preparation room, paste pipeline system wash water, and paste cleanup water used during mechanical difficulties. An example of mechanical difficulties is cathode insertion failure which results in the paste being washed out of the cans for the purpose of recovering the cans for reuse. All of the water that contacted the paste was collected for reuse in paste formulation, and this closed system limits mercury contamination of the wastewater.

Total discharge production normalized flows measured during the sampling visit ranged from 0.03 to 0.05 liters per kilogram of finished cells, with a mean value of 0.04 and a median value of 0.05 l/kg. Composite samples were taken which included wastewater from each of the three discharge sources. The analytical results are presented in Table V-40 (page 304). Table V-41 (page 305) presents the pollutant mass loadings based on the weight of finished cells for each of the three sample days. Pollutants found in this flow-proportioned combined stream are mercury, manganese and zinc, TSS and oil and grease.

Uncooked Paste Separator - The only source of wastewater discharge from the preparation of uncooked paste is paste tool cleaning. The wastewater stream from tool cleaning estimated at less than 5 liters per day was not sampled. The paste does not contain mercury, and zinc is the only toxic pollutant expected to be found in the wastewater.

Pasted Paper With Mercury Separator - The only source of wastewater discharge during manufacture of pasted paper (with mercury) is hand washing and washing of equipment used to handle the paste.

Wastewater from the manufacture of paper separators with mercury was sampled. The measured flows ranged from 0.11 to 0.17 l/kg of applied dry paste material (0.14 l/kg mean). The analytical results for this waste stream are presented in Table V-42 (page 306). Table V-43 (page 307) presents the daily pollutant mass loadings of the paste equipment clean-up operation wastewater. Significant pollutants observed include zinc, manganese, mercury, TSS, and oil and grease.

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

The presence of TSS in significant concentrations results from washing equipment surfaces to remove process material accumulations. Oil and grease is also present in significant concentration due to the removal of equipment lubricants during the wash operation. There was considerable variability in pollutant concentrations during the three sampling days because of the sporadic nature of the hand wash and cleaning operations. One plant which manufactures and sells mercury-containing pasted paper separators (but does not make batteries) was visited. In-process controls and contract hauling are used to eliminate process wastewater discharge.

Pasted Paper Without Mercury Separator - Because this product is not unique to the manufacture of batteries, the wastewater generated is not included in the battery category.

Cell Assembly - No wastewater discharge is attributed to cell assembly. All wastewaters generated during cell assembly are allocated to separator preparation or to equipment and area cleaning.

Equipment and Area Cleanup - Equipment and area cleanup (including handwash) wastewater in the Leclanche subcategory is that which cannot be associated solely with anode, cathode, or separator production. The operations generating this wastewater are: electrolyte preparation equipment wash, electrode preparation equipment wash, cathode carrier wash, miscellaneous equipment wash, and hand washing. Out of the nineteen active Leclanche plants, twelve reported no discharge of process wastewaters. One of the nineteen did not report data on flow or discharge. The six remaining plants reported both water use and water discharge. All six reported wastewater discharge from equipment and area cleanup. Plants A, E and F reported wastewater from electrolyte preparation equipment wash; plant D reported wastewater from electrode preparation equipment wash; plant B reported wastewater from cathode carrier wash; and Plant C reported wastewater from hand wash and miscellaneous equipment wash.

Table V-44 (page 308) indicates the best available information on equipment and area cleanup wastewater discharges for the nineteen active Leclanche plants. The flow is normalized in terms of weight of finished product, and is expressed in liters discharged per kilogram of finished product.

Equipment and area cleanup wastewater samples were taken at Plants B and C. Pollutant concentrations from these sampled plants and also plant supplied data are included in Table V-45 (page 309). Table V-46 (page 310) presents pollutant mass loads expressed as milligrams discharge per kilogram of cells produced. Table V-47 presents statistics based on the values in Table V-45, and Table V-48 (page 312) presents statistics based on the values in Table V-46.

Foliar Battery Miscellaneous Wash - After receiving comments defining the differences of foliar battery production, the comments were evaluated, a visit was made to a foliar battery plant, and additional data on specific water use requirements were received. Although the chemical characteristics of the battery and the wastewater generating processes for equipment cleaning are similar to the other Leclanche plants, the physical configuration of the product creates unique problems. Minute quantities of impurities in the water can cause product failures. For this reason, separate flows were obtained for this process. Data received indicates that the production normalized flow is 0.132 liters per kilogram of cells produced. Wastewater characteristics are believed to be similar to those in Table V-45 because raw materials used are the same and washing practices are similar.

Total Process Wastewater Characteristics

Total process wastewater flow and characteristics were determined for two plants in the Leclanche subcategory which were sampled. These characteristics, which reflect the combined raw wastewater stream at each site on each of three days of sampling, are summarized statistically. The statistical summary of total process wastewater characteristics from Leclanche subcategory plants is presented in Table V-49 (page 313).

Wastewater Treatment Practices and Effluent Data Analysis

Twelve plants do not discharge any wastewater. Five of the 19 active plants in the Leclanche subcategory have wastewater treatment systems. Two plants discharge without treatment. Table V-50 (page 314) summarizes treatment in place for this subcategory. The most frequent technique was filtration, which was reported at four plants. Three plants reported pH adjustment, two reported coagulant addition, one reported skimming, and one reported carbon adsorption.

Table V-51 (page 315) shows reported effluent quality at the Leclanche plants. Comparing this table with the treatment system information shows that treatment, as practiced, has not always been very effective. Plant F, which reported high mercury and zinc effluent concentrations as shown in this table, also reported one of the more substantial treatment systems including amalgamation, pH adjustment, coagulant addition, and filtration. The treatment effectiveness at one plant was determined by sampling on three days. The results of sampling presented in Table V-52 (page 316) show that the skimming and filtration effectively lower oil and grease and TSS. However, because the pH was not controlled at the optimum level (8.8-9.3), zinc and manganese levels actually were higher after treatment than before. This indicates improper operation of the system.

LITHIUM SUBCATEGORY

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

Seven plants reported the manufacture of a total of eight different types of batteries within this subcategory. Because lithium battery technologies are rapidly changing, production patterns are also undergoing rapid change. Three of the seven identified producers were not manufacturing in this subcategory during 1976 and submitted production data for more recent years. Consequently, it is not possible to compare plant production figures for any single year. Based on the submitted figures, production ranges from less than 50 kg per year (100 lbs/yr) to 14 kkg/yr (15.5 tons/yr) and in employment from 4 to 175. One plant accounts for more than half of the total subcategory output. However, several plants reported only prototype, sample, or startup production with larger scale operations anticipated in the future. In the data base, lithium subcategory production is heavily concentrated in the northeastern U.S. with one plant in EPA Region I, two in Region III and three in Region II. The other producer was a small operation in Region IX.

While plants differ significantly in products, manufacturing processes, production volume, and employment, all report little or no wastewater discharge and relatively few process wastewater sources. Consequently, existing wastewater treatment and available effluent monitoring data are limited.

Manufacturing Processes

The manufacture of batteries in this subcategory is illustrated in the generalized process diagram shown in Figure V-11 (page 402). The manufacture of lithium anodes generally involves only mechanical forming of metallic lithium to the desired configuration. Depolarizers used with the lithium anodes are frequently blended with or dissolved in the cell electrolyte and include iodine, iron disulfide, lead iodide-lead sulfide-lead (mixed), lithium perchlorate, sulfur dioxide, thionyl chloride and titanium disulfide. Cell assembly techniques differ with specific cell designs. Usually, cell assembly is accomplished in special humidity controlled "dry" rooms. Thermal batteries manufactured in this subcategory include a heating component in addition to the anode, cathode depolarizer, and electrolyte discussed above. The relationship between the process elements and discrete wastewater sources reported at battery plants is illustrated in Figure V-12 (page 403).

Anode Operations

All cells manufactured in this subcategory employ a metallic lithium anode. The anode is generally prepared from purchased lithium sheet or foil by mechanical forming operations only, although one plant reported the preparation of a lithium alloy for use in high temperature batteries. In some cases the anode may also include a support structure of nonreactive metal such as aluminum screen. The use of pasted or powder anodes as observed in other subcategories is not reported, apparently because the high reactivity of lithium and relatively low current drains for which most (nonthermal) lithium cells are designed do not necessitate maximized anode surface areas.

Cathode Operations

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

Iron Disulfide Cathodes - Iron disulfide is used as a depolarizer in thermal batteries which use lithium anodes.

Lead Iodide Cathodes - This cathode is reported to be a mixture of lead iodide, lead sulfide and lead. Fume scrubbers are used in the production areas.

Lithium Perchlorate Cathodes - Manufacture of this type of cathode was reported only on a small scale in sample quantities. Manufacturing process details were not supplied.

Sulfur Dioxide Cathodes - The manufacture of cathodes for cells using sulfur dioxide depolarizer begins with the preparation of a porous carbon electrode structure. Binders such as teflon may be added to a carbon paste which is applied to a metallic grid. The sulfur dioxide is mixed with an organic solvent (generally acetonitrile) and one or more inorganic salts such as lithium chloride or lithium bromide. The resultant liquid organic electrolyte-depolarizer mixture is added to the cells, and they are sealed.

Thionyl Chloride Cathodes - Production of cells using thionyl chloride as the depolarizer is similar to that discussed above for sulfur dioxide depolarized cathodes except that the organic electrolyte acetonitrile is not used.

Titanium Disulfide Cathodes - Titanium disulfide cathodes are made by blending the active material (as a powder) with a binder and inserting the mixture in a metal can. Electrolyte, which is formed from dioxolane and sodium tetraphenyl boron, is added separately after insertion of the cell separator and anode.

Water Use, Wastewater Characteristics, and Wastewater Discharge

Process Water Use

As previously indicated, water use and process wastewater discharge in this subcategory is quite limited. Three of seven plants in the subcategory reported process wastewater discharges. These ranged from 3.9 l/hr to 150 l/hr. Mean and median normalized discharge flows from both dcp and visit data for each of the wastewater producing elements included in this subcategory are summarized in Table V-53 (page 317). This table also presents the production normalizing parameters upon which the reported flows are based and which were discussed in Section IV, and the annual raw waste volume for each process.

Process Wastewater Characteristics

Anode Operations - There is no process wastewater associated specifically with lithium anode manufacture.

Cathode Operations - There is no process wastewater associated with the manufacture of the following cathodes: iodine, lithium perchlorate, and titanium disulfide.

Lead Iodide Cathodes - The manufacture of lead iodide cathodes generates process wastewater from equipment cleaning. This process is separated from the ancillary floor and equipment wash because of the presence of lead. This process was not specifically sampled, however pollutant concentrations are expected to be similar to those in the iron disulfide process.

Iron Disulfide Cathodes - The manufacture of iron disulfide cathodes generates process wastewater. In the manufacture of iron disulfide cathodes, process wastewater is generated. The chemical analysis data for process wastewater from the manufacture of iron disulfide cathodes at Plant A are presented in Table V-54 (page 318). The corresponding mass loadings for this stream are shown in Table V-55 (page 319).

Sulfur Dioxide Cathodes - The manufacture of sulfur dioxide cathodes does not generate wastewater in the actual production operations, but wastewater results from air scrubbers used to control sulfur dioxide emissions. Wastewater from the scrubbers is included under ancillary operations.

Thionyl Chloride Cathodes - The manufacture of thionyl chloride cathodes is reported to generate two process wastewater streams resulting from wet air pollution control scrubbers and from washdown of spilled materials. Wastewater discharge from spills occurs only when there are accidents and since none occurred this process stream could not be sampled. Wastewater generated from air scrubbers is included under ancillary operations.

Ancillary Operations - Heating Component Production - (Heat Paper Production) - Wastewater is generated by the manufacture of heat paper for use in thermal cells manufactured in this subcategory. The heat paper production process is identical to that previously discussed in the calcium subcategory. The sampling analysis data and the corresponding mass loadings for the wastewater stream produced by heat paper production are listed in Tables V-34 and V-35 (Pages 298 and 299) which were discussed in the calcium subcategory. (Heat Pellet Production) - No process water use or discharge is generated from this process which is used in the manufacture of thermal batteries. Heat pellet production is identical to that discussed under the calcium subcategory discussion.

Cell Washing - Following assembly lithium cells can be washed. Wastewater is discharged from this process. Washing lithium cells was reported to produce process wastewater at one plant. The total volume of wastewater was about 55 gallons per week, and was periodically discharged. The production normalized discharge volume is 0.929 l/kg of cells produced. No priority pollutant chemical characteristics were reported by the plant and the operation was not characterized by sampling.

Cell Testing - After assembly, thermal cells may be immersed in a water bath to test for leakage. The contents of this bath may be discharged on an infrequent basis. Wastewater from testing of thermal cells is identical to that for calcium anode thermal batteries which was discussed on page 192.

Scrap Disposal - Lithium scrap is disposed of at some sites by reacting it with water. Although no discharge of the resultant solution is reported at present, this scrap disposal process is a potential source of process wastewater. Plant A disposes of scrap lithium off-site with a single aeration process in a settling tank. The plant reported that the resulting wastewater will be contract hauled, although no removal of material from the disposal tank had yet occurred. A sample was taken from the tank to obtain representative wastewater characteristics for a scrap disposal dump. The sample analysis data are presented in Table V-56 (page 320).

Floor and Equipment Wash - A negligible amount of water is used for floor and equipment wash.

Air Scrubbers - Wastewater is generated from air scrubbers located in various process areas in this subcategory. One plant reports an air scrubber discharge flow of 3.9 liters per hour, but completely recycles the scrubber water and did not report wastewater discharge. Another plant reported a discharge of 56.8 l/hr. Other plants also produce scrubber wastewater but did not report the volume of this wastewater stream. Scrubber discharges in this process element are not characterized in dcp data or in sampling because they are not believed to contribute any significant priority pollutants to the total wastewater discharge. The wastewater discharges from sulfide dioxide cathode production area scrubbers will contain primarily sulfurous acid and sodium sulfite (resulting from the addition of sodium hydroxide to the scrubber water). The wastewater discharges from thionyl chloride cathode production area scrubbers are expected to contain hydrochloric and sulfurous acids and sodium chloride and sodium sulfite derived from dissolution of thionyl chloride and reaction with sodium hydroxide added to the scrubber solutions. Exposure to and contamination by other pollutants will, in general, be minimal. Elimination of discharge can be accomplished either by elimination of the use of wet scrubbers or by treatment and recycle of the scrubber wastewater.

Total Process Wastewater Discharge and Characteristics

Water use and wastewater discharge are observed to be variable depending upon the particular processes used to manufacture different types of batteries. Also the total wastewater discharged, about 350,000 l/yr is low when compared to other battery subcategories. For the purposes of treatment the types of wastewater streams generated need to be considered. The heat paper production wastewater stream, as discussed under the calcium subcategory, contains hexavalent chromium.

The wastewaters from cathode operations (iron disulfide and lead iodide) contain metals, and the cell testing, lithium scrap disposal, and floor and equipment wash will also contain metals. The scrubber wastewaters contain limited amounts of pollutants. More detailed data on process wastewater and effluent characteristics are limited in this subcategory because of the present levels of production which are low.

Wastewater Treatment Practices and Effluent Data Analysis

Two plants reported zero discharge of wastewater and one plant contract hauled wastewater from one wastewater stream. Wastewater treatment practices within this subcategory are limited to pH adjustment and settling as shown in Table V-57 (page 321). Two plants reported pH adjustment of process wastewater while one plant reported only settling. Effluent monitoring data were submitted by only one plant. These data characterized the settled wastewater discharge resulting from heat paper production. They have been presented in Table V-37 (page 301) and discussed under the calcium subcategory. Treated effluent data were obtained by sampling one additional wastewater stream in the lithium subcategory. Wastewater resulting from the manufacture of iron disulfide cathodes was sampled after treatment in a settling tank which provided a short retention time for the removal of suspended solids. Analysis results for this wastewater stream are presented in Table V-58 (page 322). Several metals values (0.9 mg/l of lead and 43.5 mg/l of iron) indicate that additional treatment can be used for these wastewaters.

MAGNESIUM SUBCATEGORY

The magnesium subcategory includes manufacturing operations used to produce cells combining magnesium anodes with cathodes of different materials. Many of the cell types produced are reserve cells which are activated by electrolyte addition or by a chemical reaction which raises the cell temperature to the operating level.

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

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

Six of the eight plants manufacturing magnesium anode batteries report production in other battery manufacturing subcategories as well. Magnesium-carbon battery production is co-located with Leclanche subcategory production at two of the three plants where magnesium-carbon batteries are produced. This association is logical since cathode materials and cell assembly techniques are quite similar for these cell types. Other subcategories produced at the same site as magnesium subcategory production include the cadmium subcategory, lead subcategory, lithium subcategory, and zinc subcategory. In most cases, magnesium subcategory production accounts for less than 30 percent of the total weight of batteries produced at the plant.

A number of different process operations in the subcategory are observed to yield process wastewater. These wastewater streams differ significantly in flow rates and chemical characteristics.

Because of the limited use of water and wastewater discharge associated with magnesium subcategory operations, wastewater from magnesium subcategory production is combined with wastewaters from other subcategories at only one plant. Since no production operations are common at that site, segregation of wastewaters at that plant is feasible.

Geographically, producers in this subcategory are scattered. One plant is located in each of the U.S. EPA Regions I, III, VI and

VIII, two in Region IV, and two in Region V. No two plants are located in the same state.

Manufacturing Process

The manufacture of magnesium anode batteries is illustrated in the generalized process flow diagram of Figure V-13 (page 404). Anode manufacture generally requires mechanical forming and cutting of magnesium metal, and cleaning and chromating of the formed product. Cathodes are prepared by a variety of techniques including blending and pressing of powdered materials, as well as processes involving chemical treatment operations. Heating components (heat paper) are manufactured at one plant for assembly into magnesium anode thermal batteries. One plant reported testing assembled cells with a subsequent wastewater discharge. The relationship between the process elements and discrete wastewater sources reported at battery plants is illustrated in Figure V-14 (page 405).

Anode Operations

Anodes used in this subcategory are mechanically formed metallic magnesium, except for thermal cells where the anode is magnesium powder. In magnesium-carbon cells, the anode may be the can in which the cell is assembled. In other cell types and in some magnesium-carbon cells, the anode is cut from magnesium sheet or foil. Magnesium anodes used in magnesium-carbon cells are generally cleaned and chromated before assembly of the cells. The chromate conversion coating on the magnesium anode serves to suppress parasitic chemical reactions during storage, and to reduce self-discharge of these cells. One plant reported no generation of wastewater from chromating. These operations as well as the metal forming operations to produce magnesium cans may be performed on-site at the battery manufacturing plant or by a separate supplier. As discussed in Section IV these operations are not included in the battery manufacturing category.

Cathode Operations

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

The depolarizer for these cells, manganese dioxide, is blended with carbon and other inorganic salts such as barium and lithium chromate to enhance conductivity of the depolarizer mix.

Magnesium perchlorate electrolyte may also be added to this mixture before assembly into the cell.

Copper Chloride Cathodes - The production of copper chloride cathodes for use in reserve cells is reported to proceed by forming the powdered material into pellets which are subsequently inserted into the cell assembly.

Copper Iodide Cathodes - The manufacture of this cathode type involves mixing cuprous iodide, sulfur, and carbon and then sintering the mixture. The sintered material is subsequently ground, and then pressed on a supporting copper grid to form the cathode which is dipped in an aqueous alcohol solution prior to insertion in the battery.

Lead Chloride Cathodes - Lead chloride cathodes are reported to be produced by pressing lead chloride on a copper screen.

m-Dinitrobenzene Cathodes - Cathodes in which this material serves as the depolarizer are produced by mixing m-dinitrobenzene with carbon or graphite, ammonium thiocyanate, and glass fiber. The mixture is subsequently molded or pasted to produce a thin sheet which is in contact with a flat stainless steel current collector in the assembled cell.

Silver Chloride Cathodes - Three different processes are reported for producing silver chloride cathodes for use in reserve cells: pellet formation, silver reduction, and the electrolytic oxidation of silver.

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

In another process, silver chloride is calendered into strips and punched. The resultant material is then treated with photo developers such as hydroquinone, sodium thiosulfate, or paramethylaminophenol sulfate (ELON) to reduce the surface to metallic silver.

In the third method, silver is electrolytically oxidized in hydrochloric acid to produce silver chloride. The product of this operation is subsequently rinsed, dried, and used in assembling cells.

Vanadium Pentoxide Cathodes - Vanadium pentoxide, used as the depolarizer in magnesium anode thermal batteries, is blended with electrolyte (lithium chloride and potassium chloride) and kaolin as a dry powder and pressed to form pellets which are used in cell assembly.

Cell Assembly

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

In assembly of ammonia activated magnesium reserve cells, the ammonia which forms the electrolyte is placed in a sealed reservoir within the battery assembly. It is pumped into the cells at the time of activation of the battery. In magnesium anode thermal batteries solid electrolyte is incorporated into pellets containing the depolarizer. In seawater activated cells, the saline seawater itself serves as the electrolyte. No electrolyte is added during assembly of the cells.

Ancillary Operations

Five ancillary operations which produce wastewater were identified within the magnesium subcategory. The operations are discussed below.

Water Use, Wastewater Characteristics, and Wastewater Discharge

Process Water Use

Process water use varies considerably among manufacturers in this subcategory. As shown in the preceding manufacturing process discussion, most process operations are accomplished without the use of process water. In addition, many of the cell types produced use nonaqueous electrolytes or they are shipped without electrolyte. Mean and median normalized discharge flows from both dcp and visit data for each of the wastewater producing elements included in this subcategory are summarized in Table V-59 (page 323). This table also presents the production normalizing parameters upon which the reported flows are based and which were discussed in Section IV, and the annual raw waste volume for each process.

Wastewater Characteristics

Anode Operations - The only wastewater generating processes involved in anode manufacturing are the cleaning and chromating of magnesium anodes. The wastewaters produced by these metal finishing processes are not included in the battery manufacturing category.

Cathode Operations - As stated previously, there are seven different cathodes which are used in the production of magnesium anode batteries. The manufacture of six of these cathode types - carbon, copper iodide, copper chloride, lead chloride, m-dinitrobenzene and vanadium pentoxide - produces no wastewater. The production of silver chloride cathodes generates wastewater.

Silver Chloride Cathodes - Pellet. The formation of silver chloride powder into pellets is a dry operation.

Silver Reduction. The rinsing step following reduction generates wastewater, as do periodic dumps of spent developing solutions. Following the first rinse, the cathodes are either dipped in acetic acid and rinsed, or are just rinsed again, generating additional wastewater. Pollutant concentrations found in the waste streams from the silver chloride reduction process at Plant A are shown in the screening analysis, Table V-6 (page 261). As shown in the table, silver is the only priority pollutant at significant concentration levels. The total phenols concentration found is believed to not represent the true level of phenolic materials present because of the masking effect of the developer formulation and the analytical procedure used. This judgment is made on the basis of the chemical constituents in the developer solution.

Normalized wastewater flow from this process was 4915 l/kg. Rinse water flow from this process was found to be excessive (not adequately controlled) and exceeded the normalized flow previously confirmed by the plant (3310 l/kg), for 1976 data. Since flow was not controlled at the time of sampling, concentrations of pollutants in the total process are substantially lower than separate samples from each process step. Evidence of this is shown in the separate sample taken of the developer solution displayed in Table V-60 (page 324). Concentrations of pollutants, particularly metals and COD are significantly reduced by dilution as a result of excess usage of process water.

Electrolytic Oxidation. Process wastewater results from rinsing the electrolytic silver chloride. The electrolytic oxidation of silver foil to silver chloride in hydrochloric acid also produces wastewater. Plant A uses this method to manufacture silver chloride cathodes. Normalized wastewater flow from the rinsing operation and from the dumps of spent hydrochloric acid was measured at 145 l/kg. Flow from this process was adequately controlled and was appreciably lower than the normalized flow previously confirmed by the plant (1637 l/kg) for 1976 data. Plant A did not report any wastewater characteristics for the electrolytic forming stream, but it was characterized by sampling. The screening sample in Table V-6 (page 261) presents the pollutant characteristics of the waste stream from rinsing the product and of the spent hydrochloric acid discharged. The only toxic pollutant found significant concentrations was silver.

Cell Assembly - None of the cell assembly processes were reported to generate process wastewater.

Ancillary Operations - Several ancillary operations within this subcategory produce wastewater. Among these operations are heating element manufacture, glass bead separator processing, floor and equipment washing, cell testing, and fume scrubbing.

Heating Component Production - (Heat Paper Production) - Magnesium anode thermal batteries are activated by heat generated in a chemically reactive element (heat paper) incorporated within the cell structure. The production of heat paper for magnesium batteries is identical to the production of heat paper for calcium batteries. Barium chromate, zirconium, and fibers (such as asbestos) are the raw materials used in the process. The production of the heating component generates process wastewater as was described for the calcium subcategory. The pollutant characteristics of the heat paper manufacturing wastewater stream along with their corresponding pollutant mass loadings are presented in the discussion of calcium batteries and are displayed in Tables V-34 and V-35 (pages 298 and 299). At Plant A which produces heat paper within the magnesium subcategory, the volume of process wastewater is 308.1 l/kg. (Heat Pellet Production) - Although not reported in this subcategory, heat pellets are manufactured for thermal batteries. No process wastewater is generated from this process. Production is identical to that discussed under the calcium subcategory.

Glass Bead Separators - One manufacturer of silver chloride magnesium batteries uses glass beads as a separator material. These beads are etched with ammonium bifluroide and hydrofluoric acid. The rinse following this etch step is a source of wastewater. The plant reported 9.1 l/hr of wastewater generated and gave the following sampling data:

Pollutant	mg/l
Aluminum	1.8
Ammonia-nitrogen	17.7

Since this process is not presently active, no further discussion of waste characteristics is necessary.

Floor and Equipment Washing - The removal of contaminants from production area floors and process equipment is frequently required for hygiene and safety. This may be accomplished by dry techniques such as sweeping and vacuuming but may also require the use of water in some instances. Two plants in this subcategory reported floor washing and indicated a resultant process wastewater discharge. At one plant that reported washing floors intermittently, the washing operation used about 38 l/day of water. The discharge was not characterized in the dcp or in sampling because the operation is sporadic, and also because the floor areas would be contaminated with pollutants from another subcategory. As in other subcategories, this wastewater source may be eliminated by the use of dry floor cleanup techniques.

Cell Testing - After assembly, quality control tests on magnesium reserve cells may include activation to verify satisfactory performance. Water used in this operation (destructive testing) was reported to constitute a source of process wastewater by one manufacturer of magnesium reserve cells. Plant A utilizes a cell testing process in which a water solution of 5% sodium and magnesium salts is used to activate lead chloride magnesium reserve cells. No samples were taken and the plant did not report any data on the cell testing stream. The only major constituents of the wastewater are expected to be sodium, magnesium, chloride, and lead. This operation has a flow of 52.6 liters per kilogram of batteries produced.

Fume Scrubbing - Wastewater is discharged from fume scrubbers on dehumidifiers used to dry manufacturing areas. Process wastewater is also reported from the use of scrubbers on vent gases from drying blended electrolyte and depolarizer for use in magnesium anode thermal batteries. The wet scrubbers serve to control emissions of potassium chloride and lithium chloride electrolyte from the drying process, and these salts are consequently present in the scrubber discharge. The concentrations of these pollutants were not reported in dcp data and were not determined in sampling. However, elimination of this discharge by treatment and recycle is feasible as demonstrated in other industrial categories. This has been partially accomplished at Plant A, which by replacement of the original once-through scrubber with a recirculating scrubber, substantially lowered its discharge flow from 1652 l/kg to 206.5 l/kg.

Total Process Wastewater Discharge and Characteristics

Process operations which result in battery manufacturing wastewater are reported at four of the eight plants in the subcategory. Total process wastewater flow rates are reported to range from 0 to 42,000 l/day (11,100 gal/day). Wastewater discharges from plants in this subcategory are equally split between direct and indirect discharge. Total process wastewater discharge from magnesium subcategory processes at individual plants is presented in Table V-61 (page 325).

Actual water use and wastewater discharge are observed to be variable depending upon the particular processes used to manufacture different types of batteries. About 1.5 million l/yr is discharged by plants in this subcategory. For the purposes of treatment the types of wastewater streams generated need to be considered. The heat paper production wastewater stream, as discussed under the calcium subcategory, contains hexavalent chromium. The wastewaters from the silver chloride cathode processes contain metals and COD, and the cell testing and floor and equipment wastewaters also contain metals. The scrubber wastewaters contain limited amounts of pollutants. More detailed data on process wastewater and effluent characteristics are limited in this subcategory because of the present levels of production which are low.

Wastewater Treatment Practices and Effluent Data Analysis

Present wastewater treatment practice within this subcategory is limited. Treatment practices at most plants are limited to pH adjustment and removal of suspended solids. One plant reported the use of settling tanks followed by filtration for this purpose. Treatment in place at magnesium subcategory plants is summarized in Table V-62 (page 326). No effluent analyses specifically characterizing treated wastewater from this subcategory were supplied in the dcp.

ZINC SUBCATEGORY

Five battery product types: carbon-zinc-air, alkaline manganese, mercury-zinc, silver oxide-zinc, and nickel-zinc are manufactured within the zinc subcategory. Silver oxide-zinc cells are produced using two different oxides of silver, silver oxide (monovalent) and silver peroxide. Many produce more than one type of cell. Wastewater treatment practices and effluent quality are highly variable.

There are 17 plants in the data base for this subcategory. One plant has ceased production. During the years 1976-1979 when the data base was established, annual production in the subcategory is estimated to have been 22,300 kkg (24,500 tons), and is broken down among battery types as shown below:

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

Geographically, active plants in the zinc subcategory are concentrated primarily in the eastern and central EPA Regions. There are five plants in EPA Region IV, four plants in Region V, two plants each in Regions I, II, and VII, and one plant in Region VIII.

Although there were some variations in raw materials with manufacturing process and product variations, many of the raw materials used in producing zinc anode batteries were common to all plants. Mercury is used to produce cathodes and for amalgamation.

All batteries manufactured in this subcategory use an amalgamated zinc anode. The zinc is amalgamated to reduce anode corrosion and self-discharge of the cell. The electrolyte is an aqueous alkaline solution - usually potassium or sodium hydroxide. The zinc anodes differ considerably in physical configuration and in production technique depending upon the desired operational characteristics of the cells. This subcategory includes batteries manufactured for a variety of applications requiring different performance characteristics and physical dimensions. Six different cathode depolarizers are used in zinc anode cells: porous carbon, manganese dioxide, mercuric oxide, mercuric oxide and cadmium oxide, silver, and silver oxide. Cathodes for using these depolarizers may require several different production techniques.

Steel is used in cell cases, and paper and plastics are used in cell separators and insulating components. Other raw materials are discussed under the processes they are used in.

Manufacturing processes differ widely within the subcategory. This results in corresponding differences in process water use and wastewater discharge. A total of 25 distinct manufacturing process operations or process elements were identified. These operations are combined in various ways by manufacturers in this subcategory and they provide a rational basis for effluent limitations. Following a discussion of manufacturing processes used in the subcategory, each of the wastewater producing process elements is discussed in detail to establish wastewater sources, flow rates, and chemical characteristics.

Manufacturing Processes

The manufacture of zinc subcategory batteries is represented by the generalized process flow diagram presented in Figure V-15 (page 406). The anode and cathode variations observed in this subcategory and the ancillary operations which generate process wastewater were the basis for analysis of process wastewater generation as illustrated in Figure V-16 (page 407). As shown in the figure, several distinct wastewater streams frequently result from a single process operation or element.

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

In this part, manufacturing operations for all anode and cathode elements, wet or dry, are described. No ancillary operations are described. Under "Process Water Use" ancillary operations which generate process wastewater are described along with the wastewater flows and characteristics.

Anode Operations

Zinc anodes used in these cells usually corrode by reactions with the cell electrolyte. When these reactions occur hydrogen gas is evolved. The rate of hydrogen evolution on zinc in the cell is reduced by zinc anode amalgamation, thus reducing anode corrosion. This reduction in the rate of anode corrosion is essential to the achievement of acceptable battery life, and anode amalgamation is universal in this subcategory. Because many of the cells produced are designed for high discharge rates, powdered zinc and porous structures are used in anodes to maximize electrode surface area. Mercury requirements for amalgamation of powdered zinc are thereby increased compared to the requirement for sheet zinc, and mercury consumption in amalgamating anodes in this subcategory is typically 0.05 kg per kg of zinc as compared to 0.00035 kg per kg of zinc in the Leclanche subcategory. This increase in mercury requirements influences the choice of amalgamation techniques which may be used as well as the severity of mercury pollutant discharge problems encountered.

Amalgamation is accomplished by one of six different techniques which are discussed in the description of each anode manufacturing process. The choice of technique depends on the anode configuration and the preference of the manufacturer. Amalgamation by inclusion of mercury in the cell separator or electrolyte as observed in the manufacture of Leclanche subcategory batteries is not practiced by any manufacturer in the zinc subcategory.

Zinc Cast or Fabricated Anode - Anodes in this group are produced by casting or by stamping or forming of sheet zinc. In producing cast anodes, zinc and mercury are alloyed, and the mixture is cast to produce amalgamated anodes for use in air-depolarized cells. Because of their relatively low surface area per unit weight, these cast anodes are not suitable for use in cells designed for high discharge rates. Two plants in the data survey reported using cast anodes for carbon-zinc-air cell manufacture.

Zinc Powder - Wet Amalgamated Anode - Wet amalgamation of zinc powder is used by plants producing alkaline manganese cells and a variety of button cells with mercury and silver cathodes. In this process, zinc and mercury are mixed in an aqueous solution which generally contains either ammonium chloride or acetic acid to enhance the efficiency of amalgamation. Later, the solution is drained away and the amalgam product is rinsed, usually in several batch stages. A final alcohol rinse is frequently used to promote drying of the product. Binders such as carboxymethylcellulose (CMC) are commonly added to the dry amalgamated zinc powder to aid in compaction of the anode in the cells. When the dried amalgamated product is found to be unacceptable for use in assembling batteries, it may be returned to the amalgamation area for reprocessing and further rinsing. Figure V-17 (page 409) is a schematic diagram of the zinc powder-wet amalgamation process. Six plants in the data base reported using wet amalgamated powdered zinc processes for anode formulation. Two plants have discontinued these operations.

Zinc Powder - Gelled Amalgam Anode - The gelled amalgam process results in a moist anode gel in a single operation. The production of gelled amalgam, illustrated in Figure V-18 (page 410), begins with the combination of zinc and mercury powder in the appropriate proportions and the addition of potassium hydroxide solution to this mixture. The gelling agent which is either carboxymethylcellulose or carboxypolymethylene, is blended in the amalgam mixture to achieve the appropriate gel characteristics. Three plants produce gelled amalgam.

Zinc Powder - Dry Amalgamated Anode - In the dry amalgamation process zinc powder and metallic mercury are mixed for an extended period of time to achieve amalgamation. To control mercury vapor exposure of production workers, the mixing is commonly performed in an enclosed vented area separate from the material preparation areas. Discussions with industry personnel have indicated that this process is less costly than wet amalgamation and has resulted in satisfactory anode performance.

This process element also includes the production from zinc powder amalgamated off-site. Two plants obtain amalgam produced off-site and one produces dry, amalgamated powder.

Zinc Oxide Powder - Pasted or Pressed Anodes - Zinc oxide and mercuric oxide are mixed in a slurry. The mixture is layered onto a grid. The resultant product is allowed to dry, and finally the dried material is compressed to eliminate irregularities such as jagged edges. The anode plaques are assembled with cathode plaques to manufacture batteries which are shipped unformed, to be later formed by the customer. Only one plant reported manufacturing slurry pasted anodes which are assembled with uncharged cathodes to produce cells to be later charged by the customer. No plants reported manufacturing zinc oxide anodes pressed from dry powder and shipped unformed. However, similar operations were reported in the cadmium subcategory and by analogy such an operation might be expected in the future with zinc oxide and will fall into this process element.

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

The pressed powder technique for zinc anode formulating, illustrated in Figure V-19 (page 411), requires preparation of a dry powder mixture of both zinc oxide and mercuric oxide. A binding agent such as PVA is added to the mixture prior to application to the grids. The grids are held in place by separate molds. The grids and the powder mixture are compressed together and the resulting plaques are immersed in potassium hydroxide solution. The plaques are electrochemically formed and subsequently rinsed and dried.

The slurry paste processing method is illustrated in Figure V-20 (page 412). A slurry of zinc oxide and mercuric oxide, is prepared with water or dilute potassium hydroxide. A binding agent such as CMC may be added to the slurry. The slurry is layered onto a silver or copper screen and the material is allowed to dry prior to formation. The dried plates are immersed in a potassium hydroxide solution and formed against either positive electrodes or nickel dummy electrodes. After formation, the anodes are thoroughly rinsed to assure removal of potassium hydroxide. The plaques are dried and later compressed to eliminate irregularities such as jagged edges. Four plants reported using the pressed powder or pasted slurry technique followed by reduction for zinc anode manufacture.

Electrodeposited Zinc Anode - In this process zinc is electrodeposited on a grid and rinsed prior to amalgamation by immersion in a solution of mercuric salts. Afterwards, the plaques are either immediately dried, or rinsed and then dried. (In this process the term electrodeposition is used in the conventional sense - powdery zinc metal deposits on the grid.) The most common grid materials used in the electrodeposition process are silver and copper expanded sheets. The grids are immersed in an aqueous solution of potassium hydroxide and zinc, and an electrical current is applied causing the zinc to deposit onto the grids. When the appropriate weight gain of active material on the grids is achieved, the grids are removed from the caustic solution and subsequently rinsed in a series of tanks. At an intermediate point in the rinsing procedure, the moist material may be compressed. After completion of the rinse operation, the prepared plaques are dipped in an acidic solution containing mercuric chloride. Mercury is reduced and deposited on the surface where it forms an amalgam with the zinc. The amalgamated plaques are either rinsed and subsequently dried or immediately dried following amalgamation. Figure V-21 (page 413) is a schematic diagram of the entire electrodeposition process.

Cathode Operations

Depolarizers used in this subcategory are primarily metal oxides which are purchased from manufacturers of inorganic chemicals. In some cases depolarizer material is chemically prepared on-site because special characteristics are required for battery manufacture. Preparation of such special depolarizer materials is considered a battery manufacturing operation. Commercially available depolarizer materials may also be prepared on site at battery plants in processes equivalent to those used in inorganic chemicals manufacturing operations. Preparation of depolarizer materials which are commercially available is not considered a battery manufacturing operation. Ten distinct cathode manufacturing processes are observed in this subcategory.

Porous Carbon Cathode - Porous carbon cathodes are used in air depolarized cells. They are produced by blending carbon, manganese dioxide and water, then pressing and drying the mixture to produce an agglomerated cathode structure or "agglo." The agglo serves as a current collector for the cathode reaction and as a porous medium to carry atmospheric oxygen to the electrolyte. Control of the porosity and surface characteristics of the agglo is essential since the cathode structure must permit free flow of oxygen through the pores, but prevent flooding of the pores by electrolyte in which it is immersed. Flooding of the agglo would reduce the surface area over which reaction with oxygen could occur to such an extent that practical cell operation could not occur. The agglos are assembled with cast zinc anode plates to produce carbon-zinc air cells.

Manganese Dioxide-Carbon Cathode - Cathodes in this group are produced by blending manganese dioxide with carbon black, graphite, Portland cement, and for some special cells, mercuric oxide. Typically the cathode mixture is inserted in steel cans along with separator material. Electrolyte solution consisting of potassium hydroxide is subsequently added to the partly assembly cells. At some plants, electrolyte solution is blended with the cathode material, and the resulting mixture is molded into cylindrical structures prior to insertion in the steel cans. The separator material is placed into the interior of each can, and additional electrolyte solution is then applied. Nine plants reported producing manganese dioxide-carbon cathodes for alkaline-manganese cell manufacture. Three of these plants have since discontinued the production of alkaline-manganese cells.

Mercuric Oxide (And Mercuric Oxide-Manganese Dioxide Carbon) Cathodes - The manufacturing process for mercuric oxide cathodes is similar to that described above for manganese dioxide cathodes. Mercuric oxide, as a dry powder, is blended with graphite and sometimes with manganese dioxide, pressed into shape, and inserted in steel cell containers. Four plants produce this cathode for mercury (Ruben) cells. Production at one plant was stopped after submittal of dcp.

Mercuric Oxide-Cadmium Oxide Cathode - The mercuric oxide-cadmium oxide cathode is closely related to the mercuric oxide cathode and is manufactured by the same process except that cadmium oxide is included in the depolarizer mix. The function of the cadmium oxide is to provide continued cell operation at a reduced voltage for an interval after the mercuric oxide in the cathode is depleted. This characteristic is exploited in devices such as battery powered smoke detectors to provide a warning of impending battery failure. Production of this type of cathode was reported by one plant in the subcategory.

Silver Powder Pressed Cathode. The manufacture of pressed silver powder cathodes begins with the production of silver powder which is prepared on-site by electrodeposition. See "Ancillary Operations Producing Wastewater". The resultant powder is pressed on the surface of a silver screen or other support and sintered to achieve mechanical integrity. These electrodes may then be assembled with unformed (oxidized) zinc anodes and the resultant batteries charged prior to use.

Silver Powder Pressed and Electrolytically Oxidized Cathode - These cathodes are made from silver powder which is either purchased or produced on-site. Once the silver powder is prepared, the material is pressed on the surface of a silver grid or other support material and subsequently sintered. Next, the sintered plaques are immersed in potassium hydroxide solution and subjected to an electrical charge-discharge operation which converts the silver material to a silver oxide state. After completing this process, the formed plaques are rinsed to remove any residual caustic. Figure V-22 (page 414) is a schematic diagram of this process. Three plants reported pressing silver powder on grids to produce sintered plates which are subsequently formed.

Silver Oxide (Ag_2O) Powder Pressed Cathode - Cathodes using silver oxide powder are prepared by blending solid constituents and pressing them to produce cathode pellets for use in silver oxide-zinc button cells. Depending upon desired cell characteristics, manganese dioxide, magnesium oxide, and mercuric oxide may be added to change the cell voltage and the shape of the discharge curve. Manganese dioxide provides a period of gradual voltage decline after exhaustion of the silver oxide allowing cells used in devices such as hearing aids to "fail gracefully" and giving the owner time to replace them. Graphite is added to provide additional conductivity within the cathode while the silver is in the charged (oxide) state, and binders are typically added to improve mechanical integrity. Four plants reported manufacturing cathodes in this element.

Silver Oxide (Ag_2O) Powder - Thermally Reduced or Sintered, Electrolytically Formed Cathode - Cathode formulation using this process involves preparing a slurry paste of silver oxide powder and deionized water and layering the mixture on silver metal grids. The reinforced material is thermally reduced to silver by applying heat sufficient for sintering. The resulting plaques are positioned in tanks containing dilute potassium hydroxide solution, electrically formed, rinsed and soaked until the engineering specifications are met. Figure V-23 (page 415) is a schematic diagram of this process. Two plants reported using this process.

Silver Peroxide (AgO) Cathodes - The production of silver peroxide cathodes begins with the oxidation of silver oxide to produce silver peroxide. See Ancillary Operations Generating Wastewater. Two preparation processes are in current practice for preparing cathodes from the silver peroxide. Two plants use a chemical treatment process, and one plant uses a slurry pasting process.

The chemical treatment process starts with pelletizing of the silver peroxide powder. These cathode pellets are chemically treated in two-phases; first in a concentrated potassium hydroxide solution; and then in a concentrated potassium hydroxide-methanol mixture. After rinsing and extended soaking in potassium hydroxide, the pellets are treated with a solution of hydrazine and methanol to metallize the surface. Figure V-24 (page 416) is a schematic diagram of the process involving chemical treatment of silver peroxide pellets.

In another method currently used, silver peroxide cathodes are produced by mixing a slurry of silver peroxide powder, deionized water, and a binding agent such as carboxymethylcellulose. The slurry paste is layered on the surface of a silver metal grid and subsequently dried. Figure V-25 (page 417) is a schematic diagram of this process.

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

Process Integration - The different process operations discussed above may in principle be combined in many ways for the manufacture of batteries. Table V-63 (page 327) presents the combination of anode and cathode manufacturing processes observed in the subcategory at the present time. Of seventeen distinct process operations or functions identified in the subcategory for anode and cathode manufacture, eight are reported to result in process wastewater discharges. An additional eight ancillary process operations which produce wastewater are discussed later under "Ancillary Operations Generating Wastewater". All sixteen of these discharge sources were represented in sampling at zinc subcategory plants.

Water Use, Wastewater Characteristics, and Wastewater Discharge

Process Water Use

Mean and median normalized discharge flows from both dcp and visit data for each of the wastewater producing process elements included in this subcategory are summarized in Table V-64 (page 329). This table also presents the production normalizing parameters upon which the reported flows are based and which were discussed in Section IV, and the annual raw waste volume for each process. The water use and wastewater discharge from these process operations varies from less than 1 l/kg of production normalizing parameter for several processes to 3190 l/kg of deposited zinc for electrodeposited zinc anode manufacture. Observed flow rates for process wastewater at each zinc subcategory plant are displayed in Table V-65 (page 331).

Wastewater Characteristics

Anode Operations - Zinc Cast or Fabricated Anode - No process wastewater is generated in processing anodes by this procedure.

Zinc Powder - Wet Amalgamated Anode - There are four sources of wastewater from the wet amalgamation process: (1) spent aqueous solution discharge; (2) amalgam rinses; (3) reprocess amalgam rinses; and (4) floor area and equipment wash discharge. The discharge from amalgamation (total of above four streams) ranged from 1.4 to 10,900 liters per day at the seven plants which reported using the wet amalgamation process (2890 l/day mean). The production normalized discharge from both dcp and visit data ranges from 0.69 to 10.09 l/kg (3.8 l/kg mean). The final amalgam rinse with alcohol is generally retained and reused until ultimately contractor removed.

The wastewaters from wet amalgamation processes at two plants were sampled. The normalized discharge flow during sampling ranged from 1.88 to 6.82 l/kg (4.2 l/kg mean). The entire amalgamation process wastewater was sampled at both plants. Wastewater from amalgam preparation and equipment cleaning was combined. Another wastewater stream at one plant resulted from reprocessing amalgamated material. During the sampling visit amalgam that had been previously stored was being reprocessed intermittently throughout the three sample days. The mercury concentration in the wastewater from the "virgin" amalgam process is substantially greater than that of the reprocessed amalgam since no additional mercury is mixed into the latter material.

Table V-66 (page 332) presents the daily analysis results in units of mg/l for both sampled amalgamation processes. Higher zinc concentrations observed in wastewater from one plant result from the malfunctioning of the amalgam mixer. Each load of amalgam did not completely empty out of the tank. The tank was manually scraped to remove the residue from the mixer and the remaining material was washed from the tank with a hose. This cleaning procedure increased the volume of water used in the amalgamation process and contributed to the zinc concentrations of the wastewater. Mercury was detected in all the amalgamation samples, and was measured at relatively high concentrations in samples at Plant B.

Table V-67 (page 333) presents the pollutant mass loading in the amalgamation samples taken daily at both Plants B and A. The range, mean, and medium values in units of mg/l and mg/kg are presented in Tables V-68 and V-69 (pages 334 and 335), respectively.

Zinc Powder, Gelled Amalgam Anode - No wastewater discharge results directly from processing the gelled amalgam. However, both equipment and floor area are washed to remove impurities resulting from the amalgam processing. These maintenance procedures result in wastewater discharges.

Wastewaters from two plants (B and A) were sampled. Table V-70 (page 336) presents the analysis results of these wastewater streams. The discharge flows on a daily basis range from 0.21 to 1.67 l/kg (0.69 l/kg mean). The discharge flows measured at Plant B include the combined wastewater from equipment and floor area wash operations, whereas the flow measurements at Plant A involve wastewater from floor washing only.

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

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

Zinc concentrations in amalgamation wastewater on the first sampling day at Plant B could not be calculated. Pollutant concentrations in this wastewater stream were not measured directly but were determined by mass balance using two wastewater samples representing wastewater resulting from scrap cell deactivation and the mixed scrap cell deactivation and amalgamation wastewater. On the first day extremely high zinc concentrations in the scrap cell deactivation wastewater prevented accurate determination of zinc concentrations in the amalgamation waste stream.

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

Table V-71 (page 337) shows the daily pollutant mass loadings in units of mg/kg for both clean-up processes. Statistical analysis of these data are presented in Tables V-72 and V-73 (pages 338 and 339) for both mg/l and mg/kg analysis results, respectively.

Dry Amalgamated Zinc Powder Anodes - This process is a dry operation and involves no process wastewater discharge.

Zinc Oxide Powder, Pasted or Pressed Anodes - Since the formation operation is not conducted on-site, there is no wastewater associated with anode formation. No other sources of wastewater associated with the production of this anode type were reported.

Zinc Oxide Powder, Pasted or Pressed, Reduced Anodes - The only source of wastewater discharge is the post-formation rinse operation. Since the raw materials are comparable for the powder and the slurry techniques of preparing the plaques, the pollutant characteristics for the rinse water discharges are similar. The normalized discharge flow of the post-formation rinse based on weight of zinc applied in anode formulation ranges from 33.3 to 277.3 l/kg (142.4 l/kg mean). The rinse wastewater stream was sampled at two of these plants, Plants A and B. One plant, C, is excluded from the flow analysis because the required data were not provided in the dcp. At Plant B, plaques are rinsed in a multistage countercurrent rinse after formation.

The analysis results for each sample day from Plants A and B are presented in Table V-74 (page 340). Table V-75 (page 341) presents the pollutant mass loadings from anode preparation on a daily basis. Tables V-76 and V-77 (pages 342 and 343) show the statistical analysis of the raw wastewater data in units of mg/l and mg/kg, respectively.

Zinc Electrodeposited Anodes - The process wastewater associated with the manufacture of electrodeposited anodes are: (1) post-electrodeposition rinses, (2) amalgamation solution dump, and (3) post-amalgamation rinse.

Two plants (A and B) in the data base used the electrodeposition process. Based on the data received in the survey for Plant B and the visit data for Plant A, the discharge flows range from 1420.7 to 4966.9 liters per kilogram of zinc applied during the electrodeposition operation. Only the first two wastewater streams were sampled at Plant A because that plant does not require a rinse following the amalgamation step.

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

The other wastewater stream at Plant A which is associated with the zinc electrodeposition process is the amalgamation solution dump. At this plant, the amalgamation solution is dumped after sixteen hours of operation of a single electrodeposition line. Table V-78 (page 344) presents the chemical characteristics of two batch dumps of the spent amalgamation solution. The resulting normalized discharge flow averages one liter per kilogram of zinc applied. Table V-79 (page 345) presents chemical characteristics of the total wastewater discharge resulting from the production of electrodeposited zinc anodes. For the first and third days, these characteristics were determined by mass balance calculations from the measured characteristics of the electrodeposition rinse and amalgamation solution wastewater streams. In addition, the pollutant mass loadings on each sample day are presented in Table V-80 (page 346).

Cathode Operations - Porous Carbon Cathode - No wastewater is discharged from this operation at either of the two plants reporting the manufacture of porous carbon cathodes.

Manganese Dioxide-Carbon Cathode - The processes used to formulate the cathode material do not generate any wastewaters.

Mercuric Oxide (And Mercuric Oxide-Manganese Dioxide-Carbon) Cathodes - The cathode formulation process generates no process wastewater since the blended and pelletized materials are in dry powdered forms.

Mercuric Oxide-Cadmium Oxide Cathode - No process wastewater is generated from this process since the materials are combined in a dry powdered state, and further processing is executed under dry conditions.

Silver Powder Pressed Cathode - No process water is used and no wastewater discharge results from the production of these cathodes.

Silver Powder Pressed and Electrolytically Oxidized Cathodes - Three plants reported pressing silver powder on grids to produce sintered plaques which are subsequently formed. The post-formation rinse was the only source of wastewater and was sampled at both Plants A and B. Table V-81 (page 347) presents the normalized discharge flows which range from 79.7 to 1135.5 liters per kilogram of silver powder applied to the grid material. With the value for the second day at Plant A eliminated because of variability observed with floor area maintenance water use, the mean normalized flow is 196.25 l/kg. Analysis results are presented in Table V-82 (page 348).

Table V-83 (page 349) presents the daily pollutant mass loadings of both plants and statistical analysis in units of mg/l and mg/kg are presented in Table V-84 and V-85 (pages 350 and 351), respectively.

Silver Oxide (Ag_2O) Powder Pressed Cathodes - No wastewater is generated from this process since the materials are combined in the dry powdered state and further processing, involving pelletizing and insertion into the cell container, is done under dry conditions.

Silver Oxide (Ag_2O) Powder - Thermally Reduced or Sintered, Electrolytically Formed Cathode - The normalized wastewater flow rates for the two plants using this process ranged from 25.0 to 237.1 liters per kilogram of silver in the silver oxide applied to the grid material. These plants reported that wastewater discharges result from slurry paste preparation, formation, and post-formation rinsing. However, Plant A reported data only for post-formation rinsing (corresponding to the 25.0 l/kg), and Plant B reported data only for spent formation solutions and post-formation rinses (corresponding to the 237).

Two samples were taken at Plant B which together represent an entire post-formation rinse cycle. The rinse cycle at Plant B has two phases. The first phase involves rinsing the plaques for approximately an hour while they are still positioned inside the formation tanks, and the second phase involves removing the plaques from the tanks and subsequently submerging them in water to soak for approximately 24 hours. The analysis results of the post-formation rinse wastewater (both phases) are presented in Table V-86 (page 352) and the pollutant mass loading estimates are presented in Table V-87 (page 353). The wastewater of the first phase of the post-formation rinse operation was sampled on the second day and the discharge flow was 437.3 l/kg. This wastewater stream is highly alkaline due to the residual formation caustic.

The second phase of the rinse cycle was sampled on the third day during which the normalized discharge flow was 100.9 l/kg. The significant pollutants in this wastewater stream are mercury and silver. The higher silver concentration in the wastewater of the second rinse phase compared to that reported for the first phase is due to the fact that a smaller volume of water is contacting the surface of the plaques for a considerably longer time span.

Silver Peroxide (AgO) Cathodes - Process wastewater streams are associated with the first phase of chemical treatment. The wastewater results from (1) spent potassium hydroxide and methanol bath dumps (2) rinsing, and (3) soaking. Two Plants (A and B) reported chemically treating silver peroxide pellets. The normalized discharge flow from this chemical treatment phase range from 5.6 to 12.8 liters per kilogram of silver processed. The latter value represents the average discharge flow observed during the sampling visit at Plant B. Observed daily discharge flows ranged from 5.5 to 22.4 l/kg. Table V-88 (page 354) presents the analysis results of the wastewater sampled at Plant B which is a combination of both the spent solution dump and subsequent rinse wastewater. Analytical results vary through the three sampling days due to the batch nature of the processes and the one-hour sampling interval.

The only wastewater from the slurry pasting process is from the clean-up of utensils used to mix the slurry and apply the material to a support.

Plant C reported manufacturing reinforced silver peroxide cathodes. The wastewater was sampled at this plant. The normalized discharge flow for the sample day was 76.0 liters per kilogram of silver processed. This flow varied according to the operator's discretion in the amount of water used to wash the utensils. Table V-88 (page 354) presents the results of analysis of the wastewater from the utensil wash operation at Plant C.

Table V-89 (page 355) presents the pollutant mass loadings in the process wastewater streams of both Plants C and B. These data are the basis for the statistical summary of wastewater characteristics from processes for producing silver peroxide cathodes. The wastewater streams resulting from both pellet chemical treatment and slurry application on support material are summarized in the statistical analyses presented in Tables V-90 and V-91 (pages 356 and 357).

Nickel Impregnated Cathodes - Discussion of wastewaters from manufacture of impregnated nickel cathodes is under the cadmium subcategory. Table V-18 (page 282) and Table V-19 (page 283) present the results of the analyses in terms of concentrations and mass loadings; corresponding statistical analyses are presented in Tables V-20 (page 284) and V-21 (page 285).

Ancillary Operations Generating Wastewater - Only wastewater generating ancillary operations are described in this part. Dry ancillary operations such as soldering, punching, or shearing are not described.

Cell Washing - Many of the cells produced in this subcategory are washed prior to assembly or shipment. These cell wash operations serve to remove spilled electrolyte, oils and greases, and general soil from the cell case, and to minimize the probability of corrosion of the battery case, contacts, or devices into which the battery is placed. There are a variety of cell washing systems including both manual and automatic types, and cleaning agents including solvents, compounds and plain water.

Cell wash operations presently conducted at the seven plants reporting cell wash operations can be assigned to one of five groups based on the chemicals used to wash the cells. This scheme is used as a framework for describing each of the cell wash operations. These groups are (1) acetic acid cell wash, (2) cleaning compounds (usually containing chromic acid) cell wash, (3) methylene chloride cell wash, (4) freon cell wash, and (5) plain water cell rinse. Within each group there is at least one plant in which the cell wash operation wastewater was sampled.

The first grouping listed involves the use of acetic acid in the preliminary phase of the cell wash operation. The sealed cells are immersed in a solution consisting of acetic acid with an unspecified detergent. Afterwards, the cells are transferred from the acidic solution to a potassium hydroxide solution; thoroughly rinsed to remove any remaining chemical used to clean the cells; and dipped in a solution containing an oil base additive. Two plants reported using this technique for cleaning cells.

The second general grouping involves the use of cleaners; usually containing chromic acid. Rinsing occurs after washing these cells. Four plants in the data base reported using cleaners containing chromic acid. Wastewater from three of these cell wash operations was sampled.

The third cell wash grouping involves submerging the cells in a series of tanks containing methylene chloride, methyl alcohol and ammonium hydroxide. The wastewater from one plant which used this process was sampled. The fourth cell wash group uses freon to clean cell surfaces. Two plants presently use freon in the cell wash operations. Wastewaters were not sampled at these two plants. In the fifth cell wash group, only water (no chemical) was reported to be used to clean the cell container surfaces. Two plants are in this group, and samples were taken at one plant. A total of seven plants reported using a cell wash operation in the manufacture of zinc subcategory cells. The production normalized discharge flows are determined for each of the seven plants by using data either obtained in the dcp or during sampling visits. Table V-92 (page 358) presents the normalized discharge flows from cell wash operations at Plants A-G. Based on these data, after deleting an abnormally high flow of 34.1 l/kg, the range is 0.09 to 4.21 l/kg of finished cells (1.13 l/kg mean). The large observed variations in discharge from cell wash operations may be related primarily to differences in plant water conservation practices although cell size and plant specific washing procedures were also observed to have an influence. Table V-93 (page 359) presents the data from sampling cell wash operation wastewaters at four plants. All of the cell wash groups are represented. In the table all of the wastewater streams from cell wash operations that were sampled at each plant are combined on a flow-proportioned daily basis to achieve complete plant-by-plant raw wastewater characterizations from cell washing. Table V-94 (page 360) presents the pollutant mass loadings on a daily basis for each plant. Statistical summaries are presented in Tables V-95 and V-96 (pages 361 and 362). The normalized discharge flows range from 0.085 to 1.8 l/kg of cells produced. The low value reflects a recirculating wash operation and the high value is a composite of wastewaters from three cell wash operations at one plant.

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

Nine plants reported using water to formulate electrolyte solution. One plant reported using sodium hydroxide solution as a substitute electrolyte for potassium hydroxide solution in the manufacture of certain cells. Two plants reported adding zinc oxide to the electrolyte solution. Five plants reported no wastewater discharge from electrolyte processing. However, the remaining four plants did report wastewater discharges from electrolyte formulation primarily resulting from utensil washing.

Table V-97 (page 363) presents the analytical results of the wastewater stream sampled at Plant A. The measured flow is 0.37 l/kg of finished cells processed during the sampling day. Based on both the visit and dcp data, the wash-up operation associated with the preparation of electrolyte solution generates minimal wastewater (mean normalized flow of 0.12 l/kg). The observed pollutant mass loadings of the sampled wastewater stream at Plant A as presented in Table V-98 (page 364) do not contribute substantially to the total cell manufacture raw waste.

Silver Etching - The silver etch process prepares silver basis material for use in the zinc electrodeposition process. The silver foil is etched with nitric acid, rinsed and dried prior to electrodeposition. After use in the process, the nitric acid is collected in containers for contractor removal. Squeegees are used to wipe the etched silver foil surfaces before rinsing, and only residual acid contaminates the rinse wastewater. The only wastewater discharge results from rinsing the etched silver foil. The wastewater stream was sampled at Plant A. The process is conducted on an intermittent basis depending on the production of silver oxide-zinc cells requiring the etched material. The observed discharge flow is 49.1 l/kg of silver processed. Tables V-99 and V-100 (pages 365 and 366) present the analytical results in units of mg/l and mg/kg for the silver etch process wastewater. The pollutant characteristics of this acidic waste stream include zinc and silver. The presence of zinc probably results from process material contamination. The concentration of silver in the wastewater is high, reflecting the absence of effective silver recovery measures.

Mandatory Employee Wash - For the purpose of ensuring health and safety, some plants require the employees to wash before each work break and at the end of each work day. Since process materials are removed during the wash operation, the resultant wastewater stream is considered process wastewater from the zinc subcategory. Two plants (A and B) reported mandatory employee washing. Employee wash wastewater from both plants was sampled. The composited sample taken at Plant B is a combination of wastewaters generated from washing clothes previously worn by manufacturing process employees and from employee showers. A flow measurement was not obtained due to pipe inaccessibility. The analytical results are presented in Table V-101 (page 367). The employee wash wastewater was separately sampled at Plant A. The observed discharge flow is 0.27 l/kg of finished cells. Table V-102 (page 368) presents the analytical results of the wash wastewater stream. The most significant pollutants are suspended solids and oil and grease which are probably due to the employees handling both process materials and lubricated machinery. Table V-103 (page 369) presents the pollutant mass loadings of the employee wash wastewater stream only from Plant A.

Reject Cell Handling - Inspections are performed throughout the cell assembly process. When a cell does not meet quality control specifications, it is removed from the process line for future repairs or disposal. If a cell cannot be repaired, it is scrapped. The disposal techniques used by the zinc subcategory cell manufacturers differ according to whether the materials composing the rejected cells require deactivation. By submerging certain cells in water, the active materials are discharged to reduce the potential fire hazard in both handling and disposal of these cells. Three plants (B, C, and A) reported using water for handling reject cells. The discharge flows are minimal ranging from 0.002 to 0.03 l/kg of finished cells (0.01 l/kg mean). One plant contractor hauls the wastewater with the rejected cells to a landfill site whereas the other two plants treat the wastewater on-site. At Plant A, the discharge flow was observed to be 0.03 l/kg of finished cells. Table V-104 (page 370) presents the analysis results of the reject cell handling wastewater stream. The significant pollutants are silver, zinc, and mercury.

The reject cell wastewater was also sampled at Plant B. Analytical results for Plant B only are presented in Table V-105 (page 371). This wastewater stream is characterized by a low discharge flow (0.003 l/kg). The most significant pollutants observed are suspended solids, zinc, and mercury which are constituents of the alkaline cells being processed. Table V-106 (page 372) presents the pollutant mass loadings from the data obtained from sampling the reject cell wastewater at Plant B.

Floor Wash and Equipment Wash - Some plants maintain process floor areas and equipment by using water to remove wasted process materials and other dirt. Three plants reported using water for floor maintenance whereas the other plants generally use other means to clean the floors. These methods which do not require water include vacuuming, dry sweeping, and applying desiccant materials in instances of solution spillages. Each of the three plants that reported using water to clean process floor areas has a wastewater discharge from the cleaning operation. Two plants reported discharge flow estimates reflecting both floor area and equipment cleaning wastewater in their dcp. Based on dcp estimates and the discharge flows observed during the sampling visit at Plant A which represents floor cleaning only, the range of discharge flows is 0.0008 to 0.030 l/kg of cells produced. Table V-107 (page 373) presents the analytical results of the wastewater resulting from the floor wash operation at Plant A. Table V-108 (page 374) presents the pollutant mass loadings based on the data obtained at Plant A. Lead is a significant pollutant which apparently results from contamination with solder constituents used to attach tabs to the electrode substrate materials. In addition, suspended solids are high in the floor wash wastewater as is ammonia which is a chemical used to clean the floors.

Four plants in the data base reported using water to clean equipment used to manufacture zinc subcategory cells. All of these plants have wastewater discharges resulting from cleaning equipment used to handle process materials. As was previously cited in the floor wash discussion, two plants reported wastewater discharge estimates representing both equipment and floor cleaning. Separate equipment cleaning discharge flow estimates have been obtained in sampling wastewater at Plants A and B. At these two plants, the observed discharges averaged 5.1 l/kg and 9 l/kg of cells produced. The significant pollutants in the equipment wash wastewater streams at Plant B include suspended solids, zinc, and mercury which result from the formation operation. Table V-109 (page 375) presents the analytical results for equipment wash. The relatively high discharge flow occurred on the first sampling day because all of the equipment was washed. The same table shows the analytical results from the sample visit of Plant A. The wastewater at this plant is generated from equipment wash operations and occasional employee hand washing. The observed flow is 5.1 l/kg of cells produced. The significant pollutants in this wastewater stream are suspended solids, mercury, and zinc which result from process material contamination. Table V-110 (page 376) presents the pollutant mass loading calculated from the analytical data from Plants A and B. Statistical summaries of both the concentration and loading data are presented in Table V-111 and V-112 (pages 377 and 378), respectively.

Silver Powder Production - Silver powder for use in battery cathodes is manufactured by electrodeposition and mechanical removal. The slurry which results is filtered to recover the silver powder, and the filtrate is returned for continued use in the electrodeposition process. The wet silver powder is rinsed to remove residual acid and dried prior to storage or use in cathode manufacture. Process wastewater from the product rinse step was characterized by sampling at Plant A. Observed wastewater discharge flows range from 19.8 to 23.7 l/kg (21.2 l/kg mean). The results of analyses of samples from this wastewater source are presented in Table V-113 (page 379). Table V-114 (page 380) presents corresponding pollutant mass loading data.

Silver Peroxide Production - Silver peroxide is produced from silver oxide or silver nitrate by two chemical oxidation processes. The results of analysis of wastewater samples from peroxide production are presented in Table V-115 (page 381) and corresponding pollutant mass loadings in Table V-116 (page 382).

Total Process Wastewater Discharge and Characteristics

Wastewater discharge from zinc subcategory manufacturing operations varies between 0 and 26,000 l/hr (7,000 gal/hr). The variation may be understood primarily on the basis of the variations among these plants in the mix of production operations used, and also on the observed differences in water conservation practices in the subcategory.

Total process wastewater flow and characteristics were determined for eight plants in the zinc subcategory which were sampled. These characteristics, reflecting the combined raw wastewater streams from all zinc subcategory process operations at each site on each of up to three days of sampling, are summarized statistically in Table V-117 (page 383). Prevailing discharge and treatment patterns in this subcategory generally preclude directly sampling a total raw wastewater stream because wastewaters from individual process operations are often treated or discharged separately. Consequently, the total process wastewater characterisics shown in Table V-117 were determined for each plant by mass balance calculations from analyses of wastewater samples from individual process operations.

As Table V-117 shows, concentrations of some pollutants were observed to vary over a wide range. These variations may generally be related to variations in manufacturing processes discussed in the preceding pages. Despite the observed variations, it may be seen that the most significant pollutants are generally consistent from plant to plant and that waste treatment requirements of all of the sampled plants are quite similar.

Wastewater Treatment Practices and Effluent Data Analysis

The plants in this subcategory reported the practice of numerous wastewater treatment technologies (Table V-118, page 384) including pH adjustment, sulfide precipitation, carbon adsorption, amalgamation, sedimentation, and filtration. Several indicated the recovery of some process materials from wastewater streams. In addition to the wastewater treatment systems reported in dcp, a complete system combining in-process controls with ion exchange and wastewater recycle has been installed at one plant, which will ultimately eliminate the discharge of wastewater effluent. Process changes at another plant have also eliminated process wastewater discharge since the data presented in the dcp were developed. Many of the technologies practiced (e.g., amalgamation and carbon adsorption) are aimed specifically at the removal of mercury. Effluent data and on-site observations at plants in the zinc subcategory reveal that most of the technologies employed are not effectively applied for the reduction of pollutant discharges. In some cases, such as amalgamation, this is due to treatment system design and the inherent limitations of the technologies employed. In others, such as sulfide precipitation, failure to achieve effective pollutant removal results from specific design, operation, and maintenance deficiencies at the plants employing the technologies.

An analysis of the treatment in place was done for all plants which submitted process information. Some of these plants were visited and sampled, others provided effluent data, and others just reported what treatment was in place.

As shown in Table V-119 (page 385), plants submitted limited data. Only four plants submitted data on pH which could be related to treatment performance, however the effectiveness could not be substantiated by this data alone.

At plant A which was visited with sulfide precipitation, settling, and filtration it was observed that the plant did not operate the precipitation system at optimum pH values. The results of sampling for this plant are shown in Table V-120 (page 386). In this same table the sampling data for plant B are also shown. Observations made during the plant visit indicated that nonprocess streams were mixed with battery process water, severly overloading the treatment system. Additionally, the system was not consistently operated at optimum pH values, and the treatment tanks were long overdue for sludge removal.

Another plant which was sampled had chemical precipitation, settling and filtration technology. As shown in Table V-121 (page 387), this plant had four separate treatment systems to treat wastewaters from the zinc subcategory. Observation made during sampling, however indicated that the systems were inadequately maintained. pH was not controlled properly and excessive accumulations of sludge from previously treated batches of wastewater were in the settling tanks.

Observations at two plants with settling and amalgamation in place revealed that the treatment systems were crude in design and operability. Sampling results for these two plants are in Table V-122 (page 388).

At another plant having skimming, filtration, amalgamation and carbon adsorption in place, the equipment was designed and operated inadequately. Sampling results for this plant are shown in Table V-123 (page 389).

One plant had just installed a settling, filtration and ion exchange treatment system. Because the system had just been installed and was not in full operation prior to sampling, the results shown in Table V-124 (page 390) could not be evaluated.

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 these systems are generally inadequate for treating zinc 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
CADMIUM SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
1.	Acenaphthene		ND	ND	ND	ND
2.	Acrolein		ND	ND	ND	ND
3.	Acrylonitrile		ND	ND	ND	ND
4.	Benzene		ND	ND	*	ND
5.	Benzidine		ND	ND	ND	NA
6.	Carbon Tetrachloride		ND	ND	ND	NA
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		ND	ND	ND	ND
11.	1,1,1 Trichloroethane		ND	ND	ND	ND
12.	Hexachloroethane		ND	ND	ND	NA
13.	1,1 Dichloroethane		ND	ND	ND	NA
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	ND	NA
22.	Parachlorometacresol		ND	ND	ND	NA
23.	Chloroform		0.530	0.061	0.013	*
24.	2 Chlorophenol		ND	ND	ND	NA
25.	1,2 Dichlorobenzene		ND	ND	ND	NA
26.	1,3 Dichlorobenzene		ND	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	ND	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	ND
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	ND	NA
39.	Fluoranthene		ND	ND	ND	ND
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		0.024	0.027	0.61	0.044
45.	Methyl Chloride		ND	ND	ND	ND
46.	Methyl Bromide		ND	ND	ND	ND

TABLE V-2

SCREENING ANALYSIS RESULTS
CADMIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
47. Bromoform		ND	ND	ND	ND
48. Dichlorobromomethane		ND	*	ND	ND
49. Trichlorofluoromethane		ND	ND	ND	ND
50. Dichlorodifluoromethane		ND	ND	ND	ND
51. Chlorodibromomethane		ND	ND	ND	ND
52. Hexachlorobutadiene		ND	ND	ND	NA
53. Hexachlorocyclopentadiene		ND	ND	ND	NA
54. Isophorone		ND	ND	ND	NA
55. Naphthalene		ND	ND	ND	NA
56. Nitrobenzene		ND	ND	ND	NA
57. 2 Nitrophenol		ND	ND	ND	NA
58. 4 Nitrophenol		ND	ND	ND	NA
59. 2,4 Dinitrophenol		ND	ND	ND	NA
60. 4,6 Dinitro-o-cresol		ND	ND	ND	NA
61. N-Nitrosodimethylamine		ND	ND	ND	NA
62. B-Nitrosodiphenylamine		ND	ND	ND	NA
63. N-Nitrosodi-N-propylamine		ND	ND	ND	NA
64. Pentachlorophenol		ND	ND	ND	NA
65. Phenol	0,2	ND	ND	ND	NA
66. Bis (2-Ethylhexyl) Phthalate		ND	*	*	NA
67. Butyl Benzyl Phthalate		ND	ND	ND	NA
68. Di-N-butyl Phthalate		ND	ND	ND	NA
69. Di-N-octyl Phthalate		ND	ND	ND	NA
70. Diethyl Phthalate		ND	ND	ND	NA
71. Dimethyl Phthalate		ND	ND	ND	NA
72. 1,2 Benzanthracene		ND	ND	ND	NA
73. Benzo (A) Pyrene		ND	ND	ND	NA
74. 3,4 Benzofluoranthene		ND	ND	ND	NA
75. 11, 12-Benzofluoranthene		ND	ND	ND	NA
76. Chrysene		ND	ND	ND	NA
77. Acenaphthylene		ND	ND	ND	NA
78. Anthracene		ND	ND	ND	NA
79. 1,12-Benzoperylene		ND	ND	ND	NA
80. Fluorene		ND	ND	ND	NA
81. Phenanthrene		ND	ND	ND	NA
82. 1,2,5,6 Dibenzanthracene		ND	ND	ND	NA
83. Indenopyrene		ND	ND	ND	NA
84. Pyrene		ND	ND	ND	NA
85. Tetrachloroethylene		ND	ND	ND	ND
86. Toluene		ND	*	0.025	*
87. Trichloroethylene	0,1	ND	*	ND	ND
88. Vinyl Chloride		ND	ND	ND	ND
89. Aldrin		ND	ND	ND	NA
90. Dieldrin		ND	ND	ND	NA
91. Chlordane		ND	ND	ND	NA
92. 4,4 DDT		ND	ND	ND	NA

TABLE V-2
SCREENING ANALYSIS RESULTS
CADMIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
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	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		NA	ND	ND	NA
106. PCB-1242		ND	ND	ND	NA
107. PCB-1254		ND	ND	ND	NA
108. PCB-1221		ND	ND	ND	NA
109. PCB-1232		ND	ND	ND	NA
110. PCB-1248		ND	ND	ND	NA
111. PCB-1260		ND	ND	ND	NA
112. PCB-1016		ND	ND	ND	NA
113. Toxaphene		ND	ND	ND	ND
114. Antimony	1,0	ND	ND	ND	NA
115. Arsenic	1,0	ND	ND	ND	NA
116. Asbestos		+	+	NA	NA
117. Beryllium		<0.001	<0.01	<0.01	NA
118. Cadmium	4,0	0.009	70.0	100.0	NA
119. Chromium	2,0	0.007	0.08	0.05	NA
120. Copper		0.010	0.09	0.09	NA
121. Cyanide	1,0	0.020	0.07	0.04	NA
122. Lead		0.020	0.40	0.04	NA
123. Mercury		0.0003	0.0003	0.0003	NA
124. Nickel	7,0	0.005	100.0	70.0	NA
125. Selenium		ND	ND	ND	NA
126. Silver		<0.001	<0.01	<0.1	NA
127. Thallium		ND	ND	ND	NA
128. Zinc		0.090	<0.5	<0.5	NA
129. 2,3,7,8 TCDD (Dioxin)		ND	ND	ND	NA
130. Xylenes		NA	NA	NA	NA
131. Alkyl Epoxides		NA	NA	NA	NA
Aluminum	-,-	<0.090	<0.90	<0.90	NA
Ammonia	-,-	0.12	5.76	3.57	NA
Barium	-,-	0.020	<0.06	<0.06	NA
Boron	-,-	<0.080	<0.08	<0.08	NA
Calcium	-,-	18.0	<50.0	<50.0	NA
Cobalt	-,-	<0.002	<0.02	<0.02	NA
Fluoride	-,-	1.20	1.15	1.15	NA
Gold	-,-	<0.001	ND	ND	NA

TABLE V-2
SCREENING ANALYSIS RESULTS
CADMIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
Iron	-,-	<0.1	1.00	<1.00	NA
Magnesium	-,-	7.8	7.00	7.00	NA
Manganese	-,-	0.03	0.10	0.09	NA
Molybdenum	-,-	<0.006	<0.06	<0.06	NA
Oil and Grease	-,-	6.0	<5.00	<5.00	NA
Phenols (Total)	-,-	<0.005	<0.005	0.009	NA
Phosphorus	-,-	ND	0.05	ND	NA
Sodium	-,-	8.8	400.0	510.0	NA
Strontium	-,-	NA	NA	NA	NA
TSS	-,-	<5.0	368.0	338.0	NA
Tin	-,-	0.05	0.30	<0.08	NA
Titanium	-,-	<0.006	<0.06	<0.06	NA
Vanadium	-,-	<0.002	<0.02	<0.02	±NA
Yttrium	-,-	<0.002	<0.02	<0.02	NA

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 ≤0.01 mg/l.
**	Indicates ≤0.005 mg/l.
+	For asbestos analysis; indicates presence of chrysotile fibers.

TABLE V-3

SCREENING ANALYSIS RESULTS
CALCIUM SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
1.	Acenaphthene		ND	ND	NA
2.	Acrolein		ND	ND	ND
3.	Acrylontrile		ND	ND	ND
4.	Benzene		ND	ND	ND
5.	Benzidine		ND	ND	ND
6.	Carbon Tetrachloride		ND	ND	ND
7.	Chlorobenzene		ND	ND	ND
8.	1,2,4 Trichlorobenzene		ND	ND	NA
9.	Hexachlorobenzene		ND	ND	NA
10.	1,2 Dichloroethane		ND	ND	ND
11.	1,1,1 Trichloroethane		ND	ND	ND
12.	Hexachloroethane		ND	ND	NA
13.	1,1 Dichloroethane		ND	ND	ND
14.	1,1,2 Trichloroethane		ND	0.013	ND
15.	1,1,2,2 Tetrachloroethane		ND	ND	ND
16.	Chloroethane		ND	ND	ND
17.	Bis Chloromethyl Ether		ND	ND	ND
18.	Bis 2-Chloroethyl Ether		ND	ND	NA
19.	2-Chloroethyl Vinyl Ether		ND	ND	ND
20.	2-Chloronapthalene		ND	ND	NA
21.	2,4,6 Trichlorophenol		ND	ND	NA
22.	Parachlorometacresol		ND	ND	NA
23.	Chloroform		0.055	0.038	*
24.	2 Chlorophenol		ND	ND	NA
25.	1,2 Dichlorobenzene		ND	ND	NA
26.	1,3 Dichlorobenzene		ND	ND	NA
27.	1,4 Dichlorobenzene		ND	ND	NA
28.	3,3 Dichlorobenzidine		ND	ND	NA
29.	1,1 Dichloroethylene		ND	ND	ND
30.	1,2 Trans-Dichloroethylene		ND	ND	ND
31.	2,4 Dichlorophenol		ND	ND	NA
32.	1,2 Dichloropropane		ND	ND	NA
33.	1,2 Dichloropropylene		ND	ND	ND
34.	2,4 Dimethylphenol		ND	ND	NA
35.	2,4 Dinitrotoluene		ND	ND	NA
36.	2,6 Dinitrotoluene		ND	ND	NA
37.	1,2 Diphenylhydrazine		ND	ND	NA
38.	Ethylbenzene		ND	ND	ND
39.	Fluoranthene		ND	ND	NA
40.	4 Chlorophenyl Phenyl Ether		ND	ND	NA

TABLE V-3

SCREENING ANALYSIS RESULTS
CALCIUM SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste COnc. mg/l	Analysis Blank Conc. mg/l
41.	4 Bromophenyl Phenyl Ether		ND	ND	NA
42.	Bis (2 Chloroisopropyl) Ether		ND	ND	NA
43.	Bis (2 Chloroethoxy) Methane		ND	ND	NA
44.	Methylene Chloride		0.011	0.014	*
45.	Methyl Chloride		ND	ND	ND
46.	Methyl Bromide		ND	ND	ND
47.	Bromoform		ND	ND	ND
48.	Dichlorobromomethane		ND	ND	ND
49.	Trichlorofluoromethane		ND	ND	ND
50.	Dichlorodifluoromethane		ND	ND	ND
51.	Chlorodibromomethane		ND	ND	ND
52.	Hexachlorobutadiene		ND	ND	NA
53.	Hexachlorocyclopentadiene		ND	ND	NA
54.	Isophorone		ND	ND	NA
55.	Naphthalene		ND	ND	NA
56.	Nitrobenzene		ND	ND	NA
57.	2 Nitrophenol		ND	ND	NA
58.	4 Nitrophenol		ND	ND	NA
59.	2,4 Dinitrophenol		ND	ND	NA
60.	4,6 Dinitro-o-cresol		ND	ND	NA
61.	N-Nitrosodimethylamine		ND	ND	NA
62.	N-Nitrosodiphenylamine		ND	ND	NA
63.	N-Nitrosodi-N-propylamine		ND	ND	NA
64.	Pentachlorophenol		*	*	NA
65.	Phenol		ND	ND	NA
66.	Bis (2-Ethylhexyl) Phthalate		ND	0.024	NA
67.	Butyl Benzyl Phthalate		ND	ND	NA
68.	Di-N-butyl Phthalate		*	*	NA
69.	Di-N-octyl Phthalate		ND	ND	NA
70.	Diethyl Phthalate		ND	ND	NA
71.	Dimethyl Phthalate		ND	ND	NA
72.	1,2 Benzanthracene		ND	ND	NA
73.	Benzo (A) Pyrene		ND	ND	NA
74.	3,4 Benzofluorathene		ND	ND	NA
75.	11,12-Benzofluoranthene		ND	ND	NA
76.	Chrysene		ND	ND	NA
77.	Acenaphthylene		ND	ND	NA
78.	Anthracene		ND	ND	NA
79.	1,12-Benzoperylene		ND	ND	NA
80.	Fluorene		ND	ND	NA

TABLE V-3

SCREENING ANALYSIS RESULTS
CALCIUM SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
81.	Phenanthrene		ND	ND	NA
82.	1,2,5,6 Dibenzanthracene		ND	ND	NA
83.	Indenopyrene		ND	ND	NA
84.	Pyrene		ND	ND	NA
85.	Tetrachloroethylene		ND	ND	ND
86.	Toluene		ND	*	ND
87.	Trichloroethylene		ND	ND	ND
88.	Vinyl Chloride		ND	ND	ND
89.	Aldrin		ND	ND	NA
90.	Dieldrin		ND	ND	NA
91.	Chlordane		ND	ND	NA
92.	4,4 DDT		ND	ND	NA
93.	4,4 DDE		ND	ND	NA
94.	4,4 DDD		ND	ND	NA
95.	Alpha-Endosulfan		ND	ND	NA
96.	Beta-Endosulfan		ND	ND	NA
97.	Endosulfan Sulfate		ND	ND	NA
98.	Endrin		ND	ND	NA
99.	Endrin Aldehyde		ND	ND	NA
100.	Heptachlor		ND	ND	NA
101.	Heptachlor Epoxide		ND	ND	NA
102.	Alpha-BHC		ND	ND	NA
103.	Beta-BHC		ND	ND	NA
104.	Gamma-BHC (Lindane)		ND	ND	NA
105.	Delta-BHC		ND	ND	NA
106.	PCB-1242		ND	ND	NA
107.	PCB-1254		ND	ND	NA
108.	PCB-1221		ND	ND	NA
109.	PCB-1232		ND	ND	NA
110.	PCB-1248		ND	ND	NA
111.	PCB-1260		ND	ND	NA
112.	PCB-1016		ND	ND	NA
113.	Toxaphene		ND	ND	NA
114.	Antimony		<0.005	<0.005	NA
115.	Arsenic		<0.005	<0.005	NA
116.	Asbestos		ND	+	NA
117.	Beryllium		<0.001	<0.001	NA
118.	Cadmium		0.001	0.002	NA
119.	Chromium	0,2	0.005	2.06	NA
120.	Copper		0.068	0.118	NA
121.	Cyanide		ND	ND	NA
122.	Lead		0.025	0.044	NA
123.	Mercury		<0.001	<0.001	NA

TABLE V-3

SCREENING ANALYSIS RESULTS
CALCIUM SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
124.	Nickel		0.060	0.067	NA
125.	Selenium		<0.005	<0.005	NA
126.	Silver		0.003	0.012	NA
127.	Thallium		<0.050	<0.050	NA
128.	Zinc		0.018	0.045	NA
129.	2,3,7,8 TCDD (dioxin)		ND	ND	NA
130.	Xylenes		NA	NA	NA
131.	Alkyl Epoxides		NA	NA	NA
	Aluminum	-,-	0.086	0.104	NA
	Ammonia	-,-	NA	NA	NA
	Barium	-,-	0.016	2.67	NA
	Boron	-,-	0.040	0.116	NA
	Calcium	-,-	15.4	15.9	NA
	Cobalt	-,-	0.011	0.006	NA
	Fluoride	-,-	1.7	1.7	NA
	Gold	-,-	NA	NA	NA
	Iron	-,-	0.091	0.122	NA
	Magnesium	-,-	3.47	3.66	NA
	Manganese	-,-	0.007	0.008	NA
	Molybdenum	-,-	<0.001	0.001	NA
	Oil and Grease	-,-	ND	ND	NA
	Phenols (Total)	-,-	ND	ND	NA
	Phosphorus	-,-	ND	ND	NA
	Sodium	-,-	5.73	6.06	NA
	Strontium	-,-	NA	NA	NA
	TSS	-,-	ND	21.0	NA
	Tin	-,-	0.012	0.006	NA
	Titanium	-,-	0.001	0.001	NA
	Vanadium	-,-	0.030	0.030	NA
	Yttrium	-,-	<0.001	0.001	NA

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 ≤ 0.01 mg/l.

** Indicates ≤ 0.005 mg/l.

\+ For asbestos analysis; indicates presence of chrysotile fibers.

TABLE V-4

SCREENING ANALYSIS RESULTS
LECLANCHE SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
1. Acenaphthene		ND	ND	ND
2. Acrolein		ND	ND	NA
3. Acrylonitrile		ND	ND	ND
4. Benzene		ND	ND	ND
5. Benzidine		ND	ND	NA
6. Carbon Tetrachloride		ND	ND	ND
7. Chlorobenzene		ND	ND	NA
8. 1,2,4 Trichlorobenzene		ND	ND	NA
9. Hexachlorobenzene		ND	ND	NA
10. 1, 2 Dichloroethane		ND	ND	ND
11. 1,1,1 Trichloroethane		*	ND	ND
12. Hexachloroethane		ND	ND	NA
13. 1,1 Dichloroethane		ND	ND	ND
14. 1,1,2 Trichloroethane		ND	ND	ND
15. 1,1,2,2 Tetrachloroethane		ND	*	ND
16. Chloroethane		ND	ND	NA
17. Bis Chloromethyl Ether		ND	ND	NA
18. Bis 2-Chloroethyl Ether		ND	ND	NA
19. 2-Chloroethyl Vinyl Ether		ND	ND	NA
20. 2-Chloronaphthalene		ND	ND	NA
21. 2,4,6 Trichlorophenol		ND	ND	NA
22. Parachlorometacresol		ND	ND	NA
23. Chloroform		0.043	*	ND
24. 2 Chlorophenol		ND	ND	NA
25. 1,2 Dichlorobenzene		ND	ND	NA
26. 1,3 Dichlorobenzene		ND	ND	NA
27. 1,4 Dichlorobenzene		ND	ND	NA
28. 3,3 Dichlorobenzidine		ND	ND	NA
29. 1,1 Dichloroethylene		ND	ND	ND
30. 1,2 Trans-Dichloroethylene		ND	ND	NA
31. 2,4 Dichlorophenol		ND	ND	NA
32. 1,2 Dichloropropane		ND	ND	ND
33. 1,2 Dichloropropylene		ND	ND	ND
34. 2,4 Dimethylphenol		ND	ND	ND
35. 2,4 Dinitrotoluene		ND	ND	NA
36. 2,6 Dinitrotoluene		ND	ND	NA
37. 1,2 Diphenylhydrazine		ND	ND	NA
38. Ethylbenzene		ND	ND	ND
39. Fluoranthene		ND	ND	NA
40. 4 Chlorophenyl Phenyl Ether		ND	ND	NA
41. 4 Bromophenyl Phenyl Ether		ND	ND	NA
42. Bis (2 Chloroisopropyl) Ether		ND	ND	NA
43. Bis (2 Chloroethoxy) Methane		ND	ND	NA
44. Methylene Chloride	1,0	*	ND	0.006
45. Methyl Chloride		ND	ND	ND

TABLE V-4

SCREENING ANALYSIS RESULTS
LECLANCHE SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
46. Methyl Bromide		ND	ND	ND
47. Bromoform		ND	ND	ND
48. Dichlorobromomethane		*	ND	ND
49. Trichlorofluoromethane		ND	ND	ND
50. Dichlorodifluoromethane		ND	ND	ND
51. Chlorodibromomethane		*	ND	ND
52. Hexachlorobutadiene		ND	ND	NA
53. Hexachlorocyclopentadiene		ND	ND	NA
54. Isophorone		ND	ND	NA
55. Naphthalene		ND	ND	NA
56. Nitrobenzene		ND	ND	NA
57. 2 Nitrophenol		ND	ND	NA
58. 4 Nitrophenol		ND	ND	NA
59. 2,4 Dinitrophenol		ND	ND	NA
60. 4,6 Dinitro-o-cresol		ND	ND	NA
61. N-Nitrosodimethylamine		ND	ND	NA
62. B-Nitrosodiphenylamine		ND	ND	NA
63. N-Nitrosodi-N-propylamine		ND	ND	NA
64. Pentachlorophenol		ND	ND	NA
65. Phenol		ND	*	NA
66. Bis (2-Ethylhexyl) Phthalate		ND	*	NA
67. Butyl Benzyl Phthalate		ND	*	NA
68. Di-N-butyl Phthalate		ND	*	NA
69. Di-N-octyl Phthalate	0,1	*	ND	NA
70. Diethyl Phthalate		ND	0.016	NA
71. Dimethyl Phthalate		*	*	NA
72. 1,2 Benzanthracene		ND	ND	NA
73. Benzo (A) Pyrene		ND	ND	NA
74. 3,4 Benzofluoranthene		ND	ND	NA
75. 11, 12-Benzofluoranthene		ND	ND	NA
76. Chrysene		ND	ND	NA
77. Acenaphthylene		ND	ND	NA
78. Anthracene		ND	ND	NA
79. 1,12-Benzoperylene		ND	ND	NA
80. Fluorene		ND	ND	NA
81. Phenanthrene		ND	ND	NA
82. 1,2,5,6 Dibenzanthracene		ND	ND	NA
83. Indenopyrene		ND	ND	NA
84. Pyrene		ND	ND	NA
85. Tetrachloroethylene	0,1	ND	ND	ND
86. Toluene	0,2	*	ND	ND
87. Trichloroethylene	0,1	ND	ND	ND
88. Vinyl Chloride	0,1	ND	ND	ND
89. Aldrin		ND	ND	NA
90. Dieldrin		ND	ND	NA
91. Chlordane		ND	ND	NA

TABLE V-4

SCREENING ANALYSIS RESULTS
LECLANCHE SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
92. 4,4 DDT		ND	ND	NA
93. 4,4 DDE		ND	ND	NA
94. 4,4 DDD		ND	ND	NA
95. Alpha-Endosulfan		ND	ND	NA
96. Beta-Endosulfan		ND	ND	NA
97. Endosulfan Sulfate		ND	ND	NA
98. Endrin		ND	ND	NA
99. Endrin Aldehyde		ND	ND	NA
100. Heptachlor		ND	ND	NA
101. Heptachlor Epoxide		ND	ND	NA
102. AlphaBHC		ND	ND	NA
103. BetaBHC		ND	ND	NA
104. GammaBHC (Lindane)		ND	ND	NA
105. DeltaBHC		ND	ND	NA
106. PCB1242		ND	ND	NA
107. PCB1254		ND	ND	NA
108. PCB1221		ND	ND	NA
109. PCB1232		ND	ND	NA
110. PCB1248		ND	ND	NA
111. PCB1260		ND	ND	NA
112. PCB1016		ND	ND	NA
113. Toxaphene		ND	ND	NA
114. Antimony	0,3	ND	1.00	NA
115. Arsenic	0,4	ND	ND	NA
116. Asbestos		ND	ND	NA
117. Beryllium		<0.001	<0.01	NA
118. Cadmium	0,5	<0.002	0.10	NA
119. Chromium	1,2	<0.005	0.20	NA
120. Copper	4,2	<0.009	1.00	NA
121. Cyanide		ND	0.018	NA
122. Lead	4,3	<0.02	0.018	NA
123. Mercury	5,1	0.020	6.00	NA
124. Nickel	1,3	<0.005	4.00	NA
125. Selenium	1,0	ND	ND	NA
126. Silver		<0.001	<0.01	NA
127. Thallium		ND	ND	NA
128. Zinc	0,2	0.080	2000.0	NA
129. 2,3,7,8 TCDD (Dioxin)		ND	ND	NA
130. Xylenes		NA	NA	NA
131. Alkyl Epoxides		NA	NA	NA
Aluminum		<0.09	<0.09	NA
Ammonia	-,-	NA	ND	NA
Barium	-,-	0.010	0.40	NA
Boron	-,-	0.100	2.00	NA
Calcium	-,-	52.000	150.0	NA
Cobalt	-,-	<0.002	<0.02	NA

TABLE V-4

SCREENING ANALYSIS RESULTS
LECLANCHE SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
Fluoride	-,-	1.200	2.20	NA
Gold	-,-	ND	ND	NA
Iron	-,-	<0.10	5.00	NA
Magnesium	-,-	7.500	33.00	NA
Manganese	-,-	0.02	10.0	NA
Molybdenum	-,-	<0.006	0.20	NA
Oil and Grease	-,-	ND	ND	ND
Phenols (Total)	-,-	1.600	14.9	NA
Phosphorus	-,-	0.240	0.82	NA
Sodium	-,-	66.00	180.0	NA
Strontium	-,-	NA	NA	NA
TSS	-,-	ND	1630.0	NA
Tin	-,-	<0.008	3.00	NA
Titanium	-,-	<0.006	ND	NA
Vanadium	-,-	<0.002	ND	NA
Yttrium	-,-	<0.002	ND	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 ≤0.01 mg/l.
**	Indicates ≤0.005 mg/l.

TABLE V-5

SCREENING ANALYSIS RESULTS
LITHIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw[1] Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw[2] Waste Conc. mg/l	Analysis Blank Conc. mg/l
1. Acenaphthene		ND	ND	NA	ND	NA
2. Acrolein		ND	ND	ND	ND	ND
3. Acrylonitrile		ND	ND	ND	ND	ND
4. Benzene		ND	ND	ND	ND	ND
5. Benzidine		ND	ND	NA	ND	NA
6. Carbon Tetrachloride		ND	ND	ND	ND	ND
7. Chlorobenzene		ND	ND	ND	ND	ND
8. 1,2,4 Trichlorobenzene		ND	ND	NA	ND	NA
9. Hexachlorobenzene		ND	ND	NA	ND	NA
10. 1,2 Dichloroethane		ND	ND	ND	ND	ND
11. 1,1,1 Trichloroethane		ND	ND	ND	*	ND
12. Hexachloroethane		ND	ND	NA	ND	NA
13. 1,1 Dichloroethane		ND	ND	ND	ND	ND
14. 1,1,2 Trichloroethane		ND	0.013	ND	ND	ND
15. 1,1,2,2 Tetrachloroethane		ND	ND	ND	ND	ND
16. Chloroethane		ND	ND	ND	ND	ND
17. Bis Chloromethyl Ether		ND	ND	ND	ND	ND
18. Bis 2-Chloroethyl Ether		ND	ND	NA	ND	NA
19. 2-Chloroethyl Vinyl Ether		ND	ND	ND	ND	ND
20. 2-Chloronaphthalene		ND	ND	NA	ND	NA
21. 2,4,6 Trichlorophenol		ND	ND	NA	ND	NA
22. Parachlorometacresol		ND	ND	NA	ND	NA
23. Chloroform		0.055	0.038	*	0.012	*
24. 2-Chlorophenol		ND	ND	NA	ND	NA
25. 1,2 Dichlorobenzene		ND	ND	NA	ND	NA
26. 1,3 Dichlorobenzene		ND	ND	NA	ND	NA
27. 1,4 Dichlorobenzene		ND	ND	NA	ND	NA
28. 3,3 Dichlorobenzidine		ND	ND	NA	ND	NA
29. 1,1 Dichloroethylene		ND	ND	ND	ND	ND
30. 1,2 Trans-Dichloroethylene		ND	ND	ND	ND	ND
31. 2,4 Dichlorophenol		ND	ND	NA	ND	NA
32. 1,2 Dichloropropane		ND	ND	ND	ND	ND
33. 1,2 Dichloropropylene		ND	ND	ND	ND	ND
34. 2,4 Dimethylphenol		ND	ND	NA	ND	NA
35. 2,4 Dinitrotoluene		ND	ND	NA	ND	NA
36. 2,6 Dinitrotoluene		ND	ND	NA	ND	NA

TABLE V-5

SCREENING ANALYSIS RESULTS
LITHIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw[1] Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw[2] Waste Conc. mg/l	Analysis Blank Conc. mg/l
37. 1,2 Diphenylhydrazine		ND	ND	NA	ND	NA
38. Ethylbenzene		ND	ND	ND	ND	ND
39. Fluoranthene		ND	ND	NA	ND	NA
40. 4 Chlorophenyl Phenyl Ether		ND	ND	NA	ND	NA
41. 4 Bromophenyl Phenyl Ether		ND	ND	NA	ND	NA
42. Bis (2-Chloroisopropyl) Ether		ND	ND	NA	ND	NA
43. Bis (2-Chloroethoxy) Methane		ND	ND	NA	ND	NA
44. Methylene Chloride		0.011	0.014	*	0.016	*
45. Methyl Chloride		ND	ND	ND	ND	ND
46. Methyl Bromide		ND	ND	ND	ND	ND
47. Bromoform		ND	ND	ND	ND	ND
48. Dichlorobromomethane		ND	ND	ND	ND	ND
49. Trichlorofluoromethane		ND	ND	ND	ND	ND
50. Dichlorodifluoromethane		ND	ND	ND	ND	ND
51. Chlorodibromomethane		ND	ND	ND	ND	ND
52. Hexachlorobutadiene		ND	ND	NA	ND	NA
53. Hexachlorocyclopentadiene		ND	ND	NA	ND	NA
54. Isophorone		ND	ND	NA	ND	NA
55. Naphthalene		ND	ND	NA	ND	NA
56. Nitrobenzene		ND	ND	NA	ND	NA
57. 2 Nitrophenol		ND	ND	NA	ND	NA
58. 4 Nitrophenol		ND	ND	NA	ND	NA
59. 2,4 Dinitrophenol		ND	ND	NA	ND	NA
60. 4,6 Dinitro-o-cresol		ND	ND	NA	ND	NA
61. N-Nitrosodimethylamine		ND	ND	NA	ND	NA
62. B-Nitrosodiphenylamine		ND	ND	NA	ND	NA
63. N-Nitrosodi-N-propylamine		ND	ND	NA	ND	NA
64. Pentachlorophenol		*	*	NA	ND	NA
65. Phenol		ND	ND	NA	ND	NA
66. Bis (2-Ethylhexyl) Phthalate		ND	0.024	NA	0.013	NA
67. Butyl Benzyl Phthalate		ND	ND	NA	*	NA
68. Di-N-butyl Phthalate		*	*	NA	ND	NA
69. Di-N-octyl Phthalate		ND	ND	NA	ND	NA
70. Diethyl Phthalate		ND	ND	NA	ND	NA
71. Dimethyl Phthalate		ND	ND	NA	ND	NA
72. 1,2 Benzanthracene		ND	ND	NA	ND	NA
73. Benzo (A) Pyrene		ND	ND	NA	ND	NA
74. 3,4 Benzofluoranthene		ND	ND	NA	ND	NA
75. 11, 12-Benzofluoranthene		ND	ND	NA	ND	NA

TABLE V-5

SCREENING ANALYSIS RESULTS
LITHIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw^1 Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw^2 Waste Conc. mg/l	Analysis Blank Conc. mg/l
76. Chrysene		ND	ND	NA	ND	NA
77. Acenaphthylene		ND	ND	NA	ND	NA
78. Anthracene		ND	ND	NA	ND	NA
79. 1,12-Benzoperylene		ND	ND	NA	ND	NA
80. Fluorene		ND	ND	NA	ND	NA
81. Phenanthrene		ND	ND	NA	ND	NA
82. 1,2,5,6 Dibenzanthracene		ND	ND	NA	ND	NA
83. Indenopyrene		ND	ND	NA	ND	NA
84. Pyrene		ND	ND	NA	ND	NA
85. Tetrachloroethylene		ND	ND	ND	ND	ND
86. Toluene		ND	*	ND	*	ND
87. Trichloroethylene		ND	ND	ND	ND	ND
88. Vinyl Chloride		ND	ND	ND	ND	ND
89. Aldrin		ND	ND	NA	ND	NA
90. Dieldrin		ND	ND	NA	ND	NA
91. Chlordane		ND	ND	NA	ND	NA
92. 4,4 DDT		ND	ND	NA	ND	NA
93. 4,4 DDE		ND	ND	NA	ND	NA
94. 4,4 DDD		ND	ND	NA	ND	NA
95. Alpha-Endosulfan		ND	ND	NA	ND	NA
96. Beta-Endosulfan		ND	ND	NA	ND	NA
97. Endosulfan Sulfate		ND	ND	NA	ND	NA
98. Endrin		ND	ND	NA	ND	NA
99. Endrin Aldehyde		ND	ND	NA	ND	NA
100. Heptachlor		ND	ND	NA	ND	NA
101. Heptachlor Epoxide		ND	ND	ND	ND	ND
102. Alpha-BHC		ND	ND	NA	ND	NA
103. Beta-BHC		ND	ND	NA	ND	NA
104. Gamma-BHC (Lindane)		ND	ND	NA	ND	NA
105. Delta-BHC		ND	ND	NA	ND	NA
106. PCB-1242		ND	ND	NA	ND	NA
107. PCB-1254		ND	ND	NA	ND	NA
108. PCB-1221		ND	ND	NA	ND	NA
109. PCB-1232		ND	ND	NA	ND	NA
110. PCB-1248		ND	ND	NA	ND	NA
111. PCB-1260		ND	ND	NA	ND	NA
112. PCB-1016		ND	ND	NA	ND	NA
113. Toxaphene		ND	ND	NA	ND	NA

TABLE V-5

SCREENING ANALYSIS RESULTS
LITHIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw[1] Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw[2] Waste Conc. mg/l	Analysis Blank Conc. mg/l
114. Antimony		<0.005	<0.005	NA	<0.005	NA
115. Arsenic		<0.005	<0.005	NA	<0.005	NA
116. Asbestos		NA	630+	NA	2.4+	NA
117. Beryllium		<0.001	<0.001	NA	<0.001	NA
118. Cadmium	0,1	0.001	0.002	NA	0.025	NA
119. Chromium	0,1	0.005	2.06	NA	0.015	NA
120. Copper		0.068	0.118	NA	0.109	NA
121. Cyanide		ND	0.00	NA	0.14	NA
122. Lead	0,1	0.025	0.00	NA	4.93	NA
123. Mercury		<0.005	<0.005	NA	<0.001	NA
124. Nickel		0.060	0.067	NA	0.235	NA
125. Selenium		<0.005	<0.005	NA	<0.005	NA
126. Silver		0.003	0.012	NA	0.001	NA
127. Thallium		<0.050	<0.050	NA	<0.050	NA
128. Zinc		0.018	0.045	NA	0.473	NA
129. 2,3,7,8 TCDD (Dioxin)		ND	ND	NA	ND	NA
130. Xylenes		NA	NA	NA	NA	NA
131. Alkyl Epoxides		NA	NA	NA	NA	NA
Aluminum	-,-	0.086	0.104	NA	0.287	NA
Ammonia	-,-	NA	NA	NA	NA	NA
Barium	-,-	0.016	2.67	NA	0.059	NA
Boron	-,-	0.040	0.116	NA	0.193	NA
Calcium	-,-	15.4	15.9	NA	22.8	NA
Cobalt	-,-	0.011	0.006	NA	0.176	NA
Fluoride	-,-	1.7	1.7	NA	3.05	NA
Gold	-,-	NA	NA	NA	NA	NA
Iron	-,-	0.091	0.122	NA	54.9	NA
Lithium		<0.050	<0.050	NA	<0.050	NA
Magnesium	-,-	3.47	3.66	NA	3.78	NA
Manganese	-,-	0.007	0.008	NA	1.60	NA
Molybdenum	-,-	<0.001	<0.001	NA	0.021	NA
Oil and Grease	-,-	ND	0.00	NA	ND	NA
Phenols (Total)	-,-	ND	0.00	NA	ND	NA
Phosphorus	-,-	0.00	0.00	NA	1.56	NA
Sodium	-,-	5.73	6.06	NA	6.44	NA
Strontium	-,-	NA	NA	NA	NA	NA
TSS	-,-	ND	21.0	NA	39.0	NA
Tin	-,-	0.012	0.006	NA	0.023	NA
Titanium	-,-	0.001	0.001	NA	0.001	NA
Vanadium	-,-	0.030	0.030	NA	0.035	NA
Yttrium	-,-	<0.001	<0.001	NA	0.023	NA

TABLE V-5

SCREENING ANALYSIS RESULTS
LITHIUM SUBCATEGORY

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 ≤0.01 mg/l.
**	Indicates ≤0.005 mg/l.
1.	Heat Paper Production Wastewater
2.	Cathode Process Wastewater
+	For asbestos analysis; indicates presence of chrysotile fibers

TABLE V-6

SCREENING ANALYSIS RESULTS
MAGNESIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc.1/ mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc.2/ mg/l	Raw Waste Conc.3/ mg/l
1. Acenaphthene		ND	ND	ND	ND	ND	ND
2. Acrolein		ND	ND	ND	ND	ND	ND
3. Acrylonitrile		ND	ND	ND	ND	ND	ND
4. Benzene		ND	ND	ND	*	ND	ND
5. Benzidine		ND	ND	NA	ND	ND	ND
6. Carbon Tetrachloride		ND	ND	ND	ND	ND	ND
7. Chlorobenzene		ND	ND	ND	ND	ND	ND
8. 1,2,4 Trichlorobenzene		ND	ND	NA	ND	ND	ND
9. Hexachlorobenzene		ND	ND	NA	ND	ND	ND
10. 1,2 Dichloroethane		ND	ND	ND	ND	ND	ND
11. 1,1,1 Trichloroethane		ND	ND	ND	ND	ND	ND
12. Hexachloroethane		ND	ND	NA	ND	ND	ND
13. 1,1 Dichloroethane		ND	0.013	ND	ND	ND	ND
14. 1,1,2 Trichloroethane		ND	ND	ND	ND	ND	ND
15. 1,1,2,2 Tetrachloroethane		ND	ND	ND	ND	ND	ND
16. Chloroethane		ND	ND	ND	ND	ND	ND
17. Bis Chloromethyl Ether		ND	ND	ND	ND	ND	ND
18. Bis 2-Chloroethyl Ether		ND	ND	ND	ND	ND	ND
19. 2-Chloroethyl Vinyl Ether		ND	ND	ND	ND	ND	ND
20. 2-Chloronaphthalene		ND	ND	NA	ND	ND	ND
21. 2,4,6 Trichlorophenol		ND	ND	NA	ND	ND	ND
22. Parachlorometacresol		ND	ND	NA	ND	ND	ND
23. Chloroform		0.055	0.038	*	0.380	0.155	0.140
24. Chlorophenol		ND	ND	NA	ND	ND	ND
25. 1,2 Dichlorobenzene		ND	ND	NA	ND	ND	ND
26. 1,3 Dichlorobenzene		ND	ND	NA	ND	ND	ND
27. 1,4 Dichlorobenzene		ND	ND	NA	ND	ND	ND
28. 3,3 Dichlorobenzidine		ND	ND	NA	ND	ND	ND
29. 1,1 Dichloroethylene		ND	ND	ND	ND	ND	ND
30. 1,2 Trans-Dichloroethylene		ND	ND	ND	ND	ND	ND
31. 2,4 Dichlorophenol		ND	ND	NA	ND	ND	ND
32. 1,2 Dichloropropane		ND	ND	ND	ND	ND	ND
33. 1,2 Dichloropropylene		ND	ND	ND	ND	ND	ND
34. 2,4 Dimethylphenol		ND	ND	NA	ND	ND	ND
35. 2,4 Dinitrotoluene		ND	ND	NA	ND	ND	ND
36. 2,6 Dinitrotoluene		ND	ND	NA	ND	ND	ND
37. 1,2 Diphenylhydrazine		ND	ND	NA	ND	ND	ND

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SCREENING ANALYSIS RESULTS
MAGNESIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc.1/ mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc.2/ mg/l	Raw Waste Conc.3/ mg/l
38. Ethylbenzene		ND	ND	ND	ND	ND	ND
39. Fluoranthene		ND	NA	NA	ND	ND	ND
40. 4 Chlorophenyl Phenyl Ether		ND	NA	NA	ND	ND	ND
41. 4 Bromophenyl Phenyl Ether		ND	NA	NA	ND	ND	ND
42. Bis(2 Chloroisopropyl) Ether		ND	NA	NA	ND	ND	ND
43. Bis(2 Chloroethoxy) Methane		ND	NA	NA	ND	ND	ND
44. Methylene Chloride		0.011	0.014	*	ND	ND	0.011
45. Methyl Chloride		ND	ND	ND	ND	ND	ND
46. Methyl Bromide		ND	ND	ND	ND	ND	ND
47. Bromoform		ND	ND	ND	ND	ND	ND
48. Dichlorobromomethane		ND	ND	ND	ND	ND	0.026
49. Trichlorofluoromethane		ND	ND	ND	ND	ND	ND
50. Dichlorodifluoromethane		ND	ND	ND	ND	ND	ND
51. Chlorodibromomethane		ND	ND	ND	ND	ND	ND
52. Hexachlorobutadiene		ND	ND	NA	ND	ND	ND
53. Hexachlorocyclopentadiene		ND	ND	NA	ND	ND	ND
54. Isophorone		ND	ND	NA	ND	ND	ND
55. Naphthalene		ND	ND	NA	ND	ND	ND
56. Nitrobenzene		ND	ND	NA	ND	ND	ND
57. 2 Nitrophenol		ND	ND	NA	ND	ND	ND
58. 4 Nitrophenol		ND	ND	NA	ND	ND	ND
59. 2,4 Dinitrophenol		ND	ND	NA	ND	ND	ND
60. 4,6 Dinitro-o-cresol		ND	ND	NA	ND	ND	ND
61. N-Nitrosodimethylamine		ND	ND	NA	ND	ND	ND
62. N-Nitrosodiphenylamine		ND	ND	NA	ND	ND	ND
63. N-Nitrosodi-N-propylamine		ND	ND	NA	ND	ND	ND
64. Pentachlorophenol		*	*	NA	ND	ND	0.051
65. Phenol		ND	ND	NA	ND	ND	ND
66. Bis (2-Ethylhexyl) Phthalate		ND	0.024	NA	*	ND	ND
67. Butyl Benzyl Phthalate		ND	ND	NA	ND	ND	ND
68. Di-N-butyl Phthalate		*	*	NA	ND	ND	ND
69. Di-N-octyl Phthalate		ND	ND	NA	ND	ND	ND
70. Diethyl Phthalate		ND	ND	NA	ND	ND	ND
71. Dimethyl Phthalate		ND	ND	NA	ND	ND	ND
72. 1,2 Benzanthracene		ND	ND	NA	ND	ND	ND
73. Benzo (A) Pyrene		ND	ND	NA	ND	ND	ND
74. 3,4 Benzofluoranthene		ND	ND	NA	ND	ND	ND

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SCREENING ANALYSIS RESULTS
MAGNESIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. 1/ mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. 2/ mg/l	Raw Waste Conc. 3/ mg/l
75. 11,12-Benzofluoranthene		ND	ND	NA	ND	ND	ND
76. Chrysene		ND	ND	NA	ND	ND	ND
77. Acenaphthylene		ND	ND	NA	ND	ND	ND
78. Anthracene		ND	ND	NA	ND	ND	ND
79. 1,12-Benzoperylene		ND	ND	NA	ND	ND	ND
80. Fluorene		ND	ND	NA	ND	ND	ND
81. Phenanthrene		ND	ND	NA	ND	ND	ND
82. 1,2,5,6 Dibenzanthracene		ND	ND	NA	ND	ND	ND
83. Indenopyrene		ND	ND	NA	ND	ND	ND
84. Pyrene		ND	ND	NA	ND	ND	ND
85. Tetrachloroethylene		ND	ND	ND	ND	ND	ND
86. Toluene		ND	*	ND	ND	*	*
87. Trichloroethylene		ND	ND	ND	ND	*	*
88. Vinyl Chloride		ND	ND	ND	ND	ND	ND
89. Aldrin		ND	ND	NA	ND	ND	ND
90. Dieldrin		ND	ND	NA	ND	ND	ND
91. Chlordane		ND	ND	NA	ND	ND	ND
92. 4,4 DDT		ND	ND	NA	ND	ND	ND
93. 4,4 DDE		ND	ND	NA	ND	ND	ND
94. 4,4 DDD		ND	ND	NA	ND	ND	ND
95. Alpha-Endosulfan		ND	ND	NA	ND	ND	ND
96. Beta-Endosulfan		ND	ND	NA	ND	ND	ND
97. Endosulfan Sulfate		ND	ND	NA	ND	ND	ND
98. Endrin		ND	ND	NA	ND	ND	ND
99. Endrin Aldehyde		ND	ND	NA	ND	ND	ND
100. Heptachlor		ND	ND	NA	ND	ND	ND
101. Heptachlor Epoxide		ND	ND	NA	ND	*	ND
102. Alpha-BHC		ND	ND	NA	ND	*	*
103. Beta-BHC		ND	ND	NA	ND	ND	ND
104. Gamma-BHC (Lindane)		ND	ND	NA	ND	ND	ND
105. Delta-BHC		ND	ND	NA	ND	ND	*
106. PCB-1242		ND	ND	NA	ND	ND	ND
107. PCB-1254		ND	ND	NA	ND	ND	ND
108. PCB-1221		ND	ND	NA	ND	ND	ND
109. PCB-1232		ND	ND	NA	ND	ND	ND
110. PCB-1248		ND	ND	NA	ND	ND	ND
111. PCB-1260		ND	ND	NA	ND	ND	ND

TABLE V-6

SCREENING ANALYSIS RESULTS MAGNESIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc.1/ mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc.2/ mg/l	Raw Waste Conc.3/ mg/l
112. PCB-1016		ND	ND	NA	ND	ND	ND
113. Toxaphene		ND	ND	NA	ND	ND	ND
114. Antimony		<0.005	<0.005	NA	<0.015	<0.015	<0.015
115. Arsenic		<0.005	<0.005	NA	<0.015	<0.015	<0.015
116. Asbestos	1,0	ND	+	NA	+	+	+
117. Beryllium		<0.001	<0.001	NA	0.001	<0.001	<0.001
118. Cadmium	0,1	0.001	0.001	NA	<0.005	<0.005	<0.005
119. Chromium	1,2	0.005	2.06	NA	<0.01	<0.01	0.088
120. Copper		0.068	0.118	NA	0.015	0.011	0.180
121. Cyanide		ND	ND	NA	ND	ND	ND
122. Lead		0.025	0.044	NA	<0.050	<0.050	<0.050
123. Mercury		0.001	0.001	NA	<0.0003	<0.0003	<0.0004
124. Nickel		0.060	0.067	NA	<0.050	<0.050	<0.050
125. Selenium		<0.005	<0.005	NA	<0.015	<0.015	<0.015
126. Silver		0.003	0.012	NA	<0.002 4/	0.039 4/	0.248 4/
127. Thallium		<0.050	<0.050	NA	<0.015	<0.015	<0.015
128. Zinc		0.018	0.045	NA	0.066	0.035	0.130
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)		ND	ND	NA	ND	ND	ND
Aluminum	-,-	0.086	0.104	NA	0.300	0.260	0.270
Ammonia	-,-	NA	NA	NA	<0.050	2.013	0.004
Barium	-,-	0.016	2.67	NA	0.013	0.015	0.015
Boron	-,-	0.040	0.116	NA	<0.020	<0.020	<0.020
BOD	-,-	NA	NA	NA	<1.000	40.268	NA
Calcium	-,-	15.4	15.9	NA	6.460	6.720	7.740
Chlorides	-,-	NA	NA	NA	17.0	54.309	2010.0
Cobalt	-,-	0.011	0.006	NA	<0.005	<0.005	<0.005
COD	-,-	NA	ND	NA	<5.00	140.0	NA
Iron	-,-	0.091	0.122	NA	0.064	<0.030	0.560
Magnesium	-,-	3.47	3.66	NA	2.210	2.380	2.470
Manganese	-,-	0.007	0.008	NA	<0.010	<0.010	0.014
Molybdenum	-,-	<0.001	0.001	NA	<0.010	<0.010	<0.010
Oil and Grease	-,-	ND	ND	NA	<0.500	<0.500	<0.500
Phenols (Total)	-,-	ND	ND	NA	<0.020	0.001	0.004
Sodium	-,-	5.73	6.06	NA	24.500	300.0	24.60
Tin	-,-	0.012	0.006	NA	<0.010	<0.010	<0.010

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SCREENING ANALYSIS RESULTS
MAGNESIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc.1/ mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc.2/ mg/l	Raw Waste Conc.3/ mg/l
Titanium	-,-	0.001	0.001	NA	<0.005	<0.005	0.530
TOC	-,-	NA	NA	NA	<2.000	42.201	NA
TSS	-,-	ND	21.0	NA	<1.000	0.705	0.283
Vanadium	-,-	0.030	0.030	NA	<0.005	<0.005	<0.005
Yttrium	-,-	<0.001	0.001	NA	<0.005	<0.005	<0.005

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 ≤0.01 mg/l.
** Indicates ≤0.005 mg/l.
1/ Process water from heat paper production.
2/ Process water from silver chloride surface reduced cathode element.
3/ Process water from silver chloride electrolytically oxidized cathode element.
4/ Silver analysis done by EPA Method 272.1 or 272.2.
+ For asbestos analysis; indicates presence of chrysotile fibers.

TABLE V-7

SCREENING ANALYSIS RESULTS
ZINC SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
1	Acenaphthene		ND	NA	ND	NA	ND	ND	ND	NA
2	Acrolein		ND	ND	ND	ND	ND	ND	ND	ND
3	Acrylonitrile		ND	ND	ND	ND	ND	ND	ND	ND
4	Benzene		ND	*	*	ND	ND	ND	ND	ND
5	Benzidine		ND	NA	ND	NA	ND	ND	ND	NA
6	Carbon Tetrachloride		ND	ND	ND	ND	ND	ND	ND	ND
7	Chlorobenzene		ND	ND	ND	ND	ND	ND	ND	ND
8	1,2,4 Trichlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
9	Hexachlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
10	1,2 Dichloroethane		ND	ND	ND	ND	ND	ND	ND	ND
11	1,1,1 Trichloroethane	1,0	ND	4.2	6.4	ND	ND	*	*	ND
12	Hexachloroethane		ND	NA	ND	NA	ND	ND	ND	NA
13	1,1 Dichloroethane		ND	0.018	0.079	ND	ND	*	ND	ND
14	1,1,2 Trichloroethane		ND	ND	*	ND	ND	ND	ND	ND
15	1,1,2,2 Tetrachloroethane		ND	ND	ND	ND	ND	ND	ND	ND
16	Chloroethane		ND	ND	ND	ND	ND	ND	ND	ND
17	Bis Chloromethyl Ether		ND	ND	ND	ND	ND	ND	ND	ND
18	Bis 2-Chloroethyl Ether		ND	ND	ND	NA	ND	ND	ND	NA
19	2-Chloroethyl Vinyl Ether		ND	ND	ND	ND	ND	ND	ND	NA
20	2-Chloronaphthalene		ND	NA	ND	NA	ND	ND	ND	NA
21	2,4,6 Trichlorophenol		ND	NA	*	NA	ND	ND	ND	NA
22	Parachlorometacresol		ND	NA	ND	NA	ND	ND	ND	NA
23	Chloroform		0.086	ND	ND	ND	ND	ND	ND	ND
24	2-Chlorophenol		ND	NA	*	NA	ND	ND	ND	NA
25	1,2 Dichlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
26	1,3 Dichlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
27	1,4 Dichlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
28	3,3 Dichlorobenzidine		ND	NA	ND	NA	ND	ND	ND	NA
29	1,1 Dichloroethylene		ND	0.64	0.42	ND	ND	ND	ND	ND
30	1,2 Trans-Dichloroethylene		ND	0.016	ND	ND	ND	ND	ND	ND
31	2,4 Dichlorophenol		ND	ND	NA	NA	ND	ND	NA	ND
32	1,2 Dichloropropane		ND	ND	ND	ND	ND	ND	ND	ND
33	1,2 Dichloropropylene		ND	ND	ND	ND	ND	ND	ND	ND
34	2,4 Dimethylphenol		ND	NA	ND	NA	ND	ND	ND	NA
35	2,4 Dinitrotoluene		ND	NA	ND	NA	ND	ND	ND	NA
36	2,6 Dinitrotoluene		ND	NA	ND	NA	ND	ND	ND	NA
37	1,2 Diphenylhydrazine		ND	NA	ND	NA	ND	ND	ND	NA
38	Ethylbenzene		ND	*	0.032	ND	ND	ND	ND	ND
39	Fluoranthene		ND	NA	ND	NA	ND	ND	ND	NA
40	4 Chlorophenyl Phenyl Ether		ND	NA	ND	NA	ND	ND	ND	NA
41	4 Bromophenyl Phenyl Ether		ND	NA	ND	NA	ND	ND	ND	NA

TABLE V-7

SCREENING ANALYSIS RESULTS
ZINC SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
42	Bis(2 Chlorcisopropyl) Ether		ND	NA	ND	NA	ND	ND	ND	NA
43	Bis(2 Chloroethoxy) Methane		ND	NA	ND	NA	ND	ND	ND	NA
44	Methylene Chloride	1,1	ND	0.35	8.4	ND	ND	0.022	0.031	0.018
45	Methyl Chloride		ND	ND	ND	ND	ND	ND	ND	ND
46	Methyl Bromide		ND	ND	ND	ND	ND	ND	ND	ND
47	Bromoform		ND	ND	ND	ND	ND	ND	ND	ND
48	Dichlorobromomethane		ND	ND	ND	ND	ND	ND	ND	ND
49	Trichlorofluoromethane		ND	ND	ND	ND	ND	ND	ND	ND
50	Dichlorodifluoromethane		ND	ND	ND	ND	ND	ND	ND	ND
51	Chlorodibromomethane		ND	ND	ND	ND	ND	ND	ND	ND
52	Hexachlorobutadiene		ND	NA	ND	NA	ND	ND	ND	NA
53	Hexachlorocyclopentadiene		ND	NA	ND	NA	ND	ND	ND	NA
54	Isophorone		ND	NA	ND	NA	ND	ND	ND	NA
55	Naphthalene		ND	NA	0.190	NA	ND	ND	ND	NA
56	Nitrobenzene		ND	NA	ND	NA	ND	ND	ND	NA
57	2 Nitrophenol		ND	NA	ND	NA	ND	ND	ND	NA
58	4 Nitrophenol		ND	NA	ND	NA	ND	ND	ND	NA
59	2,4 Dinitrophenol		ND	NA	ND	NA	ND	ND	ND	NA
60	4,6 Dinitro-o-cresol		ND	NA	ND	NA	ND	ND	ND	NA
61	N-Nitrosodimethylamine		ND	NA	ND	NA	ND	ND	ND	NA
62	N-Nitrosodiphenylamine		ND	NA	ND	NA	ND	ND	ND	NA
63	N-Nitrosodi-N-propylamine		ND	NA	ND	NA	ND	ND	ND	NA
64	Pentachlorophenol		ND	NA	ND	NA	ND	0.040	0.027	NA
65	Phenol		ND	NA	0.06	NA	ND	ND	*	NA
66	Bis(2-Ethylhexyl) Phthalate		*	NA	*	NA	ND	0.012	0.031	NA
67	Butyl Benzyl Phthalate		ND	NA	ND	NA	ND	*	*	NA
68	Di-N-Butyl Phthalate		*	NA	*	NA	*	*	*	NA
69	Di-N-octyl Phthalate		ND	NA	ND	NA	ND	ND	ND	NA
70	Diethyl Phthalate		ND	NA	*	NA	ND	ND	ND	NA
71	Dimethyl Phthalate		ND	NA	ND	NA	ND	ND	ND	NA
72	1,2 Benzanthracene		ND	NA	ND	NA	ND	ND	ND	NA
73	Benzo(A)Pyrene		ND	NA	ND	NA	ND	ND	ND	NA
74	3,4 Benzofluoranthene		ND	NA	ND	NA	ND	ND	ND	NA
75	11,12-Benzofluoranthene		ND	NA	ND	NA	ND	ND	ND	NA
76	Chrysene		ND	NA	ND	NA	ND	ND	ND	NA
77	Acenaphthylene		ND	NA	ND	NA	ND	ND	NA	
78	Anthracene		ND	NA	ND	NA	ND	*	ND	NA
79	1,12-Benzoperylene		ND	NA	ND	NA	ND	ND	ND	NA
80	Fluorene		ND	NA	ND	NA	ND	ND	ND	NA
81	Phenanthrene		ND	NA	ND	NA	ND	*	ND	NA
82	1,2,5,6 Dibenzanthracene		ND	NA	ND	NA	ND	ND	ND	NA

TABLE V-7

SCREENING ANALYSIS RESULTS
ZINC SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
83	Indenopyrene		ND	NA	ND	NA	ND	ND	ND	NA
84	Pyrene		ND	NA	ND	NA	ND	ND	ND	NA
85	Tetrachloroethylene		ND	0.025	*	ND	ND	*	*	ND
86	Toluene	0,1	ND	0.11	0.055	ND	ND	*	*	ND
87	Trichloroethylene	2,0	ND	0.39	0.045	ND	ND	*	*	ND
88	Vinyl Chloride		ND	ND	ND	ND	ND	ND	ND	ND
89	Aldrin		ND	NA	ND	NA	ND	ND	ND	NA
90	Dieldrin		ND	NA	ND	NA	ND	ND	ND	NA
91	Chlordane		ND	NA	ND	NA	ND	ND	ND	NA
92	4,4 DDT		ND	NA	ND	NA	ND	ND	ND	NA
93	4,4 DDE		ND	NA	ND	NA	ND	ND	ND	NA
94	4,4 DDD		ND	NA	ND	NA	ND	ND	ND	NA
95	Alpha-Endosulfan		ND	NA	ND	NA	ND	ND	ND	NA
96	Beta-Endosulfan		ND	NA	ND	NA	ND	ND	ND	NA
97	Endosulfan Sulfate		ND	NA	ND	NA	ND	ND	ND	NA
98	Endrin		ND	NA	ND	NA	ND	ND	ND	NA
99	Endrin Aldehyde		ND	NA	ND	NA	ND	ND	ND	NA
100	Heptachlor		ND	NA	ND	NA	ND	ND	ND	NA
101	Heptachlor Epoxide		ND	NA	ND	NA	ND	ND	ND	NA
102	Alpha-BHC		ND	NA	ND	NA	ND	ND	ND	NA
103	Beta-BHC		ND	NA	ND	NA	ND	ND	ND	NA
104	Gamma-BHC (Lindane)		ND	NA	ND	NA	ND	ND	ND	NA
105	Delta-BHC		ND	NA	ND	NA	ND	ND	ND	NA
106	PCB-1242		ND	NA	ND	NA	ND	ND	ND	NA
107	PCB-1254		ND	NA	ND	NA	ND	ND	ND	NA
108	PCB-1221		ND	NA	ND	NA	ND	ND	ND	NA
109	PCB-1232		ND	NA	ND	NA	ND	ND	ND	NA
110	PCB-1248		ND	NA	ND	NA	ND	ND	ND	NA
111	PCB-1260		ND	NA	ND	NA	ND	ND	ND	NA
112	PCB-1016		ND	NA	ND	NA	ND	ND	ND	NA
113	Toxaphene		ND	NA	ND	NA	ND	ND	ND	NA
114	Antimony	1,0	ND	0.07	ND	NA	ND	ND	ND	NA
115	Arsenic	1,0	ND	ND	ND	NA	ND	ND	ND	NA
116	Asbestos		ND	ND	ND	NA	ND	ND	ND	NA
117	Beryllium		<0.001	<0.001	<0.001	NA	<0.001	ND	<0.001	NA
118	Cadmium	0,1	<0.002	0.16	<0.002	NA	<0.002	0.060	0.030	NA
119	Chromium	5,0	<0.005	2.13	<0.005	NA	0.020	0.020	0.020	NA
120	Copper		<0.006	0.078	0.047	NA	0.030	0.100	0.100	NA
121	Cyanide	1,2	ND	ND	ND	NA	<0.005	0.001	0.001	NA
122	Lead	0,1	<0.02	<0.02	<0.02	NA	<0.02	0.100	0.100	NA
123	Mercury	12,0	0.0060	110	0.06	NA	0.100	0.800	0.800	NA

TABLE V-7

SCREENING ANALYSIS RESULTS
ZINC SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
124	Nickel	1,0	<0.005	<0.005	<0.005	NA	<0.005	0.010	0.050	NA
125	Selenium		ND	ND	0.08	NA	ND	0.080	ND	NA
126	Silver	6,0	<0.001	0.192	0.036	NA	<0.001	0.010	0.020	NA
127	Thallium		ND	ND	ND	NA	ND	ND	ND	NA
128	Zinc	13,2	0.170	21.0	0.226	NA	0.200	10	40	NA
129	2,3,7,8 TCDD (Dioxin)		NA	NA	NA	NA	NA	NA	NA	NA
130	Xylenes		NA	NA	NA	NA	NA	NA	NA	NA
131	Alkyl Epoxides		NA	NA	NA	NA	NA	NA	NA	NA
	Aluminum	-,-	0.068	0.387	0.217	NA	<0.09	3.00	2.00	NA
	Ammonia	-,-	NA	NA	NA	NA	0.12	11.3	1.81	NA
	Barium	-,-	0.026	0.029	0.358	NA	<0.006	<0.006	<0.006	NA
	Boron	-,-	<0.05	0.316	0.321	NA	<0.08	<0.08	<0.08	NA
	Calcium	-,-	<5.0	<5.0	<5.0	NA	66.0	25.0	14.0	NA
	Cobalt	-,-	<0.005	<0.005	<0.005	NA	<0.002	0.003	0.004	NA
	Fluoride	-,-	1.10	2.65	1.90	NA	0.13	0.44	0.23	NA
	Gold	-,-	ND	ND	ND	NA	ND	ND	ND	NA
	Iron	-,-	0.17	2.06	62.8	NA	<0.1	0.50	0.30	NA
	Magnesium	-,-	2.600	1.50	1.90	NA	30.00	5.90	3.10	NA
	Manganese	-,-	<0.005	0.45	0.377	NA	<0.006	2.00	0.80	NA
	Molybdenum	-,-	<0.005	0.015	<0.005	NA	<0.006	0.04	0.02	NA
	Oil & Grease	-,-	3.3	6.00	3.7	NA	1.0	8.00	8.00	NA
	Phenols (Total)	-,-	0.018	0.110	0.180	NA	ND	ND	0.001	NA
	Phosphorus	-,-	ND	1.73	1.54	NA	0.11			NA
	Sodium	-,-	18.80	1570	1580	NA	4.20	410	260	NA
	Strontium	-,-	NA	NA	NA	NA	NA			NA
	TSS	-,-	ND	270	38.0	NA	5.0	428	476.6	NA
	Tin	-,-	<0.005	<0.005	<0.005	NA	<0.008	0.07	0.05	NA
	Titanium	-,-	<0.015	<0.015	<0.015	NA	<0.006	0.02	0.01	NA
	Vanadium	-,-	<0.012	<0.12	<0.12	NA	<0.002	0.002	0.004	NA
	Yttrium	-,-	<0.016	<0.16	<0.16	NA	<0.002	0.002	0.003	NA

TABLE V-7

SCREENING ANALYSIS RESULTS
ZINC SUBCATEGORY

ND	Not detected.
NA	Not analyzed (includes Xylenes and 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.
*	Indiactes ≤0.01 mg/l.
**	Indicates ≤0.005 mg/l.

TABLE V-8
VERIFICATION PARAMETERS

	PARAMETERS	CADMIUM SUBCATEGORY	CALCIUM SUBCATEGORY	LECLANCHE SUBCATEGORY	LITHIUM SUBCATEGORY	MAGNESIUM SUBCATEGORY	ZINC SUBCATEGORY
11	1,1,1-Trichloroethane						x
13	1,1-Dichloroethane						x
14	1,1,2-Trichloroethane		x		x	x	
23	Chloroform		x		x	x	
29	1,1-Dichloroethylene						x
30	1,2 Trans-dichloroethylene						x
38	Ethylbenzene						x
44	Methylene Chloride	x	x		x	x	x
55	Naphthalene						x
64	Pentachlorophenol						x
66	Bis(2-ethyl hexyl)Phthalate		x		x	x	x
70	Diethyl Phthalate			x			x
85	Tetrachloroethylene						x
86	Toluene						x
87	Trichloroethylene	x					x
114	Antimony			x			x
115	Arsenic			x			x
116	Asbestos		x		x	x	
118	Cadmium	x	x	x	x	x	x
119	Chromium	x	x	x	x	x	x
120	Copper		x	x	x	x	x
121	Cyanide	x					x
122	Lead	x	x	x	x	x	x
123	Mercury	x		x			x
124	Nickel	x	x	x	x	x	x
125	Selenium			x			x
126	Silver		x		x	x	x

TABLE V-8
VERIFICATION PARAMETERS

	PARAMETERS	CADMIUM SUBCATEGORY	CALCIUM SUBCATEGORY	LECLANCHE SUBCATEGORY	LITHIUM SUBCATEGORY	MAGNESIUM SUBCATEGORY	ZINC SUBCATEGORY
128	Zinc	x	x	x	x	x	x
	Aluminum						x
	Ammonia	x				x	x
	Barium					x	
	Cobalt	x	x		x	x	
	COD					x	
	Fluoride					x	
	Iron		x		x	x	x
	Manganese		x	x	x	x	x
	Phenols (Total)	x		x		x	x
	Oil & Grease	x	x	x	x	x	x
	TSS (Total Suspended Solids)	x	x	x	x	x	x
	pH	x	x	x	x	x	x

TABLE V-9

CADMIUM SUBCATEGORY PROCESS ELEMENTS
(Reported Manufacture)

	Anodes		
Cathodes	Cadmium Pasted and Pressed Powder	Cadmium Electrodeposited	Cadmium Impregnated
Mercuric Oxide Powder Pressed	X		
Silver Powder Pressed	X		
Nickel Powder Pressed	X		
Nickel Electrodeposited			X
Nickel Impregnated	X	X	X

Ancillary Operations

Cell Wash

Electrolyte Preparation

Floor and Equipment Wash

Employee Wash

Cadmium Powder Production

Silver Powder Production

Nickel Hydroxide Production

Cadmium Hydroxide Production

TABLE V-10

NORMALIZED DISCHARGE FLOWS CADMIUM SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Total Raw Waste Volume (l/yr) (10^{6})	Production Normalizing Parameter
Anodes				
Pasted & Pressed Powder	2.7	1.0	0.948	Weight of Cadmium
Electrodeposited	697.0	697.0	80.9	Weight of Cadmium
Impregnated	998.0	998.0	179.6	Weight of Cadmium
Cathodes				
Nickel Electrodeposited	569.0	569.0	0.680	Weight of Nickel Applied
Nickel Impregnated	1640.0	1720.0	274.2	Weight of Nickel Applied
Ancillary Operations				
Cell Wash	4.93	3.33	4.71	Weight of Cells Produced
Electrolyte Preparation	0.08	0.08	0.037	Weight of Cells Produced
Floor and Equipment Wash	12.0	2.40	7.78	Weight of Cells Produced
Employee Wash	1.5	1.5	0.068	Weight of Cells Produced
Cadmium Powder Production	65.7	65.7	27.0	Weight of Cadmium Powder Produced
Silver Powder Production	21.2	21.2	0.80	Weight of Silver Powder Produced
Cadmium Hydroxie Production	0.9	0.9	1.6	Weight of Cadmium Used
Nickel Hydroxide Production	110.0	110.0	170.0	Weight of Nickel Used

TABLE V-11

POLLUTANT CONCENTRATIONS IN CADMIUM PASTED AND PRESSED POWDER ANODE ELEMENT WASTE STREAMS

			mg/l	
	Temperature (Deg C)	29.0	29.0	31.0
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	285.0	365.0	151.0
119	Chromium, Total	0.011	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
121	Cyanide, Total	0.101	0.000	9.45
	Cyanide, Amn. to Chlor.	0.099	0.000	9.40
122	Lead	0.050	0.000	0.02
123	Mercury	0.000	0.000	0.000
124	Nickel	40.50	2.780	13.50
128	Zinc	0.530	0.350	0.350
	Ammonia	2.90	0.67	1.15
	Cobalt	0.000	0.000	0.000
	Phenols, Total	0.042	0.013	0.062
	Oil & Grease	5.0	1960.0	500.0
	Total Suspended Solids	808.	1036.0	1270.0
	pH, minimum	10.0	9.6	9.0
	pH, maximum	10.0	9.6	9.0

TABLE V-12

POLLUTANT MASS LOADINGS IN THE CADMIUM PASTED AND PRESSED POWDER ANODE ELEMENT WASTE STREAMS

			mg/kg	
	Flow (l/kg)	1.533	1.781	2.680
	Temperature (Deg C)	29.0	29.0	31.0
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	437.0	650.0	404.6
119	Chromium, Total	0.017	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
121	Cyanide, Total	0.155	0.000	25.32
	Cyanide, Amn. to Chlor.	0.152	0.000	25.19
122	Lead	0.077	0.000	0.054
123	Mercury	0.000	0.000	0.000
124	Nickel	62.1	4.952	36.18
128	Zinc	0.813	0.623	0.938
	Ammonia	4.446	1.193	3.082
	Cobalt	0.000	0.000	0.000
	Phenols, Total	0.064	0.023	0.166
	Oil & Grease	7.67	3491.0	1340.0
	Total Suspended Solids	1239.0	1845.0	3403.0
	pH, minimum	10.0	9.6	9.0
	pH, maximum	10.0	9.6	9.0

TABLE V-13

POLLUTANT CONCENTRATIONS IN THE CADMIUM ELECTRODEPOSITED ANODE ELEMENT WASTE STREAMS

			mg/l	
	Temperature (Deg C)	24.6	21.6	24.7
44	Methylene chloride	0.00	0.00	*
87	Trichloroethylene	*	*	*
118	Cadmium	108.2	129.5	46.17
119	Chromium, Total	0.000	0.001	0.0000
	Chromium, Hexavalent	0.000	0.000	0.000
121	Cyanide, Total	0.021	0.020	0.024
	Cyanide, Amn. to Chlor.	I	I	I
122	Lead	0.000	0.000	0.0000
123	Mercury	0.0006	0.0003	0.0006
124	Nickel	0.080	0.084	0.048
128	Zinc	0.009	0.006	0.002
	Ammonia	2.27	2.49	4.07
	Cobalt	0.000	0.000	0.000
	Phenols, Total	0.012	0.012	0.012
	Oil & Grease	5.1	5.1	5.5
	Total Suspended Solids	187.7	177.6	14.9
	pH, minimum	2.9	4.5	3.7
	pH, maximum	11.9	11.8	11.7

I - Interference
* - ≤ 0.01

TABLE V-14

POLLUTANT MASS LOADINGS IN THE CADMIUM ELECTRODEPOSITED ANODE ELEMENT WASTE STREAMS

		mg/kg		
	Flow (l/kg)	691.0	697.0	697.0
	Temperature (Deg C)	24.6	21.6	24.7
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.068	0.069	0.070
118	Cadmium	74700.0	90200.0	32160.0
119	Chromium, Total	0.000	0.423	0.093
	Chromium, Hexavalent	0.000	0.000	0.000
121	Cyanide, Total	14.28	14.12	16.53
	Cyanide, Amn. to Chlor.	I	I	I
122	Lead	0.000	0.000	0.093
123	Mercury	0.4128	0.2116	0.3939
124	Nickel	55.28	58.34	33.63
128	Zinc	6.04	4.482	1.542
	Ammonia	1566.0	1734.0	2835.0
	Cobalt	0.000	0.000	0.000
	Phenols, Total	8.24	8.29	8.29
	Oil & Grease	3490.0	3548.0	3815.0
	Total Suspended Solids	129600.0	123700.0	10400.0
	pH, minimum	2.9	4.5	3.7
	pH, maximum	11.9	11.8	11.7

I - Interference

TABLE V-15

POLLUTANT CONCENTRATIONS AND MASS LOADINGS IN THE CADMIUM IMPREGNATED ANODE ELEMENT WASTE STREAMS

		mg/l		mg/kg	
	Flow (1/kg)			800.	1284.
	Temperature (Deg C)	21.6	14.2	21.6	14.2
44	Methylene chloride	*	0.00	0.00	0.00
87	Trichloroethylene	*	*	0.00	0.00
118	Cadmium	63.3	0.110	50700.	141.2
119	Chromium, Total	0.190	0.100	152.1	128.4
	Chromium, Hexavalent	I	I	I	I
121	Cyanide, Total	0.060	0.020	48.00	25.70
	Cyanide, Amn. to Chlor.	0.020	0.000	16.00	0.000
122	Lead	0.000	0.000	0.000	0.000
123	Mercury	0.0007	0.0300	0.5602	38.52
124	Nickel	3.300	1.200	2641.	1541.
128	Zinc	0.060	0.020	48.00	25.70
	Ammonia	3.20	1.40	2560.	1800.
	Cobalt	0.110	0.040	88.0	51.36
	Phenols, Total	0.030	0.010	24.00	12.80
	Oil & Grease	2.7	2.3	2160.	2930.
	Total Suspended Solids	354.1	54.0	283400.	69300.
	pH, minimum	5.2	7.0	5.2	7.0
	pH, maximum	13.5	13.0	13.5	13.0

I - Interference
* - ≤ 0.01

TABLE V-16

POLLUTANT CONCENTRATIONS IN THE NICKEL ELECTRODEPOSITED CATHODE ELEMENT WASTE STREAMS

		mg/l		
	Temperature (Deg C)	11.0	12.0	10.0
44	Methylene chloride	0.00	*	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	0.048	0.090	0.013
119	Chromium, Total	0.000	0.000	0.013
	Chromium, Hexavalent	0.000	0.000	0.007
121	Cyanide, Total	0.042	0.040	0.011
	Cyanide, Amn. to Chlor.	0.042	0.016	0.000
122	Lead	0.000	0.000	0.000
123	Mercury	0.0160	0.000	0.0320
124	Nickel	1.980	6.01	1.550
128	Zinc	0.000	0.000	0.000
	Ammonia	0.00	0.00	0.00
	Cobalt	0.000	0.250	0.053
	Phenols, Total	0.006	0.042	0.014
	Oil & Grease	1.0	2.0	2.0
	Total Suspended Solids	0.0	5.0	0.0
	pH, minimum	7.1	5.2	7.0
	pH, maximum	7.1	5.8	7.2

* - ≤ 0.01

TABLE V-17

POLLUTANT MASS LOADINGS IN THE NICKEL ELECTRODEPOSITED CATHODE ELEMENT WASTE STREAMS

			mg/kg	
	Flow (l/kg)	97.7	416.3	1167.0
	Temperature (Deg C)	11.0	12.0	10.0
44	Methylene chloride	0.00	0.042	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	4.688	37.47	15.17
119	Chromium, Total	0.000	0.000	8.17
	Chromium, Hexavalent	0.000	0.000	0.000
121	Cyanide, Total	4.102	16.65	12.84
	Cyanide, Amn. to Chlor.	4.102	6.66	0.000
122	Lead	0.000	0.000	0.000
123	Mercury	1.563	0.000	37.34
124	Nickel	193.4	2502.0	1809.0
128	Zinc	0.000	0.000	0.000
	Ammonia	0.000	0.000	0.000
	Cobalt	0.000	104.1	61.9
	Phenols, Total	0.586	17.49	16.34
	Oil & Grease	97.7	833.0	2334.0
	Total Suspended Solids	0.000	2082.0	0.000
	pH, minimum	7.1	5.2	7.0
	pH, maximum	7.1	5.8	7.2

TABLE V-18

POLLUTANT CONCENTRATIONS IN THE NICKEL IMPREGNATED CATHODE ELEMENT WASTE STREAMS

mg/l

		PLANT A			PLANT C			PLANT D		PLANT B	
	Temperature (Deg C)	28.6	16.7	30.2	51.5	38.7	43.9	16.0	16.0	71.9	69.9
44	Methylene chloride	0.00	0.00	*	0.00	*	*	0.00	0.00	0.00	0.00
87	Trichloroethylene	*	*	*	*	0.00	*	*	*	0.00	0.00
118	Cadmium	79.2	25.46	10.73	0.020	0.039	0.142	0.026	0.004	13.38	0.772
119	Chromium, Total	0.178	0.086	0.045	0.049	0.138	0.109	0.000	0.000	0.002	0.002
	Chromium, Hexavalent	0.0000	0.0000	0.0000	0.000	I	I	0.000	0.000	0.0000	0.0000
121	Cyanide, Total	0.025	0.033	0.023	0.046	0.072	0.008	0.000	0.000	0.286	0.051
	Cyanide, Amn. to Chlor.	0.018	0.016	0.017	0.046	0.008	0.000	0.000	0.000	0.000	0.000
122	Lead	0.010	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000
123	Mercury	0.0009	0.0113	0.0004	0.0012	0.0003	0.0274	0.000	0.000	0.000	0.000
124	Nickel	514.0	189.2	120.1	21.10	9.19	44.71	59.00	1.960	199.2	14.45
128	Zinc	0.045	0.027	0.055	0.120	0.324	0.027	0.220	0.150	0.303	0.712
	Ammonia	8.64	9.39	9.03	8.46	8.14	3.46	NA	NA	86.6	18.92
	Cobalt	0.000	0.000	0.000	0.264	0.209	1.275	4.700	0.081	0.101	0.001
	Phenols, Total	0.007	0.006	0.006	0.008	0.024	0.013	0.015	0.000	0.025	0.086
	Oil & Grease	27.6	7.4	6.2	1.0	1.3	6.9	2.4	3.0	6.1	6.1
	Total Suspended Solids	1163.0	341.9	185.2	2690.0	644.0	92.5	96.0	28.0	87.9	64.8
	pH, minimum	4.1	4.0	5.2	9.7	6.5	8.0	7.7	8.5	1.0	1.0
	pH, maximum	13.1	13.0	12.8	12.0	10.0	11.5	10.9	10.5	14.0	14.0

I - Interference
NA - Not Analyzed
* - ≤ 0.01

TABLE V-19

POLLUTANT MASS LOADINGS IN THE NICKEL IMPREGNATED CATHODE ELEMENT WASTE STREAMS

mg/kg

		PLANT A			PLANT C			PLANT D		PLANT B	
	Flow (l/kg)	1817.0	1630.0	1621.0	1363.0	1954.0	1638.0	1934.0	3869.0	228.3	197.3
	Temperature (Deg C)	28.6	16.7	30.2	51.5	38.7	43.9	16.0	16.0	71.9	69.9
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
118	Cadmium	143900.0	41500.0	17390.0	27.26	76.2	232.6	50.1	15.48	3050.0	152.3
119	Chromium, Total	323.4	140.2	72.9	66.8	269.7	178.5	0.000	0.000	0.457	0.395
	Chromium (Hexavalent	0.0000	0.0000	0.0000	0.000	I	I	0.000	0.000	0.0000	0.0000
121	Cyanide, Total	45.43	53.8	37.28	62.7	140.7	13.10	0.000	0.000	65.3	10.06
	Cyanide, Amn. to Chlor.	32.71	26.08	27.56	62.7	15.63	0.000	0.000	0.000	0.0000	0.0000
122	Lead	18.17	0.000	0.000	0.000	39.08	0.000	0.000	0.000	0.000	0.000
123	Mercury	1.635	18.42	0.648	1.636	0.586	44.88	0.000	0.000	0.000	0.000
124	Nickel	933938.0	308396.0	194682.0	28759.0	17957.0	73235.0	114106.0	7583.0	45477.0	2851.0
128	Zinc	81.8	44.01	89.2	163.6	633.0	44.23	425.5	580.0	69.2	140.5
	Ammonia	15700.0	15310.0	14640.0	11530.0	15190.0	5670.0	NA	NA	19770.0	3733.0
	Cobalt	0.000	0.000	0.000	359.8	408.4	2088.0	9090.0	313.4	23.06	0.197
	Phenols, Total	12.72	9.78	9.73	10.90	46.90	21.29	29.01	0.000	5.71	16.97
	Oil & Grease	50100.0	12060.0	10050.0	1363.0	2540.0	11300.0	4642.0	11610.0	1293.0	1204.0
	Total Suspended Solids	2113000.0	557000.0	300200.0	3666000.0	1258000.0	151500.0	185700.0	111000.0	20080.0	12790.0
	pH, minimum	4.1	4.0	5.2	9.7	6.5	8.0	7.7	8.5	1.0	1.0
	pH, maximum	13.0	13.0	12.8	12.0	10.0	11.5	10.9	10.5	14.0	14.0

I - Interference
NA - Not Analyzed

TABLE V-20

STATISTICAL ANALYSIS (mg/l) OF THE NICKEL IMPREGNATED CATHODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	16.0	71.9	38.3	34.5	10	0	10
44	Methylene chloride	0.00	*	*	0.00	3	7	10
87	Trichloroethylene	0.00	*	*	*	7	3	10
118	Cadmium	0.004	79.2	12.98	0.457	10	0	10
119	Chromium, Total	0.000	0.178	0.061	0.047	8	2	10
	Chromium, Hexavalent	0.0000	0.0000	0.0000	0.0000	8	0	8
121	Cyanide, Total	0.000	0.386	0.054	0.029	8	2	10
	Cyanide, Amn. to Chlor.	0.000	0.046	0.011	0.004	5	2	10
122	Lead	0.000	0.02	0.000	0.000	2	8	10
123	Mercury	0.0000	0.0274	0.0042	0.0004	6	4	10
124	Nickel	1.960	514.0	117.3	51.85	10	0	10
128	Zinc	0.027	0.712	0.198	0.135	10	0	10
	Ammonia	3.46	86.6	19.08	8.55	8	0	10
	Cobalt	0.000	4.700	0.663	0.091	7	3	10
	Phenols, Total	0.000	0.086	0.019	0.008	9	1	10
	Oil & Grease	1.0	27.6	6.8	6.1	10	0	10
	Total Suspended Solids	28.0	2690.0	539.0	140.6	10	0	10
	pH, minimum	1.0	9.7	5.6	5.9	10	0	10
	pH, maximum	10.0	14.0	12.2	12.4	10	0	10

* - ≤ 0.01

TABLE V-21

STATISTICAL ANALYSIS (mg/kg) OF THE NICKEL IMPREGNATED CATHODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (l/kg)	197.3	3869.0	1625.0	1634.0
	Temperature (Deg C)	16.0	71.9	38.3	34.4
44	Methylene Chloride	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
118	Cadmium	15.48	143900.0	20640.0	192.5
119	Chromium, Total	0.000	323.4	105.2	69.9
	Chromium, Hexavalent	0.000	0.000	0.000	0.000
121	Cyanide, Total	0.000	140.7	42.84	41.36
	Cyanide, Amn. to Chlor.	0.000	62.7	16.47	7.82
122	Lead	0.000	9.08	5.73	0.000
123	Mercury	0.0000	44.88	6.78	0.617
124	Nickel	2851.0	934000.0	172700.0	59300.0
128	Zinc	44.01	633.0	227.1	114.9
	Ammonia	3733.0	19770.0	12780.0	14915.0
	Cobalt	0.000	9090.0	1228.0	168.2
	Phenols, Total	0.000	46.90	16.30	11.81
	Oil & Grease	1204.0	50100.0	10630.0	7350.0
	Total Suspended Solids	12790.0	3666000.0	838000.0	243000.0
	pH, minimum	1.0	9.7	5.6	5.9
	pH, maximum	10.0	14.0	12.2	12.4

TABLE V-22

POLLUTANT CONCENTRATIONS IN THE FLOOR AND EQUIPMENT WASH ELEMENT WASTE STREAMS

		mg/l
	Temperature (Deg C)	16.0
44	Methylene chloride	NA
87	Trichloroethylene	NA
118	Cadmium	29.20
119	Chromium, Total	0.081
	Chromium, Hexavalent	0.000
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.000
123	Mercury	0.000
124	Nickel	9.08
128	Zinc	12.90
	Ammonia	NA
	Cobalt	5.040
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	NA
	pH, minimum	7.9
	pH, maximum	7.9

NA - Not Analyzed

TABLE V-23

POLLUTANT MASS LOADINGS IN THE FLOOR AND EQUIPMENT WASH ELEMENT WASTE STREAMS

		mg/kg
	Flow (l/kg)	0.246
	Temperature (Deg C)	16.0
44	Methylene chloride	NA
87	Trichloroethylene	NA
118	Cadmium	7.18
119	Chromium, Total	0.020
	Chromium, Hexavalent	0.000
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.000
123	Mercury	0.000
124	Nickel	2.232
128	Zinc	3.171
	Ammonia	NA
	Cobalt	1.239
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	NA
	pH, minimum	7.9
	pH, maximum	7.9

NA - Not Analyzed

TABLE V-24

POLLUTANT CONCENTRATIONS IN EMPLOYEE WASH ELEMENT WASTE STREAMS

		mg/l		
	Temperature (Deg C)	31.0	32.0	32.0
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	0.002	0.130	0.076
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
121	Cyanide, Total	0.000	0.030	0.036
	Cyanide, Amn. to Chlor.	0.000	0.025	0.036
122	Lead	0.00	0.00	0.00
123	Mercury	0.000	0.000	0.000
124	Nickel	0.000	0.130	0.260
128	Zinc	0.190	0.240	0.050
	Ammonia	0.00	0.00	0.00
	Cobalt	0.000	0.000	0.000
	Phenols, Total	0.007	0.010	0.000
	Oil & Grease	1.0	212.0	288.0
	Total Suspended Solids	0.0	280.0	312.0
	pH, minimum	7.3	6.8	7.9
	pH, maximum	7.3	6.8	7.9

TABLE V-25

POLLUTANT MASS LOADINGS IN EMPLOYEE WASH ELEMENT WASTE STREAMS

		mg/kg		
	Flow (l/kg)	1.475	1.475	1.475
	Temperature (Deg C)	31.0	32.0	32.0
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	0.003	0.192	0.112
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
121	Cyanide, Total	0.000	0.044	0.053
	Cyanide, Amn. to Chlor.	0.000	0.037	0.053
122	Lead	0.000	0.000	0.000
123	Mercury	0.0000	0.0000	0.0000
124	Nickel	0.000	0.192	0.383
128	Zinc	0.280	0.354	0.074
	Ammonia	0.000	0.000	0.000
	Cobalt	0.000	0.000	0.000
	Phenols, Total	0.010	0.015	0.000
	Oil & Grease	1.475	312.6	424.7
	Total Suspended Solids	0.000	412.9	460.1
	pH, minimum	7.3	6.8	7.9
	pH, maximum	7.3	6.8	7.9

TABLE V-26

MEAN CONCENTRATIONS AND POLLUTANT MASS LOADINGS IN THE CADMIUM POWDER ELEMENT WASTE STREAMS

		Mean (mg/l)	Mean (mg/kg)
	Flow (l/kg)		65.7
	Temperature (Deg C)	21.9	21.9
44	Methylene chloride	0.00	0.00
87	Trichloroethylene	0.00	0.00
118	Cadmium	177.3	11650.0
119	Chromium, Total	0.004	0.263
	Chromium, Hexavalent	0.000	0.000
121	Cyanide, Total	0.026	1.708
	Cyanide, Amn. to Chlor.	0.000	0.000
122	Lead	0.000	0.000
123	Mercury	0.0077	0.506
124	Nickel	0.062	4.073
128	Zinc	4274.0	280800.0
	Ammonia	5.16	339
	Cobalt	0.000	0.000
	Phenols, Total	0.022	1.445
	Oil & Grease	4.4	298.1
	Total Suspended Solids	17.5	1150.0
	pH, minimum	1.3	1.3
	pH, maximum	3.3	3.3

TABLE V-27

CADMIUM SUBCATEGORY EFFLUENT FLOW RATES FROM INDIVIDUAL PLANTS

PLANT ID	FLOW RATE 1/day
A	15700
B	>450000
C	145000
D	>450000
E	0
F	54500
G	3780
H	0
I	1890
J	67000

TABLE V-28

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

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	14.0	66.8	29.6	25.4	12	0	12
44	Methylene chloride	0.00	0.027	*	*	6	6	12
87	Trichloroethylene	0.00	*	*	*	9	3	12
118	Cadmium	0.000	186.5	37.06	17.27	11	1	12
119	Chromium, Total	0.000	0.756	0.198	0.086	12	0	12
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	12	12
121	Cyanide, Total	0.000	0.364	0.079	0.023	9	2	11
	Cyanide, Amn. to Chlor.	0.000	0.354	0.040	0.000	8	3	11
122	Lead	0.000	0.400	0.161	0.123	3	1	4
123	Mercury	0.000	0.0250	0.003	0.0004	8	4	12
124	Nickel	0.570	281.2	61.8	19.20	12	0	12
126	Silver+	0.000	13.90	8.467	9.89	3	1	4
128	Zinc	0.000	2489.0	270.4	0.150	11	1	12
	Ammonia	1.94	80.8	15.17	6.69	9	0	9
	Cobalt	0.000	1.572	0.390	0.047	7	5	12
	Phenols, Total	0.000	0.080	0.018	0.0049	10	1	11
	Oil & Grease	0.8	20.2	7.2	5.7	11	0	11
	Total Suspended Solids	13.0	2290.0	325.1	72.0	12	0	12
	pH Minimum	1.0	7.1	3.4	2.6	12	0	12
	pH Maximum	2.5	14.0	11.6	12.9	12	0	12

+ - Not a cadmium subcategory verification parameter, analyzed only where silver cathodes produced
* - ≤ 0.01

TABLE V-29

TREATMENT IN-PLACE AT CADMIUM SUBCATEGORY PLANTS

PLANT ID	TREATMENT IN-PLACE	DISCHARGE 1/
A	Settling lagoon; material recovery	D
B	Lagooning, sand filter, pH adjust (Replaced by additional treatment and 100% recycle)	D (Zero)
C	pH adjust, coagulant addition, clarifier, filtration	I
D	Settling, pH adjust, in-process Cd, Ni recovery	I
E	Lagooning - offsite	Zero 2/
F	None	Zero
G	none	Zero 2/
H	pH adjust, clarification, ion exchange	D 2/
I	ph adjust	I
J	1) pH adjust, coagulant addition, clarification, sand filtration 2) Ion exchange	D
K	Settling	I
L	pH adjust, settling, filtration	D
M	None	Zero

1/ I = Indirect
D = Direct
2/ No longer active in the cadmium subcategory.

TABLE V-30

PERFORMANCE OF ALKALINE PRECIPITATION, SETTLING AND FILTRATION - CADMIUM SUBCATEGORY

TREATMENT SYSTEM I

Pollutant or Pollutant Property		Concentrations (mg/l)			
		Day 1		Day 2	
		Raw	Treated	Raw	Treated
118	Cadmium	0.026	0.490	0.004	0.140
124	Nickel	59.0	1.760	1.960	0.800
128	Zinc	0.220	0.0160	0.150	0.000
	Cobalt	4.700	0.020	0.081	0.024
	Oil and Grease	2.4	1.2	3.0	0.0
	TSS	96.0	0.00	28.0	0.0
	pH	7.7-10.9	8.9	8.5-10.5	8.5-10.5

TREATMENT SYSTEM II

		Concentration (mg/l)					
		Day 1		Day 2		Day 3	
		Raw	Treated	Raw	Treated	Raw	Treated
118	Cadmium	0.000	0.030	0.007	0.008	0.000	0.010
124	Nickel	0.610	0.620	1.500	0.550	0.570	0.500
126	Silver	12.00	0.220	24.10	0.240	13.90	0.270
128	Zinc	0.180	1.400	0.440	3.100	0.380	2.800
	Cobalt	0.000	2.200	2.700	2.700	0.000	3.000
	Oil & Grease	NA	NA	NA	NA	NA	NA
	TSS	27.0	51.0	23.0	216.0	13.0	18.0
	pH	2.0-2.6	6.7-11.4	2.2-2.5	9.2	2.1-2.5	9.9

NA - Not Analyzed

TABLE V-31

PERFORMANCE OF SETTLING - CADMIUM SUBCATEGORY

Pollutant or Pollutant Property		Concentration (mg/l)		
		Day 1	Day 2	Day 3
118	Cadmium	0.100	0.061	0.250
124	Nickel	0.820	0.800	1.000
128	Zinc	2.000	0.150	1.970
	Cobalt	0.000	0.000	0.012
	Oil and Grease	1.0	2.0	3.0
	TSS	11.0	8.0	10.0
	pH	11-12	11.1-12.3	11.1-12.5

TABLE V-32

CADMIUM SUBCATEGORY EFFLUENT QUALITY (FROM DCP)

PLANT ID NO.	TOTAL DISCHARGE FLOW 1/hr	(gal/hr)	pH	Oil&Grease (mg/l)	TSS (mg/l)	Cd (mg/l)	Co (mg/l)	Ni (mg/l)	Ag (mg/l)	Zn (mg/l)
A	114	(30)				1.1		6.7		
B	114000*	(30000)				0.01		0.034		
C	27250	(7200)	7-14			8.1		18.5		
D	33160*	(8760)	12.4	3	150	41.0		46.0		
E	23	(6.1)				0.1		<0.08	<0.02	
F	7880	(2081)	7.5			0.04		0.09		
G+	4630	(1220)				0.26	0.08	0.54		
G++	7040	(1860)						0.34		
HH	49500					3.73		3.06		75

* - Combined discharge includes wastewater from other subcategories and categories.
\+ - Effluent from pH adjustment and clarification
++ - Effluent from ion exchange

TABLE V-33

NORMALIZED DISCHARGE FLOWS
CALCIUM SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Total Raw Waste Volume (l/yr)	Production Normalizing Parameter
Heat Paper Production	115.4	24.1	1.3×10^5	Weights of Reactants
Cell Testing	0.014	0.014	200	Weights of Cells Produced

TABLE V-34

POLLUTANT CONCENTRATIONS IN THE HEAT PAPER PRODUCTION ELEMENT WASTE STREAM

		mg/l	
		Plant B	Plant A
	Temperature (°C)	20	17
14	1,1,2-trichloroethane	0.00	0.013
23	Chloroform	*	0.038
44	Methylene Chloride	0.00	0.14
66	Bis(2-ethylhexy) Phthalate	0.00	0.024
116	Asbestos+	0.0	630.0
118	Cadmium	0.000	0.002
119	Chromium	120.0	2.064
120	Copper	0.150	0.118
122	Lead	0.000	0.044
124	Nickel	0.000	0.067
126	Silver	0.000	0.012
128	Zinc	0.110	0.045
	Cobalt	0.000	0.006
	Iron	0.520	0.122
	Manganese	0.021	0.008
	Oil & Grease	0.0	0.0
	Total Suspended Solids	715.0	21.0
	pH, Minimum	2.9	6.2
	pH, Maximum	4.7	6.2

+ Chrysotile fibers - millions of fibers/liter
* ≤0.01

TABLE V-35

POLLUTANT MASS LOADINGS IN THE HEAT PAPER PRODUCTION ELEMENT WASTE STREAM

		mg/kg Plant B	Plant A
	Flow (l/kg)	99.9	14.0
	Temperature (°C)	20	17
14	1,1,2-trichloroethane	0.00	0.182
23	Chloroform	0.00	0.532
44	Methylene Chloride	0.00	0.196
66	Bis (2-ethylhexy) Phthalate	0.00	0.336
116	Asbestos+	0.0	8820.0
118	Cadmium	0.000	0.028
119	Chromium	12000.0	28.90
120	Copper	15.0	1.652
122	Lead	0.000	0.616
124	Nickel	0.000	0.938
126	Silver	0.000	0.168
128	Zinc	11.0	0.630
	Cobalt	0.000	0.084
	Iron	51.9	1.708
	Manganese	2.10	0.112
	Oil & Grease	0.0	0.0
	Total Suspended Solids	71400.0	294.0
	pH, Minimum	2.9	6.2
	pH, Maximum	4.7	6.2

Chrysotile fibers - millions of fibers/kg

TABLE V-36

TREATMENT IN-PLACE AT CALCIUM SUBCATEGORY PLANTS

PLANT ID	TREATMENT IN-PLACE	DISCHARGE 1/
A	pH adjust, settling	I
B	None	Zero
C	None	I

1/ I = Indirect

TABLE V-37

EFFLUENT CHARACTERISTICS FROM CALCIUM SUBCATEGORY MANUFACTURING OPERATIONS -DCP DATA

PLANT A

Flow Rate l/hr	Cd mg/l	Ba mg/l	Cr mg/l
1385.+	0.01	20.0	0.20

+ - Intermittent flow, average is ≤45 l/hr on a monthly basis

TABLE V-38

LECLANCHE SUBCATEGORY ELEMENTS
(Reported Manufacture)

	Anodes			
	Zinc Sheet Metal			Zinc Powder
Cathodes (and Electrolyte Form)	Cooked Paste Separator	Uncooked-Paste Separator	Paper Separator Prepared On or Off-Site	Plastic Separator
MnO_2 Cathode (and Electrolyte with Mercury)	---	---	X	---
MnO_2 Cathodes (and Electrolyte without Mercury)	X	X	X	---
MnO_2 Cathode (and Gelled Electrolyte with Mercury)	---	---	X	X
Carbon Cathode	---	---	X	---
Silver Cathode	---	X	---	---
Pasted MnO_2 Cathode	---	---	---	X
Ancillary Operations				
Equipment Area Cleanup			X	

TABLE V-39

NORMALIZED DISCHARGE FLOWS
LECLANCHE SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Total Raw Waste Volume (l/yr) (10^6)	Production Normalizing Parameter
<u>Ancillary Operations</u>				
Separator Cocked Paste	0.04	0.04	3.2	Weight of Cells Produced
Separator Uncooked Paste	nil	nil	nil	Weight of Cells Produced
Separator Pasted Paper with Mercury	0.14	0.14	0.015	Weight of Dry Paste Materials
Equipment and Area Cleanup	0.38	0	9.65	Weight of Cells Produced

TABLE V-40

POLLUTANT CONCENTRATIONS IN THE COOKED PASTE SEPARATOR ELEMENT WASTE STREAMS

		mg/l		
	Temperature (Deg C)	59.9	59.9	59.9
70	Diethyl phthalate	*	*	*
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.000	0.016	0.021
119	Chromium, Total	0.042	0.004	0.004
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	0.030	0.083	0.130
122	Lead	0.000	0.000	0.000
123	Mercury	0.0060	0.1600	0.1500
124	Nickel	0.000	0.054	0.097
125	Selenium	0.000	0.000	0.000
128	Zinc	0.110	94.0	148.0
	Manganese	0.130	5.48	14.20
	Phenols, Total	0.011	0.009	0.009
	Oil & Grease	13.0	39.0	11.0
	Total Suspended Solids	119.0	41.0	62.0
	pH, Minimum	5.1	5.1	5.9
	pH, Maximum	6.8	6.8	6.3

* - ≤ 0.01

TABLE V-41

POLLUTANT MASS LOADINGS IN THE COOKED PASTE SEPARATOR ELEMENT WASTE STREAMS

		mg/kg		
	Flow (l/kg)	0.047	0.045	0.025
	Temperature (Deg C)	59.9	59.9	59.9
70	Diethyl phthalate	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.001	0.001	0.001
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	0.004	0.004	0.003
122	Lead	0.000	0.000	0.000
123	Mercury	0.0003	0.0072	0.0038
124	Nickel	0.002	0.002	0.002
125	Selenium	0.000	0.000	0.000
128	Zinc	4.011	4.228	3.750
	Manganese	0.140	0.246	0.360
	Phenols, Total	0.001	0.000	0.000
	Oil & Grease	0.613	1.754	0.279
	Total Suspended Solids	5.615	1.844	1.571
	pH, Minimum	5.1	5.1	5.9
	pH, Maximum	6.8	6.8	6.3

TABLE V-42

POLLUTANT CONCENTRATIONS IN THE PAPER SEPARATOR (WITH MERCURY) ELEMENT WASTE STREAMS

			mg/l	
	Temperature (Deg C)	31.0	31.1	30.0
70	Diethyl phthalate	*	*	*
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.470	0.015	0.024
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	0.110	0.081	0.085
122	Lead	0.070	0.000	0.000
123	Mercury	0.4000	0.1600	0.1400
124	Nickel	0.140	0.020	0.027
125	Selenium	0.000	0.000	0.000
128	Zinc	1.160	0.410	0.230
	Manganese	1.150	1.250	0.430
	Phenols, Total	0.011	0.090	0.046
	Oil & Grease	16.0	7.0	83.0
	Total Suspended Solids	140.0	7.0	96.0
	pH, Minimum	8.3	7.5	8.5
	pH, Maximum	8.3	8.5	8.6

* - ≤ 0.01

TABLE V-43

POLLUTANT MASS LOADINGS IN THE PAPER SEPARATOR (WITH MERCURY) ELEMENT WASTE STREAMS

			mg/kg	
	Flow (l/kg)	0.109	0.174	0.152
	Temperature (Deg C)	31.0	31.1	30.0
70	Diethyl phthalate	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.051	0.003	0.004
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	0.012	0.014	0.013
122	Lead	0.008	0.000	0.000
123	Mercury	0.0436	0.0278	0.0228
124	Nickel	0.015	0.003	0.004
125	Selenium	0.000	0.000	0.000
128	Zinc	0.126	0.071	0.035
	Manganese	0.125	0.218	0.065
	Phenols, Total	0.001	0.016	0.007
	Oil & Grease	1.740	1.218	12.64
	Total Suspended Solids	15.23	1.218	14.62
	pH, Minimum	8.3	7.5	8.5
	pH, Maximum	8.3	8.5	8.6

TABLE V-44

NORMALIZED FLOW OF ANCILLARY OPERATION WASTE STREAMS

PLANT NO.	SAMPLING DATA MEAN VALUE, l/kg	SURVEY DATA, l/kg
1	-	0.05
2	-	0
3	-	0
4	-	0
5 (B)	0.01	0.04
6	-	0
7	-	0
8	-	0
9	-	0
10	-	0
11	-	0
12 (C)	0.01	-
13 (D)	-	6.37
14	-	0
15	-	0
16 (E)	-	0.44
17	-	0.44
18	-	0
19	-	0

TABLE V-45

POLLUTANT CONCENTRATIONS IN THE EQUIPMENT AND AREA CLEANUP ELEMENT WASTE STREAMS

mg/l

		PLANT B			PLANT C			PLANT E1/	PLANT B1/	PLANT D
	Temperature (Deg C)	59.9	43.3	60.0	31.0	30.5	30.1			
70	Diethyl phthalate	*	*	*	*	*	*			
114	Antimony	0.000	0.000	0.000	0.000	0.000	0.000			
115	Arsenic	0.070	0.090	0.640	0.000	0.000	0.000			
118	Cadmium	0.036	0.020	0.088	0.054	0.043	0.189			
119	Chromium, Total	0.250	0.130	2.880	0.014	0.022	0.283			
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0.000	0.000			
120	Copper	0.220	0.160	3.220	0.094	0.770	0.108			
122	Lead	0.070	0.000	0.940	0.000	0.000	0.000			0.03
123	Mercury	I	I	I	0.0170	0.0300	0.0310	117.0	0.033	1.42
124	Nickel	0.780	0.220	10.10	0.5670	0.334	0.369			0.0070
125	Selenium	0.070	0.090	0.600	0.000	0.000	0.000			
128	Zinc	220.0	325.0	680.0	98.0	42.44	33.83	1640.0	410.0	
	Manganese	140.0	3.82	383.0	33.89	21.82	13.30			
	Phenols, Total	0.059	I	I	0.056	0.253	0.044			
	Oil & Grease	33.0	482.0	36.0	9.80	438.5	96.1			24.6
	Total Suspended Solids	2610.0	4220.0	14230.0	357.2	395.0	471.1			
	pH, Minimum	7.5	7.5	8.5	6.2	6.1	6.1			
	pH, Maximum	10.4	10.4	9.7	8.6	9.0	8.7			

I - Interference
* - ≤ 0.01
1/- Dcp data

TABLE V-46

POLLUTANT MASS LOADINGS IN THE EQUIPMENT AND AREA CLEANUP ELEMENT WASTE STREAMS

mg/kg

		PLANT B			PLANT C			PLANT E1/	PLANT B1/	PLANT D
	Flow (l/kg)	0.008	0.011	0.011	0.010	0.010	0.010	0.44	0.04	6.3
	Temperature (Deg C)	59.9	43.3	60.0	31.0	30.5	30.1			
70	Diethyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00			
114	Antimony	0.000	0.000	0.000	0.000	0.000	0.000			
115	Arsenic	0.001	0.001	0.007	0.000	0.000	0.000			
118	Cadmium	0.000	0.000	0.001	0.001	0.000	0.002			
119	Chromium, Total	0.002	0.001	0.032	0.000	0.000	0.003			
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0.000	0.000			
120	Copper	0.002	0.002	0.036	0.001	0.001	0.001			
122	Lead	0.001	0.000	0.011	0.000	0.000	0.000			
123	Mercury	I	I	I	0.0000	0.0000	0.0000			0.1
124	Nickel	0.007	0.002	0.114	0.006	0.003	0.004	51.5	0.001	9.0
125	Selenium	0.001	0.001	0.007	0.000	0.000	0.000			0.0
128	Zinc	1.840	3.553	7.66	0.981	0.431	0.339	722.0	16.4	
	Manganese	1.171	0.042	4.316	0.339	0.222	0.133			
	Phenols, Total	0.000	I	I	0.001	0.003	0.000			
	Oil & Grease	0.276	5.270	0.406	0.098	4.458	0.962			157.0
	Total Suspended Solids	21.83	46.14	160.4	3.576	4.016	4.718			
	pH, Minimum	7.5	7.5	8.5	6.2	6.1	6.1			
	pH, Maximum	10.4	10.4	9.7	8.6	9.0	8.7			

I - Interference
1/- Dcp data

TABLE V-47

STATISTICAL ANALYSIS (mg/l) OF THE EQUIPMENT AND AREA CLEANUP ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	30.1	60.0	45.1	37.1	6	0	6
70	Diethyl phthalate	*	*	*	*	6	0	6
114	Antimony	0.000	0.000	0.000	0.000	0	6	6
115	Arsenic	0.000	0.640	0.133	0.035	3	3	6
118	Cadmium	0.020	0.189	0.072	0.049	6	0	6
119	Chrcmium, Total	0.014	2.880	0.597	0.190	6	0	6
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	6	6
120	Copper	0.094	3.220	0.650	0.134	6	0	6
122	Lead	0.000	0.940	0.1490	0.000	3	4	7
123	Mercury	0.0170	117.0	19.76	0.0320	6	0	6
124	Nickel	0.007	10.10	1.768	0.369	7	0	7
125	Selenium	0.000	0.600	0.127	0.035	3	3	6
128	Zinc	33.83	1640.0	431.0	272.5	8	0	8
	Manganese	3.820	383.0	99.3	27.86	6	0	6
	Phenols, Total	0.044	0.253	0.103	0.058	4	0	4
	Oil & Grease	9.80	482.0	160.0	36.00	7	0	7
	Total Suspended Solids	357.2	14230.0	3714.0	1541.0	6	0	6
	pH, Minimum	6.1	8.5	7.0	6.9	6	0	6
	pH, Maximum	8.6	10.4	9.5	9.4	6	0	6

* - ≤0.01

TABLE V-48

STATISTICAL ANALYSIS (mg/kg) OF THE EQUIPMENT AND AREA CLEANUP ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (l/kg)	0.008	0.011	0.010	0.010
	Temperature (Deg C)	30.1	60.0	45.1	37.1
70	Diethyl phthalate	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.007	0.001	0.000
118	Cadmium	0.000	0.002	0.001	0.000
119	Chromium, Total	0.000	0.032	0.007	0.002
	Chromium, Hexavalent	0.000	0.000	0.000	0.000
120	Copper	0.001	0.036	0.007	0.001
122	Lead	0.000	0.190	0.029	0.000
123	Mercury	0.000	51.5	10.09	0.0005
124	Nickel	0.002	0.114	0.026	0.006
125	Selenium	0.000	0.007	0.001	0.000
128	Zinc	0.339	722.0	94.2	2.697
	Manganese	0.042	4.316	1.037	0.281
	Phenols, Total	0.000	0.003	0.001	0.001
	Oil & Grease	0.098	157.0	24.07	0.962
	Total Suspended Solids	3.576	160.4	40.11	13.27
	pH, Minimum	6.1	8.5	7.0	6.9
	pH, Maximum	8.6	10.4	9.5	9.4

TABLE V-49

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

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Flow (l/day)	636.0	5880.0	2640.0	1920.0	6	0	6
	Temperature (Deg C)	30.1	59.9	55.3	43.8	6	0	6
70	Diethyl phthalate	*	*	*	*	6	0	6
114	Antimony	0.000	0.000	0.000	0.000	0	6	6
115	Arsenic	0.000	0.197	0.038	0.005	3	3	6
118	Cadmium	0.016	0.173	0.062	0.041	6	0	6
119	Chromium, Total	0.013	0.889	0.207	0.033	6	0	6
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	6	6
120	Copper	0.095	1.081	0.263	0.099	6	0	6
122	Lead	0.000	0.289	0.051	0.003	3	3	6
123	Mercury	0.0414	0.1287	0.0788	0.0742	6	0	6
124	Nickel	0.086	3.177	0.764	0.318	6	0	6
125	Selenium	0.000	0.185	0.035	0.005	3	3	6
128	Zinc	30.57	311.8	119.3	98.2	6	0	6
	Manganese	5.155	127.7	36.62	21.60	6	0	6
	Phenols, Total	0.006	0.236	0.061	0.031	6	0	6
	Oil & Grease	10.2	391.8	109.5	56.8	6	0	6
	Total Suspended Solids	341.7	4420.0	1150.0	464.3	6	0	6
	pH, Minimum	5.1	6.2	5.7	6.0	6	0	6
	pH, Maximum	8.6	10.4	9.5	9.4	6	0	6

* - ≤0.01

TABLE V-50

TREATMENT IN-PLACE AT LECLANCHE SUBCATEGORY PLANTS

PLANT ID	TREATMENT IN-PLACE	DISCHARGE 1/
A	None	I
B	None	Zero
C	None	I
D	None	Zero
E	Grease trap, sand filter, activated carbon; retention and reuse of paste area clean-up water in paste preparation	I
F	None	Zero
G	Retention and reuse of paste application washwater, contract removal of other wastes	Zero
H	None	Zero
I	None	Zero
J	None	Zero
K	None	Zero
L	None	I
M	pH adjust, coagulant addition, vacuum filtration	I
N	Settling, skimming	I 2/
O	None	Zero
P	None	Zero
Q	Chemical reduction, pH adjust, coagulant addition, pressure filter	I
R	Chemical reduction, pH adjust, coagulant addition, pressure filter	I
S	None	Zero
T	None	Zero

1/ I = Indirect
D = Direct
2/ Production discontinued

TABLE V-51

LECLANCHE SUBCATEGORY EFFLUENT QUALITY
(FROM DCP)

	PLANT F	PLANT E
Flow, l/kg	6.37	6.37
Flow, l/hr	2168	83
PARAMETER mg/l		
Oil & Grease	24.6	-
Lead	0.03	-
Mercury	1.42	3.15
Nickel	0.007	-
Zinc	-	658.0

TABLE V-52

TREATMENT EFFECTIVENESS AT PLANT B
(TREATMENT CONSISTS OF SKIMMING AND FILTRATION)

mg/l

		Day 1		Day 2		Day 3	
		Raw Waste	Treated Effluent	Raw Waste	Treated Effluent	Raw Waste	Treated Effluent
118	Cadmium	0.012	0.018	0.016	0.005	0.021	0.004
119	Chromium	0.000	0.000	0.004	0.000	0.004	0.000
120	Copper	0.078	0.002	0.083	0.000	0.130	0.007
122	Lead	0.000	0.000	0.000	0.000	0.000	0.000
123	Mercury	0.130	0.011	0.160	0.007	0.150	0.100
124	Nickel	0.034	0.038	0.054	0.054	0.097	0.076
128	Zinc	85.00	118.0	94.0	103.0	148.0	115.0
	Manganese	2.97	15.30	5.48	8.53	14.20	8.51
	Oil & Grease	13.0	4.2	39.0	4.8	11.0	3.5
	TSS	119.0	10.0	41.0	4.0	62.0	1.0
	pH	5.1-6.8	6.2-7.0	5.1-6.8	6.2-7.0	5.9-6.3	5.6-5.9

TABLE V-53

NORMALIZED DISCHARGE FLOWS LITHIUM SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Total Raw Waste Volume (l/yr) (10^6)	Production Normalizing Parameter
Cathodes				
Lead Iodide	63.08	63.08	0.020	Weight of Lead
Iron Disulfide	7.54	7.54	0.17	Weight of Iron Disulfide
Ancillary Operations				
Heat Paper Production[1]	115.4	24.1	0.038	Weight of Reactants
Lithium Scrap Disposal	nil	nil	nil	Weight of Cells Produced
Cell Testing	0.014	0.014	0.0002	Weight of Cells Produced
Cell Wash	0.929	0.929	0.013	Weight of Cells Produced
Air Scrubbers	10.59	10.59	0.11	Weight of Cells Produced
Floor and Equipment Wash	0.094	0.094	0.0013	Weight of Cells Produced

[1] Same as for calcium subcategory

TABLE V-54

POLLUTANT CONCENTRATIONS IN THE IRON DISULFIDE CATHODE ELEMENT WASTE STREAM

		mg/l
	Temperature (°C)	18.0
14	1,1,2-trichloroethane	0.00
23	Chloroform	0.012
44	Methylene Chloride	0.91
66	Bis (2-ethylhexyl) phthalate	0.013
116	Asbestos	2.4+
118	Cadmium	0.025
119	Chromium	0.015
120	Copper	0.109
122	Lead	4.94
124	Nickel	0.235
126	Silver	0.001
128	Zinc	0.473
	Cobalt	0.176
	Iron	54.9
	Lithium	0.00
	Manganese	1.60
	Oil & Grease	<5.0
	Total Suspended Solids	39.0
	pH, Minimum	5.6
	pH, Maximum	5.8

TABLE V-55

POLLUTANT MASS LOADINGS IN THE IRON DISULFIDE CATHODE ELEMENT WASTE STREAM

		mg/kg
	Flow (l/kg)	7.54
	Temperature (°C)	18.0
14	1,1,2-trichloroethane	0.00
23	Chloroform	0.090
44	Methylene Chloride	0.121
66	Bis (2-ethylhexyl) phthalate	0.098
116	Asbestos	18.1+
118	Cadmium	0.189
119	Chromium	0.113
120	Copper	0.822
122	Lead	37.2
124	Nickel	1.77
126	Silver	0.007
128	Zinc	3.57
	Cobalt	1.23
	Iron	414.0
	Lithium	0.00
	Manganese	12.1
	Oil & Grease	0.0
	Total Suspended Solids	294.0
	pH, Minimum	5.6
	pH, Maximum	5.8

+ Chrysotile fibers - millions of fibers/kg

TABLE V-56

POLLUTANT CONCENTRATIONS IN THE LITHIUM SCRAP DISPOSAL WASTE STREAM

		mg/l
14	1,1,2-trichloroethane	*
23	Chloroform	*
44	Methylene Chloride	0.00
66	Bis(2-ethylhexyl)phthalate	0.00
116	Asbestos	NA
118	Cadmium	0.000
119	Chromium	0.013
120	Copper	0.025
122	Lead	0.000
124	Nickel	0.22
126	Silver	0.000
128	Zinc	0.12
	Cobalt	0.000
	Iron	52.00
	Lithium	0.59
	Manganese	0.032
	Oil & Grease	1.0
	Total Suspended Solids	69.0
	pH, Minimum	5.7
	pH, Maximum	5.7

* - ≤0.01
NA - Not analyzed

TABLE V-57

TREATMENT IN-PLACE AT LITHIUM SUBCATEGORY PLANTS

PLANT ID	TREATMENT IN-PLACE	DISCHARGE 1/
A	None	I
B	None	Zero
C	pH adjust, settling	I
D	Filtration	I
E	pH adjust	I
F	Settling; contract haul	Zero
	pH adjust	D
G	None	Zero

1/ I = Indirect
D = Direct

TABLE V-58

EFFLUENT CHARACTERISTICS OF IRON DISULFIDE CATHODE ELEMENT WASTE STREAM AFTER SETTLING TREATMENT

		mg/l
14	1,1,2-trichloroethane	NA
23	Chloroform	NA
44	Methylene chloride	NA
66	Bis (2-ethylhexyl) phthalate	NA
116	Asbestos	NA
118	Cadmium	0.000
119	Chromium	0.021
120	Copper	0.092
122	Lead	0.920
124	Nickel	0.058
126	Silver	0.000
128	Zinc	0.000
	Cobalt	0.250
	Iron	0.000
	Lithium	43.5
	Manganese	0.00
	Oil & Grease	0.980
	Total Suspended Solids	NA
		NA

NA - Not Analyzed

TABLE V-59

NORMALIZED DISCHARGE FLOWS MAGNESIUM SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Total Raw Waste Volume (l/yr) (10^6)	Production Normalizing Parameter
Cathodes				
Silver Chloride Cathode-Chemically Reduced	4915.0	4915.0	0.65	Weight of Silver Processed
Silver Chloride Cathode-Electrolytic	145.0	145.0	0.11	Weight of Silver Processed
Ancillary Operations				
Air Scrubbers	206.5	206.5	0.45	Weight of Cells Produced
Cell Testing	52.6	52.6	0.091	Weight of Cells Produced
Separator Processing	[1]	[1]	0	Weight of Cells Produced
Floor and Equipment Wash	0.094	0.094	0.013	Weight of Cells Produced
Heat Paper Production[2]	115.4	24.1	0.26	Weight of Reactants

[1] Cannot be calculated from present information.
[2] Same as for calcium subcategory.

TABLE V-60

POLLUTANT CONCENTRATIONS IN THE DEVELOPER SOLUTION OF THE SILVER CHLORIDE REDUCED CATHODE ELEMENT WASTE STREAM

23.	chloroform	0.091
66.	bis(2-ethylhexyl)phthalate	*
86.	toluene	0.0190
114.	antimony	<0.015
115.	arsenic	<0.015
117.	beryllium	<0.001
118.	cadmium	<0.005
119.	chromium	<0.010
120.	copper	0.022
121.	cyanide	<0.010
122.	lead	0.170
123.	mercury	<0.0003
124.	nickel	<0.050
125.	selenium	<0.015
126.	silver	0.340
127.	thallium	<0.015
128.	zinc	0.049
	aluminum	0.200
	ammonia	60.0
	barium	0.008
	boron	0.038
	BOD	1200.0
	calcium	4.160
	chlorides	1100.0
	cobalt	<0.005
	COD	4100.0
	iron	0.064
	magnesium	2.640
	manganese	<0.010
	molybdenum	<0.010
	oil and grease	<0.500
	phenols (total)	0.040
	sodium	7000.0
	tin	<0.010
	titanium	<0.050
	TOC	1200.0
	TSS	21.0
	vanadium	<0.005
	yttrium	<0.005

TABLE V-61

MAGNESIUM SUBCATEGORY PROCESS WASTEWATER FLOW RATES FROM INDIVIDUAL FACILITIES

Plant ID	Flow Rate (l/day)
A	4.18×10^4
B	0
C	872
D	0
E	2990
F	+
G	0
H	0

+ Not Available

TABLE V-62

TREATMENT IN-PLACE AT MAGNESIUM SUBCATEGORY PLANTS

PLANT ID	TREATMENT IN-PLACE	DISCHARGE 1/
A	None	Zero
B	pH adjust, settling, filtration	D 2/
C	None	Zero
D	pH adjust, filtration	I
E	pH adjust, settling, clarification, filtration	I 3/
F	Filtration	I 3/
G	None	Zero
H	None	Zero

1/ I = Indirect
D = Direct
2/ Not presently active in this subcategory.
3/ Wastewater combined from more than one subcategory

TABLE V-63

ZINC SUBCATEGORY PROCESS ELEMENTS
(REPORTED MANUFACTURE)

Zinc Anodes

Cathodes	Cast or Fabricated	Zinc Powder Wet Amalgamated	Gelled Amalgam	Dry Amalgamated	Pasted or Pressed on Grid	Zinc Oxide Powder Pasted or Pressed-Reduced	Electro-deposited
Porous Carbon (Agglo)	X						
Manganese Dioxide-Carbon		X	X	X			
Mercuric Oxide (and Mercuric Oxide-Manganese Dioxide-Carbon)		X	X				
Mercuric Oxide-Cadmium Oxide		X					
Silver Powder							
Pressed					X		
Pressed and Electrolytically Oxidized						X	X
Silver Oxide Powder							
Reduced-Sintered and Electrolytically Formed						X	X
Pressed		X					
Blended (MnO2, Mg20)		X	X				
Blended (Incl. HgO)		X	X				

TABLE V-63

ZINC SUBCATEGORY PROCESS ELEMENTS
(Reported Manufacture)

Zinc Anodes

Cathodes	Cast or Fabricated	Zinc Powder Wet Amalgamated	Zinc Powder Gelled Amalgam	Zinc Powder Dry Amalgamated	Zinc Powder Pasted or Pressed on Grid	Zinc Oxide Powder Pasted or Pressed-Reduced	Electro-deposited
Silver Peroxide Powder			X	X			X
Nickel-Sintered, Impregnated and Formed						X	
Ancillary Operations							
Cell Wash							
Electrolyte Preparation							
Silver Etch							
Mandatory Employee Wash							
Reject Cell Handling							
Floor Wash							
Equipment Wash							
Silver Powder Production							
Silver Peroxide Production							

TABLE V-64

NORMALIZED DISCHARGE FLOWS
ZINC SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Total Raw Waste Volume (l/yr) (10^6)	Production Normalizing Parameter
Anodes				
Zinc Powder-Wet Amalgamated	3.8	2.2	5.60	Weight of Zinc
Zinc Powder-Gelled Amalgam	0.68	0.68	0.475	Weight of Zinc
Zinc Oxide Powder-Pasted or Pressed Reduced	143.0	117.0	4.86	Weight of Zinc
Zinc Electrodeposited	3190.0	3190.0	15.60	Weight of Zinc Deposited
Cathodes				
Silver Powder Pressed and Electrolytically Oxidized	196.0	196.0	7.90	Weight of silver Applied
Silver Oxide (Ag_2O) Powder-Thermally Reduced or Sintered, Electrolytically Formed	131.0	131.0	0.066	Weight of Silver Applied
Silver Peroxide Powder	31.4	12.8	0.230	Weight of Silver Applied
Nickel Impregnated and Formed	1640.0	1720.0	nil	Weight of Nickel Applied

TABLE V-64

NORMALIZED DISCHARGE FLOWS ZINC SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Total Raw Waste Volume (l/yr) (10^6)	Production Normalizing Parameter
Ancillary Operations				
Cell Wash	1.13	0.335	19.11	Weight of Cells Produced
Electrolyte Preparation	0.12	0	1.26	Weight of Cells Produced
Silver Etch	49.1	49.1	0.003	Weight of Silver Processed
Mandatory Employee Wash	0.27	0.27	2.61	Weight of Cells Produced
Reject Cell Handling	0.01	0.002	0.022	Weight of Cells Produced
Floor and Equipment Wash	7.23	7.23	1.42	Weight of Cells Produced
Silver Peroxide Production	52.5	52.2	0.365	Weight of Silver in Silver Peroxide Produced
Silver Powder Production	21.2	21.2	0.800	Weight of Silver Powder Produced

TABLE V-65

OBSERVED FLOW RATES FOR EACH PLANT IN THE ZINC SUBCATEGORY

Plant ID	Observed Flow Rate (l/day) DCP Data	Mean Visit Data
A	+	3772.5
B	25432.2	101892.2
C	3494.2	
D	+	
E	16118.2	27271.2
F	4008.0	23305.5
G	77516.8	
H	144000.0	54186.1
I	0	
J	16.0	
K	27500.0	11506.4
L	10900.8	
M	0	
N	22619.2	9687.1
O	4542.4	
P	21206.4	13471.6

+ - Data Not Available

TABLE V-66

POLLUTANT CONCENTRATIONS IN THE ZINC POWDER-WET AMALGAMATED ANODE ELEMENT WASTE STREAMS

mg/l

		PLANT A			PLANT B		
	Temperature (Deg C)	14.0	21.0	18.0	28.0	28.0	28.0
11	1,1,1-Trichloroethane	*	*	*	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.030	NA	NA	NA
29	1,1-Dichloroethylene	0.00	0.00	*	NA	NA	NA
30	1,2-Trans-dichloroethylene	0.00	0.00	*	NA	NA	NA
38	Ethylbenzene	0.00	0.00	0.00	NA	NA	NA
44	Methylene chloride	0.00	0.00	*	0.00	0.00	0.00
55	Naphthalene	*	*	*	NA	NA	NA
64	Pentachlorophenol	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	0.041	*	0.070
70	Diethyl phthalate	0.00	0.00	*	NA	NA	NA
85	Tetrachloroethylene	*	0.00	0.00	NA	NA	NA
86	Toluene	0.00	0.00	0.00	NA	NA	NA
87	Trichloroethylene	0.00	0.00	*	0.00	*	0.00
114	Antimony	0.000	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.080	0.140	0.080	0.000	0.000	0.000
118	Cadmium	0.002	0.006	0.000	0.000	0.000	0.000
119	Chromium, Total	0.140	0.210	0.034	0.003	0.005	0.018
	Chromium, Hexavalent	0.110	0.140	0.030	0.000	0.000	0.000
120	Copper	0.006	0.010	0.011	0.036	0.021	0.000
121	Cyanide, Total	0.000	0.027	0.000	0.000	0.000	0.000
	Cyanide, Amn. to Chlor.	I	I	I	0.000	0.000	0.000
122	Lead	0.000	0.000	0.000	0.000	0.000	0.000
123	Mercury	I	I	I	0.600	0.5000	0.2600
124	Nickel	0.000	0.000	0.000	0.000	0.000	0.000
125	Selenium	0.000	0.000	0.000	NA	NA	NA
126	Silver	0.000	0.000	0.000	0.0220	0.0140	0.0200
128	Zinc	35.30	22.00	47.40	450.0	1050.0	206.0
	Aluminum	0.000	0.000	0.000	NA	NA	NA
	Ammonia	NA	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA	NA
	Manganese	0.030	0.055	0.090	0.040	0.030	0.010
	Phenols, Total	0.088	0.055	0.110	0.000	0.000	0.000
	Oil & Grease	2.0	2.8	9.2	10.0	9.0	22.0
	Total Suspended Solids	0.0	32.0	25.0	5.0	5.0	5.0
	pH, Minimum	8.8	8.2	8.4	4.3	4.3	4.3
	pH, Maximum	8.8	8.5	8.8	6.5	6.5	6.5

I - Interference
NA - Not Analyzed
* - ≤0.01

TABLE V-67

POLLUTANT MASS LOADINGS IN THE ZINC POWDER-WET AMALGAMATED ANODE ELEMENT WASTE STREAMS

mg/kg

		PLANT A			PLANT B		
	Flow (l/kg)	5.168	6.82	6.82	2.379	1.884	2.159
	Temperature (Deg C)	14.0	21.0	18.0	28.0	28.0	28.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.205	NA	NA	NA
29	1,1-Dichloroethylene	0.00	0.00	0.00	NA	NA	NA
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	NA	NA	NA
38	Ethylbenzene	0.00	0.00	0.00	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	NA	NA	NA
64	Pentachlorophenol	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	0.098	0.00	0.151
70	Diethyl phthalate	0.00	0.00	0.00	NA	NA	NA
85	Tetrachloroethylene	0.00	0.00	0.00	NA	NA	NA
86	Toluene	0.00	0.00	0.00	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.413	0.955	0.546	0.000	0.000	0.000
118	Cadmium	0.010	0.041	0.000	0.000	0.000	0.000
119	Chromium, Total	0.724	1.432	0.232	0.007	0.009	0.039
	Chromium, Hexavalent	0.568	0.955	0.205	0.000	0.000	0.000
120	Copper	0.031	0.068	0.075	0.086	0.040	0.000
121	Cyanide, Total	0.000	0.184	0.000	0.000	0.000	0.000
	Cyanide, Amn. To Chlor.	I	I	I	0.000	0.000	0.000
122	Lead	0.000	0.000	0.000	0.000	0.000	0.000
123	Mercury	I	I	I	1.427	0.942	0.5616
124	Nickel	0.000	0.000	0.000	0.000	0.000	0.000
125	Selenium	0.000	0.000	0.000	NA	NA	NA
126	Silver	0.000	0.000	0.000	0.0520	0.0260	0.0430
128	Zinc	182.4	150.0	323.2	1071.0	1079.0	444.7
	Aluminum	0.000	0.000	0.000	NA	NA	NA
	Ammonia	NA	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA	NA
	Manganese	0.155	0.375	0.614	0.095	0.057	0.022
	Phenols, Total	0.455	0.375	0.750	0.000	0.000	0.000
	Oil & Grease	10.34	19.09	62.7	23.79	16.96	47.49
	Total Suspended Solids	0.000	218.2	170.5	11.90	9.42	10.70
	pH, Minimum	8.8	8.2	8.4	4.3	4.3	4.3
	pH, Maximum	8.8	8.5	8.8	6.5	6.5	6.5

I - Interference
NA - Not Analyzed

TABLE V-68

STATISTICAL ANALYSIS (mg/l) OF THE ZINC POWDER-WET AMALGAMATED ANODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	14.0	28.0	22.6	24.5	6	0	6
11	1,1,1-Trichloroethane	0.00	*	*	*	3	3	6
13	1,1-Dichloroethane	0.00	0.030	0.010	0.00	1	2	3
29	1,1-Dichloroethylene	0.00	*	*	0.00	1	2	3
30	1,2-Trans-dichloroethylene	0.00	*	*	0.00	1	2	3
38	Ethylbenzene	0.00	0.00	0.00	0.00	0	3	3
44	Methylene chloride	0.00	*	*	0.00	1	5	6
55	Naphthalene	*	*	*	*	3	0	3
64	Pentachlorophenol	NA	NA	NA	NA			
66	Bis(2-ethylhexyl)phthalate	*	0.070	0.037	0.041	3	0	3
70	Diethyl phthalate	0.00	*	*	0.00	1	2	3
85	Tetrachloroethylene	0.00	*	*	0.00	1	2	3
86	Toluene	0.00	0.00	0.00	0.00	0	3	3
87	Trichloroethylene	0.00	*	*	0.00	2	4	6
114	Antimony	0.000	0.000	0.000	0.000	0	6	6
115	Arsenic	0.000	0.140	0.050	0.040	3	3	6
118	Cadmium	0.000	0.006	0.001	0.000	2	4	6
119	Chromium, Total	0.003	0.210	0.068	0.026	6	0	6
	Chromium, Hexavalent	0.000	0.140	0.047	0.015	3	3	6
120	Copper	0.000	0.036	0.014	0.011	5	1	6
121	Cyanide, Total	0.000	0.027	0.005	0.000	1	5	6
	Cyanide, Amn. to Chlor.	0.000	0.000	0.000	0.000	0	3	3
122	Lead	0.000	0.000	0.000	0.000	0	6	6
123	Mercury	0.260	0.6000	0.4533	0.5000	3	0	3
124	Nickel	0.000	0.000	0.000	0.000	0	6	6
125	Selenium	0.000	0.000	0.000	0.000	0	3	3
126	Silver	0.000	0.0220	0.0093	0.0070	3	3	6
128	Zinc	22.00	1050.0	301.8	126.7	6	0	6
	Aluminum	0.000	0.000	0.000	0.000	0	3	3
	Ammonia	NA	NA	NA	NA			
	Iron	NA	NA	NA	NA			
	Manganese	0.010	0.090	0.043	0.035	6	0	6
	Phenols, Total	0.000	0.110	0.042	0.027	3	3	6
	Oil & Grease	2.0	22.0	9.2	9.1	6	0	6
	Total Suspended Solids	0.0	32.0	12.0	5.0	5	1	6
	pH, Minimum	64.3	3.8	6.4	6.3	6	0	6
	pH, Maximum	6.5	8.8	7.6	7.5	6	0	6

NA - Not Analyzed
* - ≤0.01

TABLE V-69

STATISTICAL ANALYSIS (mg/kg) OF THE ZINC POWDER-WET AMALGAMATED ANODE ELEMENT WASTE STREAMS

		Minimum	Maximum	Mean	Median
	Flow (l/kg)	1.884	6.82	4.205	3.774
	Temperature (Deg. C)	14.0	28.0	22.6	24.5
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.205	0.068	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	0.00	0.151	0.083	0.098
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.055	0.319	0.207
118	Cadmium	0.000	0.041	0.009	0.000
119	Chromium, Total	0.007	1.432	0.407	0.135
	Chromium, Hexavalent	0.000	0.955	0.288	0.102
120	Copper	0.000	0.086	0.050	0.054
121	Cyanide, Total	0.000	0.184	0.031	0.000
	Cyanide, Amn. to Chlor.	0.000	0.000	0.000	0.000
122	Lead	0.000	0.000	0.000	0.000
123	Mercury	0.5616	1.427	0.977	0.9420
124	Nickel	0.000	0.000	0.000	0.000
125	Selenium	0.000	0.000	0.000	0.000
126	Silver	0.000	0.0520	0.0202	0.0130
128	Zinc	150.0	1979.0	692.0	384.0
	Aluminum	0.000	0.000	0.000	0.000
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.022	0.614	0.220	0.125
	Phenols, Total	0.000	0.750	0.263	0.188
	Oil & Grease	10.34	62.7	30.07	21.44
	Total Suspended Solids	0.000	218.2	70.1	11.35
	pH, Minimum	4.3	8.8	6.4	6.3
	pH, Maximum	6.5	8.8	7.6	7.5

NA - Not Analyzed

TABLE V-70

POLLUTANT CONCENTRATIONS IN THE ZINC POWDER-GELLED AMALGAM ANODE ELEMENT WASTE STREAMS

		PLANT A			PLANT B		
				mg/l			
	Temperature (Deg C)	21.0	26.0	22.0	16.0	15.0	16.0
11	1,1,1-Trichloroethane	*	NA	0.025	*	*	0.00
13	1,1-Dichloroethane	NA	NA	NA	*	NA	NA
29	1,1-Dichloroethylene	NA	NA	NA	0.00	NA	NA
30	1,2-Trans-dichloroethylene	NA	NA	NA	0.00	NA	NA
38	Ethylbenzene	NA	NA	NA	0.00	NA	NA
44	Methylene chloride	0.00	NA	0.00	0.023	0.00	0.00
55	Naphthalene	NA	NA	NA	0.00	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00	0.042	0.00	0.00
66	Bis(2-ethylhexyl)phthalate	0.014	0.013	0.042	0.011	*	*
70	Diethyl phthalate	NA	NA	NA	0.00	NA	NA
85	Tetrachloroethylene	NA	NA	NA	*	NA	NA
86	Toluene	NA	NA	NA	*	NA	NA
87	Trichloroethylene	*	NA	*	*	0.00	*
114	Antimony	0.000	0.000	0.000	0.000	0.000	0.000
115	Arsenic	1.060	1.050	0.810	0.000	0.080	0.070
118	Cadmium	0.080	0.120	0.071	0.063	0.006	0.008
119	Chromium, Total	0.000	0.040	0.068	0.021	0.014	0.005
	Chrcmium, Hexavalent	0.000	0.000	I	0.000	0.000	I
120	Copper	0.670	0.540	0.620	0.101	0.081	0.054
121	Cyanide, Total	NA	NA	NA	0.001	0.005	0.000
	Cyanide, Amn. to Chlor.	NA	NA	NA	0.005	0.005	0.000
122	Lead	0.000	0.000	0.000	0.102	0.000	0.000
123	Mercury	I	I	I	0.814	0.4700	0.5000
124	Nickel	0.000	0.000	0.000	0.010	0.025	0.000
125	Selenium	NA	NA	NA	NA	NA	NA
126	Silver	0.000	0.000	0.000	0.0100	0.0020	0.0130
128	Zinc	1100.0	750.0	440.0	NA	133.0	17.60
	Aluminum	NA	NA	NA	3.130	NA	NA
	Ammonia	10.40	5.30	4.70	11.55	1.57	0.17
	Iron	NA	NA	NA	0.522	NA	NA
	Manqanese	0.110	3.420	4.650	2.086	0.170	0.210
	Phenols, Total	0.003	NA	0.000	0.000	0.000	0.100
	Oil & Grease	33.0	NA	26.0	7.8	6.0	0.0
	Total Suspended Solids	97.0	100.0	NA	413.5	257.5	545.0
	pH, minimum	13.2	13.2	12.9	NA	NA	NA
	pH, maximum	13.5	13.2	13.4	NA	NA	NA

I - Interference
NA - Not Analyzed
* - ≤ 0.01

TABLE V-71

POLLUTANT MASS LOADINGS IN THE ZINC POWDER-GELLED AMALGAM ANODE ELEMENT WASTE STREAMS.

mg/kg

		PLANT A			PLANT B		
	Flow (1/kg)	0.228	0.212	0.314	0.646	1.077	1.668
	Temperature (Deg C)	21.0	26.0	22.0	16.0	15.0	16.0
11	1,1,1-Trichloroethane	0.00	NA	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	NA	NA	NA	0.00	NA	NA
29	1,1-Dichloroethylene	NA	NA	NA	0.00	NA	NA
30	1,2-Trans-dichloroethylene	NA	NA	NA	0.00	NA	NA
38	Ethylbenzene	NA	NA	NA	0.00	NA	NA
44	Methylene chloride	0.00	NA	NA	0.015	0.00	0.00
55	Naphthalene	NA	NA	NA	0.00	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00	0.027	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.003	0.003	0.013	0.007	0.00	0.00
70	Diethyl phthalate	NA	NA	NA	0.00	NA	NA
85	Tetrachloroethylene	NA	NA	NA	0.00	NA	NA
86	Toluene	NA	NA	NA	0.00	NA	NA
87	Trichloroethylene	0.00	NA	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.242	0.223	0.255	0.000	0.086	0.117
118	Cadmium	0.018	0.025	0.022	0.040	0.006	0.013
119	Chromium Total	0.000	0.0080	0.021	0.013	0.015	0.008
	Chromium, Hexavalent	0.000	0.000	I	0.000	0.000	I
120	Copper	0.153	0.115	0.195	0.065	0.087	0.090
121	Cyanide, Total	NA	NA	NA	0.001	0.005	0.000
	Cyanide, Amn. to Chlor.	NA	NA	NA	0.003	0.005	0.000
122	Lead	0.000	0.000	0.000	0.066	0.000	0.000
123	Mercury	I	I	I	0.5260	0.5060	0.8340
124	Nickel	0.000	0.000	0.000	0.007	0.027	0.000
125	Selenium	NA	NA	NA	0.041	NA	NA
128	Zinc	250.7	159.1	138.3	NA	143.3	29.35
	Aluminum	NA	NA	NA	2.024	NA	NA
	Ammonia	2.370	1.124	1.477	7.47	1.692	0.283
	Iron	NA	NA	NA	0.337	NA	NA
	Manganese	0.025	0.725	1.462	1.349	0.183	0.350
	Phenols, Total	0.001	NA	0.000	0.000	0.000	0.167
	Oil & Grease	7.52	NA	8.17	5.02	6.46	0.000
	Total Suspended Solids	22.11	21.21	NA	267.3	277.4	909.0
	pH, minimum	13.2	13.2	12.9	NA	NA	NA
	pH, maximum	13.5	13.2	13.4	NA	NA	NA

I - Interference

NA - Not Analyzed

TABLE V-72

STATISTICAL ANALYSIS (mg/l) OF THE ZINC POWDER-GELLED AMALGAM ANODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	15.0	26.0	20.3	18.5	6	0	6
11	1,1,1-Trichloroethane	0.00	0.025	0.005	*	4	1	5
13	1,1-Dichloroethane	*	*	*	*	1	0	1
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0	1	1
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	1	1
38	Ethylbenzene	0.00	0.00	0.00	0.00	0	1	1
44	Methylene chloride	0.00	0.023	0.005	0.00	1	4	5
55	Naphthalene	0.00	0.00	0.00	0.00	0	1	1
64	Pentachlorophenol	0.00	0.042	0.007	0.00	1	5	6
66	Bis(2-ethylhexyl) phthalate	*	0.042	0.013	0.012	6	0	6
70	Diethyl phthalate	0.00	0.00	0.00	0.00	0	1	1
85	Tetrachloroethylene	*	*	*	*	1	0	1
86	Toluene	*	*	*	*	1	0	1
87	Trichloroethylene	0.00	*	*	*	4	1	5
114	Antimony	0.00	0.00	0.00	0.00	0	6	6
115	Arsenic	0.000	1.060	0.512	0.445	5	1	6
118	Cadmium	0.006	0.120	0.058	0.067	6	0	6
119	Chromium, Total	0.000	0.068	0.025	0.017	5	1	6
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	4	4
120	Copper	0.054	0.670	0.344	0.321	6	0	6
121	Cyanide, Total	0.000	0.005	0.002	0.001	2	1	3
	Cyanide, Amn. to Chlor.	0.000	0.005	0.003	0.005	2	1	3
122	Lead	0.000	0.102	0.017	0.000	1	5	6
123	Mercury	0.4700	0.8144	0.5948	0.5000	3	0	3
124	Nickel	0.000	0.025	0.006	0.000	2	4	6
125	Selenium	0.063	0.063	0.063	0.063	1	0	1
126	Silver	0.0000	0.0130	0.0042	0.0010	3	3	6
128	Zinc	17.60	1100.0	488.1	444.0	5	0	5
	Aluminum	3.130	3.130	3.130	3.130	1	0	1
	Ammonia	0.17	11.55	5.61	5.00	6	0	6
	Iron	0.522	0.522	0.522	0.522	1	0	1
	Manganese	0.110	4.650	1.744	1.148	6	0	6
	Phenols, Total	0.000	0.100	0.021	0.000	2	3	5
	Oil & Grease	0.000	33.0	14.6	7.77	4	1	5
	Total Suspended Solids	97.0	545.0	282.6	257.5	5	0	5
	pH, minimum	12.9	13.2	13.1	13.2	3	0	3
	pH, maximum	13.2	13.5	13.4	13.4	3	0	3

NA - Not Analyzed
* - ≤0.01

TABLE V-73

STATISTICAL ANALYSIS (mg/kg) OF THE ZINC POWDER-GELLED AMALGAM ANODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (l/kg)	0.212	1.668	0.691	0.480
	Temperature (Deg C)	15.0	26.0	20.3	18.5
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.003	0.00
44	Methylene chloride	0.00	0.015	0.003	0.00
55	Napthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	0.00	0.027	0.004	0.00
66	Bis(2-ethylhexyl) phthalate	0.00	0.013	0.004	0.003
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.255	0.154	0.170
118	Cadmium	0.006	0.040	0.021	0.020
119	Chromium, Total	0.000	0.021	0.011	0.011
	Chromium, Hexavalent	0.000	0.000	0.000	0.000
120	Copper	0.000	0.005	0.002	0.001
121	Cyanide, Total	0.065	0.020	0.117	0.102
	Cyanide, Amn. to Chlor.	0.000	0.005	0.003	0.003
122	Lead	0.000	0.066	0.011	0.000
123	Mercury	0.5060	0.834	0.622	0.5260
124	Nickel	0.000	0.027	0.006	0.000
125	Selenium	0.040	0.040	0.040	0.040
126	Silver	0.000	0.0220	0.0050	0.0010
128	Zinc	29.35	250.7	144.1	144.3
	Aluminum	2.024	2.024	2.024	2.024
	Ammonia	0.283	7.47	2.402	1.584
	Iron	0.337	0.337	0.337	0.337
	Manganese	0.025	1.462	0.682	0.538
	Phenols, Total	0.000	0.167	0.033	0.000
	Oil & Grease	0.000	8.17	5.436	6.46
	Total Suspended Solids	21.21	909.0	299.4	267.3
	pH, Minimum	12.9	13.2	13.1	13.2
	pH, Maximum	13.2	13.5	13.4	13.4

TABLE V-74

POLLUTANT CONCENTRATIONS IN THE ZINC OXIDE POWDER-PASTED OR PRESSED, REDUCED ANODE ELEMENT WASTE STREAMS

		PLANT A		PLANT B	
		mg/l			
	Temperature (Deg C)	15.0	13.0	15.0	10.0
11	1,1,1-Trichloroethane	0.00	*	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	*	*
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	*	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	*	*
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.080	0.110	0.000	0.000
118	Cadmium	0.071	0.058	0.011	0.034
119	Chromium, Total	0.025	0.059	0.000	0.000
	Chromium, Hexavalent	0.000	I	0.000	0.000
120	Copper	0.300	0.610	0.000	NA
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.078	0.140	0.000	NA
123	Mercury	0.1000	0.1600	0.000	0.0140
124	Nickel	0.000	0.023	0.000	0.050
125	Selenium	0.000	0.000	0.000	0.000
126	Silver	0.1200	0.2700	0.000	0.000
128	Zinc	53.00	129.0	0.280	2.840
	Aluminum	0.000	0.480	0.000	NA
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.010	0.006	0.000	0.000
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	122.0	96.0	5.0	5.0
	pH, Minimum	11.9	11.4	9.4	9.4
	pH, Maximum	11.9	11.4	9.4	9.4

I - Interference
NA - Not Analyzed
* - ≤ 0.01

TABLE V-75

POLLUTANT MASS LOADINGS IN THE ZINC OXIDE POWDER-PASTED OR PRESSED, REDUCED ANODE ELEMENT WASTE STREAMS

mg/kg

		PLANT A		PLANT B	
	Flow (l/kg)	81.9	151.0	315.4	239.2
	Temperature (Deg C)	15.0	13.0	15.0	10.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	6.56	16.65	0.000	0.000
118	Cadmium	5.818	8.78	3.470	8.13
119	Chromium, Total	2.049	8.93	0.000	0.000
	Chromium, Hexavalent	0.000	I	0.000	0.000
120	Copper	24.58	92.4	0.000	NA
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	6.39	21.20	0.000	NA
123	Mercury	8.20	24.22	0.0000	3.349
124	Nickel	0.000	3.482	0.000	11.96
125	Selenium	0.000	0.000	0.000	0.000
126	Silver	9.83	40.88	0.0000	0.0000
128	Zinc	4343.0	19530.0	88.3	679.0
	Aluminum	0.000	72.7	0.000	NA
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.819	0.908	0.000	0.000
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	10000.0	14530.0	1577.0	1196.0
	pH, Minimum	11.9	11.4	9.4	9.4
	pH, Maximum	11.9	11.4	9.4	9.4

I - Interference
NA - Not Analyzed

TABLE V-76.

STATISTICAL ANALYSIS (mg/l) OF THE ZINC OXIDE POWDER-PASTED OR PRESSED, REDUCED ANODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	10.0	15.0	12.9	14.0	4	0	4
11	1,1,1-Trichloroethane	0.00	*	*	0.00	1	3	4
13	1,1-Dichloroethane	0.00	*	*	*	2	2	4
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
38	Ethylbenzene	0.00	0.00	0.00	0.00	0	4	4
44	Methylene chloride	0.00	*	*	0.00	1	3	4
55	Naphthalene	0.00	0.00	0.00	0.00	0	4	4
64	Pentachlorophenol	NA	NA	NA	NA			
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA			
70	Diethyl phthalate	0.00	0.00	0.00	0.00	0	4	4
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0	4	4
86	Toluene	0.00	*	*	*	2	2	4
87	Trichloroethylene	0.00	0.00	0.00	0.00	0	4	4
114	Antimony	0.000	0.000	0.000	0.000	0	4	4
115	Arsenic	0.000	0.110	0.047	0.040	2	2	4
118	Cadmium	0.011	0.071	0.044	0.046	4	0	4
119	Chromium, Total	0.000	0.059	0.021	0.013	2	2	4
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	3	3
120	Copper	0.000	0.610	0.303	0.300	2	1	3
121	Cyanide, Total	NA	NA	NA	NA			
	Cyanide, Amn. To Chlor.	NA	NA	NA	NA			
122	Lead	0.000	0.140	0.073	0.078	2	1	3
123	Mercury	0.0000	0.1600	0.0685	0.0570	3	1	4
124	Nickel	0.000	0.050	0.018	0.012	2	2	4
125	Selenium	0.000	0.000	0.000	0.000	0	4	4
126	Silver	0.000	0.2700	0.0975	0.0600	2	2	4
128	Zinc	0.280	129.0	46.30	27.92	4	0	4
	Aluminum	0.000	0.480	0.160	0.000	1	2	3
	Ammonia	NA	NA	NA	NA			
	Iron	NA	NA	NA	NA			
	Manganese	0.000	0.010	0.004	0.003	2	2	4
	Phenols, Total	NA	NA	NA	NA			
	Oil & Grease	NA	NA	NA	NA			
	Total Suspended Solids	5.0	122.0	57.0	50.5	4	0	4
	pH, Minimum	NA	NA	NA	NA			
	pH, Maximum	NA	NA	NA	NA			

NA - Not Analyzed
* - ≤0.01

TABLE V-77

STATISTICAL ANALYSIS (mg/kg) OF THE ZINC OXIDE POWDER-PASTED OR PRESSED, REDUCED ANODE ELEMENT WASTE STREAMS

		Minimum	Maximum	Mean	Median
	Flow (l/kg)	81.9	315.4	197.0	195.3
	Temperature (Deg C)	10.0	15.0	12.9	14.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Napthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	1.262	0.375	0.120
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	16.7	5.80	3.28
118	Cadmium	3.470	8.78	6.55	6.98
119	Chromium, Total	0.000	8.93	2.745	1.024
	Chromium, Hexavalent	0.000	0.000	0.000	0.000
120	Copper	0.000	92.4	38.98	24.58
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.000	21.20	9.20	6.39
123	Mercury	0.0000	24.22	8.94	5.772
124	Nickel	0.000	11.96	3.861	1.741
125	Selenium	0.000	0.000	0.000	0.000
126	Silver	0.0000	40.88	12.68	4.917
128	Zinc	88.3	19530.0	6160.0	2511.0
	Aluminum	0.000	72.7	24.22	0.000
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.000	0.908	0.432	0.410
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	1196.0	14530.0	6830.0	5787.0
	pH, Minimum	9.4	11.9	10.5	10.4
	pH, Maximum	9.4	11.9	10.5	10.4

NA - Not Analyzed

TABLE V-78

POLLUTANT CONCENTRATIONS IN THE SPENT AMALGAMATION SOLUTION WASTE STREAM

		mg/l	
	Temperature (Deg C)	16.0	10.0
11	1,1,1-Trichloroethane	NA	NA
13	1,1-Dichloroethane	NA	NA
29	1,1-Dichloroethylene	NA	NA
30	1,2-Trans-dichloroethylene	NA	NA
38	Ethylbenzene	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
64	Pentachlorophenol	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA
70	Diethyl phthalate	NA	NA
85	Tetrachloroethylene	NA	NA
86	Toluene	NA	NA
87	Trichloroethylene	NA	NA
114	Antimony	0.000	0.000
115	Arsenic	0.000	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	13.10	15.10
	Chromium, Hexavalent	0.000	0.000
120	Copper	3.390	0.300
121	Cyanide, Total	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA
122	Lead	68.0	16.40
123	Mercury	53000.0	30000.0
124	Nickel	8.84	9.10
125	Selenium	0.000	0.000
126	Silver	0.2800	0.0460
128	Zinc	1300.0	1200.0
	Aluminum	0.300	0.450
	Ammonia	0.14	0.14
	Iron	NA	NA
	Manganese	0.840	0.980
	Phenols, Total	NA	NA
	Oil & Grease	NA	NA
	Total Suspended Solids	160.0	11.0
	pH, Minimum	1.3	1.0
	pH, Maximum	1.3	1.0

NA - Not Analyzed

TABLE V-79

POLLUTANT CONCENTRATIONS IN THE ZINC ELECTRODEPOSITED ANODE ELEMENT WASTE STREAMS

		mg/l		
	Temperature (Deg C)	9.0	10.0	7.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00
29	1,1-Dichloroethylene	*	*	*
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00
55	Napthalene	0.00	0.00	*
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.000	0.000	0.000
119	Chromium, Total	0.016	0.006	0.013
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	0.012	0.020	0.008
121	Cyanide, Total	0.010	0.005	0.005
	Cyanide, Amn. to Chlor.	0.005	0.005	0.005
122	Lead	0.039	0.000	0.007
123	Mercury	30.78	0.0000	13.35
124	Nickel	0.005	0.000	0.004
125	Selenium	0.000	0.000	0.000
126	Silver	0.0651	0.0310	0.4298
128	Zinc	12.15	12.20	12.43
	Aluminum	0.000	0.000	0.000
	Ammonia	1.40	0.28	0.28
	Iron	NA	NA	NA
	Manganese	0.000	0.000	0.000
	Phenols, Total	0.007	0.000	0.000
	Oil & Grease	1.0	7.6	4.1
	Total Suspended Solids	10.1	10.0	3.4
	pH, Minimum	9.3	10.5	9.6
	pH, Maximum	12.2	12.1	12.2

NA - Not Analyzed
* - ≤ 0.01

TABLE V-80

POLLUTANT MASS LOADINGS IN THE ZINC ELECTRODEPOSITED ANODE ELEMENT WASTE STREAMS

		mg/kg		
	Flow (l/kg)	4658.0	5370.0	4874.0
	Temperature (Deg C)	9.0	10.0	7.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.000	0.000	0.017
119	Chromium, Total	72.7	32.21	61.9
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	55.72	107.4	39.62
121	Cyanide, Total	46.56	26.84	24.36
	Cyanide, Amn. to Chlor.	23.28	26.84	24.36
122	Lead	183.8	0.000	35.47
123	Mercury	143400.0	0.0000	65100.0
124	Nickel	23.90	0.000	19.68
125	Selenium	0.000	0.000	0.000
126	Silver	303.4	166.4	2095.0
128	Zinc	56600.0	65500.0	60600.0
	Aluminum	0.811	0.000	0.973
	Ammonia	6520.0	1503.0	1364.0
	Iron	NA	NA	NA
	Manganese	2.271	0.000	2.120
	Phenols, Total	32.59	0.000	0.000
	Oil and Grease	4660.0	40800.0	2000.0
	Total Suspended Solids	46990.0	53680.0	16590.0
	pH, Minimum	NA	10.5	NA
	pH, Maximum	NA	12.1	NA

NA - Not Analyzed

TABLE V-81

NORMALIZED FLOWS OF POST-FORMATION RINSE WASTE STREAMS

WASTE STREAM	PLANT ID	1/kg	PLANT MEAN
Post-formation Rinsing	A	79.7*	
	A	1135.5*1/	
	A	100.9*	90.3
	B	262.6	
	B	341.8	302.2
	C	+	
	Mean		196.25
	Median		196.25

* - This flow rate reflects the combined wastewater from post-formation rinsing, floor area maintenance, and lab analysis.

\+ - Data not provided in survey.

1/ - Value for this day eliminated from statistical analysis because of extreme variability in floor area maintenance water use.

TABLE V-82

POLLUTANT CONCENTRATIONS IN THE SILVER POWDER PRESSED AND ELECTROLYTICALLY OXIDIZED CATHODE ELEMENT WASTE STREAMS

		PLANT A			PLANT B	
			mg/l			
	Temperature (Deg C)	14.0	15.0	15.0	15.0	15.0
11	1,1,1-Trichloroethane	0.00	*	*	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	*	*
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	*	*	*	0.00	0.00
55	Naphthalene	*	*	*	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA	NA
70	Diethyl phthalate	*	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0.00
86	Toluene	0.00	*	0.00	*	*
87	Trichloroethylene	*	*	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.110	0.000	0.000	0.000	0.000
118	Cadmium	0.082	0.008	0.065	0.055	0.004
119	Chromium, Total	0.007	0.007	11.60	0.000	0.000
	Chromium, Hexavalent	I	0.000	0.000	0.000	0.000
120	Copper	1.210	4.110	4.730	0.000	0.000
121	Cyanide, Total	NA	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA	NA
122	Lead	0.690	0.200	0.820	0.000	0.000
123	Mercury	0.0600	0.0090	0.0170	0.0110	0.0710
124	Nickel	0.250	0.050	0.590	0.048	0.000
125	Selenium	0.000	0.000	0.000	0.000	0.000
126	Silver	0.640	0.3200	1.480	3.880	3.200
128	Zinc	235.0	29.40	59.0	0.000	0.000
	Aluminum	0.000	0.000	4.440	0.000	0.000
	Ammonia	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA
	Manganese	0.009	0.024	0.040	0.000	0.008
	Phenols, Total	NA	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA	NA
	Total Suspended Solids	362.0	86.0	217.0	5.0	49.0
	pH, Minimum	10.6	11.8	10.6	11.0	10.8
	pH, Maximum	11.8	11.8	10.6	11.0	11.0

NA - Not Analyzed
* - ≤ 0.01

TABLE V-83
POLLUTANT MASS LOADINGS IN THE SILVER POWDER PRESSED AND ELECTROLYTICALLY OXIDIZED CATHODE ELEMENT WASTE STREAMS

mg/kg

		PLANT A			PLANT B	
	Flow (l/kg)	79.7	1136.0	100.9	262.6	341.8
	Temperature (Deg C)	14.0	15.0	15.0	15.0	15.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00
55	Napththalene	0.00	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA	NA
70	Diethyl phthalate	0.040	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000	0.000
115	Arsenic	8.77	0.000	0.000	0.000	0.000
118	Cadmium	6.53	9.08	6.56	14.45	1.367
119	Chromium, Total	0.558	7.95	1171.0	0.000	0.000
	Chromium, Hexavalent	I	0.000	0.000	0.000	0.000
120	Copper	96.4	4670.0	477.4	0.000	0.000
121	Cyanide, Total	NA	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA	NA
122	Lead	54.98	227.1	82.8	0.000	0.000
123	Mercury	4.781	10.22	1.716	2.889	24.27
124	Nickel	19.9	56.78	59.55	12.61	0.000
125	Selenium	0.000	0.000	0.000	0.000	0.000
126	Silver	51.00	363.4	149.4	1019.0	1093.0
128	Zinc	18730.	33380.	5955.	0.000	0.000
	Aluminum	0.000	0.000	488.1	0.000	0.000
	Ammonia	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA
	Manganese	0.717	27.25	4.037	0.000	2.735
	Phenols, Total	NA	NA	NA	NA	NA
	Oils & Grease	NA	NA	NA	NA	NA
	Total Suspended Solids	28850.0	97700.0	21900.0	1313.0	16750.0
	pH, Minimum	10.6	11.8	10.6	11.0	10.8
	pH, Maximum	11.8	11.8	10.6	11.0	11.0

I - Interference
NA - Not Analyzed

TABLE V-84

STATISTICAL ANALYSIS (mg/l) OF THE SILVER POWDER PRESSED AND ELECTROLYTICALLY OXIDIZED CATHODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	14.0	15.0	15.0	15.0	5	0	5
11	1,1,1-Trichloroethane	0.00	*	*	0.00	2	3	5
13	1,1-Dichloroethane	0.00	*	*	0.00	2	3	5
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0	3	4
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	5	5
38	Ethylbenzene	0.00	0.00	0.00	0.00	0	5	5
44	Methylene chloride	0.00	*	*	*	3	2	5
55	Naphthalene	0.00	*	*	*	3	2	5
64	Pentachlorophenol	NA	NA	NA	NA			
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA			
70	Diethyl phthalate	0.00	*	*	0.00	1	4	5
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0	5	5
86	Toluene	0.00	*	*	*	3	2	5
87	Trichloroethylene	0.00	*	*	0.00	2	3	5
114	Antimony	0.000	0.000	0.000	0.000	0	5	5
115	Arsenic	0.000	0.110	0.020	0.000	1	4	5
118	Cadmium	0.004	0.082	0.043	0.055	5	0	5
119	Chromium, Total	0.000	11.60	2.323	0.007	3	2	5
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	4	4
120	Copper	0.000	4.730	2.010	1.210	3	2	5
121	Cyanide, Total	NA	NA	NA	NA			
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA			
122	Lead	0.000	0.820	0.342	0.200	3	2	5
123	Mercury	0.0090	0.0710	0.0336	0.0170	5	0	5
124	Nickel	0.000	0.590	0.188	0.050	4	1	5
125	Selenium	0.000	0.000	0.000	0.000	0	5	5
126	Silver	0.3200	3.880	1.904	1.480	5	0	5
128	Zinc	0.000	235.0	64.7	29.40	3	2	5
	Aluminum	0.000	4.440	0.888	0.000	1	4	5
	Ammonia	NA	NA	NA	NA			
	Iron	NA	NA	NA	NA			
	Manganese	0.000	0.040	0.016	0.009	4	1	5
	Phenols, Total	NA	NA	NA	NA			
	Oil & Grease	NA	NA	NA	NA			
	Total Suspended Solids	5.0	362.0	143.8	86.0	5	0	5
	pH, Minimum	10.6	11.8	11.0	10.8	5	0	5
	pH, Maximum	10.6	11.8	11.2	11.0	5	0	5

NA - Not Analyzed
* - ≤0.01

TABLE V-85

STATISTICAL ANALYSIS (mg/kg) OF THE SILVER POWDER PRESSED AND ELECTROLYTICALLY OXIDIZED CATHODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (l/kg)	79.7	1136.0	384.1	262.6
	Temperature (Deg C)	14.0	15.0	15.0	15.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl)Phthalate	NA	NA	NA	NA
70	Diethyl Phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	8.77	1.753	0.000
118	Cadmium	1.367	14.45	7.60	6.56
119	Chromium, Total	0.000	1171.0	235.9	0.558
	Chromium, Hexavalent	0.000	0.000	0.000	0.000
120	Copper	0.000	4667.0	1048.0	96.4
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.000	227.1	73.0	54.98
123	Mercury	1.716	24.27	8.775	4.781
124	Nickel	0.000	59.55	29.77	19.92
125	Selenium	0.000	0.000	0.000	0.000
126	Silver	51.00	1094.0	535.3	363.4
128	Zinc	0.000	33380.0	11610.0	5955.0
	Aluminum	0.000	448.1	89.6	0.000
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.000	27.25	6.95	2.735
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	1313.0	97650.0	33290.0	21900.0
	pH, Minimum	10.6	11.8	11.0	10.8
	pH, Maximum	10.6	11.8	11.2	11.0

NA - Not Analyzed

TABLE V-86

POLLUTANT CONCENTRATIONS IN THE SILVER OXIDE (Ag_2O) POWDER-THERMALLY REDUCED AND SINTERED, ELECTROLYTICALLY FORMED CATHODE ELEMENT WASTE STREAMS

		mg/l	
	Temperature (Deg C)	10.0	16.0
11	1,1,1-Trichloroethane	0.00	0.00
13	1,1-Dichloroethane	*	0.00
29	1,1-Dichloroethylene	*	*
30	1,2-Trans-dichloroethylene	0.00	0.00
38	Ethylbenzene	0.00	0.00
44	Methylene chloride	*	0.00
55	Naphthalene	*	*
64	Pentachlorophenol	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA
70	Diethyl phthalate	*	*
85	Tetrachloroethylene	0.00	0.00
86	Toluene	0.00	0.00
87	Trichloroethylene	0.00	0.00
114	Antimony	0.000	0.000
115	Arsenic	0.000	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.010	0.007
	Chromium, Hexavalent	0.000	0.000
120	Copper	0.002	0.000
121	Cyanide, Total	0.006	0.000
	Cyanide, Amn. to Chlor.	0.000	0.000
122	Lead	0.000	0.000
123	Mercury	0.0130	0.0200
124	Nickel	0.000	0.000
125	Selenium	0.000	0.000
126	Silver	0.3000	16.70
128	Zinc	0.017	0.011
	Aluminum	0.350	0.000
	Ammonia	0.84	0.28
	Iron	NA	NA
	Manganese	0.000	0.000
	Phenols, Total	0.004	0.017
	Oil & Grease	12.0	9.3
	Total Suspended Solids	6.1	1.0
	pH, Minimum	12.4	9.0
	pH, Maximum	12.4	9.0

NA - Not Analyzed
* - ≤ 0.01

TABLE V-87
POLLUTANT MASS LOADINGS IN THE SILVER OXIDE (Ag_2O) POWDER-THERMALLY REDUCED AND SINTERED, ELECTROLYTICALLY FORMED CATHODE ELEMENT WASTE STREAMS

		mg/kg	
	Flow (l/kg)	437.4	100.9
	Temperature (Deg C)	10.0	16.0
11	1,1,1-Trichloroethane	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00
38	Ethylbenzene	0.00	0.00
44	Methylene chloride	0.00	0.00
55	Naphthalene	0.00	0.00
64	Pentachlorophenol	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA
70	Diethyl phthalate	0.00	0.00
85	Tetrachloroethylene	0.00	0.00
86	Toluene	0.00	0.00
87	Trichloroethylene	0.00	0.00
114	Antimony	0.000	0.000
115	Arsenic	0.000	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	4.374	0.707
	Chromium, Hexavalent	0.000	0.000
120	Copper	0.875	0.000
121	Cyanide, Total	2.624	0.000
	Cyanide, Amn. to Chlor.	0.000	0.000
122	Lead	0.000	0.000
123	Mercury	5.686	2.019
124	Nickel	0.000	0.000
125	Selenium	0.000	0.000
126	Silver	131.2	1686.0
128	Zinc	7.44	1.110
	Aluminum	153.1	0.000
	Ammonia	367.4	28.26
	Iron	NA	NA
	Manganese	0.000	0.000
	Phenols, Total	1.750	1.716
	Oil & Grease	5250.0	939.0
	Total Suspended Solids	2668.0	100.9
	pH, Minimum	12.4	9.0
	pH, Maximum	12.4	9.0

NA - Not Analyzed

TABLE V-88
POLLUTANT CONCENTRATIONS IN THE SILVER PEROXIDE (AgO) POWDER CATHODE ELEMENT WASTE STREAMS

		PLANT C	PLANT B		
			mg/l		
	Temperature (Deg C)	38.0	NA	NA	NA
11	1,1,1-Trichloroethane	0.00	0.00	*	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	*	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	*	*	0.00
55	Naphthalene	*	*	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA
70	Diethyl phthalate	*	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	i	i	i
118	Cadmium	0.000	5.99	2.250	3.380
119	Chromium, Total	0.008	0.220	0.088	0.160
	Chromium, Hexavalent	0.000	I	I	I
120	Copper	0.013	0.000	0.000	0.000
121	Cyanide, Total	0.007	NA	NA	NA
	Cyanide, Amn. to Chlor.	0.000	NA	NA	NA
122	Lead	0.000	0.000	0.000	0.000
123	Mercury	0.0070	I	I	I
124	Nickel	0.008	0.000	0.000	0.000
125	Selenium	0.000	i	i	i
126	Silver	45.20	71.0	48.60	8.80
128	Zinc	0.450	0.014	0.050	0.030
	Aluminum	0.000	0.000	0.000	3.560
	Ammonia	1.10	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.000	0.000	0.000	0.000
	Phenols, Total	0.000	NA	NA	NA
	Oil & Grease	16.0	NA	NA	NA
	Total Suspended Solids	620.0	310.0	178.0	730.0
	pH, Minimum	9.0	10.0	11.0	10.0
	pH, Maximum	9.0	11.0	13.0	13.0

I - Interference
NA - Not Analyzed
* - ≤ to 0.01
i - Invalid Analysis

TABLE V-89

POLLUTANT MASS LOADINGS IN THE SILVER PEROXIDE (AgO) POWDER CATHODE ELEMENT WASTE STREAMS

		PLANT C	PLANT B		
			mg/kg		
	Flow (l/kg)	75.7	5.539	22.35	10.42
	Temperature (Deg C)	38.0	NA	NA	NA
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	i	i	i
118	Cadmium	0.000	33.18	50.30	35.22
119	Chromium, Total	0.606	1.219	1.967	1.667
	Chromium, Hexavalent	0.000	I	I	I
120	Copper	0.984	0.000	0.000	0.000
121	Cyanide, Total	0.530	NA	NA	NA
	Cyanide, Amn. to Chlor.	0.000	NA	NA	NA
122	Lead	0.000	0.000	0.000	0.000
123	Mercury	0.5300	I	I	I
124	Nickel	0.606	0.000	0.000	0.000
125	Selenium	0.000	i	i	i
126	Silver	3422.0	393.3	1086.0	91.7
128	Zinc	34.07	0.078	1.118	0.313
	Aluminum	0.000	0.000	0.000	37.10
	Ammonia	83.3	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.000	0.000	0.000	0.000
	Phenols, Total	0.000	NA	NA	NA
	Oil & Grease	1211.0	NA	NA	NA
	Total Suspended Solids	46930.0	1717.0	3978.0	7610.0
	pH, Minimum	9.0	10.0	11.0	10.0
	pH, Maximum	9.0	11.0	13.0	13.0

I - Interference
NA - Not Analyzed
i - Invalid Analysis

TABLE V-90

STATISTICAL ANALYSIS (mg/l) OF THE SILVER PEROXIDE (AgO) POWDER CATHODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	38.0	3.80	3.08	3.80	1	0	1
11	1,1,1-Trichloroethane	0.00	*	*	0.00	1	3	4
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00	0	4	4
29	1,1-Dichloroethylene	0.00	*	*	0.00	1	3	4
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
38	Ethylbenzene	0.00	0.00	0.00	0.00	0	4	4
44	Methylene chloride	0.00	*	*	*	2	2	4
55	Naphthalene	0.00	*	*	*	2	2	4
64	Pentachlorophenol	NA	NA	NA	NA			
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA			
70	Diethyl phthalate	0.00	*	*	0.00	1	3	4
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0	4	4
86	Toluene	0.00	0.00	0.00	0.00	0	4	4
87	Trichloroethylene	0.00	0.00	0.00	0.00	0	4	4
114	Antimony	0.000	0.000	0.000	0.000	0	4	4
115	Arsenic	0.000	0.000	0.000	0.000	0	1	1
118	Cadmium	0.000	5.990	2.905	2.815	3	1	4
119	Chromium, Total	0.008	0.220	0.119	0.124	4	0	4
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	1	1
120	Copper	0.000	0.013	0.003	0.000	1	3	4
121	Cyanide, Total	0.007	0.007	0.007	0.007	1	0	1
	Cyanide, Amn. to Chlor.	0.000	0.000	0.000	0.000	0	1	1
122	Lead	0.000	0.000	0.000	0.000	0	4	4
123	Mercury	0.0070	0.0070	0.0070	0.0070	1	0	1
124	Nickel	0.000	0.008	0.002	0.000	1	3	4
125	Selenium	0.000	0.000	0.000	0.000	0	1	1
126	Silver	8.80	71.0	43.40	46.90	4	0	4
128	Zinc	0.014	0.450	0.136	0.040	4	0	4
	Aluminum	0.000	3.560	0.890	0.000	1	3	4
	Ammonia	1.10	1.10	1.10	1.10	1	0	1
	Iron	NA	NA	NA	NA			
	Manganese	0.000	0.000	0.000	0.000	0	4	4
	Phenols, Total	0.000	0.000	0.000	0.000	0	1	1
	Oil & Grease	16.0	16.0	16.0	16.0	1	0	1
	Total Suspended Solids	178.0	730.0	459.5	465.0	4	0	4
	pH, Minimum	9.0	11.0	10.0	10.0	4	0	4
	pH, Maximum	9.0	13.0	11.5	12.0	4	0	4

NA - Not Analyzed
* - ≤ 0.01

TABLE V-91

STATISTICAL ANALYSIS (mg/kg) OF THE SILVER PEROXIDE (AgO) POWDER CATHODE ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (l/kg)	5.539	75.7	28.50	16.39
	Temperature (Deg C)	38.0	38.0	38.0	38.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000	0.000
118	Cadmium	0.000	50.29	29.67	34.20
119	Chromium, Total	0.606	1.967	1.365	1.443
	Chromium, Hexavalent	0.000	0.000	0.000	0.000
120	Copper	0.000	0.984	0.246	0.000
121	Cyanide, Total	0.530	0.530	0.530	0.530
	Cyanide, Amn. to Chlor.	0.000	0.000	0.000	0.000
122	Lead	0.000	0.000	0.000	0.000
123	Mercury	0.5300	0.5300	0.5300	0.5300
124	Nickel	0.000	0.606	0.151	0.000
125	Selenium	0.000	0.000	0.000	0.000
126	Silver	91.7	3442.0	1248.0	740.0
128	Zinc	0.078	34.07	8.89	0.715
	Aluminum	0.000	37.10	9.27	0.000
	Ammonia	83.3	83.3	83.3	83.3
	Iron	NA	NA	NA	NA
	Manganese	0.000	0.000	0.000	0.000
	Phenols, Total	0.076	0.076	0.076	0.076
	Oil & Grease	1211.0	1211.0	1211.0	1211.0
	Total Suspended Solids	1717.0	46930.0	15060.0	5792.0
	pH, Minimum	9.0	11.0	10.0	10.0
	pH, Maximum	9.0	13.0	11.5	12.0

NA - Not Analyzed

TABLE V-92

PRODUCTION NORMALIZED DISCHARGES FROM CELL WASH ELEMENT

WASTE STREAM	PLANT ID	DCP DATA 1/kg	MEAN SAMPLING DATA 1/kg
Cell Wash Wastewater	A		0.088
	B	4.21	
	C		1.62
	D	+	
	E		0.345
	F	0.334	
	G		0.209

	RANGE 1/kg	MEAN 1/kg	MEDIAN 1/kg
	.088-4.21	1.13	0.340

+ - Abnormally high flow (34.1 l/kg) deleted from consideration.

TABLE V-93
POLLUTANT CONCENTRATIONS IN THE CELL WASH ELEMENT WASTE STREAMS
mg/l

		PLANT G			PLANT E			PLANT A			PLANT C		
	Temperature (Deg C)	29.9	30.3	31.1	NA	58.0	56.0	34.0	34.0	34.0	NA	NA	NA
11	1,1,1-Trichloroethane	0.006	0.006	0.016	*	*	*	0.00	0.00	0.00	*	*	*
13	1,1-Dichloroethane	NA	NA	NA	0.00	*	0.00	NA	NA	NA	*	*	*
29	1,1-Dichloroethylene	NA	NA	NA	0.00	*	0.00	NA	NA	NA	*	*	*
30	1,2-Trans-dichloroethylene	NA	NA	NA	0.00	*	0.00	NA	NA	NA	0.00	*	*
38	Ethylbenzene	NA	NA	NA	0.00	0.004	0.00	NA	NA	NA	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	*	0.00	0.00	0.00	0.00	*	*	*
55	Naphthalene	NA	NA	NA	*	0.023	*	NA	NA	NA	*	*	0.00
64	Pentachlorophenol	0.00	NA	0.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	0.011	0.111	0.021	NA	NA	NA	0.161	0.057	0.033	NA	NA	NA
70	Diethyl phthalat	NA	NA	NA	*	*	*	NA	NA	NA	*	*	*
85	Tetrachloroethylene	NA	NA	NA	0.00	*	0.00	NA	NA	NA	0.00	*	0.00
86	Toluene	NA	NA	NA	0.00	0.004	0.00	NA	NA	NA	0.00	0.00	0.00
87	Trichloroethylene	0.012	*	*	*	*	0.00	0.00	0.00	0.00	*	*	*
114	Antimony	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000	0.000	0.067	0.000	0.000	0.000	0.000	i	i	i
118	Cadmium	0.004	0.002	0.010	0.008	0.181	0.013	0.006	0.010	0.008	0.103	0.100	0.124
119	Chromium, Total	0.032	0.035	0.146	9.68	73.1	15.40	256.0	253.0	318.0	0.026	0.002	0.026
	Chromium, Hexavalent	0.000	0.000	0.000	8.60	59.14	15.00	I	I	I	0.000	0.000	0.000
120	Copper	0.272	0.282	0.629	0.033	0.187	0.010	0.370	0.540	0.430	0.103	0.078	0.120
121	Cyanide, Total	NA	NA	NA	0.014	0.018	0.017	3.900	7.20	2.100	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	I	I	I	3.900	4.900	2.100	NA	NA	NA
122	Lead	0.011	0.024	0.136	0.000	0.109	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123	Mercury	0.0190	0.0220	0.2930	0.970	5.343	1.330	I	I	I	0.2030	0.5860	0.4080
124	Nickel	3.824	6.49	24.39	0.210	1.540	0.350	4.680	8.64	6.86	0.880	0.685	1.054
125	Selenium	NA	NA	NA	0.000	0.046	0.000	NA	NA	NA	i	i	i
126	Silver	0.0000	0.0000	0.0000	0.0170	1.346	0.0330	0.0080	0.0150	0.0060	0.4930	0.2600	0.2600
128	Zinc	3.669	3.681	12.41	0.430	12.74	0.710	18.40	32.90	29.40	1.897	2.217	1.435
	Aluminum	NA	NA	NA	0.000	0.166	0.000	NA	NA	NA	0.000	0.000	0.000
	Ammonia	1.46	8.37	2.25	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Manganese	17.64	24.04	69.6	0.068	0.607	0.150	14.80	38.40	25.20	0.063	0.094	0.059
	Phenols, Total	0.015	0.017	0.014	0.088	0.023	0.021	0.000	0.000	0.000	NA	NA	NA
	Oil & Grease	41.4	71.6	49.8	3.0	29.7	11.0	104.0	205.0	134.0	NA	NA	NA
	Total Suspended Solids	21.6	51.9	161.3	33.0	13.7	0.0	29.0	38.0	42.0	29.5	34.3	28.7
	pH, Minimum	8.9	8.1	9.7	NA	NA	NA	5.8	6.4	5.8	8.0	7.5	7.5
	pH, Maximum	11.4	11.0	11.9	NA	NA	NA	5.8	6.4	5.8	11.5	11.9	12.0

I - Interference
NA - Not Analyzed
* - ≤ 0.01
i - Invalid Analysis

TABLE V-94
POLLUTANT MASS LOADINGS IN THE CELL WASH ELEMENT WASTE STREAMS
mg/kg

		PLANT G			PLANT E			PLANT A			PLANT C		
	Flow (l/kg)	0.194	0.224	0.220	0.575	0.295	0.603	0.085	0.089	0.090	1.485	1.562	1.804
	Temperature (Deg C)	29.9	30.3	31.1	NA	58.0	56.0	34.0	34.0	34.0	NA	NA	NA
11	1,1,1-Trichloroethane	0.001	0.001	0.004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
29	1,1-Dichloroethylene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
38	Ethylbenzene	NA	NA	NA	0.00	0.001	0.00	NA	NA	NA	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA	0.00	0.007	0.00	NA	NA	NA	0.00	0.00	0.00
64	Pentachlorophenol	0.00	NA	0.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	0.007	0.025	0.005	NA	NA	NA	0.014	0.005	0.003	NA	NA	NA
70	Diethyl phthalat	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
85	Tetrachloroethylene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
86	Toluene	NA	NA	NA	0.00	0.001	0.00	NA	NA	NA	0.00	0.00	0.00
87	Trichloroethylene	0.002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	i	i	i
118	Cadmium	0.001	0.000	0.002	0.005	0.053	0.008	0.001	0.001	0.001	0.152	0.156	0.223
119	Chromium, Total	0.006	0.008	0.032	5.571	21.58	9.29	21.81	22.59	28.56	0.038	0.003	0.046
	Chromium, Hexavalent	0.000	0.000	0.000	4.949	17.45	9.05	I	I	I	0.000	0.000	0.000
120	Copper	0.053	0.063	0.139	0.019	0.055	0.006	0.032	0.048	0.039	0.153	0.122	0.217
121	Cyanide, Total	NA	NA	NA	0.008	0.005	0.010	0.332	0.643	0.189	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	I	I	I	0.332	0.438	0.189	NA	NA	NA
122	Lead	0.002	0.005	0.030	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123	Mercury	0.0040	0.0050	0.0650	0.5580	1.576	0.802	I	I	I	0.3010	0.915	0.736
124	Nickel	0.471	1.457	5.373	0.121	0.454	0.211	0.399	0.772	0.616	1.307	1.071	0.902
125	Selenium	NA	NA	NA	0.000	0.013	0.000	NA	NA	NA	i	i	i
126	Silver	0.0000	0.0000	0.0000	0.0100	0.3970	0.0200	0.0010	0.0010	0.0010	0.732	0.4061	0.4690
128	Zinc	0.711	0.826	2.734	0.247	3.759	0.428	1.567	2.938	2.640	2.817	3.463	2.590
	Aluminum	NA	NA	NA	0.000	0.049	0.000	NA	NA	NA	0.000	0.000	0.000
	Ammonia	0.282	1.878	0.495	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Manganese	3.417	5.394	15.33	0.039	0.179	0.090	1.261	3.429	2.263	0.093	0.146	0.107
	Phenols, Total	0.003	0.004	0.003	0.051	0.007	0.013	0.000	0.000	0.000	NA	NA	NA
	Oil & Grease	8.02	16.06	10.97	1.726	8.77	6.64	8.86	18.31	12.03	NA	NA	NA
	Total Suspended Solids	4.189	11.65	35.53	18.99	4.046	0.000	2.470	3.393	3.772	43.73	53.62	51.74
	pH, Minimum	8.9	8.0	9.7	NA	NA	NA	5.8	6.4	5.8	8.0	7.5	7.5
	pH, Maximum	11.4	11.0	11.9	NA	NA	NA	5.8	6.4	5.8	11.5	11.9	12.0

I - Interference
NA - Not Analyzed
* - <0.01
i - Invalid Analysis

TABLE V-95

STATISTICAL ANALYSIS (mg/l) OF THE CELL WASH ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	PTS
	Temperature (Deg C)	29.9	58.0	32.3	34.0	8	0	8
11	1,1,1-Trichloroethane	0.00	0.016	0.002	*	9	3	12
13	1,1-Dichloroethane	0.00	*	*	*	4	2	6
29	1,1-Dichloroethylene	0.00	*	*	*	4	2	6
30	1,2-Trans-dichloroethylene	0.00	*	*	*	3	3	6
38	Ethylbenzene	0.00	0.004	0.001	0.00	1	5	6
44	Methylene chloride	0.00	*	*	0.00	4	8	12
55	Naphthalene	0.00	0.023	0.004	*	5	1	6
64	Pentachlorophenol	0.00	0.00	0.00	0.00	0	2	2
66	Bis(2-ethylhexyl) phthalate	0.011	0.161	0.069	0.046	6	0	6
70	Diethyl phthalate	*	*	*	*	6	0	6
85	Tetrachloroethylene	0.00	*	*	*	2	4	6
86	Toluene	0.00	0.004	0.001	0.00	1	5	6
87	Trichloroethylene	0.00	0.012	0.001	*	8	4	12
114	Antimony	0.000	0.000	0.000	0.000	0	12	12
115	Arsenic	0.000	0.067	0.007	0.000	1	8	9
118	Cadmium	0.002	0.181	0.047	0.010	12	0	12
119	Chromium, Total	0.002	318.0	77.1	4.913	12	0	12
	Chromium, Hexavalent	0.000	59.14	9.19	0.000	3	6	9
120	Copper	0.010	0.629	0.254	0.229	12	0	12
121	Cyanide, Total	0.014	7.20	2.208	1.059	6	0	6
	Cyanide, Amn. to Chlor.	2.100	4.900	3.633	3.900	3	0	3
122	Lead	0.000	0.136	0.015	0.000	4	8	12
123	Mercury	0.0191	5.343	1.019	0.4081	9	0	9
124	Nickel	0.210	24.39	4.967	2.682	12	0	12
125	Selenium	0.000	0.046	0.015	0.000	1	2	3
126	Silver	0.0000	1.345	0.2030	0.0160	9	3	12
128	Zinc	0.430	32.90	9.99	3.675	12	0	12
	Aluminum	0.000	0.166	0.028	0.000	1	5	6
	Ammonia	1.46	8.37	4.03	2.25	3	0	3
	Iron	NA	NA	NA	NA			
	Manganese	0.059	69.6	15.89	7.70	12	0	12
	Phenols, Total	0.000	0.088	0.020	0.015	6	3	9
	Oil & Grease	3.0	205.0	72.2	49.8	9	0	9
	Total Suspended Solids	0.0	161.3	40.3	31.3	11	1	12
	pH, Minimum	5.8	9.7	7.5	7.5	9	0	9
	pH, Maximum	5.8	12.0	9.7	11.4	9	0	9

NA - Not Analyzed
* - ≤ 0.01

TABLE V-96

STATISTICAL ANALYSIS (mg/kg) OF THE CELL WASH ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (l/kg)	0.085	1.804	0.602	0.260
	Temperature (Deg C)	29.9	58.0	32.3	34.0
11	1,1,1-Trichloroethane	0.00	0.004	0.001	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.001	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Napthalene	0.00	0.007	0.001	0.00
64	Pentachlorophenol	0.00	0.00	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.003	0.024	0.010	0.006
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.001	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.020	0.002	0.000
118	Cadmium	0.000	0.223	0.050	0.003
119	Chromium, Total	0.003	28.56	9.13	2.808
	Chromium, Hexavalent	0.000	17.45	3.494	0.000
120	Copper	0.006	0.217	0.079	0.054
121	Cyanide, Total	0.005	0.643	0.198	0.099
	Cyanide, Amn. to Chlor.	0.189	0.438	0.319	0.332
122	Lead	0.000	0.030	0.003	0.000
123	Mercury	0.0040	1.576	0.5510	0.5580
124	Nickel	0.121	5.37	1.202	0.756
125	Selenium	0.000	0.013	0.004	0.000
126	Silver	0.0000	0.7320	0.1690	0.0060
128	Zinc	0.247	3.759	2.060	2.615
	Aluminum	0.000	0.049	0.008	0.000
	Ammonia	0.282	1.878	0.885	0.495
	Iron	NA	NA	NA	NA
	Manganese	0.039	15.33	2.646	0.720
	Phenols, Total	0.000	0.051	0.009	0.003
	Oil & Grease	1.726	18.31	10.15	8.86
	Total Suspended Solids	0.000	53.6	19.43	7.92
	pH, Minimum	5.8	9.7	7.5	7.5
	pH, Maximum	5.8	12.0	9.7	11.4

NA - Not Analyzed

TABLE V-97

POLLUTANT CONCENTRATIONS IN THE ELECTROLYTE PREPARATION ELEMENT WASTE STREAMS

		mg/l
	Temperature (Deg C)	NA
11	1,1,1-Trichloroethane	0.00
13	1,1-Dichloroethane	0.00
29	1,1-Dichloroethylene	0.00
30	1,2-Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.00
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.000
115	Arsenic	i
118	Cadmium	0.000
119	Chromium, Total	0.000
	Chromium, Hexavalent	0.000
120	Copper	0.000
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.000
123	Mercury	0.0400
124	Nickel	0.220
125	Selenium	i
126	Silver	0.790
128	Zinc	19.20
	Aluminum	0.000
	Ammonia	NA
	Iron	NA
	Manganese	0.000
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	70.0
	pH Minimum	12.8
	pH Maximum	12.8

NA - Not Analyzed
i - Invalid Analysis

TABLE V-98

POLLUTANT MASS LOADINGS IN THE ELECTROLYTE PREPARATION ELEMENT WASTE STREAMS

		mg/kg
	Flow (l/kg)	0.365
	Temperature (Deg C)	NA
11	1,1,1-Trichloroethane	0.00
13	1,1-Dichloroethane	0.00
29	1,1-Dichloroethylene	0.00
30	1,2-Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.00
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.000
115	Arsenic	i
118	Cadmium	0.000
119	Chromium, Total	0.000
	Chromium, Hexavalent	0.000
120	Copper	0.000
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.000
123	Mercury	0.0146
124	Nickel	0.080
125	Selenium	i
126	Silver	0.2884
128	Zinc	7.01
	Aluminum	0.000
	Ammonia	NA
	Iron	NA
	Manganese	0.000
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	25.55
	pH, Minimum	12.8
	pH, Maximum	12.8

NA - Not Analyzed
i - Invalid Analysis

TABLE V-99

POLLUTANT CONCENTRATIONS IN THE SILVER ETCH ELEMENT WASTE STREAMS

		mg/l
	Temperature (Deg C)	10.0
11	1,1,1-Trichloroethane	0.00
13	1,1-Dichloroethane	0.00
29	1,1-Dichloroethylene	*
30	1,2-Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.00
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.000
115	Arsenic	0.000
118	Cadmium	0.040
119	Chromium, Total	0.009
	Chromium, Hexavalent	0.000
120	Copper	0.088
121	Cyanide, Total	0.010
	Cyanide, Amn. to Chlor.	0.000
122	Lead	0.047
123	Mercury	0.0090
124	Nickel	0.000
125	Selenium	0.000
126	Silver	36.30
128	Zinc	1.060
	Aluminum	0.650
	Ammonia	2.00
	Iron	NA
	Manganese	0.013
	Phenols, Total	0.011
	Oil & Grease	0.000
	Total Suspended Solids	7.0
	pH, Minimum	2.6
	pH, Maximum	3.6

NA - Not Analyzed

* - ≤ 0.01

TABLE V-100

POLLUTANT MASS LOADINGS IN THE SILVER ETCH ELEMENT WASTE STREAMS

		mg/kg
	Flow (l/kg)	49.04
	Temperature (Deg C)	10.0
11	1,1,1-Trichloroethane	0.00
13	1,1-Dichloroethane	0.00
29	1,1-Dichloroethylene	0.00
30	1,2-Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.00
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.000
115	Arsenic	0.000
118	Cadmium	1.962
119	Chromium, Total	0.441
	Chromium, Hexavalent	0.000
120	Copper	4.316
121	Cyanide, Total	0.490
	Cyanide, Amn. to Chlor.	0.000
122	Lead	2.305
123	Mercury	0.4414
124	Nickel	0.000
125	Selenium	0.000
126	Silver	1780.0
128	Zinc	51.99
	Aluminum	31.88
	Ammonia	98.1
	Iron	NA
	Manganese	0.638
	Phenols, Total	0.539
	Oil & Grease	0.000
	Total Suspended Solids	343.3
	pH, Minimum	2.6
	pH, Maximum	3.6

NA - Not Analyzed

TABLE V-101

POLLUTANT CONCENTRATIONS IN THE LAUNDRY WASH AND EMPLOYEE SHOWER ELEMENT WASTE STREAMS

mg/l

	Temperature (Deg C)	27.0	28.0	30.0
11	1,1,1-Trichloroethane	*	*	*
13	1,1-Dichloroethane	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	*	*	0.00
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA
70	Diethyl phthalate	*	*	*
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	*	*	*
114	Antimony	NA	0.000	0.000
115	Arsenic	NA	0.000	0.000
118	Cadmium	NA	0.071	0.100
119	Chromium, Total	NA	0.000	0.000
	Chromium, Hexavalent	NA	0.000	0.000
120	Copper	NA	0.230	0.450
121	Cyanide, Total	0.030	0.014	0.000
	Cyanide, Amn. to Chlor.	I	I	I
122	Lead	NA	0.000	0.043
123	Mercury	NA	9.40	I
124	Nickel	NA	0.000	0.025
125	Selenium	NA	0.000	0.000
126	Silver	NA	1.460	0.4300
128	Zinc	NA	0.820	1.220
	Aluminum	NA	0.160	0.160
	Ammonia	NA	NA	NA
	Iron	NA	NA	NA
	Manganese	NA	0.350	0.400
	Phenols, Total	0.190	0.053	0.084
	Oil & Grease	270.0	5.2	14.0
	Total Suspended Solids	42.0	72.0	23.0
	pH, Minimum	4.7	6.4	5.5
	pH, Maximum	7.7	7.2	6.9

I - Interference
NA - Not Analyzed
* - ≤ 0.01

TABLE V-102

POLLUTANT CONCENTRATIONS IN THE MANDATORY EMPLOYEE WASH ELEMENT WASTE STREAMS

			mg/1	
	Temperature (Deg C)	17.0	29.0	26.0
11	1,1,1 - Trichloroethane	0.00	0.00	0.00
13	1,1 - Dichloroethane	NA	NA	NA
29	1,1 - Dichloroethane	NA	NA	NA
30	1,2 - Trans-dichloroethylene	NA	NA	NA
38	Ethylbenzene	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00
66	Bis(2-ethylhexyl)phthalate	*	*	*
70	Diethyl phthalate	NA	NA	NA
85	Tetrachloroethylene	NA	NA	NA
86	Toluene	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.000	0.000	0.000
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	0.027	0.014	0.024
121	Cyanide, Total	0.000	0.000	0.000
	Cyanide, Amn. to Chlor.	0.000	0.000	0.000
122	Lead	0.000	0.000	0.000
123	Mercury	0.0000	0.0000	0.0000
124	Nickel	0.000	0.000	0.000
125	Selenium	NA	NA	NA
126	Silver	0.0000	0.0000	0.0000
	Zinc	0.100	0.150	0.150
	Aluminum	NA	NA	NA
	Ammonia	6.23	0.73	0.13
	Iron	NA	NA	NA
	Manganese	0.230	0.095	0.360
	Phenols, Total	0.022	0.035	I
	Oil & Grease	8.3	2.0	42.0
	Total Suspended Solids	133.3	84.0	55.0
	pH, Minimum	NA	NA	NA
	pH, Maximum	NA	NA	NA

I - Interference
NA - Not Analyzed
* - ≤ 0.01

TABLE V-103

POLLUTANT MASS LOADINGS IN THE MANDATORY EMPLOYEE WASH ELEMENT WASTE STREAMS

		mg/kg		
	Flow (l/kg)	0.266	0.266	0.266
	Temperature	17.0	29.0	26.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00
13	1,1-Dichloroethane	NA	NA	NA
29	1,1-Dichloroethylene	NA	NA	NA
30	1,2-Trans-dichloroethylene	NA	NA	NA
38	Ethylbenzene	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00
66	Bis(2-ethylhexyl)phthalate	0.00	0.00	0.00
70	Diethyl phthalate	NA	NA	NA
85	Tetrachloroethylene	NA	NA	NA
86	Toluene	NA	NA	NA
87	Trichloroethylene	NA	NA	NA
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.000	0.000	0.000
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	0.007	0.004	0.006
121	Cyanide, Total	0.000	0.000	0.000
	Cyanide, Amn. to Chlor.	0.000	0.000	0.000
122	Lead	0.000	0.000	0.000
123	Mercury	0.0000	0.0000	0.0000
124	Nickel	0.000	0.000	0.000
125	Selenium	NA	NA	NA
126	Silver	0.0000	0.0000	0.0000
128	Zinc	0.027	0.040	0.040
	Aluminum	NA	NA	NA
	Ammonia	1.657	0.194	0.035
	Iron	NA	NA	NA
	Manganese	0.061	0.025	0.096
	Phenols, Total	0.006	0.009	I
	Oil & Grease	2.208	0.532	11.17
	Total Suspended Solids	35.46	22.34	14.63
	pH, Minimum	NA	NA	NA
	pH, Maximum	NA	NA	NA

I - Interference
NA - Not Analyzed

TABLE V-104

POLLUTANT CONCENTRATIONS IN THE REJECT CELL HANDLING ELEMENT WASTE STREAMS

		mg/l
	Temperature (Deg C)	NA
11	1,1,1 - Trichloroethane	NA
13	1,1 - Dichloroethane	NA
29	1,1 - Dichloroethylene	NA
30	1,2 - Trans-dichloroethylene	NA
38	Ethylbenzene	NA
44	Methylene chloride	NA
55	Naphthalene	NA
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl)phthalate	NA
70	Diethyl phthalate	NA
85	Tetrachloroethylene	NA
86	Toluene	NA
87	Trichloroethylene	NA
114	Antimony	NA
115	Arsenic	NA
118	Cadmium	0.023
119	Chromium, Total	0.095
	Chromium, Hexavalent	NA
120	Copper	5.460
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.341
123	Mercury	17.00
124	Nickel	0.571
125	Selenium	NA
126	Silver	3.590
128	Zinc	156.0
	Aluminum	106.0
	Ammonia	NA
	Iron	0.565
	Manganese	0.175
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	NA
	pH, Minimum	NA
	pH, Maximum	NA

NA - Not Analyzed

TABLE V-105

POLLUTANT CONCENTRATIONS IN THE REJECT CELL HANDLING ELEMENT WASTE STREAMS

			mg/l	
	Temperature (Deg C)	18.0	19.0	18.0
11	1,1,1 - Trichloroethane	*	0.00	0.00
13	1,1 - Dichloroethane	NA	NA	NA
29	1,1 - Dichloroethylene	NA	NA	NA
30	1,2 - Trans-dichloroethylene	NA	NA	NA
38	Ethylbenzene	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.038	0.078	*
70	Diethyl phthalate	NA	NA	NA
85	Tetrachloroethylene	NA	NA	NA
86	Toluene	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.100	0.190	0.150
118	Cadmium	0.000	0.000	0.000
119	Chromium, Total	0.000	0.016	0.009
	Chromium, Hexavalent	0.000	I	0.000
120	Copper	0.076	0.300	0.320
121	Cyanide, Total	0.096	0.000	0.069
	Cyanide, Amn. to Chlor.	0.008	0.000	0.000
122	Lead	0.057	0.000	0.000
123	Mercury	0.4700	1.000	0.3700
124	Nickel	0.007	0.070	0.180
125	Selenium	NA	NA	NA
126	Silver	0.0000	0.0000	0.0000
128	Zinc	730.0	495.0	206.0
	Aluminum	NA	NA	NA
	Ammonia	5.57	8.89	1.370
	Iron	NA	NA	NA
	Manganese	0.021	0.150	0.290
	Phenols, Total	0.000	0.000	0.120
	Oil & Grease	13.3	6.0	19.0
	Total Suspended Solids	762.0	500.0	1310.0
	pH, minimum	NA	NA	NA
	pH, maximum	NA	NA	NA

I - Interference
NA - Not Analyzed
* - ≤ 0.01

TABLE V-106

POLLUTANT MASS LOADINGS IN THE REJECT CELL HANDLING ELEMENT WASTE STREAMS

		mg/kg		
	Flow (l/kg)	0.003	0.002	0.003
	Temperature (Deg C)	18.0	19.0	18.0
11	1,1,1 - Trichloroethane	0.00	0.00	0.00
13	1,1 - Dichloroethane	NA	NA	NA
29	1,1 - Dichloroethylene	NA	NA	NA
30	1,2 - Trans-dichloroethylene	NA	NA	NA
38	Ethylbenzene	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.00	0.00	0.00
70	Diethyl phthalate	NA	NA	NA
85	Tetrachloroethylene	NA	NA	NA
86	Toluene	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.000	0.000	0.000
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	0.000	I	0.000
120	Copper	0.000	0.001	0.001
121	Cyanide, Total	0.000	0.000	0.000
	Cyanide, Amn. to Chlor.	0.000	0.000	0.000
122	Lead	0.000	0.000	0.000
123	Mercury	0.0010	0.0020	0.0010
124	Nickel	0.000	0.000	0.001
125	Selenium	NA	NA	NA
126	Silver	0.0000	0.0000	0.0000
128	Zinc	1.995	0.902	0.563
	Aluminum	NA	NA	NA
	Ammonia	0.015	0.016	0.004
	Iron	NA	NA	NA
	Manganese	0.000	0.00	0.001
	Phenols, Total	0.000	0.00	0.000
	Oil & Grease	0.036	0.011	0.052
	Total Suspended Solids	2.082	0.911	3.580
	pH, minimum	NA	NA	NA
	pH, maximum	NA	NA	NA

I - Interference
NA - Not Analyzed

TABLE V-107

POLLUTANT CONCENTRATIONS IN THE FLOOR WASH ELEMENT WASTE STREAM

		mg/l
	Temperature (Deg C)	NA
11	1,1,1 - Trichloroethane	NA
13	1,1 - Dichloroethane	NA
29	1,1 - Dichloroethylene	NA
30	1,2 - Trans-dichloroethylene	NA
38	Ethylbenzene	NA
44	Methylene chloride	NA
55	Naphthalene	NA
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	NA
85	Tetrachloroethylene	NA
86	Toluene	NA
87	Trichloroethylene	NA
114	Antimony	0.000
115	Arsenic	0.000
118	Cadmium	0.040
119	Chromium, Total	0.350
	Chromium, Hexavalent	0.000
120	Copper	0.230
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	4.130
123	Mercury	I
124	Nickel	0.380
125	Selenium	0.000
126	Silver	49.50
128	Zinc	600.0
	Aluminum	5.830
	Ammonia	120.0
	Iron	NA
	Manganese	0.340
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	2800.0
	pH, minimum	NA
	pH, maximum	NA

I - Interference
NA - Not Analyzed

TABLE V-108

POLLUTANT MASS LOADINGS IN THE FLOOR WASH ELEMENT WASTE STREAM

		mg/kg
	Flow (l/kg)	0.296
	Temperature (Deg C)	NA
11	1,1,1 - Trichloroethane	NA
13	1,1 - Dichloroethane	NA
29	1,1 - Dichloroethylene	NA
30	1,2 - Trans-dichloroethylene	NA
38	Ethylbenzene	NA
44	Methylene chloride	NA
55	Naphthalene	NA
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	NA
85	Tetrachloroethylene	NA
86	Toluene	NA
87	Trichloroethylene	NA
114	Antimony	0.000
115	Arsenic	0.000
118	Cadmium	0.012
119	Chromium, Total	0.103
	Chromium, Hexavalent	0.000
120	Copper	0.068
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	1.221
123	Mercury	I
124	Nickel	0.112
125	Selenium	0.000
126	Silver	14.64
128	Zinc	177.4
	Aluminum	1.724
	Ammonia	35.48
	Iron	NA
	Manganese	0.101
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	828.0
	pH, minimum	NA
	pH, maximum	NA

I - Interference
NA - Not Analyzed

TABLE V-109

POLLUTANT CONCENTRATIONS IN THE EQUIPMENT WASH ELEMENT WASTE STREAMS

		PLANT B			PLANT A
		mg/l			
	Temperature (Deg C)	18.8	10.0	50.0	NA
11	1,1,1 - Trichloroethane	0.00	0.00	0.00	*
13	1,1 - Dichloroethane	*	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	*
38	Ethylbenzene	0.00	0.00	0.00	*
44	Methylene chloride	0.00	0.00	0.00	*
55	Naphthalene	0.00	0.00	0.00	*
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	*	0.00	*	*
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	*	*	*	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.006	0.100	0.090	0.000
118	Cadmium	0.188	0.015	0.021	0.024
119	Chromium, Total	0.000	0.000	0.012	0.011
	Chromium, Hexavalent	0.000	I	0.000	0.000
120	Copper	0.005	NA	0.026	0.042
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.005	NA	0.000	0.000
123	Mercury	0.1188	0.4000	0.0380	0.2200
124	Nickel	0.128	0.020	0.038	0.100
125	Selenium	0.000	0.050	0.070	0.000
126	Silver	0.0344	0.0000	0.3500	0.960
128	Zinc	8.03	0.660	1.400	1.790
	Aluminum	0.124	NA	0.000	0.000
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.020	0.000	0.020	0.072
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	51.5	112.0	68.0	98.0
	pH, minimum	12.0	11.8	12.0	5.6
	pH, maximum	12.2	11.8	12.2	6.5

I - Interference
NA - Not Analyzed
* - ≤ to 0.01

TABLE V-110

POLLUTANT MASS LOADINGS IN THE EQUIPMENT WASH ELEMENT WASTE STREAMS

		PLANT B			PLANT A
			mg/kg		
	Flow (l/kg)	16.64	6.79	3.470	5.090
	Temperature (Deg C)	18.8	10.0	50.0	NA
11	1,1,1 - Trichloroethane	0.00	0.00	0.00	0.00
13	1,1 - Dichloroethane	0.00	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.097	0.679	0.312	0.000
118	Cadmium	3.131	0.102	0.073	0.122
119	Chromium, Total	0.000	0.000	0.042	0.056
	Chromium, Hexavalent	0.000	I	0.000	0.000
120	Copper	0.084	NA	0.090	0.214
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.083	NA	0.000	0.000
123	Mercury	1.977	2.717	0.1320	1.120
124	Nickel	2.131	0.136	0.132	0.509
125	Selenium	0.000	0.340	0.243	0.000
126	Silver	0.5730	0.000	1.214	4.887
128	Zinc	133.7	4.484	4.857	9.111
	Aluminum	2.057	NA	0.000	0.000
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.337	0.000	0.069	0.366
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	856.0	761.0	235.9	498.8
	pH, minimum	12.0	11.8	12.0	5.6
	pH, maximum	12.2	11.8	12.2	6.5

I - Interference
NA - Not Analyzed

TABLE V-111

STATISTICAL ANALYSIS (mg/l) OF THE EQUIPMENT WASH ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	10.0	50.0	19.3	18.8	3	0	3
11	1,1,1 - Trichloroethane	0.00	*	*	0.00	1	3	4
13	1,1 - Dichloroethane	0.00	*	*	0.00	1	3	4
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
38	Ethylbenzene	0.00	*	*	0.00	1	3	4
44	Methylene chloride	0.00	*	*	0.00	1	3	4
55	Naphthalene	0.00	*	*	0.00	1	3	4
64	Pentachlorophenol	NA	NA	NA	NA			
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA			
70	Diethyl phthalate	0.00	*	*	*	3	1	4
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0	4	4
86	Toluene	0.00	*	*	*	3	1	4
87	Trichloroethylene	0.00	0.00	0.00	0.00	0	4	4
114	Antimony	0.000	0.000	0.000	0.000	0	4	4
115	Arsenic	0.000	0.100	0.049	0.048	3	1	4
118	Cadmium	0.015	0.188	0.062	0.023	4	0	4
119	Chromium, Total	0.000	0.012	0.006	0.006	2	2	4
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	3	3
120	Copper	0.005	0.042	0.024	0.026	3	0	3
121	Cyanide, Total	NA	NA	NA	NA			
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA			
122	Lead	0.000	0.005	0.002	0.000	1	2	3
123	Mercury	0.0380	0.4000	0.1942	0.1694	4	0	4
124	Nickel	0.020	0.128	0.072	0.069	4	0	4
125	Selenium	0.000	0.070	0.030	0.025	2	2	4
126	Silver	0.0000	0.960	0.3361	0.1922	3	1	4
128	Zinc	0.660	8.03	2.971	1.595	4	0	4
	Aluminum	0.000	0.124	0.041	0.000	1	2	3
	Ammonia	NA	NA	NA	NA			
	Iron	NA	NA	NA	NA			
	Manganese	0.000	0.072	0.028	0.020	3	1	4
	Phenols, Total	NA	NA	NA	NA			
	Oil & Grease	NA	NA	NA	NA			
	Total Suspended Solids	51.4	112.0	82.4	83.0	4	0	4
	pH, minimum	5.6	12.0	10.3	11.9	4	0	4
	pH, maximum	6.5	12.2	10.7	12.0	4	0	4

NA - Not Analyzed
* - ≤ 0.01

TABLE V-112

STATISTICAL ANALYSIS (mg/kg) OF THE EQUIPMENT WASH ELEMENT WASTE STREAMS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (l/kg)	3.470	16.64	8.00	5.942
	Temperature (Deg C)	10.0	50.0	19.3	18.8
11	1,1,1 - Trichloroethane	0.00	0.00	0.00	0.00
13	1,1 - Dichloroethane	0.00	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.679	0.272	0.205
118	Cadmium	0.073	3.131	0.857	0.112
119	Chromium, Total	0.000	0.056	0.024	0.021
	Chromium, Hexavalent	0.000	0.000	0.000	0.000
120	Copper	0.084	0.214	0.129	0.090
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.000	0.083	0.028	0.000
123	Mercury	0.1320	2.717	1.486	1.548
124	Nickel	0.132	2.131	0.727	0.322
125	Selenium	0.000	0.340	0.146	0.121
126	Silver	0.0000	4.887	1.668	0.894
128	Zinc	4.484	133.7	38.03	6.98
	Aluminum	0.000	2.057	0.686	0.000
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.000	0.366	0.193	0.203
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	235.9	856.0	587.9	630.0
	pH, minimum	5.6	12.0	10.4	11.9
	pH, maximum	6.5	12.2	10.7	12.0

NA - Not Analyzed

TABLE V-113

POLLUTANT CONCENTRATIONS IN THE SILVER POWDER PRODUCTION ELEMENT WASTE STREAMS

			mg/l	
	Temperature (Deg C)	14.0	15.0	14.0
11	1,1,1 - Trichloroethane	0.00	0.00	0.00
13	1,1 - Dichloroethane	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	*	*	*
55	Naphthalene	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.000	0.007	0.000
119	Chromium, Total	0.700	1.520	0.580
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	4.350	10.50	4.370
121	Cyanide, Total	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA
122	Lead	0.160	0.280	0.000
123	Mercury	0.0080	0.0000	0.0000
124	Nickel	0.610	1.450	0.570
125	Selenium	0.000	0.000	0.000
126	Silver	12.00	24.10	13.90
128	Zinc	0.180	0.440	0.380
	Aluminum	3.400	12.00	0.480
	Ammonia	NA	NA	NA
	Iron	NA	NA	NA
	Manganese	0.110	0.078	0.100
	Phenols, Total	NA	NA	NA
	Oil & Grease	NA	NA	NA
	Total Suspended Solids	27.0	23.0	13.0
	pH, minimum	2.0	2.2	2.1
	pH, maximum	2.6	2.5	2.5

NA - Not Analyzed
* - ≤ 0.01

TABLE V-114

POLLUTANT MASS LOADINGS IN THE SILVER POWDER PRODUCTION ELEMENT WASTE STREAMS

		mg/kg		
	Flow (l/kg)	23.72	20.14	19.80
	Temperature (Deg C)	14.0	15.0	14.0
11	1,1,1 - Trichloroethane	0.00	0.00	0.00
13	1,1 - Dichloroethane	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000
118	Cadmium	0.000	0.141	0.000
119	Chromium, Total	16.60	30.61	11.48
	Chromium, Hexavalent	0.000	0.000	0.000
120	Copper	103.1	211.5	86.6
121	Cyanide, Total	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA
122	Lead	3.794	5.64	0.000
123	Mercury	0.1897	0.0000	0.0000
124	Nickel	14.46	29.20	11.29
125	Selenium	0.000	0.000	0.000
126	Silver	284.5	485.4	275.2
128	Zinc	4.268	8.86	7.52
	Aluminum	80.6	241.7	9.50
	Ammonia	NA	NA	NA
	Iron	NA	NA	NA
	Manganese	2.608	1.571	1.980
	Phenols, Total	NA	NA	NA
	Oil & Grease	NA	NA	NA
	Total Suspended Solids	641.0	463.3	257.4
	pH, minimum	2.0	2.2	2.1
	pH, maximum	2.6	2.5	2.5

NA - Not Analyzed

TABLE V-115

POLLUTANT CONCENTRATIONS IN THE SILVER PEROXIDE PRODUCTION ELEMENT WASTE STREAMS

		mg/l
	Temperature (Deg C)	NA
11	1,1,1-Trichloroethane	*
13	1,1-Dichloroethane	0.00
29	1,1-Dichloroethylene	0.00
30	1,2-Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	*
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.000
115	Arsenic	5.910
118	Cadmium	0.000
119	Chromium, Total	0.090
	Chromium, Hexavalent	I
120	Copper	0.000
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.000
123	Mercury	0.0370
124	Nickel	0.000
125	Selenium	4.800
126	Silver	0.770
128	Zinc	0.075
	Aluminum	0.000
	Ammonia	NA
	Iron	NA
	Manganese	0.000
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	31.0
	pH, Minimum	11.0
	pH, Maximum	12.5

I - Interference
NA - Not Analyzed
* - ≤ 0.01

TABLE V-116

POLLUTANT MASS LOADINGS IN THE SILVER PEROXIDE PRODUCTION ELEMENT WASTE STREAMS

		mg/kg
	Flow (l/kg)	14.28
	Temperature (Deg C)	NA
11	1,1,1-Trichloroethane	0.00
13	1,1-Dichloroethane	0.00
29	1,1-Dichloroethylene	0.00
30	1,2-Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.043
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.000
115	Arsenic	84.4
118	Cadmium	0.000
119	Chromium, Total	1.285
	Chromium, Hexavalent	I
120	Copper	0.000
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.000
123	Mercury	0.5284
124	Nickel	0.000
125	Selenium	68.5
126	Silver	11.00
128	Zinc	1.071
	Aluminum	0.000
	Ammonia	NA
	Iron	NA
	Manganese	0.000
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	442.7
	pH, Minimum	11.00
	pH, Maximum	12.5

I - Interference
NA - Not Analyzed

TABLE V-117

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

		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	7.1	30.0	23.8	16.8	19	0	19
11	1,1,1-Trichloroethane	0.00	7.79	0.340	*	12	11	23
13	1,1-Dichloroethane	0.00	0.033	0.002	0.00	7	8	15
29	1,1-Dichloroethylene	0.00	1.187	0.079	0.00	5	10	15
30	1,2-Trans-dichloroethylene	0.00	0.030	0.002	0.00	2	13	15
38	Ethylbenzene	0.00	*	*	0.00	2	13	15
44	Methylene chloride	0.00	0.649	0.028	0.00	10	13	23
55	Naphthalene	0.00	0.031	*	0.00	7	8	15
64	Pentachlorophenol	0.00	*	*	0.00	1	7	8
66	Bis(2-ethylhexyl)phthalate	*	3.816	0.632	0.028	8	0	8
70	Diethyl phthalate	0.00	*	*	0.00	7	8	15
85	Tetrachloroethylene	0.00	0.046	0.003	0.00	3	12	15
86	Toluene	0.00	0.204	0.014	0.00	7	8	15
87	Trichloroethylene	0.00	0.723	0.032	0.00	10	13	23
114	Antimony	0.000	0.130	0.006	0.000	1	22	23
115	Arsenic	0.000	0.148	0.034	0.004	13	9	22
118	Cadmium	0.000	0.460	0.064	0.014	18	5	23
119	Chromium, Total	0.000	30.00	2.901	0.036	21	2	23
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	20	20
120	Copper	0.000	2.881	0.464	0.103	22	0	22
121	Cyanide, Total	0.000	0.106	0.011	0.001	8	5	13
	Cyanide, Amn. to Chlor.	0.000	0.005	0.002	0.000	5	7	12
122	Lead	0.000	0.196	0.031	0.000	10	12	22
123	Mercury	0.0007	29.98	3.409	0.1085	21	0	21
124	Nickel	0.000	20.29	2.300	0.064	22	0	22
125	Selenium	0.000	0.012	0.001	0.000	3	13	16
126	Silver	0.0000	12.20	1.830	0.1243	16	7	23
128	Zinc	0.026	156.9	31.21	13.30	23	0	23
	Aluminum	0.000	2.109	0.466	0.148	12	3	15
	Ammonia	0.15	7.98	2.60	1.10	9	0	9
	Iron	0.099	4.000	2.639	3.819	3	0	3
	Manganese	0.000	58.67	5.661	0.069	21	2	23
	Phenols, Total	0.000	3.570	0.352	0.016	15	1	16
	Oil & Grease	0.5	31200.	2230.0	13.9	16	0	16
	Total Suspended Solids	3.4	6460.0	636.0	80.2	23	0	23
	pH, Minimum	1.0	10.8	6.7	7.9	20	0	20
	pH, Maximum	9.8	13.5	11.9	12.1	20	0	20

* - ≤ 0.01

TABLE V-118

TREATMENT IN-PLACE AT ZINC SUBCATEGORY PLANTS

PLANT ID	TREATMENT IN-PLACE	DISCHARGE 1/
A	Chemical reduction	I
B	pH adjust, settling, filtration	D
C	Settling, pH adjust, in-process Cd, Ni recovery	I
D	Settling	D
E	Filtration, carbon adsorption, lagooning	D
F	None	Zero
G	None	Zero
H	pH adjust, settling	Zero 2/
I	pH adjust	I
J	Skimming, sand filter, amalgamation, carbon adsorption	I
K	pH adjust, coagulant addition, sulfide precipitation, clarification	I
L	pH adjust, coagulant addition, sulfide precipitation, clarification	I
M	None	I
N	Settling, sand filtration, carbon adsorption	I
O	Chemical reduction, settling	I
P	Chemical reduction, settling	I
Q	Settling (upgraded to settling, filtration, ion exchange, metal recovery)	I

1/ I = Indirect
D = Direct
2/ Not presently active in this subcategory

TABLE V-119
TREATMENT PRACTICES AND EFFLUENT QUALITY AT ZINC SUBCATEGORY PLANTS EFFLUENT ANALYSIS

PLANT ID	Treatment	Cd	Cr	Cu	Cn	Pb	Hg	Ni	Ag	Zn	NH_3	Fe	Mn	TSS	pH
A	pH Adjust Settle-Filter			0.8			0.04			1.3					
B	Settle	0.20		1.0	0.005		0.01			2.0				30.	6.0-9.5
C	Settle	0.10		8.	0.01	0.8		0.16	0.02	274.		2.52	0.84		
	Filter-Carbon Adsorption	ND		10.		10.	0.0017	10.	10.	.37		10.	0.50	10.	
D	Skim-Filter-Carbon Adsorption						0.0086			2.1			4.1		11.7
E	pH Adjust-Chem Precipitation Settle-Filter						0.20								
F	pH Adjust-Chem Precipitation-Settle		0.10				0.01			0.70					
G	None		0.21				0.13			0.74		10.	2.9	92.	
H	Filter-Carbon Adsorption						0.0005	ND		0.03					
I	Amalgamation-Settle						0.076			3.99					
J	Amalgamation-Settle		<0.005	0.047		0.011	0.33	0.005	1.24	0.291	8.		0.281	200.	11.2
K	Settle			0.0403		0.006	0.19	<0.005	0.143	0.194	15.	0.235			8.2

ND - Not Detected

TABLE V-120

PERFORMANCE OF SULFIDE PRECIPITATION ZINC SUBCATEGORY

		Plant A				Plant B		
	Pollutant or Pollutant Parameter	Day 1 (mg/l)		Day 2 (mg/l)		Zinc Subcat Only (mg/l)	Combined Wastes (Including HgO Production) (mg/l)	
		Raw Waste	Effluent	Raw Waste	Effluent	Effluent	Raw Waste	Effluent
118	Cadmium	0.000	0.000	0.000	0.000	0.000	0.160	0.000
119	Chromium	24.40	0.210	30.00	1.000	0.005	2.130	0.000
120	Copper	0.097	0.014	0.500	0.000	0.032	0.078	0.047
121	Cyanide	0.015	0.000	0.000	0.000	0.032	0.000	0.053
122	Lead	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123	Mercury	I	0.000	0.2654	0.0197	I	110.0	0.060
124	Nickel	0.430	0.075	0.800	0.000	0.035	0.000	0.000
126	Silver	0.000	0.012	0.000	0.000	0.013	0.088	0.000
128	Zinc	13.30	26.50	40.00	7.00	0.100	21.00	0.226
	Iron	NA	NA	4.000	2.000	NA	2.06	62.8
	Manganese	1.500	1.890	30.00	0.900	0.760	0.450	0.377
	Oil & Grease	31220.0	7.0	3340.0	14.0	2.9	6.7	380.0
	TSS	1700.0	5.0	4600.0	26.0	26.0	270.0	380.0
	pH Minimum	7.8	6.8	7.8	7.0	6.8	-	-
	pH Maximum	9.8	6.9	9.8	7.0	7.3	-	-

I - Analytical Interference
NA - Not Analyzed

TABLE V-121
PERFORMANCE OF LIME, SETTLE, AND FILTER - ZINC SUBCATEGORY

		TREATMENT SYSTEM I						TREATMENT SYSTEM II			
		Day 1		Day 2		Day 3		Day 2		Day 3	
		Raw Waste	Effluent	Raw Waste	Effluent	Raw Waste	Effluent	Raw Waste	Effluent	Raw Waste	Effluent
118	Cadmium	0.026	0.490	0.004	0.140	2.040	0.067	0.071	0.012	0.058	0.004
119	Chromium (Total)	0.000	0.000	0.000	0.000	0.081	0.006	0.025	0.014	0.059	0.018
120	Copper	NA	NA	NA	NA	NA	NA	0.300	0.081	0.610	0.200
121	Cyanide	0.000	0.000	0.000	0.000	0.000	0.000	NA	NA	NA	NA
122	Lead	NA	NA	NA	NA	NA	NA	0.078	0.000	0.140	0.000
123	Mercury	0.000	0.000	0.000	0.000	100.0	0.000	0.100	0.074	0.160	0.080
124	Nickel	59.0	1.760	1.960	0.800	1100.0	0.500	0.000	0.000	0.023	0.020
126	Silver	NA	NA	NA	NA	NA	NA	0.120	0.025	0.270	0.007
128	Zinc	0.220	0.016	0.150	0.000	9.26	0.000	53.0	9.57	129.0	7.02
	Iron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Manganese	NA	NA	NA	NA	NA	NA	0.010	0.210	0.006	0.000
	Oil & Grease	2.4	1.2	3.0	0.0	1.5	1.5	NA	NA	NA	NA
	TSS	96.0	0.0	28.0	0.0	401.0	0.0	122.0	30.0	96.0	32.0
	pH minimum	7.7	8.9	8.5	8.5	2.1	9.8	11.9	11.9	11.4	9.4
	pH maximum	10.9	8.9	10.5	10.5	2.1	9.8	11.9	11.9	11.4	9.9

		TREATMENT SYSTEM III						TREATMENT SYSTEM IV	
		Day 1		Day 2		Day 3			
		Raw Waste	Effluent	Raw Waste	Effluent	Raw Waste	Effluent	Raw Waste	Effluent
118	Cadmium	0.000	0.029	0.007	0.008	0.000	0.011	0.008	0.000
119	Chromium (Total)	0.700	0.020	1.520	0.059	0.580	0.018	0.007	0.005
120	Copper	4.35	26.8	10.50	29.90	4.370	15.30	4.110	0.100
121	Cyanide	NA	NA	NA	NA	NA	NA	NA	NA
122	Lead	0.160	0.000	0.280	0.000	0.000	0.000	0.200	0.000
123	Mercury	0.008	0.000	0.000	0.000	0.000	0.030	0.009	0.008
124	Nickel	0.610	0.620	1.450	0.550	0.570	0.500	0.050	0.130
126	Silver	12.00	0.220	24.10	0.240	13.90	0.270	0.320	0.042
128	Zinc	0.180	1.410	0.440	3.090	0.380	2.840	29.40	1.180
	Iron	NA	NA	NA	NA	NA	NA	NA	NA
	Manganese	0.110	0.160	0.078	0.010	0.100	0.090	0.024	0.011
	Oil & Grease	NA	NA	NA	NA	NA	NA	NA	NA
	TSS	27.0	51.0	23.0	216.0	13.0	18.0	86.0	17.0
	pH minimum	2.0	6.7	2.2	9.2	2.1	9.9	11.8	9.2
	pH maximum	2.6	11.4	2.5	9.2	2.5	9.9	11.8	9.2

TABLE V-122

PERFORMANCE OF AMALGAMATION - ZINC SUBCATEGORY

mg/l

Plant A

		Day 2	Day 3
118	Cadmium	0.008	0.007
119	Chromium	0.018	0.006
120	Copper	0.110	0.200
122	Lead	0	0.036
123	Mercury	0.083	0.370
124	Nickel	0.015	0.019
126	Silver	0	0
128	Zinc	190.0	64.0
	Manganese	0.20	0.15
	Oil & Grease	5.7	0
	TSS	395.0	370.0

Plant B

		Before Amalgamation	After Amalgamation
118	Cadmium	0.008	0.0
119	Chromium	15.10	15.60
120	Copper	0.300	0.720
122	Lead	016.40	7.88
123	Mercury	30000.0	2600.0
124	Nickel	9.10	7.30
126	Silver	0.046	0.120
128	Zinc	1200.0	870.0
	Manganese	0.980	12.60
	Oil & Grease	NA	14.0
	TSS	11.0	220.0
	pH	1.0	1.6

NA - Not analyzed

TABLE V-123

PERFORMANCE OF SKIMMING, FILTRATION, AMALGAMATION, AND CARBON ADSORPTION - ZINC SUBCATEGORY

			mg/l	
		Day 1	Day 2	Day 3
118	Cadmium	0.110	0.078	0.010
119	Chromium	0.061	0.017	0.004
120	Copper	0.420	0.500	0.330
122	Lead	0.0	0.0	0.0
123	Mercury	I	I	I
124	Nickel	0.500	1.29	0.82
126	Silver	0.0	0.0	0.0
128	Zinc	736.0	480.0	455.0
	Manganese	4.60	9.60	7.10
	Oil & Grease	58.0	69.0	37.0
	TSS	100.0	9.0	69.0
	pH	12.8 - 13.6	11.8 - 13.2	11.4 - 13.2

I - Analytical interference

TABLE V-124

PERFORMANCE OF SETTLING, FILTRATION AND ION EXCHANGE - ZINC SUBCATEGORY

		mg/l	
		Day 2	Day 3
118	Cadmium	0.026	0.024
119	Chromium	0.027	0.036
120	Copper	0.033	0.042
122	Lead	0.0	0.0
123	Mercury	0.021	0.059
124	Nickel	0.0	0.0
126	Silver	1.13	0.880
128	Zinc	0.94	0.59
	Manganese	0.007	0.005
	TSS	36.0	44.0
	pH	12.1	12.6

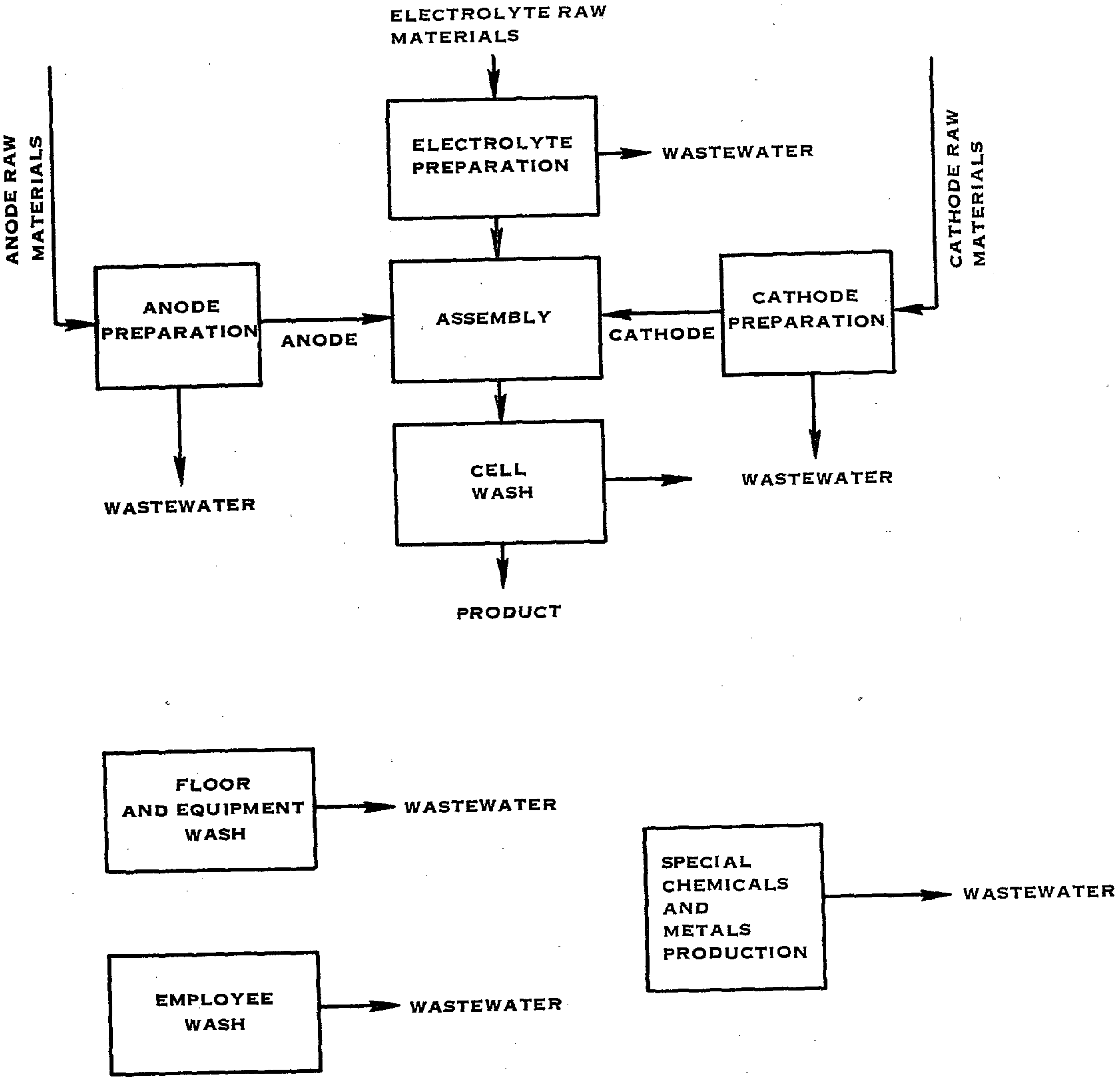

FIGURE V-1
GENERALIZED CADMIUM SUBCATEGORY MANUFACTURING PROCESS

FIGURE V-2

CADMIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources (Subelements)
Anode Manufacture	Pasted and Pressed Powder	• Process Area Clean-up
	Electrodeposited	• Product Rinses • Spent Caustic • Scrubbers
	Impregnated	• Sintered Stock Preparation Clean-up • Impregnated Rinses • Spent Impregnation Caustic • Product Cleaning • Pre-formation Soak • Spent Formation Caustic • Post-formation Rinse
Cathode Manufacture	Silver Powder Pressed	• No Process Wastewater
	Nickel Pressed Powder	• No Process Wastewater
	Nickel Electrodeposited	• Spent Caustic • Post-formation Rinse
	Nickel Impregnated	• Sintered Stock Preparation Clean-up • Impregnation Rinses • Impregnation Scrubbers • Product Cleaning • Impregnated Plaque Scrub • Pre-formation Soak • Spent Formation Caustic • Post Formation Rinses • Impregnation Equipment Wash • Nickel Recovery Filter Wash • Nickel Recovery Scrubber
	Mercuric Oxide Powder Pressed	• No Process Wastewater
Ancillary Operations	Cell Wash	• Cell Wash

FIGURE V-2

CADMIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources (Subelements)
Ancillary Operations	Electrolyte Preparation	. Equipment Wash
	Floor and Equipment Wash	. Floor and Equipment Wash
	Employee Wash	. Employee Wash
	Cadmium Powder Production	. Product Rinses . Scrubber
	Silver Powder Production	. Product Rinses
	Nickel Hydroxide Production	. Product Rinses
	Cadmium Hydroxide Production	. Seal Cooling Water

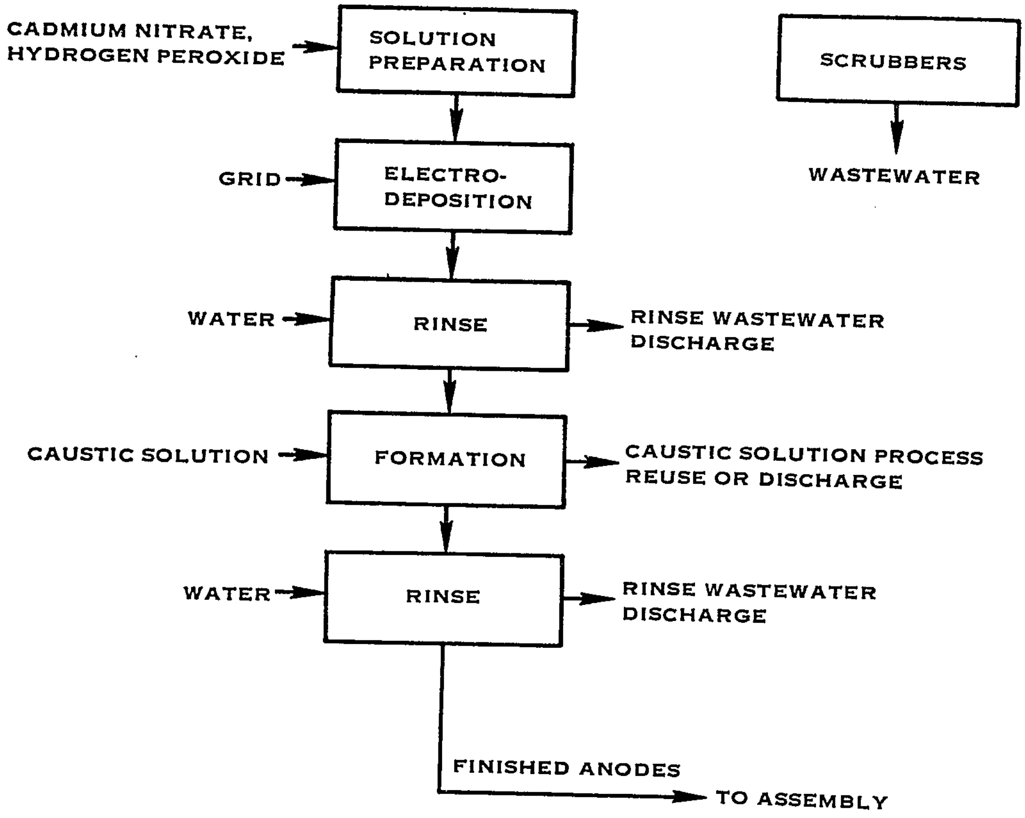

FIGURE V-3
PRODUCTION OF CADMIUM ELECTRODEPOSITED ANODES

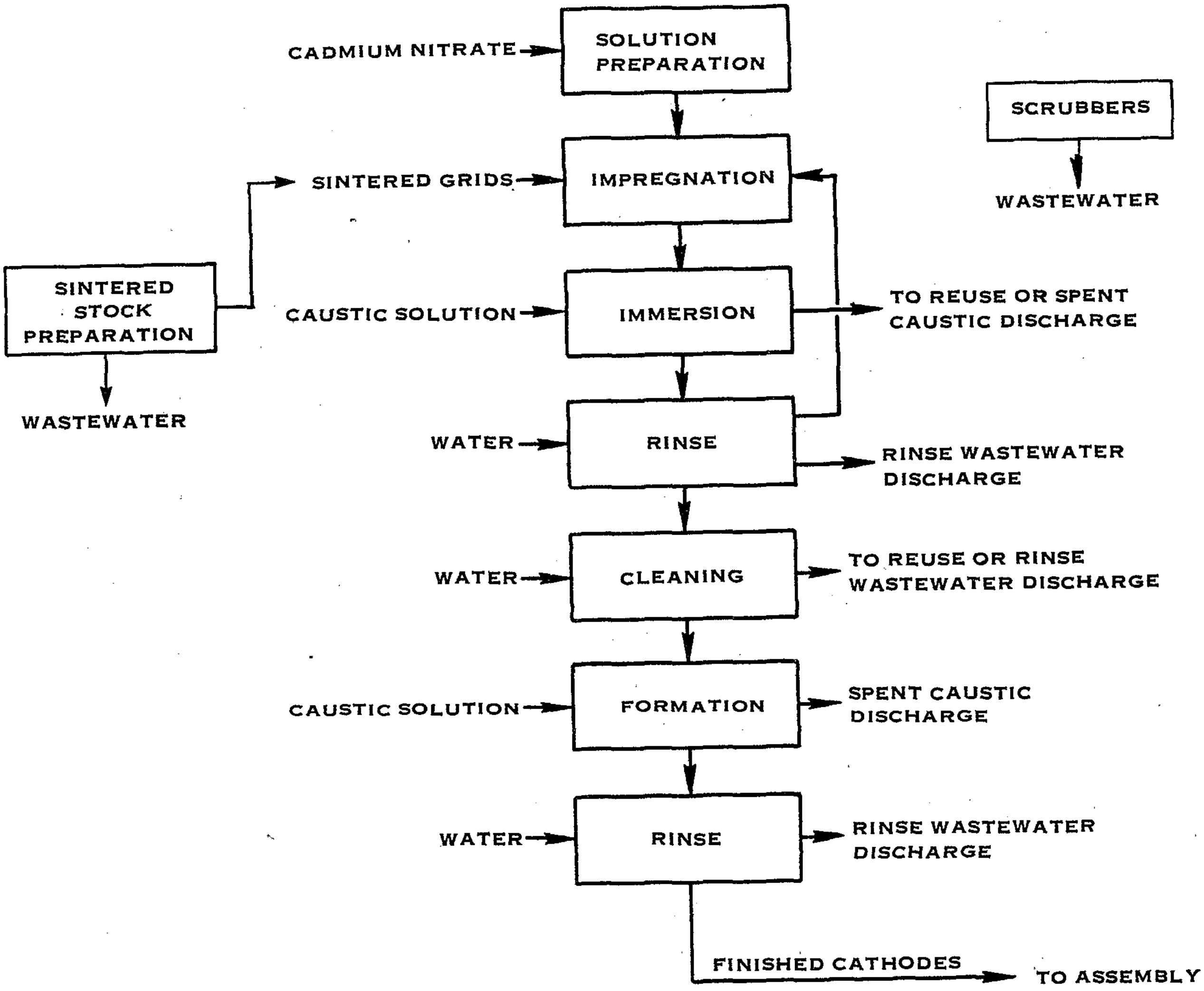

FIGURE V-4
PRODUCTION OF CADMIUM IMPREGNATED ANODES

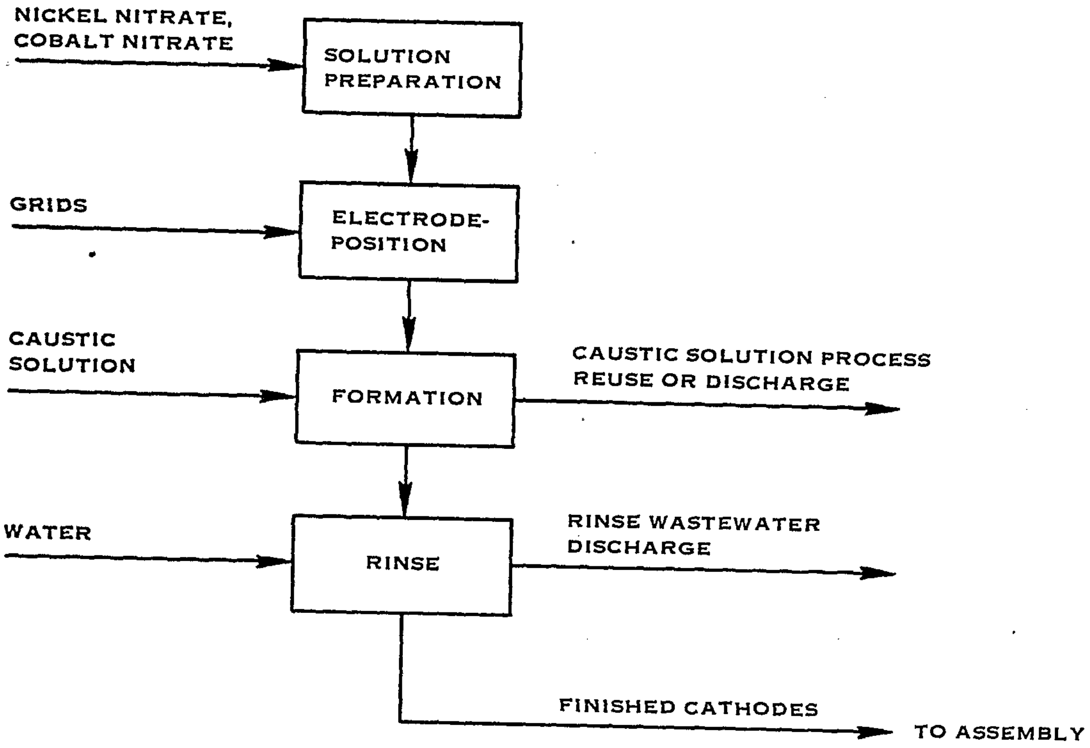

FIGURE V-5
PRODUCTION OF NICKEL ELECTRODEPOSITED CATHODES

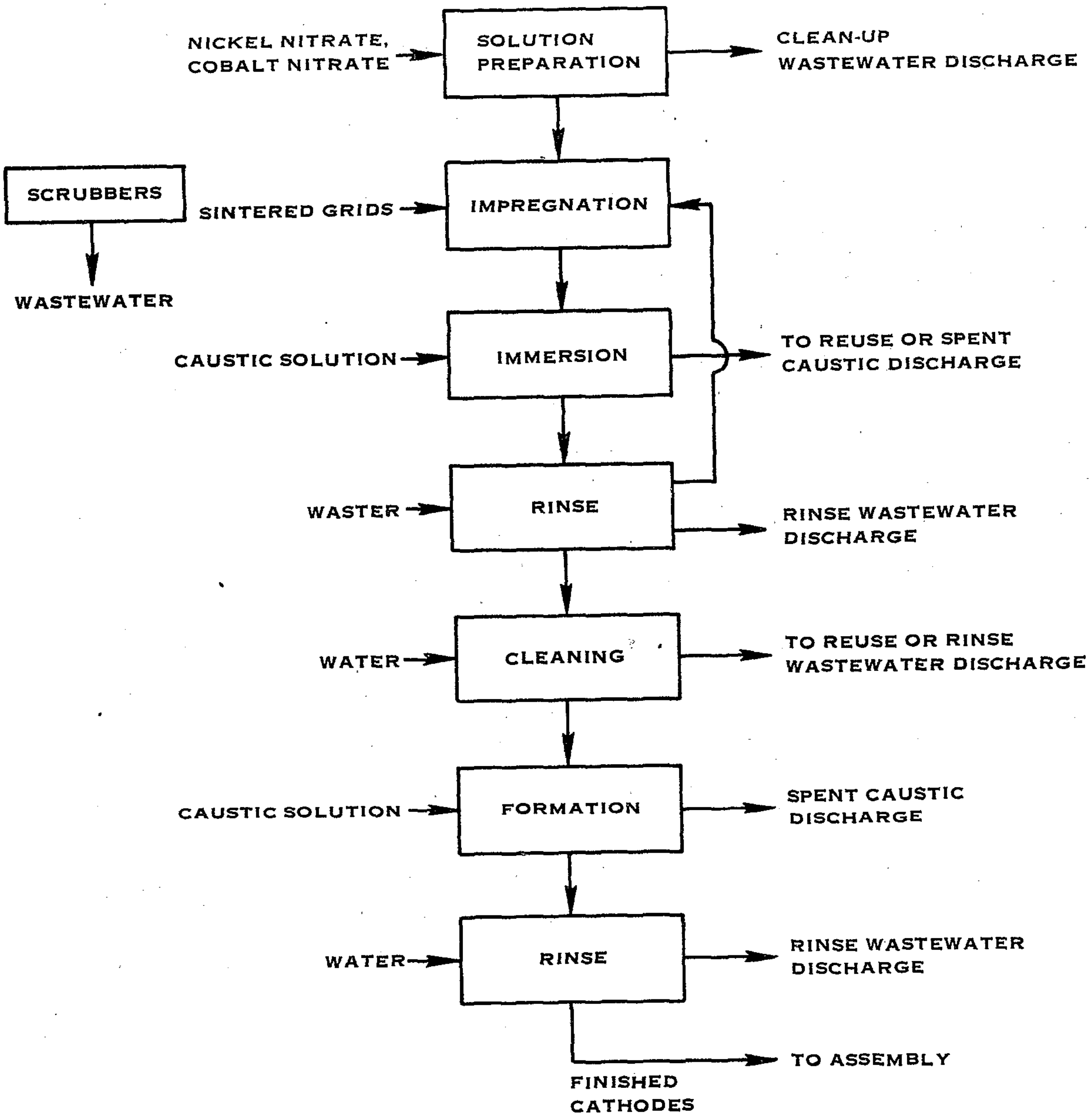

FIGURE V-6
PRODUCTION OF NICKEL IMPREGNATED CATHODES

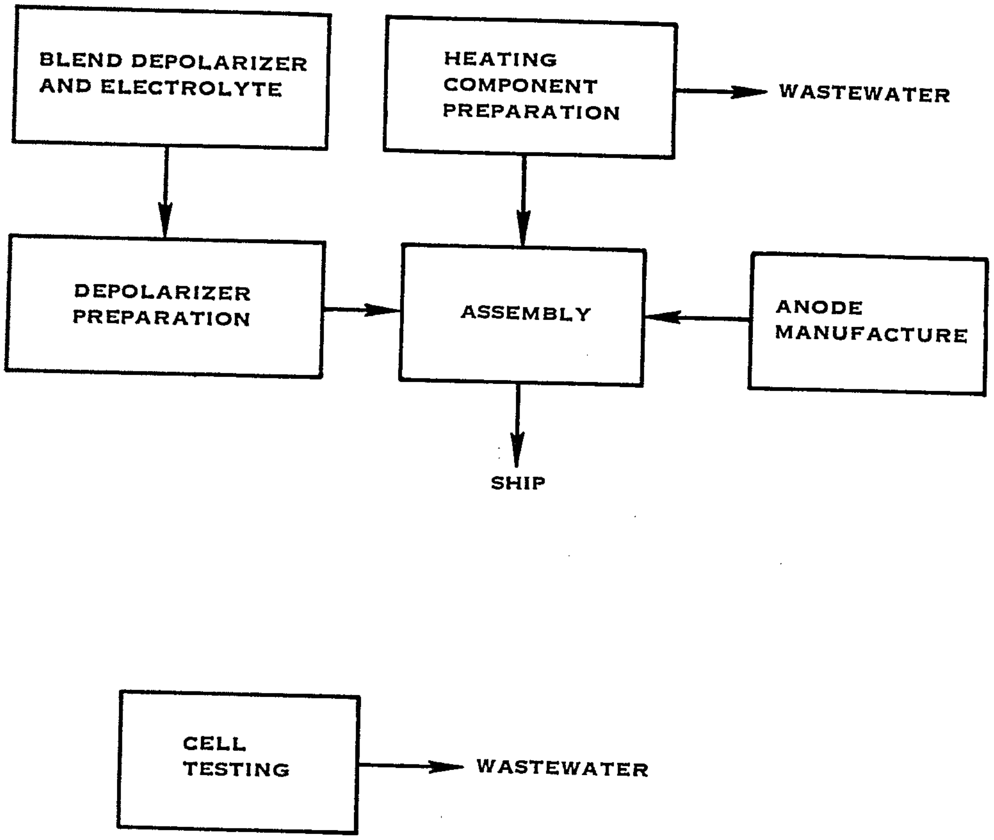

FIGURE V-7
GENERALIZED CALCIUM SUBCATEGORY MANUFACTURING PROCESS

FIGURE V-8

CALCIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources (Subelements)
Anode Manufacture	Vapor Deposited	. No Process Wastewater
	Fabricated	. No Process Wastewater
Cathode Manufacture	Calcium Chromate	. No Process Wastewater
	Tungstic Oxide	. No Process Wastewater
	Potassium Dichromate	. No Process Wastewater
Ancillary	Heating Component Production:	
	Heat Paper	. Slurry Preparation . Filtrate Discharge
	Heat Pellet	. No Process Wastewater
	Cell Testing	. Leak Testing

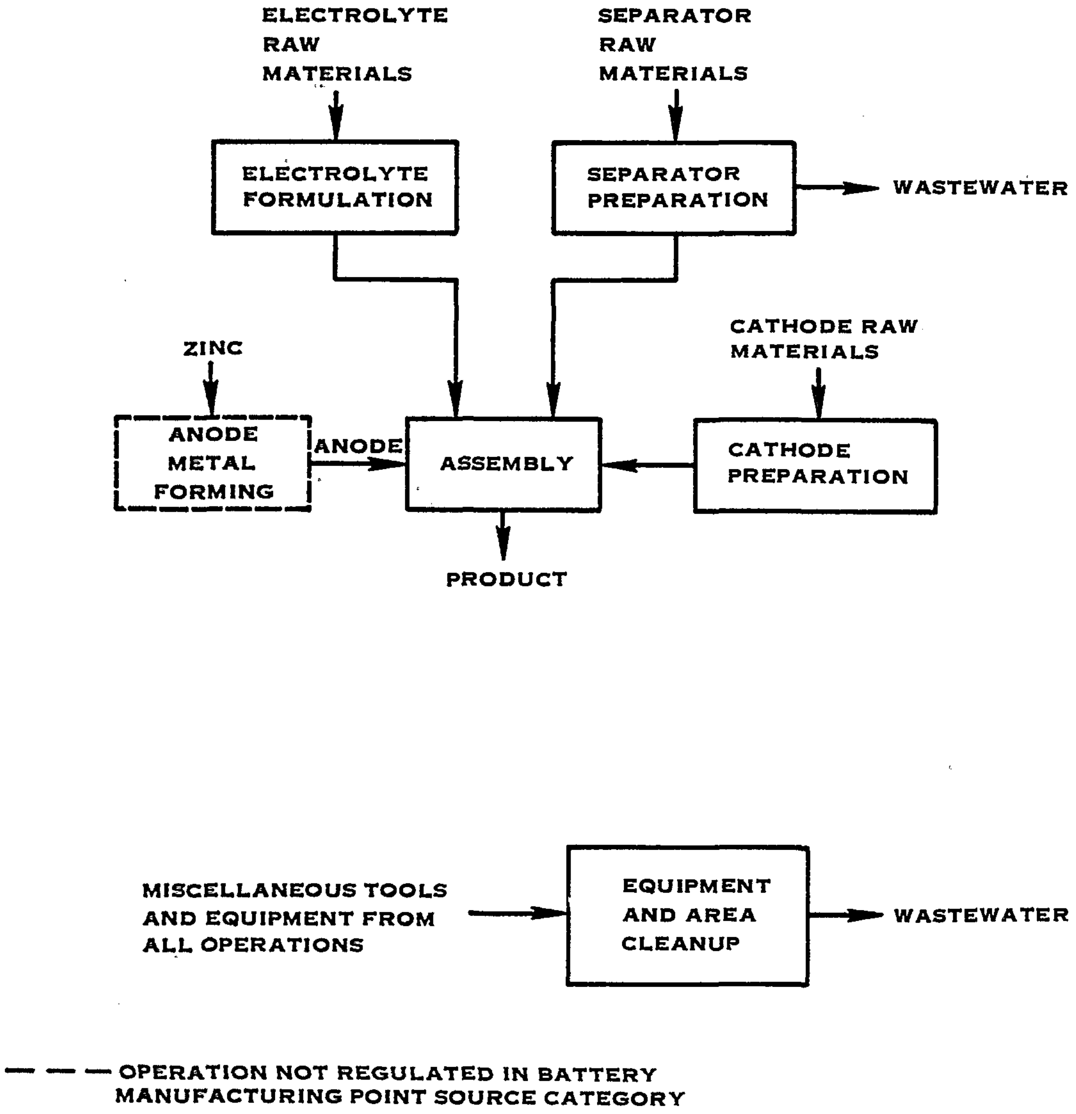

FIGURE V-9
GENERALIZED SCHEMATIC FOR LECLANCHE CELL MANUFACTURE

FIGURE V-10

LECLANCHE SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources
Anode Manufacture	Zinc Powder	. No Process Wastewater
Cathode	Manganese Dioxide - Pressed - Electrolyte with Mercury - Electrolyte without Mercury - Gelled Electrolyte with Mercury	. No Process Wastewater
	Carbon (Porous)	. No Process Wastewater
	Silver Chloride	. No Process Wastewater
	Manganese Dioxide - Pasted	. No Process Wastewater
Ancillary Operations	Separators	
	Cooked Paste	. Paste Setting
	Uncooked Paste	. Equipment Wash
	Pasted Paper with Mercury	. Equipment Wash
	Equipment and Area Cleanup	. Electrolyte Preparation . Assembly Equipment Wash . Employee Wash . Electrode Preparation Equipment Wash . Miscellaneous Equipment Wash
	Foliar Battery Miscellaneous Wash	. Miscellaneous Equipment and Area Wash

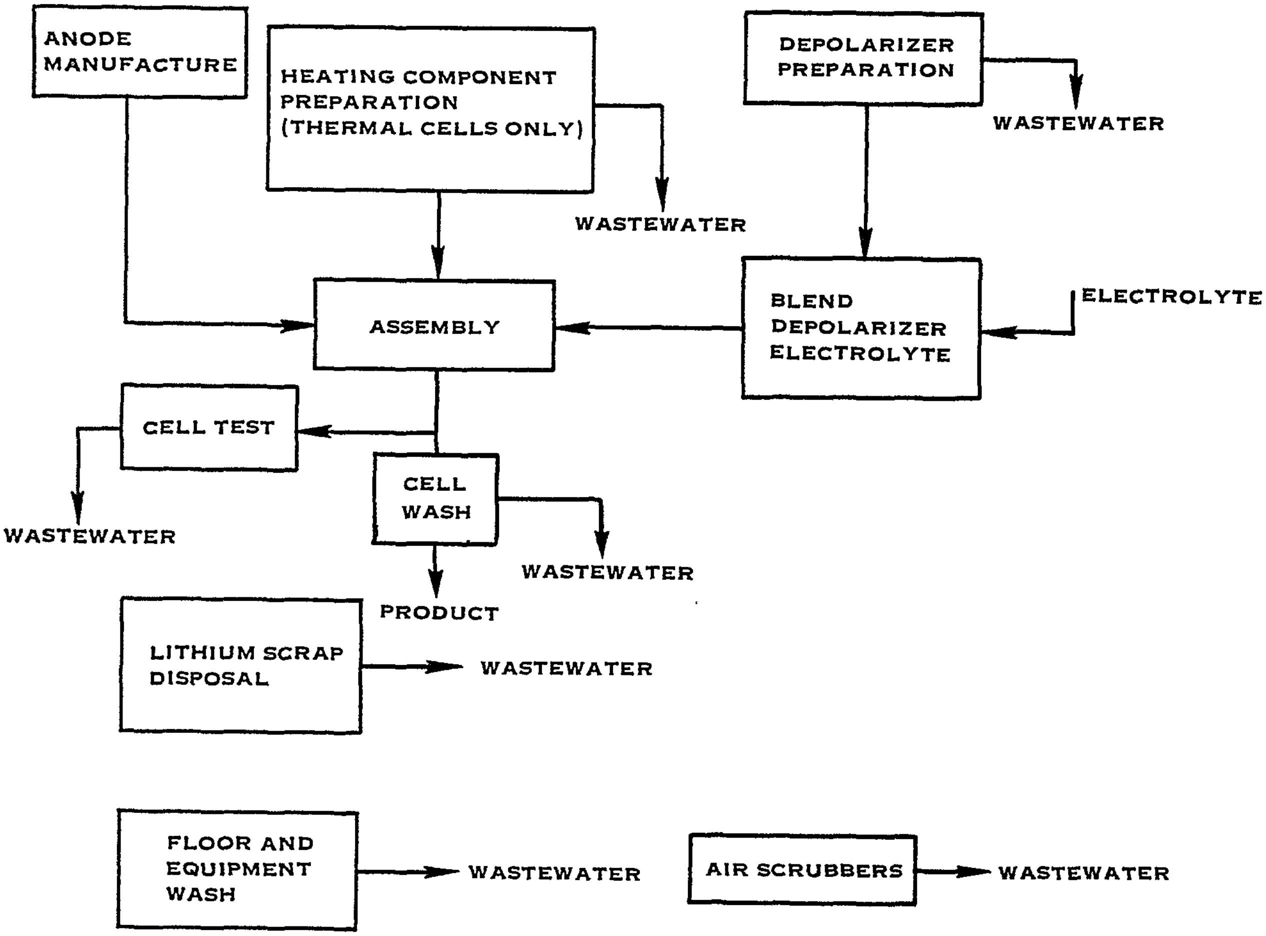

FIGURE V-11
GENERALIZED LITHIUM SUBCATEGORY MANUFACTURING PROCESS

FIGURE V-12

LITHIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources (Subelements)
Anode Manufacture	Formed and Stamped	• No Process Wastewater
Cathode Manufacture	Iodine	• No Process Wastewater
	Iron Disulfide	• Product Treatment
	Lead Iodide	• Equipment Wash
	Lithium Perchlorate	• No Process Wastewater
	Sulfur Dioxide	• Spills*
	Thionyl Chloride	• Spills*
	Titanium Disulfide	• No Process Wastewater
Ancillary Operations	Heating Component Production:	
	Heat Paper	• Filtrate Discharge • Slurry Preparation
	Heat Pellets	• No Process Wastewater
	Lithium Scrap Disposal	• Scrap Disposal
	Cell Testing	• Leak Testing
	Floor and Equipment Wash	• Floor and Equipment Wash
	Air Scrubbers	• Blowdown from various production areas
	Cell Wash	• Cell Wash

* - Wastewater discharged from air scrubbers for the manufacture of these cathodes is included with ancillary operations.

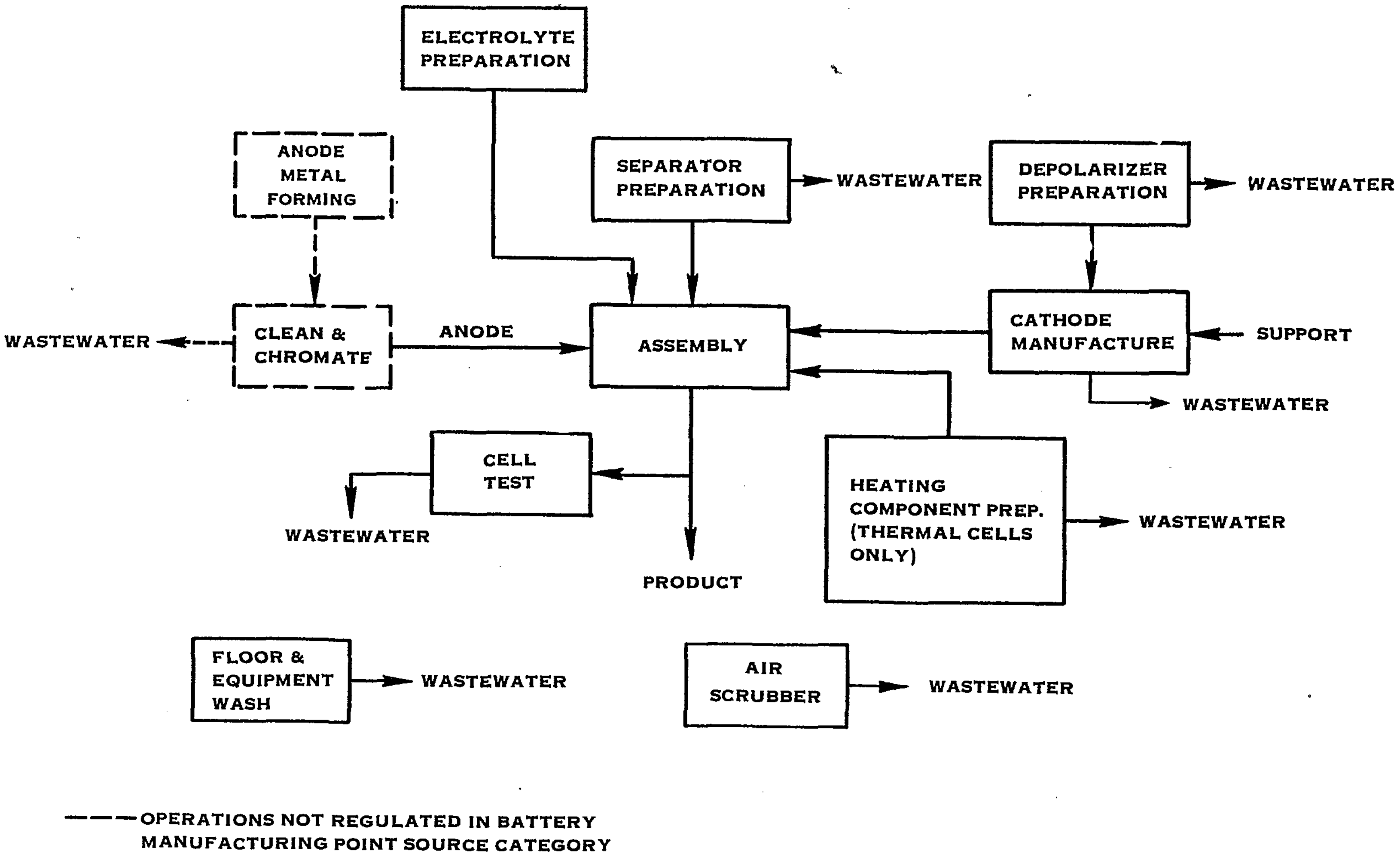

FIGURE V-13

GENERALIZED MAGNESIUM SUBCATEGORY MANUFACTURING PROCESS

FIGURE V-14

MAGNESIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Source (Subelements)
Anode Manufacture	Magnesium Powder	. No Process Wastewater
Cathode Manufacture	Carbon	. No Process Wastewater
	Copper Chloride	. No Process Wastewater
	Copper Iodide	. No Process Wastewater
	Lead Chloride	. No Process Wastewater
	M-Dinitrobenzene	. No Process Wastewater
	Silver Chloride - Chemically Reduced	. Product Rinsing
	Silver Chloride-Electrolytic	. Product Rinsing
	Silver Chloride	. No Process Wastewater
	Vanadium Pentoxide	. No Process Wastewater
Ancillary Operations	Heating Component Production:	
	Heat Paper	. Filtrate . Slurry Preparation
	Heat Pellets	. No Process Wastewater
	Cell Testing	. Activation of Sea-Water Reserve Batteries
	Separator Processing	. Etching Solution . Product Rinsing
	Floor and Equipment Wash	. Floor and Equipment Wash
	Air Scrubbers	. Blowdown from Various Production Areas

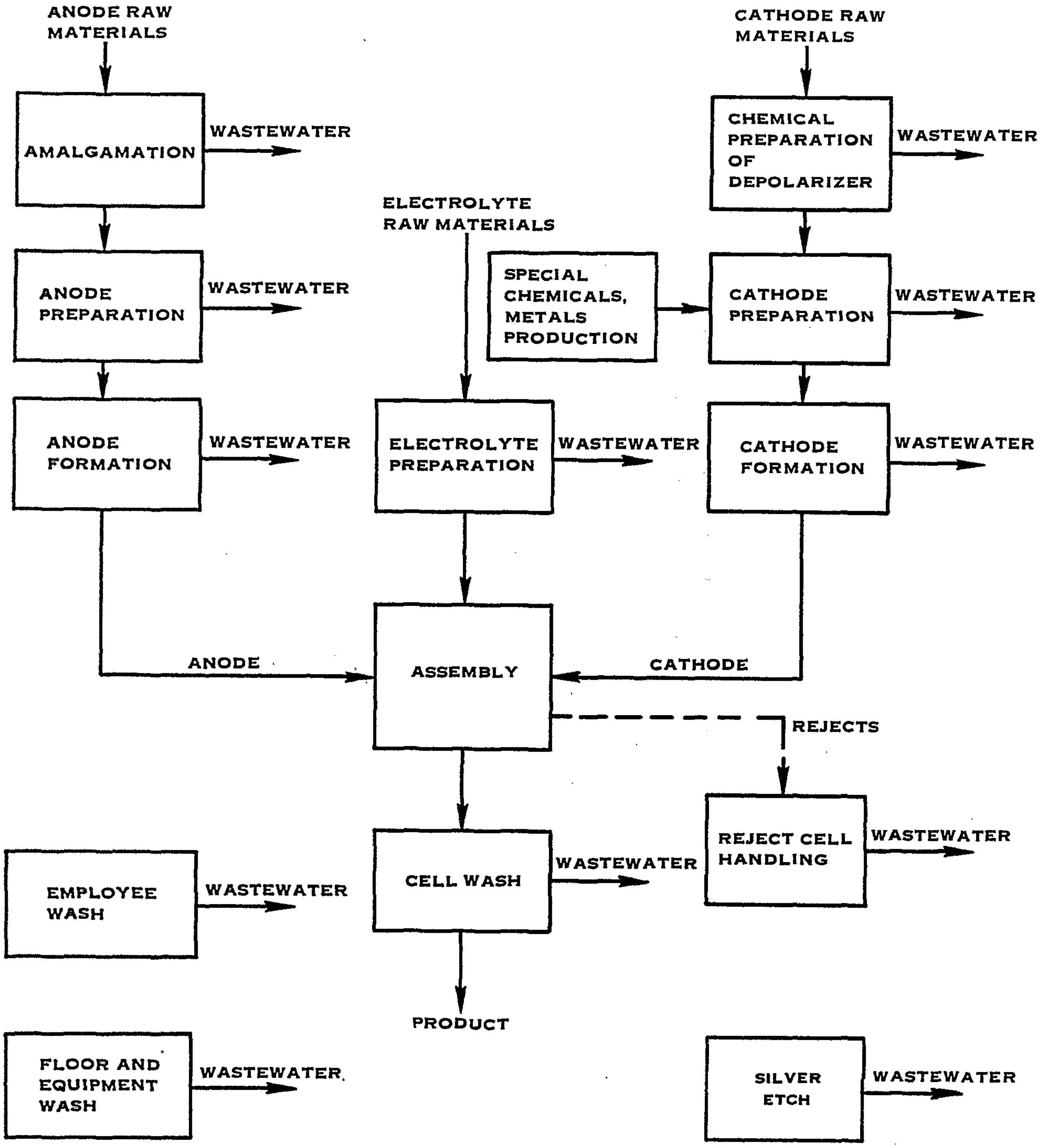

FIGURE V-15
GENERALIZED ZINC SUBCATEGORY MANUFACTURING PROCESSES

FIGURE V-16

ZINC SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources
Anode Manufacture	Cast or Fabricated	• No Process Wastewater
	Zinc Powder - Wet Amalgamated	• Floor Area and Equipment Clean-up • Spent Aqueous Solution • Amalgam Rinses • Reprocess Amalgam Rinses
	Zinc Powder - Gelled Amalgam	• Floor Area and Equipment Clean-up
	Zinc Powder - Dry Amalgamated	• No Process Wastewater
	Zinc Oxide Powder - Pasted or Pressed	• No Process Wastewater
	Zinc Oxide Powder - Pasted or Pressed, Reduced	• Post-formation Rinse
	Zinc Electrodeposited	• Post-electrodeposition Rinses • Spent Amalgamation Solution • Post-amalgamation Rinse
Cathode Manufacture	Porous Carbon	• No Process Wastewater
	Manganese Dioxide - Carbon	• No Process Wastewater
	Mercuric Oxide (and mercuric oxide - manganese dioxide carbon)	• No Process Wastewater
	Mercuric Oxide - Cadmium Oxide	• No Process Wastewater
	Silver Powder Pressed	• No Process Wastewater
	Silver Powder Pressed and Electrolytically Oxidized (Formed)	• Post-formation Rinse

FIGURE V-16

ZINC SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources
Cathode Manufacture (Contd.)	Silver Oxide (Ag_2O) Powder	. No Process Wastewater
	Silver Oxide (Ag_2O) Powder - Thermally Reduced or Sintered, Electrolytically Formed	. Slurry Paste Preparation . Spent Caustic Formation . Post-formation Rinse
	Silver Peroxide (AgO) Powder	. Utensil Wash . Spent Solution . Product Rinse . Product Soak
	Nickel Impregnated and Formed	Refer to Cadmium Subcategory Analysis (Figure V-2)
Ancillary Operations	Cell Wash	. Acetic Acid Cell Wash . Chromic Acid Containing Cell Wash . Methylene Chloride Cell Wash . Freon Cell Wash . Non-chemical Cell Wash
	Electrolyte Preparation	. Equipment Wash
	Silver Etch	. Product Rinse
	Mandatory Employee Wash	. Employee Wash
	Reject Cell Handling	. Reject Cell Handling
	Floor Wash and Equipment Wash	. Floor and Equipment Wash
	Silver Powder Production	. Product Rinse
	Silver Peroxide Production	. Product Rinses . Spent Solution

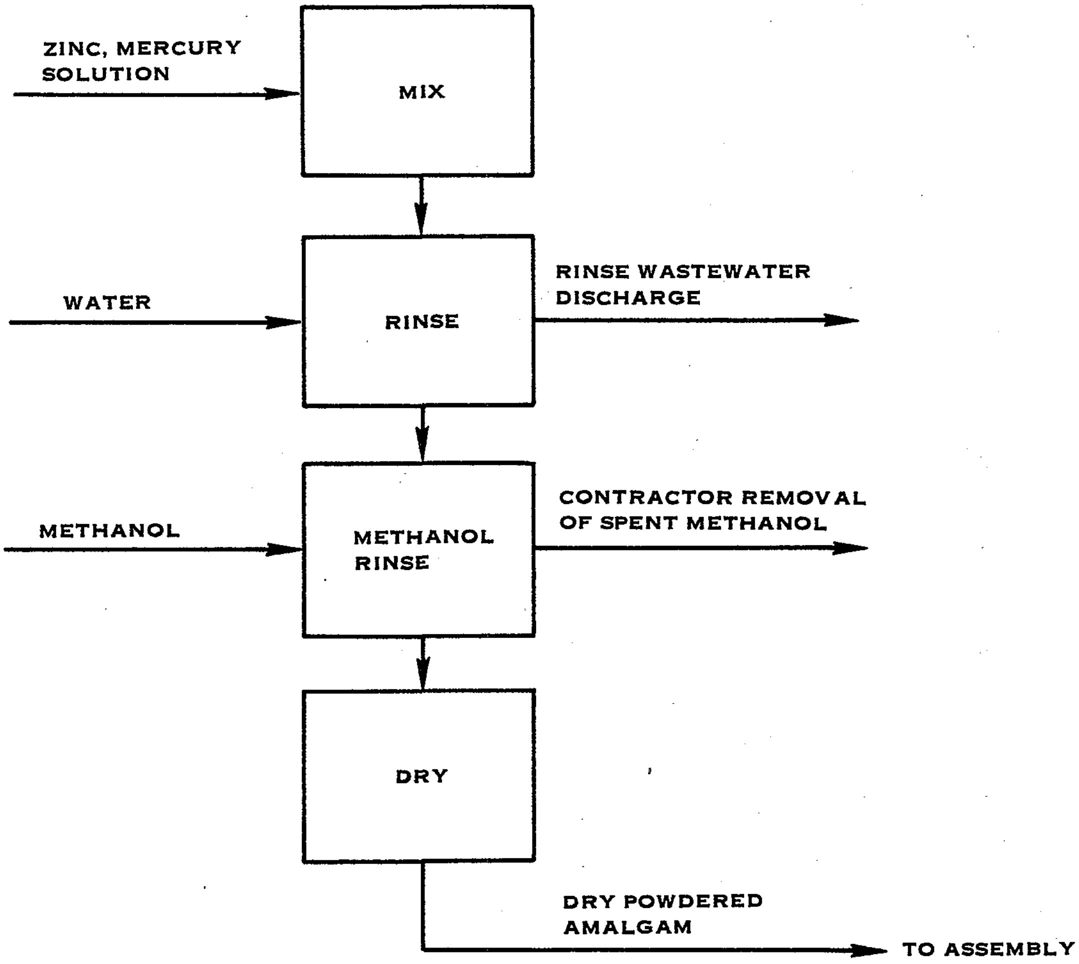

FIGURE V-17
PRODUCTION OF ZINC POWDER - WET AMALGAMATED ANODES

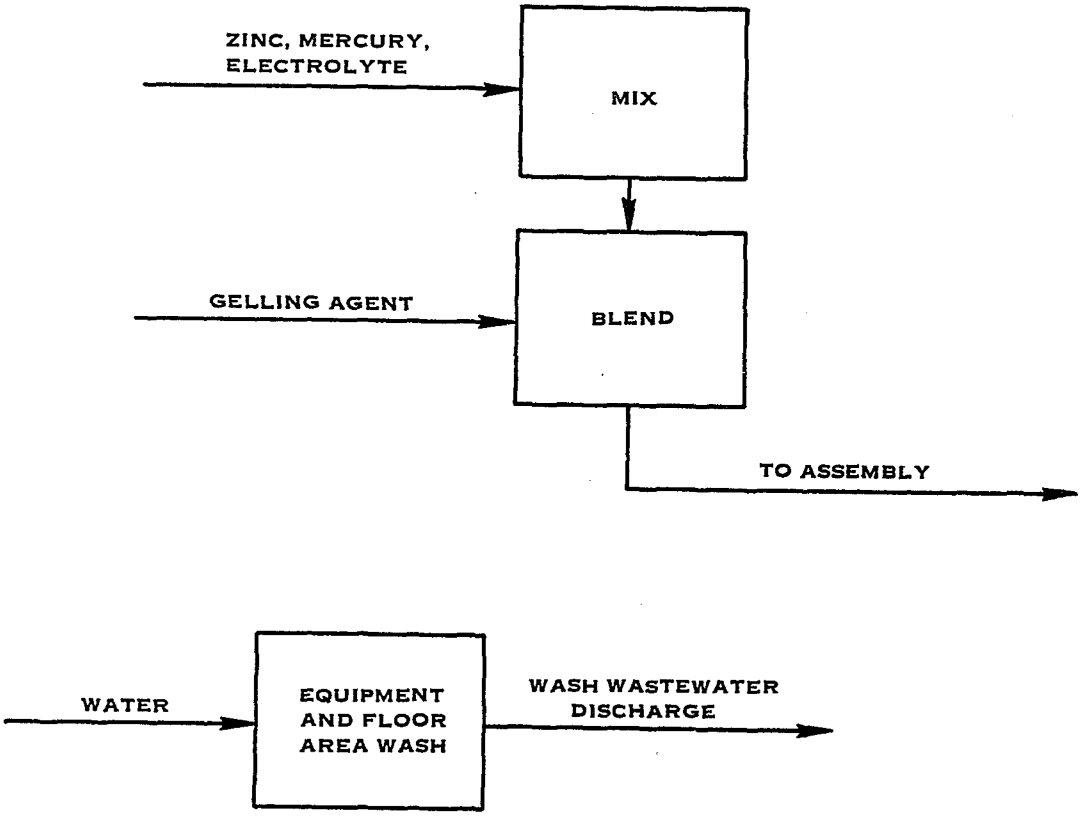

FIGURE V-18
PRODUCTION OF ZINC POWDER GELLED AMALGAM ANODES

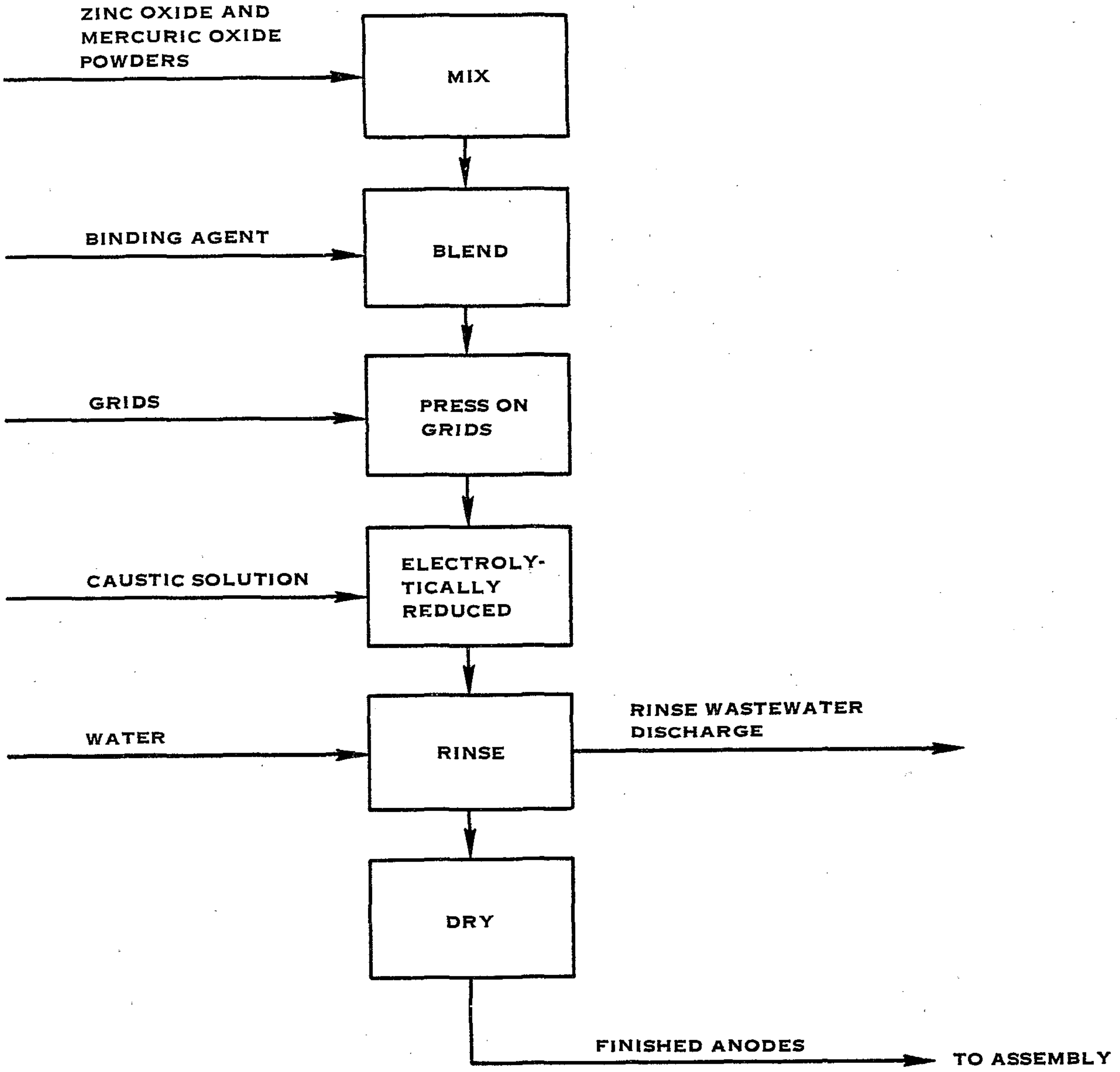

FIGURE V-19
PRODUCTION OF PRESSED ZINC OXIDE ELECTROLYTICALLY REDUCED ANODES

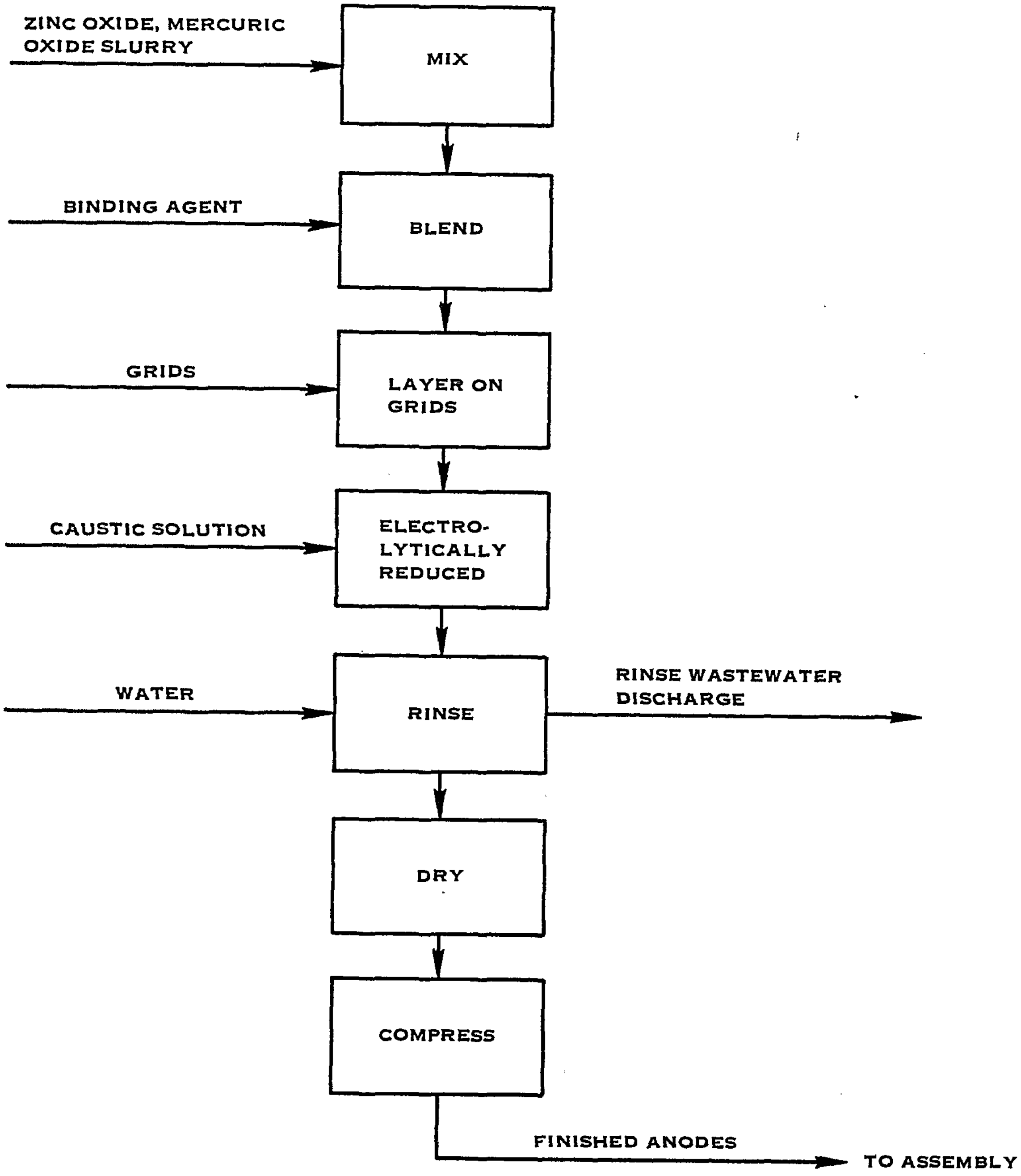

FIGURE V-20
PRODUCTION OF PASTED ZINC OXIDE ELECTROLYTICALLY REDUCED ANODES

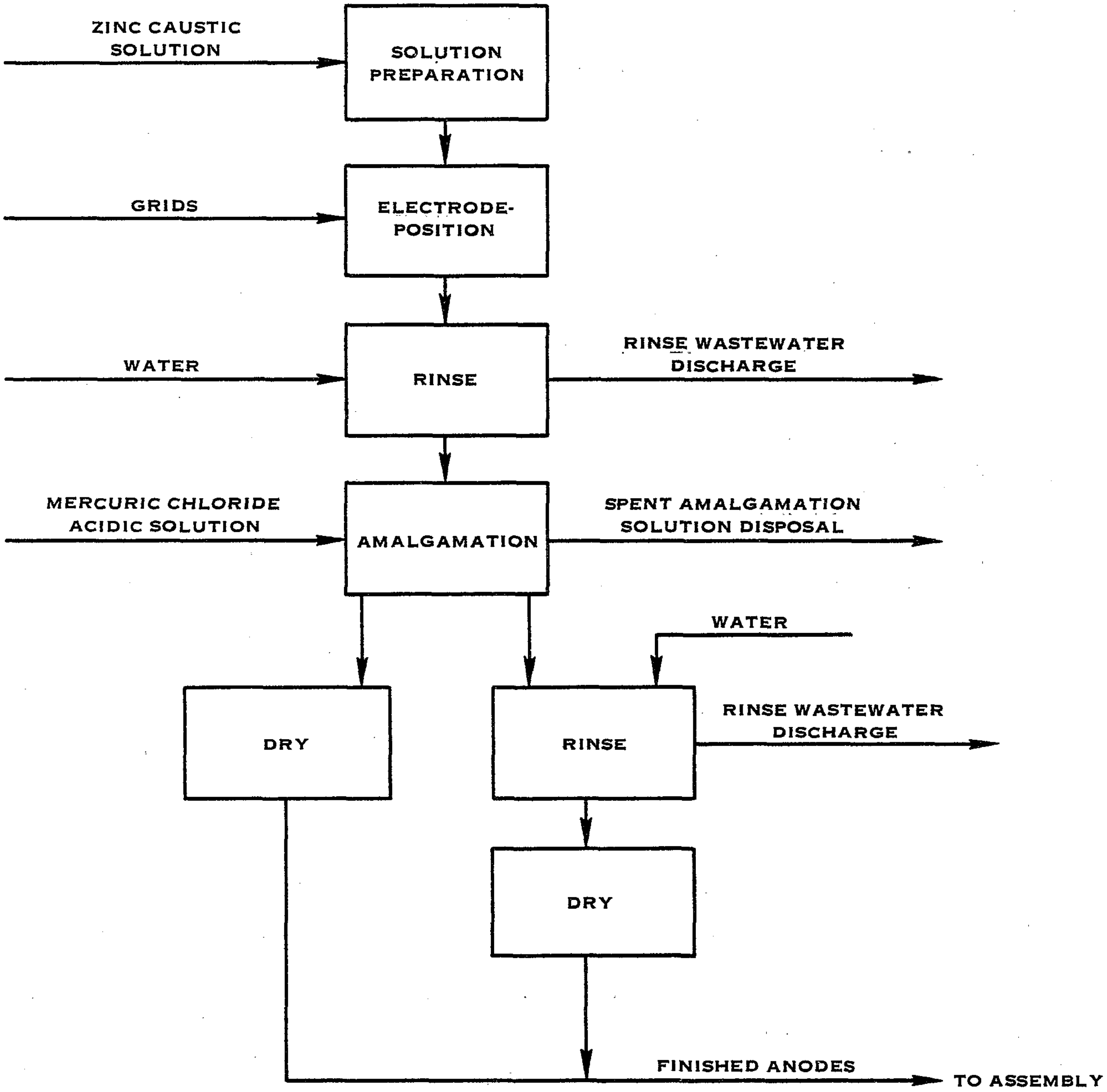

FIGURE V-21
PRODUCTION OF ELECTRODEPOSITED ZINC ANODES

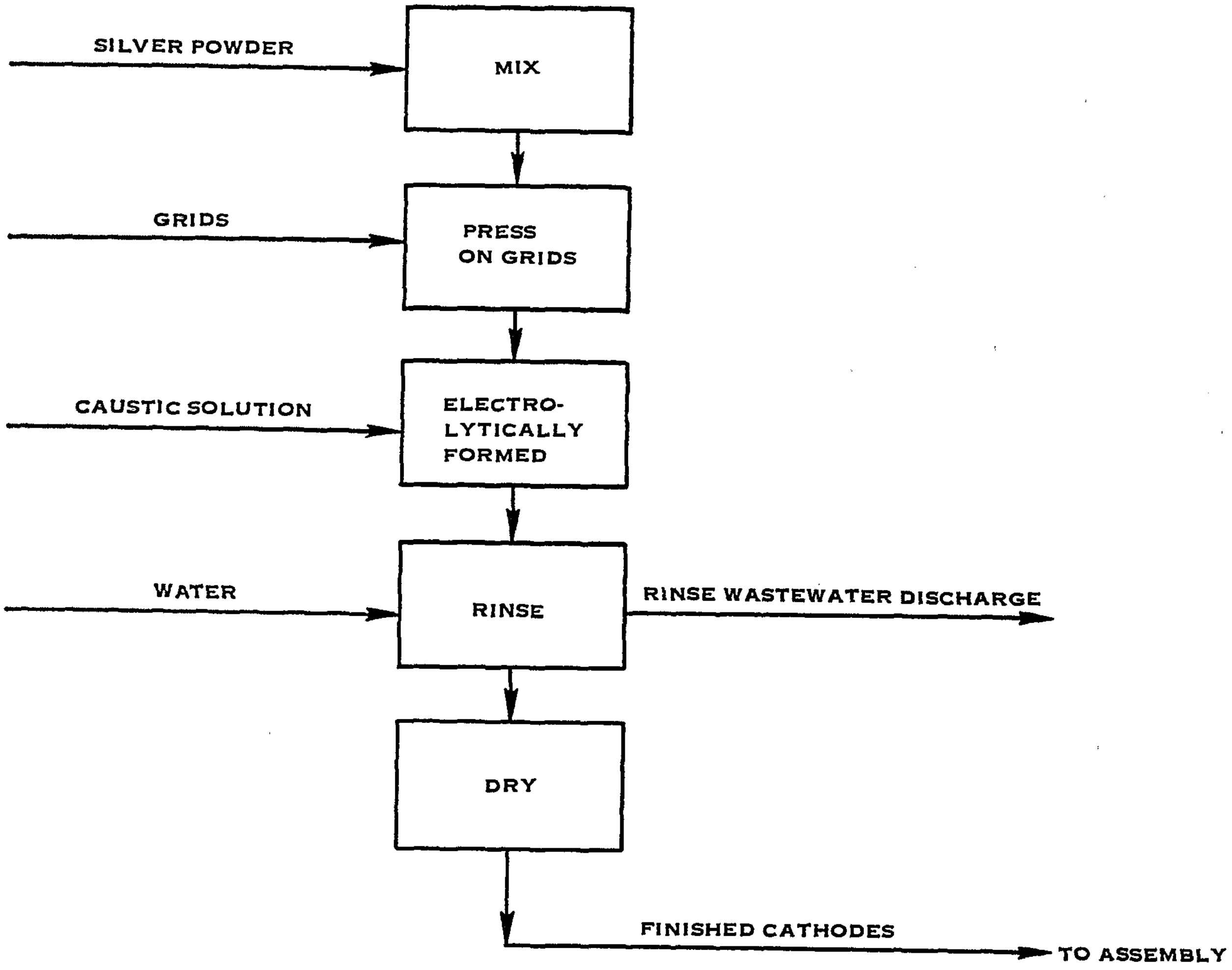

FIGURE V-22
PRODUCTION OF SILVER POWDER PRESSED ELECTROLYTICALLY OXIDIZED CATHODES

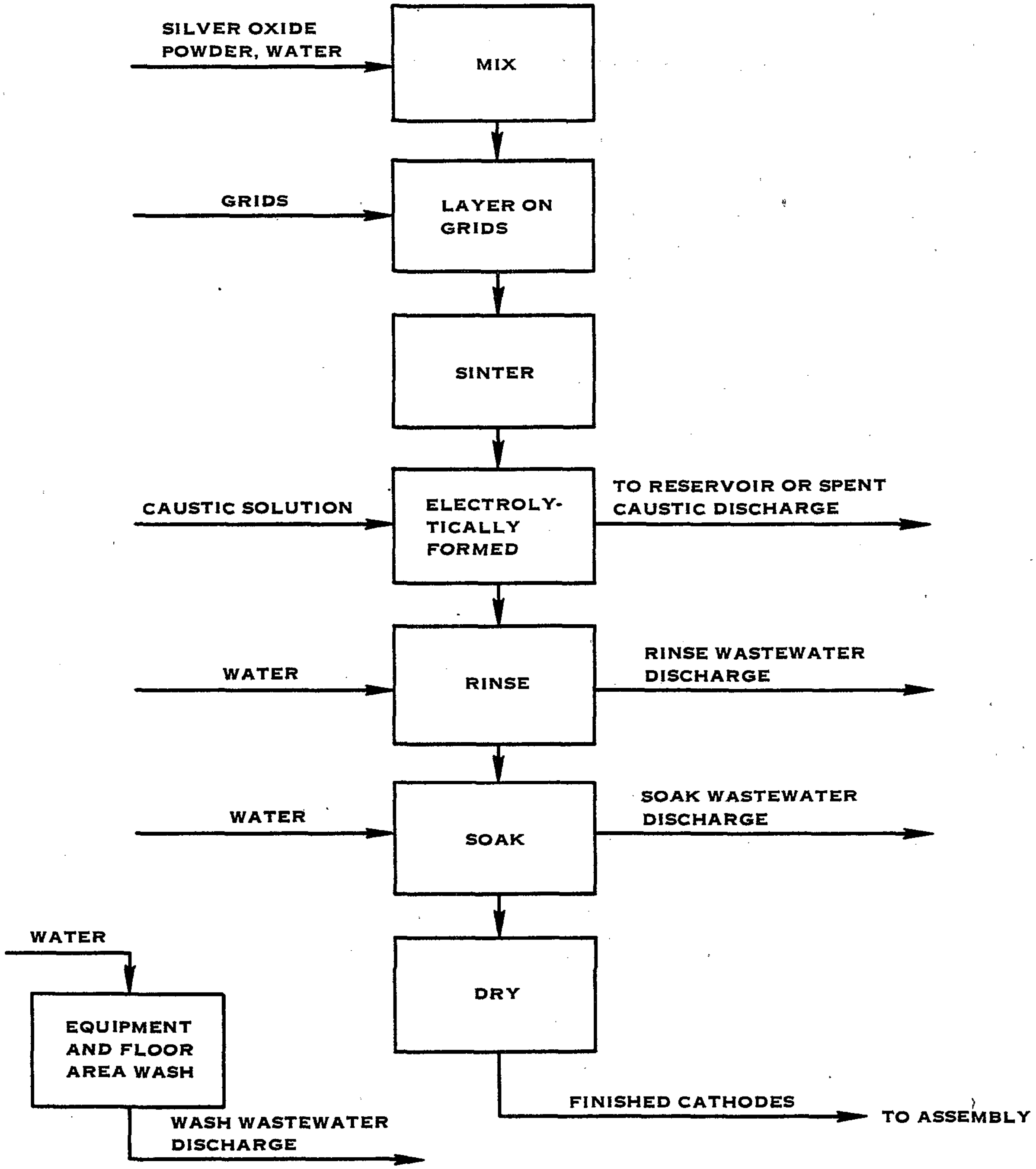

FIGURE V-23
PRODUCTION OF SILVER OXIDE (Ag_2O) POWDER THERMALLY REDUCED OR SINTERED, ELECTROLYTICALLY FORMED CATHODES

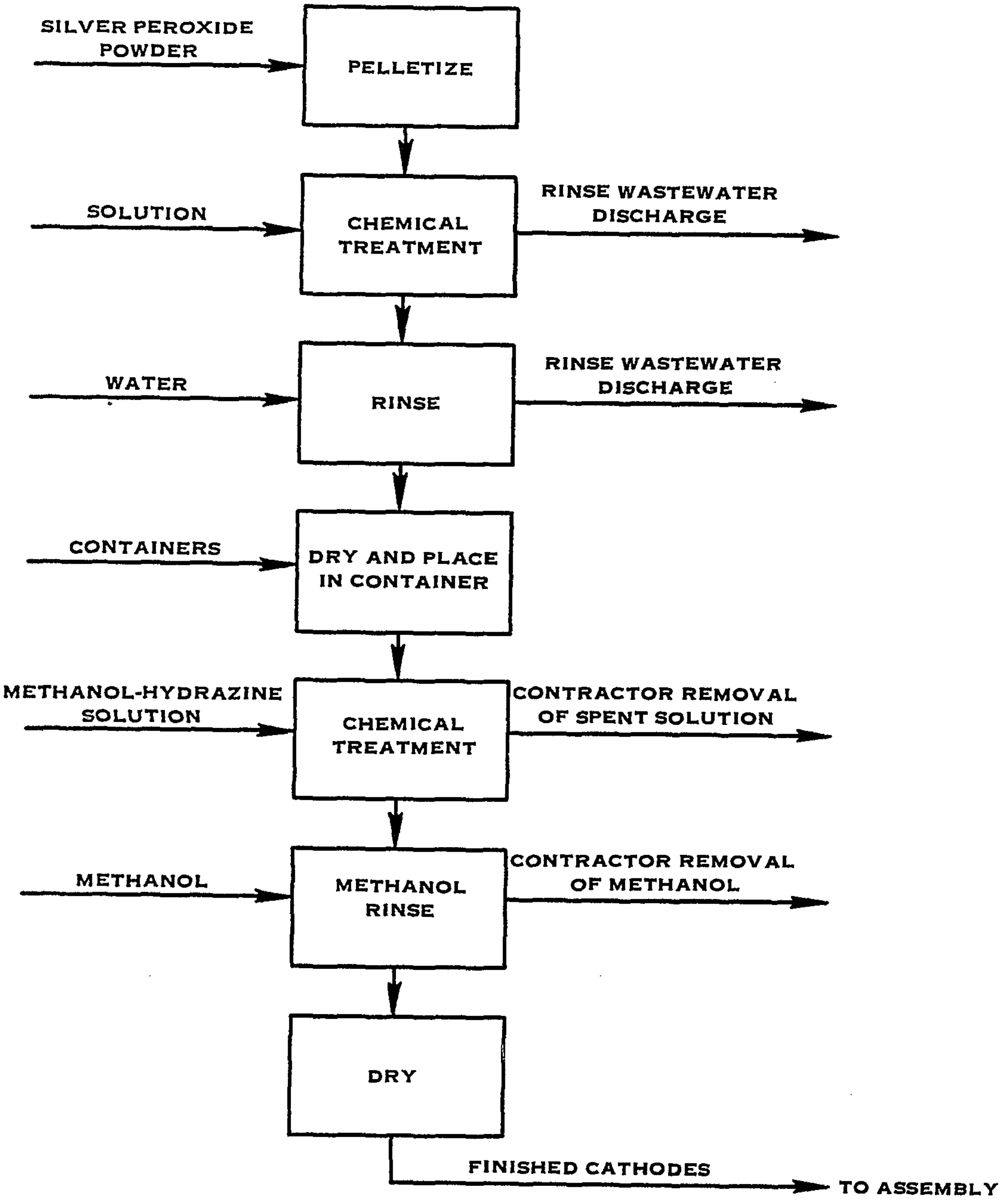

FIGURE V-24
CHEMICAL TREATMENT OF SILVER PEROXIDE CATHODE PELLETS

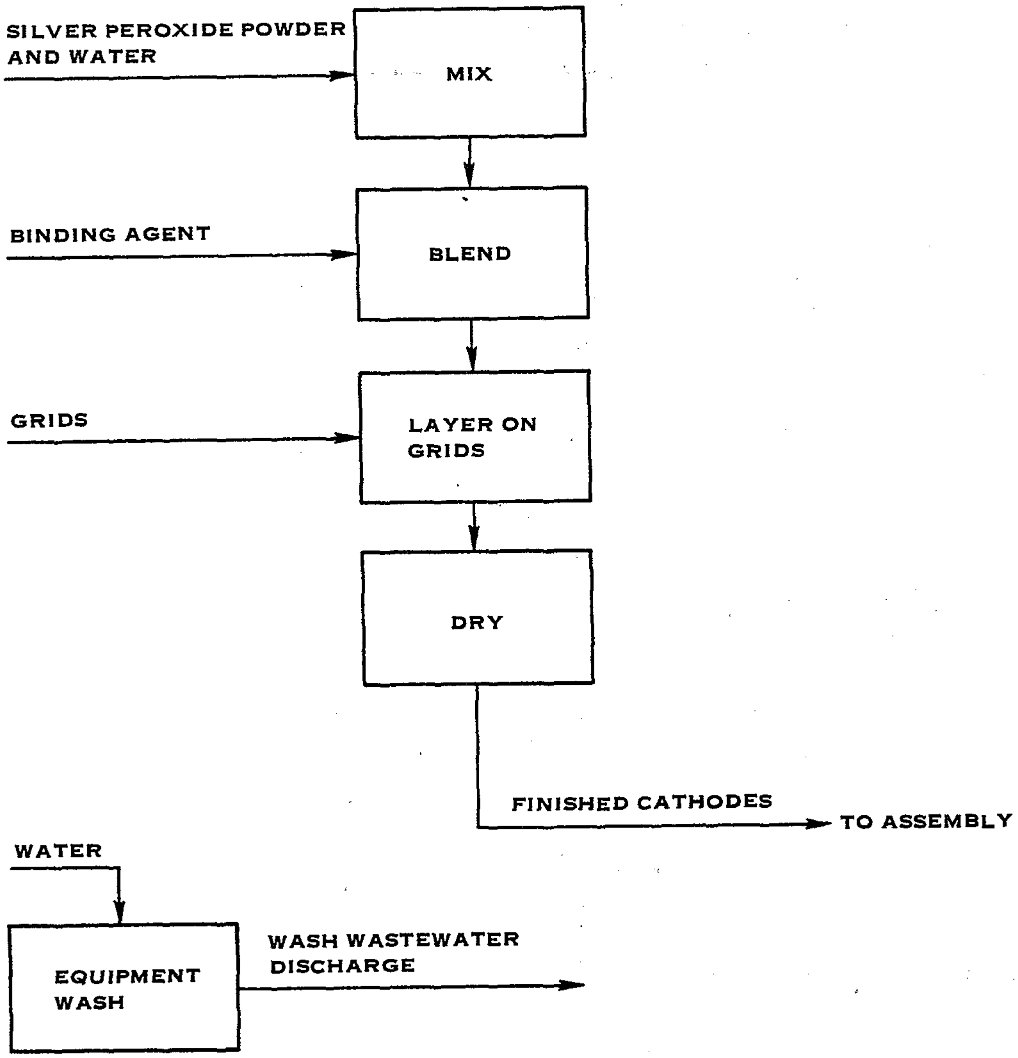

FIGURE V-25
PRODUCTION OF PASTED SILVER PEROXIDE CATHODES

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. 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 each subcategory. The rationale for that final selection is included.

VERIFICATION PARAMETERS

Pollutant parameters selected for verification sampling and analysis are listed in Table V-8 (page 271) and the subcategory for each is designated. The subsequent discussion is designed to provide information about: where the pollutant comes from - whether it is a naturally occurring element, processed metal, or manufactured compound; general physical properties and the physical form of the pollutant; toxic effects of the pollutant in humans and other animals; and behavior of the pollutant in POTW at the concentrations that might be expected from industrial dischargers.

1,1,1-Trichloroethane(11). 1,1,1-Trichloroethane is one of the two possible trichlorethanes. It is manufactured by hydrochlorinating vinyl chloride to 1,1-dichloroethane which is then chlorinated to the desired product. 1,1,1-Trichloroethane is a liquid at room temperature with a vapor pressure of 96 mm Hg at 20°C and a boiling point of 74°C. Its formula is CCl_3CH_3. It is slightly soluble in water (0.48 g/l) and is very soluble in organic solvents. U.S. annual production is greater than one-third of a million tons. 1,1,1-Trichloroethane is used as an industrial solvent and degreasing agent.

Most human toxicity data for 1,1,1-trichloroethane relates to inhalation and dermal exposure routes. Limited data are available for determining toxicity of ingested 1,1,1-trichloroethane, and those data are all for the compound itself not solutions in water. No data are available regarding its toxicity to fish and aquatic organisms. For the protection of human health from the toxic properties of 1,1,1-trichloroethane ingested through the consumption of water and fish, 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.

<u>1,1-Dichloroethane(13)</u>. 1,1-Dichloroethane, also called ethylidene dichloride and ethylidene chloride is a colorless liquid manufactured by reacting hydrogen chloride with vinyl chloride in 1,1-dichloroethane solution in the presence of a catalyst. However, it is reportedly not manufactured commercially in the U.S. 1,1-dichloroethane boils at 57°C and has a vapor pressure of 182 mm Hg at 20°C. It is slightly soluble in water (5.5 g/l at 20°C) and very soluble in organic solvents.

1,1-Dichloroethane is used as an extractant for heat-sensitive substances and as a solvent for rubber and silicone grease.

1,1-Dichloroethane is less toxic than its isomer (1,2-dichloroethane) but its use as an anesthetic has been discontinued because of marked excitation of the heart. It causes central nervous system depression in humans. There are insufficient data to derive water quality criteria for 1,1-dichloroethane.

Data on the behavior of 1,1-dichloroethane in POTW are not available. Many of the organic priority pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the organic priority pollutants. The conclusion reached by study of the limted data is that biological treatment produces only a moderate removal of 1,1-dichloroethane in POTW by degradation.

The high vapor pressure of 1,1-dichloroethane is expected to result in volatilization of some of the compound from aerobic processes in POTW. Its water solubility will result in some of the 1,1-dichloroethane which enters the POTW leaving in the effluent from the POTW.

Chloroform(23). Chloroform is a colorless liquid manufactured commercially by chlorination of methane. Careful control of conditions maximizes chloroform production, but other products must be separated. Chloroform boils at 61°C and has a vapor pressure of 200 mm Hg at 25°C. It is slightly soluble in water (8.22 g/l at 20°C) and readily soluble in organic solvents.

Chloroform is used as a solvent and to manufacture refrigerents, pharmaceuticals, plastics, and anesthetics. It is seldom used as an anesthetic.

Toxic effects of chloroform on humans include central nervous system depression, gastrointestinal irritation, liver and kidney damage and possible cardiac sensitization to adrenalin. Carcinogenicity has been demonstrated for chloroform on laboratory animals.

For the maximum protection of human health from the potential carcinogenic effects of exposure to chloroform through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero 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.

1,1-Dichloroethylene(29). 1,1-Dichloroethylene (1,1-DCE), also called vinylidene chloride, is a clear colorless liquid manufactured by dehydrochlorination of 1,1,2-trichloroethane. 1,1-DCE has the formula CCl_2CH_2. It has a boiling point of 32°C, and a vapor pressure of 591 mm Hg at 25°C. 1,1-DCE is slightly soluble in water (2.5 mg/l) and is soluble in many organic solvents. U.S. production is in the range of hundreds of thousands of tons annually.

1,1-DCE is used as a chemical intermediate and for copolymer coatings or films. It may enter the wastewater of an industrial facility as the result of decomposition of 1,1,1-trichloroethylene used in degreasing operations, or by migration from vinylidene chloride copolymers exposed to the process water.

Human toxicity of 1,1-DCE has not been demonstrated, however it is a suspected human carcinogen. Mammalian toxicity studies have focused on the liver and kidney damage produced by 1,1-DCE. Various changes occur in those organs in rats and mice ingesting 1,1-DCE.

For the maximum protection of human health from the potential carcinogenic effects due to exposure to 1,1-dichloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration should be zero based on the nonthreshold 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 0.00033 mg/l, 0.000033 mg/l and 0.0000033 mg/l.

Under laboratory conditions, dichloroethylenes have been shown to be toxic to fish. The primary effect of acute toxicity of the dichloroethylenes is depression of the central nervous system. The octanol/water partition coefficient of 1,1-DCE indicates it should not accumulate significantly in animals.

The behavior of 1,1-DCE in POTW has not been studied. However, its very high vapor pressure is expected to result in release of significant percentages of this material to the atmosphere in any treatment involving aeration. Degradation of dichloroethylene in air is reported to occur, with a half-life of 8 weeks.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory-scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces little or no degradation of 1,1-dichloroethylene. No evidence is available for drawing conclusions about the possible toxic or inhibitory effect of 1,1-DCE on POTW operation. Because of water solubility, 1,1-DCE which is not volatilized or degraded is expected to pass through POTW. Very little 1,1-DCE is expected to be found in sludge from POTW.

1,2-trans-Dichloroethylene(30). 1,1-trans-Dichloroethylene (trans-1,2-DCE) is a clear, colorless liquid with the formula CHClCHCl. Trans-1,2-DCE is produced in mixture with the cis-isomer by chlorination of acetylene. The cis-isomer has distinctly different physical properties. Industrially, the mixture is used rather than the separate isomers. Trans-1,2-DCE has a boiling point of 48°C, and a vapor pressure of 324 mm Hg at 25°C.

The principal use of 1,2-dichloroethylene (mixed isomers) is to produce vinyl chloride. It is used as a lead scavenger in gasoline, general solvent, and for synthesis of various other organic chemicals. When it is used as a solvent trans-1,2-DCE can enter wastewater streams.

Although trans-1,2-DCE is thought to produce fatty degeneration of mammalian liver, there are insufficient data on which to base any ambient water criterion.

In the one reported toxicity test of trans-1,2-DCE on aquatic life, the compound appeared to be about half as toxic as the other dichloroethylene (1,1-DCE) on the priority pollutants list.

The behavior of trans-1,2-DCE in POTW has not been studied. However, its high vapor pressure is expected to result in release of significant percentage of this compound to the atmosphere in any treatment involving aeration. Degradation of the dichloroethylenes in air is reported to occur, with a half-life of 8 weeks.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory scale studies at concentrations higher than would normally be expected in municipal wastewater. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by the study of the limited data is that biochemical oxidation produces little or no degradation of 1,2-trans-dichloroethylene. No evidence is available for drawing conclusions about the possible toxic or inhibitory effect of 1,2-trans-dichloroethylene on POTW operation. It is expected that its low molecular weight and degree of water solubility will result in trans-1,2-DCE passing through a POTW to the effluent if it is not degraded or volatilized. Very little trans-1,2-DCE is expected to be found in sludge from POTW.

Ethylbenzene(38). Ethylbenzene is a colorless, flammable liquid manufactured commercially from benzene and ethylene. Approximately half of the benzene used in the U.S. goes into the manufacture of more than three million tons of ethylbenzene annually. Ethylbenzene boils at 136°C and has a vapor pressure of 7 mm Hg at 20°C. It is slightly soluble in water (0.14 g/l at 15°C) and is very soluble in organic solvents.

About 98 percent of the ethylbenzene produced in the U.S. goes into the production of styrene, much of which is used in the plastics and synthetic rubber industries. Ethylbenzene is a constituent of xylene mixtures used as diluents in the paint industry, agricultural insecticide sprays, and gasoline blends.

Although humans are exposed to ethylbenzene from a variety of sources in the environment, little information on effects of ethylbenzene in man or animals is available. Inhalation can irritate eyes, affect the respiratory tract, or cause vertigo. In laboratory animals ethylbenzene exhibited low toxicity. There are no data available on teratogenicity, mutagenicity, or carcinogenicity of ethylbenzene.

Criteria are based on data derived from inhalation exposure limits. For the protection of human health from the toxic properties of ethylbenzene ingested through water and contaminated aquatic organisms, the ambient water quality criterion is 1.4 mg/l.

The behavior of ethylbenzene in POTW has not been studied in detail. Laboratory scale studies of the biochemical oxidation of ethylbenzene at concentrations greater than would normally be found in municipal wastewaters have demonstrated varying degrees of degradation. In one study with phenol-acclimated seed cultures 27 percent degradation was observed in a half day at 250 mg/l ethylbenzene. Another study at unspecified conditions showed 32, 38, and 45 percent degradation after 5, 10, and 20 days, respectively. Based on these results and general observations relating molecular structure to ease of degradation, the conclusion is reached that biological treatment produces only a moderate removal of ethylbenzene in POTW by degradation.

Other studies suggest that most of the ethylbenzene entering a POTW is removed from the aqueous stream to the sludge. The ethylbenzene contained in the sludge removed from the POTW may volatilize.

Methylene Chloride(44). Methylene chloride, also called dichloromethane (CH_2Cl_2), is a colorless liquid manufactured by chlorination of methane or methyl chloride followed by separation from the higher chlorinated methanes formed as coproducts. Methylene chloride boils at 40°C, and has a vapor pressure of 362 mm Hg at 20°C. It is slightly soluble in water (20 g/l at 20°C), and very soluble in organic solvents. U.S. annual production is about 250,000 tons.

Methylene chloride is a common industrial solvent found in insecticides, metal cleaners, paint, and paint and varnish removers.

Methylene chloride is not generally regarded as highly toxic to humans. Most human toxicity data are for exposure by inhalation. Inhaled methylene chloride acts as a central nervous system depressant. There is also evidence that the compound causes heart failure when large amounts are inhaled.

Methylene chloride does produce mutation in tests for this effect. In addition a bioassay recognized for its 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 carcinogenic 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 nonthreshold 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.

Naphthalene, 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.

Pentachlorophenol(64). Pentachlorophenol (C_6Cl_5OH) is a white crystalline solid produced commercially by chlorination of phenol or polychlorophenols. U.S. annual production is in excess of 20,000 tons. Pentachlorophenol melts at 190°C and is slightly soluble in water (14 mg/l). Pentachlorophenol is not detected by the 4-amino antipyrene method.

Pentachlorophenol is a bactericide and fungacide and is used for preservation of wood and wood products. It is competitive with creosote in that application. It is also used as a preservative in glues, starches, and photographic papers. It is an effective algicide and herbicide.

Although data are available on the human toxicity effects of pentachlorophenol, interpretation of data is frequently uncertain. Occupational exposure observations must be examined carefully because exposure to pentachlorophenol is frequently accompanied by exposure to other wood preservatives. Additionally, experimental results and occupational exposure observations must be examined carefully to make sure that observed effects are produced by the pentachlorophenol itself and not by the by-products which usually contaminate pentachlorophenol.

Acute and chronic toxic effects of pentachlorophenol in humans are similar; muscle weakness, headache, loss of appetite, abdominal pain, weight loss, and irritation of skin, eyes, and respiratory tract. Available literature indicates that pentachlorophenol does not accumulate in body tissues to any significant extent. Studies on laboratory animals of distribution of the compound in body tissues showed the highest levels of pentachlorophenol in liver, kidney, and intestine, while the lowest levels were in brain, fat, muscle, and bone.

Toxic effects of pentachlorophenol in aquatic organisms are much greater at pH of 6 where this weak acid is predominantly in the undissociated form than at pH of 9 where the ionic form predominates. Similar results were observed in mammals where oral lethal doses of pentachlorophenol were lower when the compound was administered in hydrocarbon solvents (un-ionized form) than when it was administered as the sodium salt (ionized form) in water.

There appear to be no significant teratogenic, mutagenic, or carcinogenic effects of pentachlorophenol.

For the protection of human health from the toxic properties of pentachlorophenol ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 1.01 mg/l.

Only limited data are available for reaching conclusions about the behavior of pentachlorophenol in POTW. Pentachlorophenol has been found in the influent to POTW. In a study of one POTW the mean removal was 59 percent over a 7 day period. Trickling filters removed 44 percent of the influent pentachlorophenol, suggesting that biological degradation occurs. The same report compared removal of pentachlorophenol of the same plant and two additional POTW on a later date and obtained values of 4.4, 19.5 and 28.6 percent removal, the last value being for the plant which was 59 percent removal in the original study. Influent concentrations of pentachloropehnol ranged from 0.0014 to 0.0046 mg/l. Other studies, including the general review of data relating molecular structure to biological oxidation, indicate that pentachlorophenol is not removed by biological treatment processes in POTW. Anaerobic digestion processes are inhibited by 0.4 mg/l pentachlorophenol.

The low water solubility and low volatility of pentachlorophenol lead to the expectation that most of the compound will remain in the sludge in a POTW. The effect on plants grown on land treated with pentachlorophenol-containing sludge is unpredicatable. Laboratory studies show that this compound affects crop germination at 5.4 mg/l. However, photodecomposition of pentachlorophenol occurs in sunlight. The effects of the various breakdown products which may remain in the soil was not found in the literature.

<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 enlarging 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 POTW 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 - butyl benzyl and di-n-octyl phthalate - would tend to remain in sludge, whereas the other four priority pollutant phthalate esters with water solubilities ranging from 50 mg/l to 4.5 mg/l would probably pass through into the POTW effluent.

Bis (2-ethylhexyl) phthalate(66). In addition to the general remarks and discussion on phthalate esters, specific information on bis(2-ethylhexyl) phthalate is provided. Little information is available about the physical properties of bis(2-ethylhexyl) phthalate. It is a liquid boiling at 387°C at 5mm Hg and is insoluble in water. Its formula is $C_6H_4(COOC_8H_{17})_2$. This priority pollutant constitutes about one third of the phthalate ester production in the U.S. It is commonly referred to as dioctyl phthalate, or DOP, in the plastics industry where it is the most extensively used compound for the plasticization of polyvinyl chloride (PVC). Bis(2-ethylhexyl) phthalate has been approved by the FDA for use in plastics in contact with food. Therefore, it may be found in wastewaters coming in contact with discarded plastic food wrappers as well as the PVC films and shapes normally found in industrial plants. This priority pollutant is also a commonly used organic diffusion pump oil where its low vapor pressure is an advantage.

For the protection of human health from the toxic properties of bis(2-ethylhexyl) phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 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 nonacclimated 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.

Diethyl phthalate (70). In addition to the general remarks and discussion on phthalate esters, specific information on diethyl phthalate is provided. Diethyl phthalate, or DEP, is a colorless liquid boiling at 296°C, and is insoluble in water. Its molecular formula is $C_6H_4(COOC_2H_5)_2$. Production of diethyl phthalate constitutes about 1.5 percent of phthalate ester production in the U.S.

Diethyl phthalate is approved for use in plastic food containers by the U.S. FDA. In addition to its use as a polyvinylchloride (PVC) plasticizer, DEP is used to plasticize cellulose nitrate for gun powder, to dilute polysulfide dental impression materials, and as an accelerator for dying triacetate fibers. An additional use which would contribute to its wide distribution in the environment is as an approved special denaturant for ethyl alcohol. The alcohol-containing products for which DEP is an approved denaturant include a wide range of personal care items such as bath preparations, bay rum, colognes, hair preparations, face and hand creams, perfumes and toilet soaps. Additionally, this denaturant is approved for use in biocides, cleaning solutions, disinfectants, insecticides, fungicides, and room deodorants which have ethyl alcohol as part of the formulation. It is expected, therefore, that people and buildings would have some surface loading of this priority pollutant which would find its way into raw wastewaters.

For the protection of human health from the toxic properties of diethyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 350 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criterion is 1800 mg/l.

Although the behavior of diethyl 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 79, 84, and 89 percent of theoretical was observed after 5, 5, and 20 days, respectively. Based on these data it is expected that diethyl phthalate will be biochemically oxidized to a lesser extent than domestic sewage by biological treatment in POTW.

Dimethyl phthalate (71). In addition to the general remarks and discussion on phthalate esters, specific information on dimethyl phthalate (DMP) is provided. DMP has the lowest molecular weight of the phthalate esters - M.W. = 194 compared to M.W. of 391 for bis(2-ethylhexyl)phthalate. DMP has a boiling point of 282°C. It is a colorless liquid, soluble in water to the extent of 5 mg/l. Its molecular formula is $C_6H_4(COOCH_3)_2$.

Dimethyl phthalate production in the U.S. is just under one percent of total phthalate ester production. DMP is used to some extent as a plasticizer in cellulosics. However, its principle specific use is for dispersion of polyvinylidene fluoride (PVDF). PVDF is resistant to most chemicals and finds use as electrical insulation, chemical process equipment (particularly pipe), and as a base for long-life finishes for exterior metal siding. Coil coating techniques are used to apply PVDF dispersions to aluminum or galvanized steel siding.

For the protection of human health from the toxic properties of dimethyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 313 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criterion is 2900 mg/l.

Based on limited data and observations relating molecular structure to ease of biochemical degradation of other organic pollutants, it is expected that dimethyl phthalate will be biochemically oxidized to a lesser extent than domestic sewage by biological treatment in POTW.

Tetrachloroethylene(85). Tetrachloroethylene (CCl_2CCl_2), also called perchloroethylene and PCE, is a colorless nonflammable liquid produced mainly by two methods - chlorination and pyrolysis of ethane and propane, and oxychlorination of dichloroethane. U.S. annual production exceeds 300,000 tons. PCE boils at 121°C and has a vapor pressure of 19 mm Hg at 20°C. It is insoluble in water but soluble in organic solvents.

Approximately two-thirds of the U.S. production of PCE is used for dry cleaning. Textile processing and metal degreasing, in equal amounts consume about one-quarter of the U.S. production.

The principal toxic effect of PCE on humans is central nervous system depression when the compound is inhaled. Headache, fatigue, sleepiness, dizziness and sensations of intoxication are reported. Severity of effects increases with vapor concentration. High integrated exposure (concentration times duration) produces kidney and liver damage. Very limited data on PCE ingested by laboratory animals indicate liver damage occurs when PCE is administered by that route. PCE tends to distribute to fat in mammalian bodies.

One report found in the literature suggests, but does not conclude, that PCE is teratogenic. PCE has been demonstrated to be a liver carcinogen in B6C3-F1 mice.

For the maximum protection of human health from the potential carcinogenic effects of exposure to tetrachloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration should be zero based on the nontheshold 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 0.008 mg/l, 0.0008 mg/l and 0.00008 mg/l.

No data were found regarding the behavior of PCE in POTW. Many of the organic priority pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the organic priority pollutants. The conclusions reached by the study of the limited data is that biological treatment produces a moderate removal of PCE in POTW by degradation. No information was found to indicate that PCE accumulates in the sludge, but some PCE is expected to be adsorbed onto settling particles. Some PCE is expected to be volatilized in aerobic treatment processes and little, if any, is expected to pass through into the effluent from the POTW.

<u>Toluene(86)</u>. Toluene is a clear, colorless liquid with a benzene like odor. It is a naturally occuring compound derived primarily from petroleum or petrochemical processes. Some toluene is obtained from the manufacture of metallurgical coke. Toluene is also referred to as toluol, methylbenzene, methacide, and phenylmethane. It is an aromatic hydrocarbon with the formula $C_6H_5CH_3$. It boils at 111°C and has a vapor pressure of 30 mm Hg at room temperature. The water solubility of toluene is 535 mg/l, and it is miscible with a variety of organic solvents. Annual production of toluene in the U.S. is greater than 2 million metric tons. Approximately two-thirds of the toluene is converted to benzene and the remaining 30 percent is divided approximately equally into chemical manufacture, and use as a paint solvent and aviation gasoline additive. An estimated 5,000 metric tons is discharged to the environment annually as a constituent in wastewater.

Most data on the effects of toluene in human and other mammals have been based on inhalation exposure or dermal contact studies. There appear to be no reports of oral administration of toluene to human subjects. A long term toxicity study on female rats revealed no adverse effects on growth, mortality, appearance and behavior, organ to body weight ratios, blood-urea, nitrogen levels, bone marrow counts, peripheral blood counts, or morphology of major organs. The effects of inhaled toluene on the central nervous system, both at high and low concentrations, have been studied in humans and animals. However, ingested toluene is expected to be handled differently by the body because it is absorbed more slowly and must first pass through the liver before reaching the nervous system. Toluene is extensively and rapidly metabolized in the liver. One of the principal metabolic products of toluene is benzoic acid, which itself seems to have little potential to produce tissue injury.

Toluene does not appear to be teratogenic in laboratory animals or man. Nor is there any conclusive evidence that toluene is mutagenic. Toluene has not been demonstrated to be positive in any in vitro mutagenicity or carcinogenicity bioassay system, nor to be carcinogenic in animals or man.

Toluene has been found in fish caught in harbor waters in the vicinity of petroleum and petrochemical plants. Bioconcentration studies have not been conducted, but bioconcentration factors have been calculated on the basis of the octanol-water partition coefficient.

For the protection of human health from the toxic properties of toluene ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 14.3 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criterion is 424 mg/l. Available data show that adverse effects on aquatic life occur at concentrations as low as 5 mg/l.

Acute toxicity tests have been conducted with toluene and a variety of freshwater fish and Daphnia magna. The latter appears to be significantly more resistant than fish. No test results have been reported for the chronic effects of toluene on freshwater fish or invertebrate species.

Only one study of toluene behavior in POTW is available. However, the biochemical oxidation of many of the priority pollutants has been investigated in laboratory scale studies at concentrations greater than those expected to be contained by most municipal wastewaters. At toluene concentrations ranging from 3 to 250 mg/l biochemical oxidation proceeded to fifty percent of the theoretical or greater. The time period varied from a few hours to 20 days depending on whether or not the seed culture was acclimated. Phenol adapted acclimated seed cultures gave the most rapid and extensive biochemical oxidation. Based on study of the limited data, it is expected that toluene will be biochemically oxidized to a lesser extent than domestic sewage by biological treatment in POTW. The volatility and relatively low water solubility of toluene lead to the expectation that aeration processes will remove significant quantities of toluene from the POTW. The EPA studied toluene removal in seven POTW. The removals ranged from 40 to 100 percent. Sludge concentrations of toluene ranged from 54×10^{-3} to 1.85 mg/l.

Trichloroethylene(87). Trichloroethylene (1,1,2-trichloroethylene or TCE) is a clear colorless liquid boiling at 87°C. It has a vapor pressure of 77 mm Hg at room temperature and is slightly soluble in water (1 g/l). U.S. production is greater than 0.25 million metric tons annually. It is produced from tetrachloroethane by treatment with lime in the presence of water.

TCE is used for vapor phase degreasing of metal parts, cleaning and drying electronic components, as a solvent for paints, as a refrigerant, for extraction of oils, fats, and waxes, and for dry cleaning. Its widespread use and relatively high volatility result in detectable levels in many parts of the environment.

Data on the effects produced by ingested TCE are limited. Most studies have been directed at inhalation exposure. Nervous system disorders and liver damage are frequent results of inhalation exposure. In the short term exposures, TCE acts as a central nervous system depressant - it was used as an anesthetic before its other long term effects were defined.

TCE has been shown to induce transformation in a highly sensitive *in vitro* Fischer rat embryo cell system (F1706) that is used for identifying carcinogens. Severe and persistant toxicity to the liver was recently demonstrated when TCE was shown to produce carcinoma of the liver in mouse strain B6C3F1. One systematic study of TCE exposure and the incidence of human cancer was based on 518 men exposed to TCE. The authors of that study concluded that although the cancer risk to man cannot be ruled out, exposure to low levels of TCE probably does not present a very serious and general cancer hazard.

TCE is bioconcentrated in aquatic species, making the consumption of such species by humans a significant source of TCE. For the protection of human health from the potential carcinogenic effects of exposure to trichloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration should be zero based on the nonthreshold 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 0.027 mg/l, 0.0027 mg/l and 0.00027 mg/l.

Only a very limited amount of data on the effects of TCE on freshwater aquatic life are available. One species of fish (fathead minnows) showed a loss of equilibrium at concentrations below those resulting in lethal effects. The limited data for aquatic life show that adverse effects occur at concentrations higher than those cited for human health risks.

In laboratory scale studies of organic priority pollutants, TCE was subjected to biochemical oxidation conditions. After 5, 10, and 20 days no biochemical oxidation occurred. On the basis of this study and general observations relating molecular structure to ease of degradation, the conclusion is reached that TCE would undergo little or no biochemical oxidation by biological treatment in a POTW. The volatility and relatively low water solubility of TCE is expected to result in volatilization of some of the TCE in aeration steps in a POTW.

Antimony(114). Antimony (chemical name - stibium, symbol Sb) classified as a nonmetal 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, ceramics, 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 schistosomiasis, 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 nonmetal 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 nonthreshold 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 x 10^{-4} mg/I 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.

Asbestos(116). Asbestos is a generic term used to describe a group of hydrated mineral silicates that can appear in a fibrous crystal form (asbestiform) and, when crushed, can separate into flexible fibers. The types of asbestos presently used commercially fall into two mineral groups: the sepentine and amphibole groups. Asbestos is minerologically stable and is not prone to significant chemical or biological degradataion in the aquatic environment. In 1978, the total consumption of asbestos in the U.S. was 583,000 metric tons. Asbestos is an excellent insulating material and is used in a wide variety of products. Based on 1975 figures, the total annual identifiable asbestos emissions are estimated at 243,527 metric tons. Land discharges account for 98.3 percent of the emissions, air discharges account for 1.5 percent, and water discharges account for 0.2 percent.

Asbestos has been found to produce a significant incidence of disease among workers occupationally exposed in mining and milling, in manufacturing, and in the use of materials containing the fiber. The predominant type of exposure has been inhalation, although some asbestos may be swallowed directly or ingested after being expectorated from the respiratory tract. Non-cancerous asbestos disease has been found among people directly exposed to high levels of asbestos as a result of excessive work exposure; much less frequently, among those with lesser exposures although there is extensive evidence of pulmonary disease among people exposed to airborne asbestos. There is little evidence of disease among people exposed to waterborne fibers.

Asbestos at the concentrations currently found in the aquatic environment does not appear to exert toxic effects on aquatic organisms. For the maximum protection of human health from the potential carcinogenic effects of exposure to asbestos through ingestion of water and contaminated aquatic organisms, the ambient water concentration should be zero based on the nonthreshold assumption of this substance. 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}. The corresponding recommended cirteria are 300,000 fibers/l , 30,000 fibers/l, and 3,000 fibers/l.

The available data indicate that technologies used at POTW for reducing levels of total suspended solids in wastewater also provide a concomitant reduction in asbestos levels. Asbestos removal efficiencies ranging from 80 percent to greater than 99 percent have been reported following sedimentation of wastewater. Filtration and sedimentation with chemical addition (i.e., lime and/or polymer) have achieved even greater percentage removals.

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 through 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 usefulness of municipal sludge.

Influent concentrations of chromium to POTW facilities have been observed by EPA to range from 0.005 to 14.0 mg/l, with a median concentration of 0.1 mg/l. The efficiencies for removal of chromium by the activated sludge process can vary greatly, depending on chromium concentration in the influent, and other operating conditions at the POTW. Chelation of chromium by organic matter and dissolution due to the presence of carbonates can cause deviations from the predicted behavior in treatment systems.

The systematic presence of chromium compounds will halt nitrification in a POTW for short periods, and most of the chromium will be retained in the sludge solids. Hexavalent chromium has been reported to severely affect the nitrification process, but trivalent chromium has litte or no toxicity to activated sludge, except at high concentrations. The presence of iron, copper, and low pH will increase the toxicity of chromium in a POTW by releasing the chromium into solution to be ingested by microorganisms in the POTW.

The amount of chromium which passes through to the POTW effluent depends on the type of treatment processes used by the POTW. In a study of 240 POTW 56 percent of the primary plants allowed more than 80 percent pass through to POTW effluent. More advanced treatment results in less pass through. POTW effluent concentrations ranged from 0.003 to 3.2 mg/l total chromium (mean = 0.197, standard deviation = 0.48), and from 0.002 to 0.1 mg/l hexavalent chromium (mean = 0.017, standard deviation = 0.020).

Chromium not passed through the POTW will be retained in the sludge, where it is likely to build up in concentration. Sludge concentrations of total chromium of over 20,000 mg/kg (dry basis) have been observed. Disposal of sludges containing very high concentrations of trivalent chromium can potentially cause problems in uncontrollable landfills. Incineration, or similar destructive oxidation processes can produce hexavalent chromium from lower valance states. Hexavalent chromium is potentially more toxic than trivalent chromium. In cases where high rates of chrome sludge application on land are used, distinct growth inhibition and plant tissue uptake have been noted.

Pretreatment of discharges substantially reduces the concentration of chromium in sludge. In Buffalo, New York, pretreatment of electroplating waste resulted in a decrease in chromium concentrations in POTW sludge from 2,510 to 1,040 mg/kg. A similar reduction occurred in Grand Rapids, Michigan, POTW where the chromium concentration in sludge decreased from 11,000 to 2,700 mg/kg when pretreatment was made a requirement.

Copper(120). Copper is a metallic element that sometimes is found free, as the native metal, and is also found in minerals such as cuprite (Cu_2O), malechite [$CuCO_3 \bullet Cu(OH)_2$], 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 5.6×10^{-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.

Cyanide(121). Cyanides are among the most toxic of pollutants commonly observed in industrial wastewaters. Introduction of cyanide into industrial processes is usually by dissolution of potassium cyanide (KCN) or sodium cyanide (NaCN) in process waters. However, hydrogen cyanide (HCN) formed when the above salts are dissolved in water, is probably the most acutely lethal compound.

The relationslhip of pH to hydrogen cyanide formation is very important. As pH is lowered to below 7, more than 99 percent of the cyanide is present as HCN and less than 1 percent as cyanide ions. Thus, at neutral pH, that of most living organisms, the more toxic form of cyanide prevails.

Cyanide ions combine with numerous heavy metal ions to form complexes. The complexes are in equilibrium with HCN. Thus, the stability of the metal-cyanide complex and the pH determine the concentration of HCN. Stability of the metal-cyanide anion complexes is extremely variable. Those formed with zinc, copper, and cadmium are not stable - they rapidly dissociate, with production of HCN, in near neutral or acid waters. Some of the complexes are extremely stable. Cobaltocyanide is very resistant to acid distillation in the laboratory. Iron cyanide complexes are also stable, but undergo photodecomposition to give HCN upon exposure to sunlight. Synergistic effects have been demonstrated for the metal cyanide complexes making zinc, copper, and cadmium, cyanides more toxic than an equal concentration of sodium cyanide.

The toxic mechanism of cyanide is essentially an inhibition of oxygen metabolism, i.e., rendering the tissues incapable of exchanging oxygen. The cyanogen compounds are true noncumulative protoplasmic poisons. They arrest the activity of all forms of animal life. Cyanide shows a very specific type of toxic action. It inhibits the cytochrome oxidase system. This system is the one which facilitates electron transfer from reduced metabolites to molecular oxygen. The human body can convert cyanide to a nontoxic thiocyanate and eliminate it. However, if the quantity of cyanide ingested is too great at one time, the inhibition of oxygen utilization proves fatal before the detoxifying reaction reduces the cyanide concentration to a safe level.

Cyanides are more toxic to fish than to lower forms of aquatic organisms such as midge larvae, crustaceans, and mussels. Toxicity to fish is a function of chemical form and concentration, and is influenced by the rate of metabolism (temperature), the level of dissolved oxygen, and pH. In laboratory studies free cyanide concentrations ranging from 0.05 to 0.15 mg/l have been proven to be fatal to sensitive fish species including trout, bluegill, and fathead minnows. Levels above 0.2 mg/l are rapidly fatal to most fish species. Long term sublethal concentrations of cyanide as low as 0.01 mg/l have been shown to affect the ability of fish to function normally, e.g., reproduce, grow, and swim.

For the protection of human health from the toxic properties of cyanide ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 0.200 mg/l.

Persistance of cyanide in water is highly variable and depends upon the chemical form of cyanide in the water, the concentration of cyanide, and the nature of other constituents. Cyanide may be destroyed by strong oxidizing agents such as permanganate and chlorine. Chlorine is commonly used to oxidize strong cyanide solutions. Carbon dioxide and nitrogen are the products of complete oxidation. But if the reaction is not complete, the very toxic compound, cyanogen chloride, may remain in the treatment system and subsequently be released to the environment. Partial chlorination may occur as part of a POTW treatment, or during the disinfection treatment of surface water for drinking water preparation.

Cyanides can interfere with treatment processes in POTW, or pass through to ambient waters. At low concentrations and with acclimated microflora, cyanide may be decomposed by microorganisms in anaerobic and aerobic environments or waste treatment systems. However, data indicate that much of the cyanide introduced passes through to the POTW effluent. The mean pass through of 14 biological plants was 71 percent. In a recent study of 41 POTW the effluent concentrations ranged from 0.002 to 100 mg/l (mean = 2.518, standard deviation = 15.6). Cyanide also enhances the toxicity of metals commonly found in POTW effluents, including the priority pollutants cadmium, zinc, and copper.

Data for Grand Rapids, Michigan, showed a significant decline in cyanide concentrations downstream from the POTW after pretreatment regulations were put in force. Concentrations fell from 0.66 mg/l before, to 0.01 mg/l after pretreatment was required.

Lead (122). Lead is a soft, malleable, ductile, bluish-gray, metallic element, usually obtained from the minerals galena (lead sulfide, PbS), anglesite (lead sulfate, $PbSO_4$), or cerussite (lead carbonate, $PbCO_3$). Because it is usually associated with the minerals 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 resistnace, sound and vibration absorption, low melting point (solders), and relatively high imperviousness to various forms of radiation. Small amounts of copper, antimony and other metals can be alloyed with lead to achieve greater hardness, stiffness, or corrosion resistance than is afforded by the pure metal. Lead compounds are used in glazes and paints. About one third of U.S. lead consumption goes into storage batteries. About half of U.S. lead consumption is from secondary lead recovery. U.S. consumption of lead is in the range of one million tons annually.

Lead ingested by humans produces a variety of toxic effects including impaired reproductive ability, disturbances in blood chemistry, neurological disorders, kidney damage, and adverse cardiovascular effects. Exposure to lead in the diet results in permanent increase in lead levels in the body. Most of the lead entering the body eventually becomes localized in the bones where it accumulates. Lead is a carcinogen or cocarcinogen in some species of experimental animals. Lead is teratogenic in experimental animals. 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 lead is normally 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.

Mercury. Mercury (123) is an elemental metal rarely found in nature as the free metal. Mercury is unique among metals as it remains a liquid down to about 39 degrees below zero. It is relatively inert chemically and is 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 nonhuman 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.

Selenium(125). Selenium (chemical symbol Se) is a nonmetallic element existing in several allotropic forms. Gray selenium, which has a metallic appearance, is the stable form at ordinary temperatures and melts at 220°C. Selenium is a major component of 38 minerals and a minor component of 37 others found in various parts of the world. Most selenium is obtained as a by-product of precious metals recovery from electrolytic copper refinery slimes. U.S. annual production at one time reached one million pounds.

Principal uses of selenium are in semi-conductors, pigments, decoloring of glass, xerography, and metallurgy. It also is used to produce ruby glass used in signal lights. Several selenium compounds are important oxidizing agents in the synthesis of organic chemicals and drug products.

While results of some studies suggest that selenium may be an essential element in human nutrition, the toxic effects of selenium in humans are well established. Lassitude, loss of hair, discoloration and loss of fingernails are symptoms of selenium poisoning. In a fatal case of ingestion of a larger dose of selenium acid, peripheral vascular collapse, pulumonary edema, and coma occurred. Selenium produces mutagenic and teratogenic effects, but it has not been established as exhibiting carcinogenic activity.

For the protection of human health from the toxic properties of selenium ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.010 mg/l. Available data show that adverse effects on aquatic life occur at concentrations higher than that cited for human toxicity.

Very few data are available regarding the behavior of selenium in POTW. One EPA survey of 103 POTW revealed one POTW using biological treatment and having selenium in the influent. Influent concentration was 0.0025 mg/l, effluent concentration was 0.0016 mg/l giving a removal of 37 percent. It is not known to be inhibitory to POTW processes. In another study, sludge from POTW in 16 cities was found to contain from 1.8 to 8.7 mg/kg selenium, compared to 0.01 to 2 mg/kg in untreated soil. These concentrations of selenium in sludge present a potential hazard for humans or other mammals eating crops grown on soil treated with selenium containing sludge.

Silver(126). Silver is a soft, lustrous, white metal that is insoluble in water and alkali. In nature, silver is found in the elemental state (native silver) and combined in ores such as argentite (Ag_2S), horn silver ($AgCl$), proustite (Ag_3AsS_3), and pyrargyrite (Ag_3SbS_3). Silver is used extensively in several industries, among them electroplating.

Metallic silver is not considered to be toxic, but most of its salts are toxic to a large number of organisms. Upon ingestion by humans, many silver salts are absorbed in the circulatory system and deposited in various body tissues, resulting in generalized or sometimes localized gray pigmentation of the skin and mucous membranes know as argyria. There is no known method for removing silver from the tissues once it is deposited, and the effect is cumulative.

Silver is recognized as a bactericide and doses from 0.000001 to 0.0005 mg/l have been reported as sufficient to sterilize water. The criterion for ambient water to protect human health from the toxic properties of silver ingested through water and through contaminated aquatic organisms is 0.050 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.

<u>Zinc(128)</u>. 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 usefulness 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 nonmagnetic. 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.

<u>Ammonia</u>. Ammonia (chemical formula NH_3) is a nonconventional pollutant. It is a colorless gas with a very pungent odor, detectable at concentrations of 20 ppm in air by the nose, and is very soluble in water (570 gm/l at 25°C). Ammonia is produced industrially in very large quantities (nearly 20 millions tons annually in the U.S.). It is converted to ammonium compounds or shipped in the liquid form (it liquifies at -33°C). Ammonia also results from natural processes. Bacterial action on nitrates or nitrites, as well as dead plant and animal tissue and animal wastes produces ammonia. Typical domestic wastewaters contain 12 to 50 mg/l ammonia.

The principal use of ammonia and its compounds is as fertilizer. High amounts are introduced into soils and the water runoff from agricultural land by this use. Smaller quantities of ammonia are used as a refrigerant. Aqueous ammonia (2 to 5 percent solution) is widely used as a household cleaner. Ammonium compounds find a variety of uses in various industries.

Ammonia is toxic to humans by inhalation of the gas or ingestion of aqueous solutions. The ionized form (NH_4^+) is less toxic than the unionized form. Ingestion of as little as one ounce of household ammonia has been reported as a fatal dose. Whether inhaled or ingested, ammonia acts destructively on mucous membrane with resulting loss of function. Aside from breaks in liquid ammonia refrigeration equipment, industrial hazard from ammonia exists where solutions of ammonium compounds may be accidently treated with a strong alkali, releasing ammonia gas. As little as 150 ppm ammonia in air is reported to cause laryngeal spasm, and inhalation of 5000 ppm in air is considered sufficient to result in death.

The behavior of ammonia in POTW is well documented because it is a natural component of domestic wastewaters. Only very high concentrations of ammonia compounds could overload POTW. One study has shown that concentrations of un-ionized ammonia greater than 90 mg/l reduce gasification in anaerobic digesters and concentrations of 140 mg/l stop digestion competely. Corrosion of copper piping and excessive consumption of chlorine also result from high ammonia concentrations. Interference with aerobic nitrification processes can occur when large concentrations of ammonia suppress dissolved oxygen. Nitrites are then produced instead of nitrates. Elevated nitrite concentrations in drinking water are known to cause infant methemoglobinemia.

Cobalt. Cobalt is a nonconventional pollutant. It is a brittle, hard, magnetic, gray metal with a reddish tinge. Cobalt ores are usually the sulfide or arsenide [smaltite-$(Co,Ni)As_2$; cobaltite-CoAsS] and are sparingly distributed in the earth's crust. Cobalt is usually produced as a by-product of mining copper, nickel, arsenic, iron, manganese, or silver. Because of the variety of ores and the very low concentrations of cobalt, recovery of the metal is accomplished by several different processes. Most consumption of cobalt is for alloys. Over two-thirds of U.S. production goes to heat resistant, magnetic, and wear resistant alloys. Chemicals and color pigments make up most of the rest of consumption.

Cobalt and many of its alloys are not corrosion resistant, therefore minor corrosion of any of the tool alloys or electrical resistance alloys can contribute to its presence in raw wastewater from a variety of manufacturing facilities. Additionally, the use of cobalt soaps as dryers to accelerate curing of unsaturated oils used in coatings may be a general source of small quantities of the metal. Several cobalt pigments are used in paints to produce yellows or blues.

Cobalt is an essential nutrient for humans and other mammals, and is present at a fairly constant level of about 1.2 mg in the adult human body. Mammals tolerate low levels of ingested water-soluble cobalt salts without any toxic symptoms; safe dosage levels in man have been stated to be 2-7 mg/kg body weight per day. A goitrogenic effect in humans is observed after the systemic administration of 3-4 mg cobalt as cobaltous chloride daily for three weeks. Fatal heart disease among heavy beer drinkers was attributed to the cardiotoxic action of cobalt salts which were formerly used as additives to improve foaming. The carcinogenicity of cobalt in rats has been verified, however, there is no evidence for the involvement of dietary cobalt in carcinogenicity in mammals.

There are no data available on the behavior of cobalt in POTW. There are no data to lead to an expectation of adverse effects of cobalt on POTW operation or the utility of sludge from POTW for crop application. Cobalt which enters POTW is expected to pass through to the effluent unless sufficient sulfide ion is present, or generated in anaerobic processes in the POTW to cause precipitation of the very insoluble cobalt sulfide.

Iron. Iron is a 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 concentrations 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 lethargy 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.

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: nonemulsifiable 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, PCB, PAH, 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 freshwater fish. It has been recommended that public water supply sources be essentially free from oil and grease.

Oil and grease in quantities of 100 l/sq km 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.

Suspended solids in water interfere with many industrial processes and cause foaming in boilers and incrustations 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 all subcategories, discussion of individual pollutant parameters selected or not selected for consideration for specific regulation are based on concentrations obtained from sampling analysis of total raw wastewater streams for each battery manufacturing element. Depending on the specific element, only one or many manufacturing wastewater streams may be included in the total raw wastewater stream. Section V addressed each element, the samples collected, and analysis of these samples. Tables from the section are referenced where appropriate within each subcategory.

Cadmium Subcategory

Pollutant Parameters Selected for Regulation. Based on verification sampling results of the manufacturing elements and wastewater sources listed in Figure V-2 (Page 392), and a careful examination of the cadmium subcategory manufacturing processes and raw materials, twelve pollutant parameters were selected to be considered for regulation in effluent limitations and standards for this subcategory. The twelve are: cadmium, chromium, cyanide, lead, mercury, nickel, silver, zinc, cobalt, oil and grease, total suspended solids, and pH. These pollutants were observed at significant levels in raw wastewater produced in this subcategory and are amenable to control by identified wastewater treatment and control practices.

Cadmium concentrations appeared in 29 of 31 raw wastewater streams in the cadmium subcategory . Since it is a cell reactant in cadmium anodes, it is involved in almost every step of the manufacturing process. The maximum cadmium concentration was 365 mg/l. Cadmium was present at levels that can be reduced by specific treatment methods. Therefore cadmium is considered for specific regulation.

Chromium concentrations appeared in 21 of 31 raw wastewater streams in the subcategory. The maximum concentration was 1.52 mg/l. Chromium is removed by specific treatment methods to levels less than some of the observed levels. Therefore chromium is considered for specific regulation.

Cyanide was found in 23 of 27 raw wastewater streams in the cadmium subcategory. The maximum concentration was 9.45 mg/l. Cyanide concentrations can be lowered by available specific treatment methods, and is therefore considered for regulation.

Lead concentrations appeared in 6 of 31 raw wastewater streams in the cadmium subcategory with appreciable levels (greater than 0.1 mg/l) observed from silver powder production. Since the maximum concentration of 0.281 mg/l can be reduced by specific treatment methods, lead is considered for specific regulation.

Mercury concentrations appeared in 15 of 31 raw wastewater streams in the cadmium subcategory. The maximum concentration was 0.032 mg/l. This priority pollutant is not an identified raw material in this subcategory. Mercury can be removed to lower concentrations by use of specific treatment methods. Accordingly, mercury is considered for specific regulation.

Nickel concentrations appeared in 30 of 31 raw wastewater streams in the cadmium subcategory. Since it is a cathode reactant and an electrode support material in cadmium anodes, nickel is involved in almost every step of the manufacturing process. The maximum nickel concentration in raw wastewater was 514 mg/l. Nickel can be removed by specific treatment methods and therefore is considered for specific regulation.

Silver concentrations appeared in 4 of 4 raw wastewater streams in the cadmium subcategory. All quantifiable concentrations were from silver powder production where the maximum concentration was 24.1 mg/l. Silver can be removed by specific treatment methods and is therefore considered for specific regulation in this subcategory.

Zinc concentrations appeared in 28 of 31 raw wastewater streams in the cadmium subcategory. The maximum zinc concentration in raw wastewater was 6,430 mg/l - in the stream from cadmium powder production. Other streams had concentrations of less than 13 mg/l. Zinc can be removed by specific treatment methods to concentrations lower than those measured in the raw wastewaters. Therefore zinc is considered for specific regulation.

Cobalt concentrations appeared in the raw wastewater in 13 of 31 streams in the cadmium subcategory. Cobalt is added to some nickel electrodes used in this subcategory. The maximum concentration was 5 mg/l. Because of its potentially toxic effect, and the fact that cobalt can be removed by specific treatment methods, cobalt is considered for specific regulation in this subcategory.

Oil and grease, a conventional pollutant, appeared at concentrations of up to 1960 mg/l in raw wastewater streams from all process elements in the cadmium subcategory. This pollutant can be removed by conventional treatment methods, and is therefore considered for regulation. Because it is present at raw waste concentrations greater than the 100 mg/l level considered acceptable for introduction into a POTW, it is considered for regulation for both indirect and direct discharges.

Suspended solids concentrations appeared in 27 of 30 raw wastewater streams from the cadmium subcategory analyzed for TSS. The maximum concentration was 2687 mg/l. Some of the TSS is comprised of hydroxides of cadmium, nickel or zinc. Because this conventional pollutant contains quantities of toxic metals, TSS requires consideration for regulation, from both direct and indirect discharges in this subcategory.

The pH of wastewater streams resulting from the manufacture of cadmium anode batteries is observed to range from 1 to 14. Acid discharges may be associated with electrodeposition, impregnation, and metal recovery processes, and with the manufacture of cadmium powder. Highly alkaline wastewaters result from electrolyte losses and from rinses following precipitation of impregnated cadmium or nickel. Since deleterious environmental effects may result from pH values outside the range of 7.5 to 10.0, regulation of this parameter in the cadmium subcategory effluents is clearly required. Further, pH must be controlled for effective removal of other pollutants present in these effluents.

<u>Pollutant Parameters Not Selected for Specific Regulation</u>. Four pollutant parameters - methylene chloride, trichloroethylene, ammonia, and total phenols - were included in verification

sampling and analysis, but were dropped from consideration for regulation in this subcategory after careful examination of concentration levels and manufacturing materials and processes.

Methylene chloride concentrations appeared in 6 of 30 raw wastewater streams from the cadmium subcategory. All values were below the quantifiable limit. Specific regulation of methylene chloride is not considered further.

Trichloroethylene concentrations appeared in 12 of the 30 raw wastewater streams from the cadmium subcategory. All values were below the quantifiable limit, therefore, specific regulation of trichloroethylene is not considered.

Ammonia concentrations appeared in 19 of 25 raw wastewater streams on which analysis was performed for this pollutant parameter in the cadmium subcategory. The maximum concentration was 86 mg/l. Other concentrations were significantly less, and were below the level achievable with available specific treatment methods. Most concentrations were in the range of ammonia concentrations found in typical domestic wastewater. Specific regulation of ammonia is therefore not considered.

"Total phenols" concentrations appeared in 24 of 27 raw wastewater streams analyzed. The maximum concentration was 0.086 mg/l. Some of the priority pollutant phenols as well as many phenols which are not priority pollutants contribute to "total phenols." Because concentrations found in this subcategory are below the levels for which practical specific treatment methods exist, and because some plant inlet water samples showed total phenols as high as 0.020 mg/l, specific regulation of "total phenols" is not considered.

Calcium Subcategory

Parameters Selected For Specific Regulation. Based on the results of verification sampling and analysis of the manufacturing elements and wastewater sources listed in Figure V-8 (page 399), and a careful review of calcium subcategory raw materials, four pollutant parameters were selected to be considered for specific regulation. These are asbestos, chromium, TSS and pH. They were observed at significant levels in raw wastewater produced in this subcategory, and are amenable to control by identified wastewater treatment and control practices.

Asbestos appeared in one of two process wastewater samples analyzed in this subcategory and is known to be used as a raw material in the heat paper production process element. Therefore, it is considered for specific regulation.

Chromium appeared in both of the process wastewater samples analyzed for verification. It is also used as a raw material in the heat paper production process element. Chromium is removed by treatment to levels less than those observed in raw wastewater samples. Therefore, chromium is considered for specific regulation.

Suspended solids appeared in both of the process wastewater samples analyzed for verification. Measured concentrations were up to 715 mg/l. Some of the TSS is comprised of asbestos and barium chromate. Because this conventional pollutant contains quantities of priority pollutants, TSS requires consideration for regulation in both direct and indirect discharges from this subcategory.

The pH of wastewater streams resulting from the manufacture of calcium anode batteries was observed to range from 2.9 to 6.2. Acidic wastewater results from the use of acidic solutions in heat paper manufacture. Since deleterious environmental effects may result from pH values outside the range of 6.0 - 9.0. regulation of this parameter in calcium subcategory effluents is clearly required. Further, pH must be controlled for effective removal of chromium present in these effluents.

<u>Parameters Not Selected For Specific Regulation</u>. Fourteen pollutant parameters - 1,1,2-trichloroethane, chloroform, methylene chloride, bis(2-ethylhexyl) phthalate, cadmium, copper, lead, nickel, silver, zinc, cobalt, iron, manganese, and oil and grease - were included in verification analyses but were dropped from consideration for regulation in this subcategory after consideration of measured concentration levels and manufacturing materials and processes.

1,1,2-trichloroethane appeared in 1 of 2 verification samples in this subcategory. The maximum concentration observed was 0.013 mg/l, which is below the level considered achievable by available treatment methods. Therefore, 1,1,2-trichloroethane is not considered for specific regulation in this subcategory.

Chloroform appeared in both wastewater samples analyzed in this subcategory. It is not a specific raw material or part of any process in the subcategory. The highest concentration observed was 0.038 mg/l. Specific treatment methods are not expected to reduce chloroform below the levels observed in raw wastewater. Therefore, chloroform is not considered for specific regulation in this subcategory.

Methylene chloride appeared in 1 of 2 wastewater samples analyzed in this subcategory. The maximum concentration observed was 0.038 mg/l, which is below the level generally achieved by available treatment methods. Therefore, methylene chloride is not considered for specific regulation in this subcategory.

Bis (2-ethylhexyl) phthalate appeared in 1 of 2 wastewater samples analyzed in this subcategory. The maximum measured concentration was 0.024 mg/l. This ester is widely used as a plasticizer which would result in its presence in plant piping and equipment. Its presence is therefore not related to a specific process source. Therefore, although the measured concentrations may exceed levels attainable by specific treatment, specific regulation of bis (2-ethylhexyl) phthalate is not considered.

Cadmium appeared in 1 of 2 wastewater samples analyzed in this subcategory. The highest measured concentration is 0.002 mg/l which is below the level which can be achieved by specific treatment. Therefore, cadmium is not considered for specific regulation in this subcategory.

Copper appeared at measurable levels in both samples analyzed in the calcium subcategory. The maximum concentration found was 0.150 mg/l. This concentration is lower than concentrations achieved by specific treatment for this metal. Therefore, copper is not considered for specific regulation.

Lead appeared in 1 of 2 wastewater samples from this subcategory. It occurred at a maximum concentration of 0.044 mg/l. Since lower concentrations are not achieved in treatment, specific regulation of lead in calcium subcategory wastewater effluents is not considered.

Nickel appeared in 1 of 2 wastewater samples analyzed in this subcategory. The highest measured concentration was 0.067 mg/l which is lower than concentrations achieved in specific treatment for this parameter. Therefore, nickel is not considered for specific regulation in this subcategory.

Silver appeared in 1 of 2 wastewater samples analyzed in the calcium subcategory. It is not used in the process and was measured at a maximum concentration of only 0.012 mg/l. Since this is below the concentration attained in treatment for this parameter, specific regulation for silver is not considered.

Zinc appeared in both wastewater samples from the calcium subcategory. The highest concentration measured was 0.110 mg/l. This is lower than concentrations generally achieved in specific treatment for this parameter. Therefore, zinc is not considered for specific regulation in this subcategory.

Cobalt appeared in one wastewater sample in this subcategory but occurred at a maximum concentration of only 0.006 mg/l. This is below the concentations of this pollutant achievable by specific treatment. Therefore, specific regulation of cobalt is not considered.

Iron appeared in both wastewater samples from the calcium subcategory. The highest measured concentration was 0.52 mg/l which is lower than the concentrations achieved in specific treatment for this parameter. Therefore, iron is not considered for specific regulation in this subcategory.

Oil and grease did not appear in wastewater samples from this subcategory. Therefore, specific regulation of this parameter is not considered.

Leclanche Subcategory

Pollutant Parameters Selected for Specific Regulation. The analysis of raw wastewater samples from the manufacturing elements (including the screening sample) and wastewater sources listed in Figure V-10 (page 401), and an evaluation of raw materials and manufacturing processes employed led to the selection of thirteen pollutant parameters for consideration for specific regulation. The parameters selected are: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc, manganese, oil and grease, total suspended solids and pH. Each has been found in raw wastewaters from plants in this subcategory at levels that are amenable to treatment and monitoring.

Arsenic concentrations appeared in 3 of 13 raw wastewater streams in the Leclanche subcategory. All concentrations appeared in ancillary operations from one plant on three sampling days. The concentration ranged from 0.07 mg/l to 0.64 mg/l. Arsenic has been determined to have carcinogenic properties, and specific treatment methods for removal of arsenic at the observed concentrations are available. Therefore, arsenic is considered for specific regulation.

Cadmium concentrations appeared in all 13 raw wastewater streams from the Leclanche subcategory. The maximum concentration was 0.47 mg/l. Cadmium is a toxic metal and can be removed by specific treatment methods to concentrations below those found in most of the raw wastewater streams. Therefore, cadmium is considered for specific regulation.

Total chromium concentrations appeared in 7 of 13 raw wastewater streams from the Leclanche subcategory. The maximum concentration was 2.88 mg/l. Chromium is a toxic metal which can be removed by specific treatment methods. Therefore, it is considered for specific regulation.

Copper concentrations appeared in all 13 raw wastewater streams from the Leclanche subcategory at concentrations up to 3.22 mg/l. Copper is not introduced as a raw material or as part of a process. However, all concentrations are above the level which can be achieved by specific treatment methods. Therefore, copper is considered for specific regulation in this subcategory.

Lead concentrations appeared in 4 of 13 raw wastewater streams sampled, and also from one analysis supplied by one plant in the Leclanche subcategory. The concentrations ranged from 0.07 mg/l to 0.94 mg/l (verification sample) and the maximum concentration was 6.0 mg/l (screening sample). All concentrations were greater than the levels which can be obtained with specific treatment methods for lead removal. Therefore, even though lead is not a raw material and is not introducted by an identified process in this subcategory it is considered for specific regulation.

Mercury concentrations appeared in 10 of 12 sampled raw wastewater streams in the Leclanche subcategory and concentrations were also reported from dcp information for three plants. The maximum concentration was 6.0 mg/l from the sampling data and 117 mg/l from dcp data. Mercury is a toxic metal used as a raw material in this subcategory. It can be removed from wastewaters by specific treatment methods at the concentrations found. Mercury is considered for specific regulation.

Nickel concentrations appeared in all 13 sampled raw wastewater streams in the Leclanche subcategory and, also one chemical analysis was supplied by one plant. The maximum concentration was 10.1 mg/l. Nickel is a toxic metal and can be removed by specific treatment methods. Therefore, nickel is considered for specific regulation.

Selenium concentrations appeared in the same 3 out of 13 raw wastewater streams in which arsenic was found in the Leclanche subcategory. The concentration range was 0.07 mg/l to 0.6 mg/l. Although selenium is not a recognized component of any of the raw materials used in this subcategory, it was reported as present in one plant's wastewater by dcp information. Because of its toxic nature and the fact that specific treatment methods can remove this pollutant parameter, selenium is considered for specific regulation.

Zinc concentrations appeared in all raw wastewater streams analyzed for zinc in the Leclanche subcategory, and also from two chemical analyses supplied by two plants. The maximum concentration from sampling was 2000 mg/l (screening) and

1640 mg/l from plant data. Zinc is a major raw material for this subcategory and can be removed by specific treatment methods. Therefore, this priority pollutant is considered for specific regulation.

Manganese concentrations appeared in all raw wastewater samples in the Leclanche subcategory. The maximum concentration was 383 mg/l, and six concentrations were 10 mg/l or greater. Manganese dioxide is a raw material for this subcategory and is generally regarded as undesirable in water used for various processes as well as for drinking water. Manganese can be removed by specific treatment methods. Therefore, manganese is considered for specific regulation.

The oil and grease parameter concentrations appeared in all raw wastewater streams, but the screening raw wastewater streams in the Leclanche subcategory. The maximum concentration was 482 mg/l and in one other sample a concentration of 438 mg/l was found. All other concentrations were below 100 mg/l. Conventional methods can be used to remove oil and grease, therefore, this parameter is considered for specific regulation.

Suspended solids were present in process wastewater streams from the Leclanche subcategory at concentrations as high as 14,200 mg/l. Additional suspended solids will result from chemical treatment of these waste streams to precipitate metallic pollutants. Although TSS is a conventional pollutant, the TSS generated in this subcategory consists of large proportions of priority pollutants. Specific treatment methods remove TSS below the levels which were found in most samples. Therefore specific regulation of TSS must be considered in this subcategory.

The pH of wastewater streams from the Leclanche subcategory was observed to range between 5.1 and 10.4. Treatment of these waste streams for removal of toxic metals may require adjustment of the pH outside of the range acceptable for discharge to surface waters - pH 7.5 to 10. Therefore, pH requires specific regulation in process wastewater effluents from this subcategory.

Pollutant Parameters Not Selected for Specific Regulation.

Three pollutant parameters included in verification sampling and analysis - diethyl phthalate, antimony, and total phenols were not selected for specific regulation. These parameters were present infrequently, or at low concentrations, in raw wastewaters and are not directly attributable to processes or raw materials used in this subcategory.

Diethyl phthalate concentrations appeared in all raw wastewaters streams in the Leclanche subcategory, but the maximum concentration was only 0.016 mg/l. This priority pollutant is not a known component of any raw material or process used in this subcategory. Because of the widespread use of diethyl phthalate as a plasticizer, the compound is found in many components of plant equipment and piping as well as various consumer products used by employees. These are not process specific sources. The concentrations are below the levels that available specific treatment methods are expected to achieve. Therefore, diethyl phthalate is not considered for specific regulation.

Antimony concentrations appeared in only the screening raw wastewater stream in the Leclanche subcategory. The detection is considered unique because antimony is not used or introduced in the raw materials of the battery manufacturing process in this subcategory. Therefore, antimony is not considered for specific regulation.

The parameter designated "total phenols" had concentrations appearing in 11 of 11 raw wastewater streams in this subcategory. The maximum concentration was 14.9 mg/l. All other values ranged from 0.009 to 0.253 mg/l. Phenols are not used in any process or as a raw material in the Leclanche subcategory. However, the maximum value was from the single sample from a wet pasting operation for which phenolic compounds are commonly used as starch paste preservatives. This operation has been discontinued since sampling the plant. Although specific removal of phenols is possible, specific treatment is costly. Many phenols are removed with oil and grease. Therefore, total phenols is not considered for specific regulation.

Lithium Subcategory

Parameters Selected For Specific Regulation. Based on the results of sampling and analysis of the manufacturing elements and wastewater sources listed in Figure V-12 (Page 403), and a careful examination of raw materials, nine pollutant parameters were selected for consideration for specific regulation. These parameters are asbestos, chromium, lead, zinc, cobalt, iron, manganese, TSS, and pH. These pollutants were found in process wastewater from this subcategory at concentrations which are amenable to control by specific treatment methods.

Asbestos appeared in 2 of 4 raw waste streams from this subcategory which were characterized by sampling. The highest measured concentration was 630 million fibers per liter. Asbestos in process waste streams from the subcategory results primarily from its use in heat paper manufacture. Therefore, asbestos is considered for specific regulations.

Chromium appeared in all four sampled waste streams in the subcategory. The highest concentration observed was 120 mg/l. This concentration results from the use of barium chromate in heat paper manufacture. Other process waste streams contain less than 0.02 mg/l of total chromium. Since chromium is known to be a process raw material in the subcategory, and it is found in process wastewater at treatable concentrations, it is considered for specific regulation.

Lead appeared in 2 of 4 sampled wastewater streams in this subcategory at concentrations of up to 4.94 mg/l. This concentration was observed in the wastewater from iron disulfide cathode manufacture. Other process waste streams contained less than 0.05 mg/l of lead. The highest concentrations of lead observed in sampling exceed the concentrations which may be achieved by treatment. Therefore, lead is considered for specific regulation.

Zinc appeared in all of the process wastewater streams from this subcategory which were characterized by sampling. The maximum observed concentration was 0.473 mg/l. This concentration exceeds levels which can be achieved by treatment. Therefore zinc is considered for specific regulation.

Cobalt appeared in 2 of 4 raw wastewater streams from the lithium subcategory. The highest measured concentration is 0.176 mg/l. Since the observed concentration is above levels which are achieved in treatment, cobalt is considered for specific regulation.

Iron appeared in all wastewater streams in this subcategory. It was measured at a maximum concentration of 54.9 mg/l. The measured concentrations are substantially higher than those achieved in treatment. Therefore iron is considered for specific regulation in this subcategory.

Manganese appeared in all wastewater streams in the lithium subcategory, with a maximum concentration of 1.60 mg/l. Manganese concentrations in all other process waste streams are less than 0.04 mg/l. Specific treatment for the removal of manganese can achieve concentrations substantially below 1.6 mg/l. Therefore manganese is considered for specific regulation.

Suspended solids appeared in all of the process waste streams characterized by sampling in this subcategory. The maximum concentration was 715 mg/l. Suspended solids in process wastewater in this subcategory contain asbestos, barium chromate, and metal hydroxides. Specific treatment methods remove TSS below the levels which were measured in all wastewater samples.

Therefore specific regulation of TSS in wastewater effluents from the lithium subcategory is considered.

The pH of 4 raw wastewater samples in the lithium subcategory ranged from 2.9 to 6.2. Acidic pH values result from the use of acidic solutions in heat paper manufacture and from the iron disulfide cathode manufacturing process. Deleterious environmental effects may result from wastewater pH values outside the range of 6.0-9.0. Further, pH must be controlled for effective removal of other pollutants from these process waste streams. Therefore, pH is considered for specific regulation.

<u>Parameters Not Selected For Regulation</u>. Ten pollutant parameters which were evaluated in verification analysis were dropped from further consideration for regulation in the lithium subcategory. These parameters were found to be present in process wastewaters infrequently, or at concentrations below those usually achieved by specific treatment methods. Pollutants dropped from consideration are: 1,1,2-trichloroethane, chloroform, methylene chloride, bis(2-ethylhexyl)phthalate, cadmium, copper, nickel, silver, lithium, and oil and grease.

1,1,2-trichloroethane appeared in 2 of 4 samples analyzed in this subcategory. The maximum concentration observed was 0.013 mg/l. Available specific treatment methods are not expected to reduce 1,1,2-trichloroethane present in wastewater below this concentration. Therefore, it is not considered for specific regulation in this subcategory.

Chloroform concentrations appeared in all of the wastewater streams analyzed in this subcategory. In two of these samples, however, it was present below the analytical quantifiable limit. The maximum reported concentration was 0.038 mg/l. This concentration is lower than those generally achieved by available specific treatment methods. Therefore, chloroform is not considered for specific regulation in the lithium subcategory.

Methylene chloride appeared in only 2 of 4 raw wastewater streams in this subcategory. The highest measured concentration was 0.016 mg/l. Available specific treatment methods are not expected to remove methylene chloride present in wastewater at the maximum concentration found. Therefore, methylene chloride is not considered for specific regulation in this subcategory.

Bis(2-ethylhexyl)phthalate appeared in 2 of 4 raw wastewater streams in this subcategory. The maximum concentration observed was 0.024 mg/l. This pollutant is not a raw material or process chemical in this battery manufacturing subcategory and is found widely distributed in industrial environments as a result of its use as a plasticizer. Therefore, bis(2-ethylhexyl)phthalate is not considered for specific regulation in this subcategory.

Cadmium appeared in 2 of 4 sampled wastewater streams in the lithium subcategory. The highest measured concentration was 0.025 mg/l. This concentration is below levels achievable by available specific treatment methods. Therefore, cadmium is not considered for specific regulation.

Copper appeared in all four wastewater streams characterized by sampling in this subcategory. The maximum measured concentration was 0.15 mg/l. Since this concentration is below the levels achieved by available specific treatment methods, copper is not considered for specific regulation in the lithium subcategory.

Nickel appeared in 3 of 4 wastewater streams in the lithium subcategory. The maximum concentration observed was 0.235 mg/l. Available specific treatment methods are not expected to achieve lower concentrations. Therefore, nickel is not considered for specific regulation in this subcategory.

Silver appeared in 2 of 4 sampled wastewater streams in the lithium subcategory. The highest measured concentration was 0.006 mg/l. This is lower than effluent concentrations achieved by available specific treatment methods. Therefore silver is not considered for specific regulation in this subcategory.

Lithium appeared in 1 of 4 sampled wastewater streams in this subcategory. The measured concentration in that sample (from lithium scrap disposal) was 0.59 mg/l. Available specific treatment methods will not reduce lithium present in wastewater below this level. Therefore, lithium is not selected for specific regulation in this subcategory.

Oil and grease appeared in only 1 of 4 wastewater streams in the lithium subcategory. The measured concentration in that stream was only 1 mg/l. This is lower than concentrations achieved by available specific treatment methods. Therefore, oil and grease is not considered for specific regulation.

Magnesium Subcategory

Parameters Selected For Specific Regulation. Based on the results of all sampling and analysis of the manufacturing elements and wastewater sources listed in Figure V-14 (Page 405), and a careful review of magnesium subcategory raw materials, seven pollutant parameters were selected to be considered for specific regulation. These are asbestos, chromium, lead, silver, TSS, COD and pH. They were observed at significant levels in raw wasterwater produced in this subcategory, and are amenable to control by identified wastewater treatment and control practices.

Asbestos appeared in all process wastewater samples analyzed in this subcategory. For the heat paper production process element asbestos is used as a raw material. For the silver chloride process elements, the presence of asbestos is attributable to plant influent and not to the processes. Asbestos is therefore considered for specific regulation.

Chromium appeared in two process wastewater samples analyzed for verification for heat paper production, and also in one raw wastewater sample for the silver chloride electrolytically oxidized cathode waste stream. Chromium is removed by treatment to levels less than those observed in raw wastewater samples. Therefore, chromium is considered for regulation.

Lead appeared in 2 of 5 process wastewater samples considered in this subcategory. The maximum concentration of 0.170 mg/l can be reduced by specific treatment. Therefore, lead is considered for regulation.

Silver appeared in all but one process wastewater sample considered in this subcategory. Two samples from the silver chloride process were at concentrations that could be treated, and also silver is a raw material for this process. Therefore, silver is considered for specific regulation.

Suspended solids appeared in all process wastewater samples considered. Measured concentrations were up to 715 mg/l, which was from heat paper production. Some of the TSS is comprised of asbestos and barium chromate. Because this conventional pollutant contains quantities of priority pollutants, TSS requires consideration for regulation in both direct and indirect discharges from this subcategory.

COD was analyzed only for samples taken in the silver chloride surface reduced cathode process element. This was done because phenolic compounds are used in the process and because of the limitations of 4AAP total phenol analysis. COD appeared at 140 mg/l for the total process, but was as high as 4100 mg/l in the developer solution. Therefore, COD is considered for specific regulation in this subcategory.

The pH of wastewater streams in this subcategory was observed to range from 1.0 to 10.6. Since deleterious environmental effects may result from pH values outside the range of 6.0 to 9.0, regulation of this parameter is required.

Parameters Not Selected For Specific Regulation. Sixteen pollutant parameters - 1,1,2-trichloroethane, chloroform, methylene chloride, dichlorobromomethane, bis(2-ethylhexyl) phthalate, di-n-octyl phthalate, toluene, cadmium, copper, mercury, nickel, zinc, cobalt, iron, manganese, and oil and grease - are not considered for regulation. They were included in verification analyses for heat paper production or detected in the silver chloride analyses, but were dropped after consideration of measured concentration levels and manufacturing materials and processes.

1,1,2-trichloroethane appeared in 1 of 5 samples considered in this subcategory. The concentration of 0.013 mg/l, is below the level considered achievable by available treatment methods. Therefore, the pollutant is not considered for specific regulation in this subcategory.

Chloroform appeared in all wastewater samples considered in this subcategory. The maximum concentration observed was 0.155 mg/l. Since both influent water samples paired with the process wastewater samples contained higher concentrations than the process water, the pollutant is not attributable to the process and is not considered for regulation.

Methylene chloride appeared in 2 of 5 samples considered in this subcategory. The maximum concentration observed was 0.038 mg/l, which is below the level generally achieved by available treatment methods. Therefore, methylene chloride is not considered for specific regulation in this subcategory.

Dichlorobromomethane appeared in 1 of 3 wastewater samples considered in this subcategory. The concentration observed was 0.026 mg/l, which is below the level generally achieved by available treatment methods. Therefore, this pollutant is not considered for specific regulation in this subcategory.

Bis(2-ethylhexyl) phthalate appeared in 2 of 5 wastewater samples considered in this subcategory. The maximum concentration was 0.024 mg/l. This ester is widely used as a plasticizer which would result in its presence in plant piping and equipment, and its presence cannot be related to a specific process source in this battery manufacturing subcategory. Therefore, although the measured concentration may exceed the level attainable by specific treatment, regulation of bis-(2-ethylhexyl) phthalate is not considered.

Di-n-octyl phthalate appeared in 1 of 3 wastewater samples considered in this subcategory. The concentration observed, 0.051 mg/l, is treatable, however, the pollutant cannot be related to a specific process source in this battery manufacturing subcategory and also does not have ambient water criteria concentrations proposed. Therefore, regulation of di-n-ocytl phthalate is not considered.

Cadmium appeared in 1 of 5 wastewater samples considered in this subcategory. The measured concentration was 0.002 mg/l, which is below the level which can be achieved by specific treatment. Therefore, cadmium is not considered for specific regulation in this subcategory.

Copper appeared in all process wastewater samples considered in this subcategory. The maximum concentration was 0.150 mg/l. This concentration is lower than concentrations achieved by specific treatment for the metal. Therefore, copper is not considered for specific regulation.

Mercury appeared in one process wastewater sample considered in this subcategory. Since the concentration observed is below specific treatment methods and since it is not known to result from the process, this pollutant is not considered for specific regulation.

Nickel appeared in 2 of 5 process wastewater samples considered in this subcategory. The highest measured concentration was 0.067 mg/l which is lower than concentrations achieved in specific treatment for this parameter. Therefore, nickel is not considered for specific regulation in this subcategory.

Zinc appeared in all process wastewater samples considered in this subcategory. The maximum concentration was 0.130 mg/l. This is lower than concentrations generally achieved in specific treatment for this parameter. Therefore zinc is not considered for specific regulation in this subcategory.

Cobalt appeared in 1 of 5 wastewater samples considered in the magnesium subcategory. The concentration was 0.006 mg/l which is below the concentrations achievable by treatment. Therefore, specific regulation is not considered.

Iron appeared in 4 of 5 wastewater samples considered in this subcategory. The maximum concentration was 0.56 mg/l which is lower than concentrations generally achieved by treatment for this parameter. Therefore, iron is not considered for regulation in this subcategory.

Oil and grease did not appear in quantifiable concentrations for any samples considered in this subcategory. Therefore, regulation is not considered.

Zinc Subcategory

Parameters Selected for Regulation. Based on verification sampling results and a careful examination of the zinc subcategory manufacturing elements and wastewater sources listed in Figure V-16 (Page 407), manufacturing processes and raw materials, seventeen pollutant parameters were selected for consideration for specific regulation in effluent limitations and standards for this subcategory. The seventeen are: arsenic, cadmium, total chromium, copper, total cyanide, lead, mercury, nickel, selenium, silver, zinc, aluminum, iron, manganese, oil and grease, total suspended solids, and pH. These pollutants were found in raw wastewaters from this subcategory at levels that are amenable to control by specific treatment methods.

Arsenic concentrations appeared in 26 of 59 raw wastewater streams from the zinc subcategory. The maximum concentration was 5.9 mg/l. Ten values were greater than 1 mg/l. Arsenic is not a raw material and is not associated with any process used in the subcategory. The arsenic probably is a contaminant in one of the raw materials. Specific treatment methods achieve lower concentrations than were found in many samples, therefore, arsenic is considered for specific regulation.

Cadmium concentrations appeared in 50 of 70 raw wastewater streams from the zinc subcategory. The maximum concentrations were 79.2 mg/l from the nickel impregnated cathode waste streams, and 5.99 mg/l from silver peroxide raw wastewater streams. All other values were less than 0.2 mg/l. Cadmium can be removed by specific treatment methods to concentrations lower than those reported for many of the samples. Therefore, cadmium is considered for specific regulation.

Total chromium concentrations appeared in 56 of 70 raw wastewater streams from the zinc subcategory. Three samples from the cell wash operation at one plant contained 253 to 318 mg/l total chromium. Other raw wastewater streams ranged from 73.1 mg/l down to 0.002 mg/l. Many of the observed concentrations are greater than the level that can be achieved with specific treatment methods. Therefore, total chromium is considered for specific regulation.

Copper concentrations appeared in 48 of 58 raw wastewater streams from the zinc subcategory. Copper is used for electrode supports in cells. It is also used as an electrical conductor in process equipment. The maximum concentration was 10.5 mg/l. Copper can be removed by specific treatment methods to levels lower than many of the observed values. Therefore, copper is considered for specific regulation in the zinc subcategory.

Total cyanide concentrations appeared in 28 of 38 raw wastewater streams. The maximum concentrations were observed in the cell wash stream from one plant where the range was 2.1 to 7.2 mg/l. Most raw wastewater streams contained less than 0.1 mg/l. However, the wastewater streams contain levels that can be treated by specific methods to achieve lower concentrations. Therefore, cyanide is considered for specific regulation.

Lead concentrations appeared in 21 of 68 raw wastewater streams in the zinc subcategory. The maximum concentration was 0.82 mg/l. Although lead is not a raw material and is not part of a process, it was present in various raw wastewater streams at seven of the eight sampled plants in this subcategory. Lead can be removed by specific treatment methods to achieve lower concentrations than most of those found. Therefore, lead is considered for specific regulation in the zinc subcategory.

Mercury concentrations appeared in 45 of 57 raw wastewater samples from the zinc subcategory. This priority pollutant is used to amalgamate zinc anodes and therefore is expected in raw wastewaters. The maximum concentration was 30.78 mg/l. Specific treatment methods can achieve mercury concentrations lower than most of the reported raw wastewater values. Therefore, mercury is considered for specific regulation in this subcategory.

Nickel concentrations appeared in 46 of 70 raw wastewater streams from the zinc subcategory. Nickel is the primary raw material for impregnated nickel cathodes in this subcategory, but it also appeared in various raw wastewater streams from all plants sampled. The maximum concentrations were 514 mg/l from the nickel cathode streams and 24.4 mg/l from cell wash streams. Nickel is considered for regulation in the zinc subcategory.

Selenium concentrations appeared in 12 of 39 raw wastewater streams from the zinc subcategory. The measured concentrations ranged from 0.046 to 4.8 mg/l. Most concentrations are above the level which can be achieved by specific treatment methods. Selenium is not a raw material nor is it a process material in this subcategory. Its presence is probably associated with the use of silver or other raw material with a high selenium content. This priority pollutant is considered for specific regulation in the zinc subcategory.

Silver concentrations appeared in 42 of 60 raw wastewater streams in the zinc subcategory. Silver is the raw material for silver oxide cathodes used in some of the batteries in this subcategory. The maximum concentration was 71 mg/l. Silver can be removed by specific treatment methods to give concentrations lower than many of the reported values. Silver is considered for specific regulation in the zinc subcategory.

Zinc, is a principal raw material in the zinc subcategory. Zinc concentrations appeared in 67 of 69 raw wastewater streams. The two streams showing zero concentrations of zinc were from two streams for silver cathodes. Nearly half of the samples contained more than 10 mg/l zinc, and the maximum concentration was 1,100 mg/l. All of the concentrations are greater than the concentration that can be achieved by specific treatment methods. Therefore, zinc is considered for specific regulation in this subcategory.

Aluminum concentrations appeared in 15 of 38 raw wastewater streams in the zinc subcategory. The maximum concentration was 106 mg/l from reject cell wastewater samples. Aluminum can be removed by specific treatment methods to levels less than those found in several of the samples. Therefore, aluminum is considered for specific regulation.

Iron concentrations appeared in two of two raw wastewater streams sampled. The maximum concentration was 0.57 mg/l. This concentration is treatable and iron is therefore considered for regulation.

Manganese concentrations appeared in 47 of 60 raw wastewater streams from the zinc subcategory. The maximum concentration was 69.6 mg/l. Manganese dioxide is a raw material for plants that make alkaline manganese cells in this subcategory. Some of the concentrations are above the level which can be achieved by specific treatment methods. Therefore, manganese is considered for specific regulation.

Phenols (total) concentrations appeared in 30 of 43 raw wastewater streams from the zinc subcategory. The maximum value was 0.12 mg/l in one raw wastewater stream. Several element streams and total plant raw wastewater streams contain treatable wastewaters, however, the concentrations detected are not environmentally significant, and only some of the concentrations detected are treatable. Therefore, total phenols is not considered for specific regulation.

Oil and grease concentrations appeared in 42 of 43 raw wastewater streams in the zinc subcategory. The maximum concentration was 205 mg/l, and half the samples contained more than 10 mg/l. Oil and grease can enter the raw wastewater from cell washing operations and from production machinery. Many oil and grease concentrations reported in this subcategory can be reduced by specific treatment methods. Some of the concentrations found are greater than are acceptable by POTW. Therefore, oil and grease are considered for specific regulation in this subcategory.

Suspended solids concentrations appeared in 66 of 68 raw wastewater samples in the zinc subcategory. The maximum concentration of total suspended solids (TSS) was 2,800 mg/l. About half the sample contained greater than 50 mg/l TSS. TSS consists of a variety of metal powders and oxides from raw materials and processes. In addition, TSS is generated by chemical precipitation methods used to remove some other pollutants. Specific treatment methods remove TSS to levels below those found in many samples. Therefore, TSS is considered for specific regulation in the zinc subcategory.

The pH of 43 raw wastewater samples in the zinc subcategory ranged from 1.0 to 13.5. Alkaline values predominated because the electrolytes in the cells in this subcategory are alkaline. Treatment of raw wastewaters for removal of other pollutant parameters can result in pH values outside the acceptable 7.5 to 10.0 range. Specific treatment methods can readily bring pH values within the prescribed limits. Therefore, pH is considered for specific regulation in the zinc subcategory.

Parameters Not Selected for Specific Regulation. Sixteen pollutant parameters which were evaluated in verification analysis were dropped from further consideration for specific regulation in the zinc subcategory. These parameters were found to be present in raw wastewaters infrequently, or at concentrations below those usually achieved by specific treatment methods. The sixteen were: 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethylene, 1,2-trans-dichloroethylene, ethylbenzene, methylene chloride, naphthalene, pentachlorophenol, bis(2-ethylhexyl) phthalate, diethyl phthalate, tetrachloroethylene, toluene, trichloroethylene, antimony, ammonia, and total phenols.

1,1,1-trichloroethane concentrations appeared in 22 of 57 raw wastewater streams analyzed for this priority pollutant parameter in the zinc subcategory. The maximum concentration was 0.025 mg/l. All but one other concentration were less than the quantifiable limit. Available specific treatment methods are not expected to remove 1,1,1-trichloroethane present in wastewater at this concentration. Therefore, this priority pollutant is not considered for specific regulation in this subcategory.

1,1-Dichloroethane concentrations appeared in 12 of 34 raw wastewater streams analyzed for this priority pollutant in the zinc subcategory. The maximum concentration was 0.03 mg/l. All other concentrations were less than the quantifiable limit. Available specific treatment methods are not expected to remove 1,1-dichloroethane present in wastewaters at this concentration. Therefore, this priority pollutant is not considered for specific regulation in this subcategory.

1,1-Dichloroethylene concentrations appeared in 12 of 36 raw wastewater streams analyzed for this priority pollutant in the zinc subcategory. All concentrations were less than the quantifiable limit. Therefore, 1,1-dichloroethylene is not considered for specific regulation in this subcategory.

1,2-Trans-dichloroethylene concentrations appeared in only 4 of 36 raw wastewater streams in the zinc subcategory. All concentrations were less than the quantifiable limit. Therefore, 1,2-trans-dichloroethylene is not considered for regulation in this subcategory.

Ethylbenzene was detected in only 2 of 32 raw wastewater samples in the zinc subcategory. The concentrations were below the quantifiable limit. Therefore, ethylbenzene is not considered for specific regulation in this subcategory.

Methylene chloride concentrations appeared in 18 of 67 raw wastewater streams in the zinc subcategory. The maximum concentration was 0.023 mg/l. All other concentrations were below the quantifiable limit. Available specific treatment methods are not expected to remove methylene chloride present in wastewater at the maximum concentration found. Therefore, methylene chloride is not considered for specific regulation in this subcategory.

Naphthalene concentrations appeared in 16 of 37 raw wastewater streams in the zinc subcategory. The maximum concentration was 0.02 mg/l. All concentrations were less than the quantifiable limit. Available treatment methods are not expected to remove naphthalene present in the wastewater at the maximum concentration found. Therefore, naphthalene is not considered for specific regulation in this subcategory.

Pentachlorophenol concentrations appeared in 1 of 14 raw wastewater streams in the zinc subcategory. The concentration was 0.042 mg/l. Available specific treatment methods are considered capable of achieving lower concentrations of this priority pollutant than the observed value. However, because pentachlorophenol was detected only once, this priority pollutant is not considered for specific regulation in this subcategory.

Bis(2-ethylhexyl) phthalate concentrations appeared in all 21 raw wastewater streams analyzed for this priority pollutant. The maximum concentration was 0.161 mg/l. Available specific treatment methods are considered capable of achieving lower concentrations of this priority pollutant than many of those reported. This priority pollutant is not a raw material or process chemical and is found distributed widely in industrial environments as a plasticizer. Therefore, bis(2-ethylhexyl) phthalate is not considered for specific regulation in this subcategory.

Diethyl phthalate concentrations appeared in 14 of 37 raw wastewater streams in the zinc subcategory. All concentrations were less than the quantifiable limit. Therefore, diethyl phthalate is not considered for specific regulation in this subcategory.

Tetrachloroethylene concentrations appeared in 5 of 38 raw wastewater streams in the zinc subcategory. All of the concentrations were less than the quantifiable limit. Therefore, tetrachloroethylene is not considered for specific regulation in this subcategory.

Toluene concentrations appeared in 10 of 67 raw wastewater streams in the zinc subcategory. All concentrations were less than the quantifiable limit. Therefore, toluene is not considered for specific regulation in this subcategory.

Trichloroethylene was found in 17 of 51 raw wastewater samples in the zinc subcategory. The only value greater than the quantifiable limit was 0.012 mg/l. Available specific treatment methods are not expected to remove trichloroethylene present in raw wastewaters at the maximum concentration found. Therefore, trichloroethylene is not considered for regulation in this subcategory.

Antimony concentrations did not appear in any of the 56 raw wastewater streams from the zinc subcategory. Antimony was included in verification sampling for this subcategory on the basis of dcp reports that antimony was present in the raw wastewaters. Antimony is not considered for specific regulation in this subcategory.

Ammonia concentrations appeared in 31 of 31 raw wastewater streams analyzed for this pollutant in the zinc subcategory. Maximum concentrations for each element stream ranged from 0.84 to 120 mg/l. The maximum concentration in total plant raw wastewater streams was 8.0 mg/l. Available specific treatment methods are not expected to remove ammonia present in total raw wastewaters at the maximum level found. Therefore, ammonia is not considered for specific regulation in this subcategory.

Summary

Table VI-1, (page 488) presents the selection of priority pollutant parameters considered for regulation for each 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 subcategories.

"Not Quantifiable" includes those pollutants which were at or below the quantifiable limits in influent, raw or effluent waters and not selected at screening, and those not quantifiable for all verification raw wastewater stream analysis within each subcategory. "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 493) summarizes the selection of nonconventional and conventional pollutant parameters for consideration for specific regulation by each subcategory.

TABLE VI-1

PRIORITY POLLUTANT DISPOSITION
BATTERY MANUFACTURING

Pollutant	Subcategory Cadmium	 Calcium	 Leclanche	 Lithium	 Magnesium	 Zinc
1 Acenapthene	ND	ND	ND	ND	ND	ND
2 Acrolein	ND	ND	ND	ND	ND	ND
3 Acrylonitrile	ND	ND	ND	ND	ND	ND
4 Benzene	ND	ND	ND	ND	ND	NQ
5 Benzidine	ND	ND	ND	ND	ND	ND
6 Carbon tetrachloride (tetrachloromethane)	ND	ND	ND	ND	ND	ND
7 Chlorobenzene	ND	ND	ND	ND	ND	ND
8 1,2,4-trichlorobenzene	ND	ND	ND	ND	ND	ND
9 Hexachlorobenzene	ND	ND	ND	ND	ND	ND
10 1,2-dichloroethane	ND	ND	ND	ND	ND	ND
11 1,1,1-trichloroethane	ND	ND	NQ	NQ	ND	NT
12 Hexachloroethane	ND	ND	ND	ND	ND	ND
13 1,1-dichloroethane	ND	ND	ND	ND	ND	NT
14 1,1,2-trichloroethane	ND	NT	ND	NT	NT	NQ
15 1,1,2,2-tetrachloroethane	ND	ND	ND	ND	ND	ND
16 Chloroethane	ND	ND	ND	ND	ND	ND
17 Bis (chloromethyl) ether	ND	ND	ND	ND	ND	ND
18 Bis (2-chloroethyl) ether	ND	ND	ND	ND	ND	ND
19 2-chloroethyl vinyl ether (mixed)	ND	ND	ND	ND	ND	ND
20 2-chloronaphthalene	ND	ND	ND	ND	ND	ND
21 2,4,6-trichlorophenol	ND	ND	ND	ND	ND	NQ
22 Parachlorometa cresol	ND	ND	ND	ND	ND	ND
23 Chloroform (trichloromethane)	SU	NT	SU	NT	SU	SU
24 2-chlorophenol	ND	ND	ND	ND	ND	NQ
25 1,2-dichlorobenzene	ND	ND	ND	ND	ND	ND
26 1,3-dichlorobenzene	ND	ND	ND	ND	ND	ND

LEGEND:

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

TABLE VI-1

PRIORITY POLLUTANT DISPOSITION
BATTERY MANUFACTURING

Pollutant		Subcategory					
		Cadmium	Calcium	Leclanche	Lithium	Magnesium	Zinc
27	1,4-dichlorobenzene	ND	ND	ND	ND	ND	ND
28	3,3-dichlorobenzidine	ND	ND	ND	ND	ND	ND
29	1,1-dichloroethylene	ND	ND	ND	ND	ND	NQ
30	1,2-trans-dichloroethylene	ND	ND	ND	ND	ND	NQ
31	2,4-dichlorophenol	ND	ND	ND	ND	ND	ND
32	1,2-dichloropropane	ND	ND	ND	ND	ND	ND
33	1,2-dichloropropylene (1,2-dichloropropene)	ND	ND	ND	ND	ND	ND
34	2,4-dimethylphenol	ND	ND	ND	ND	ND	ND
35	2,4-dinitrotoluene	ND	ND	ND	ND	ND	ND
36	2,6-dinitrotoluene	ND	ND	ND	ND	ND	ND
37	1,2-diphenylhydrazine	ND	ND	ND	ND	ND	NQ
38	Ethylbenzene	ND	ND	ND	ND	ND	ND
39	Fluoranthene	ND	ND	ND	ND	ND	ND
40	4-chlorophenyl phenyl ether	ND	ND	ND	ND	ND	ND
41	4-bromophenyl phenyl ether	ND	ND	ND	ND	ND	ND
42	Bis(2-chloroisopropyl)ether	ND	ND	ND	ND	ND	ND
43	Bis(2-chloroethoxyl)methane	ND	ND	ND	ND	ND	ND
44	Methylene chloride (dichloromethane)	NQ	NT	NQ	NT	NT	NT
45	Methyl chloride (chloromethane)	ND	ND	ND	ND	ND	ND
46	Methyl bromide (bromomethane)	ND	ND	ND	ND	ND	ND
47	Bromoform (tribromomethane)	ND	ND	ND	ND	ND	ND
48	Dichlorobromomethane	NQ	ND	NQ	ND	NT	ND
49	Trichlorofluoromethane	ND	ND	ND	ND	ND	ND
50	Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND
51	Chlorodibromomethane	ND	ND	NQ	ND	ND	ND
52	Hexachlorobutadiene	ND	ND	ND	ND	ND	ND
53	Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND
54	Isophorone	ND	ND	ND	ND	ND	ND
55	Naphthalene	ND	ND	ND	ND	ND	NT
56	Nitrobenzene	ND	ND	ND	ND	ND	ND

TABLE VI-1

PRIORITY POLLUTANT DISPOSITION
BATTERY MANUFACTURING

Pollutant		Cadmium	Calcium	Leclanche	Lithium	Magnesium	Zinc
		Subcategory					
57	2-nitrophenol	ND	ND	ND	ND	ND	ND
58	4-nitrophenol	ND	ND	ND	ND	ND	ND
59	2,4-dinitrophenol	ND	ND	ND	ND	ND	ND
60	4,6-dinitro-o-cresol	ND	ND	ND	ND	ND	ND
61	N-nitrosodimethylamine	ND	ND	ND	ND	ND	ND
62	N-nitrosodiphenylamine	ND	ND	ND	ND	ND	ND
63	N-nitrosodi-n-propylamine	ND	ND	ND	ND	ND	ND
64	Pentachlorophenol	ND	NQ	ND	NQ	NQ	SU
65	Phenol	ND	ND.	NQ	ND	ND	SU
66	Bis(2-ethylhexyl)phthalate	NQ	SU	NQ	SU	SU	SU
67	Butyl benzyl phthalate	ND	ND	NQ	NQ	ND	NQ
68	Di-N-Butyl phthalate	ND	NQ	NQ	NQ	NQ	NQ
69	Di-n-octyl phthalate	ND	ND	NQ	ND	SU	ND
70	Diethyl phthalate	ND	ND	NT	ND	ND	NQ
71	Dimethyl phthalate	ND	ND	NQ	ND	ND	ND
72	1,2-benzanthracene (benzo(a)anthracene)	ND	ND	ND	ND	ND	ND
73	Benzo(a)pyrene (3,4-benzopyrene)	ND	ND	ND	ND	ND	ND
74	3,4-Benzofluoranthene (benzo(b)fluoranthene)	ND	ND	ND	ND	ND	ND
75	11,12-benzofluoranthene (benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND
76	Chrysene	ND	ND	ND	ND	ND	ND
77	Acenaphthylene	ND	ND	ND	ND	ND	NQ
78	Anthracene	ND	ND	ND	ND	ND	NQ
79	1,12-benzoperylene (benzo(ghi)perylene)	ND	ND	ND	ND	ND	ND
80	Fluorene	ND	ND	ND	ND	ND	NQ
81	Phenanthrene	ND	ND	ND	ND	ND	NQ
82	1,2,5,6-dibenzanthracene dibenzo(,h)anthracene	ND	ND	ND	ND	ND	ND
83	Indeno(1,2,3-cd) pyrene (2,3-o-phenylene pyrene)	ND	ND	ND	ND	ND	ND
84	Pyrene	ND	ND	ND	ND	ND	NQ
85	Tetrachloroethylene	ND	ND	ND	ND	ND	NQ

TABLE VI-1

PRIORITY POLLUTANT DISPOSITION
BATTERY MANUFACTURING

	Pollutant	Subcategory					
		Cadmium	Calcium	Leclanche	Lithium	Magnesium	Zinc
86	Toluene	SU	NQ	NQ	NQ	NQ	NQ
87	Trichloroethylene	NQ	ND	ND	ND	ND	ND
88	Vinyl chloride (chloroethylene)	ND	ND	ND	ND	ND	ND
89	Aldrin	ND	ND	ND	ND	ND	ND
90	Dieldrin	ND	ND	ND	ND	ND	ND
91	Chlordane (technical mixture and metabolites)	ND	ND	ND	ND	ND	ND
92	4,4-DDT	ND	ND	ND	ND	ND	ND
93	4,4-DDE (p,p-DDX)	ND	ND	ND	ND	ND	ND
94	4,4-DDD (p,p-TDE)	ND	ND	ND	ND	ND	ND
95	Alpha-endosulfan	ND	ND	ND	ND	ND	ND
96	Beta-endosulfan	ND	ND	ND	ND	ND	ND
97	Endosulfan sulfate	ND	ND	ND	ND	ND	ND
98	Endrin	ND	ND	ND	ND	ND	ND
99	Endrin aldehyde	ND	ND	ND	ND	ND	ND
100	Heptachlor	ND	ND	ND	ND	ND	ND
101	Heptachlor epoxide (BHC hexachlorohexane)	ND	ND	ND	ND	NQ	ND
102	Alpha-BHC	NQ	NQ	NQ	NQ	NQ	NQ
103	Beta-BHC	ND	ND	ND	ND	ND	ND
104	Gamma-BHC (lindane)	ND	ND	ND	ND	ND	ND
105	Delta-BHC (PCB-poly-chlorinated biphenyls)	ND	ND	ND	ND	ND	ND
106	PCB-1232 (Arochlor 1242)	ND	ND	ND	ND	ND	ND
107	PCB-1254 (Arochlor 1254)	ND	ND	ND	ND	ND	ND
108	PCB-1221 (Arochlor 1221)	ND	ND	ND	ND	ND	ND
109	PCB-1232 (Arochlor 1232)	ND	ND	ND	ND	ND	ND
110	PCB-1248 (Arochlor 1248)	ND	ND	ND	ND	ND	ND
111	PCB-1260 (Arochlor 1260)	ND	ND	ND	ND	ND	ND
112	PCB-1016 (Arochlor 1016)	ND	ND	ND	ND	ND	ND
113	Toxaphene	ND	ND	ND	ND	ND	ND
114	Antimony	ND	NQ	SU	NQ	NQ	NQ
115	Arsenic	ND	NQ	REG	NQ	NQ	REG
116	Asbestos	SU	REG	ND	REG	REG	ND
117	Beryllium	NQ	NQ	NQ	NQ	NQ	NQ
118	Cadmium	REG	NT	REG	NT	NT	REG
119	Chromium	REG	REG	REG	REG	REG	REG
120	Copper	SU	NT	REG	NT	NT	REG
121	Cyanide	REG	ND	SU	NT	ND	REG

TABLE VI-1

PRIORITY POLLUTANT DISPOSITION
BATTERY MANUFACTURING

Pollutant		Subcategory					
		Cadmium	Calcium	Leclanche	Lithium	Magnesium	Zinc
122	Lead	REG	NT	REG	REG	REG	REG
123	Mercury	REG	NQ	REG	NQ	NT	REG
124	Nickel	REG	NT	REG	NT	NT	REG
125	Selenium	ND	NQ	REG	NQ	NQ	REG
126	Silver	Reg - NQ[1]	NT	NQ	NT	REG	REG
127	Thallium	ND	NQ	ND	NQ	NQ	ND
128	Zinc	REG	NT	REG	REG	NT	REG
129	2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	ND	ND

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[1] For all subcategory elements except silver cathodes and related processes

TABLE VI-2

Other Pollutants Considered for Regulation

	Subcategory					
	Cadmium	**Calcium**	**Leclanche**	**Lithium**	**Magnesium**	**Zinc**
Aluminum						x
Cobalt	x			x		
Iron				x	x	x
Manganese			x			x
Oil & Grease	x		x	x		x
TSS	x	x	x	x	x	x
pH	x	x	x	x	x	x
COD					x	

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

This section describes the treatment techniques currently used or available to remove or recover wastewater pollutants normally generated by the battery manufacturing industrial point source category. Included are discussions of individual end-of-pipe treatment technologies and in-plant technologies. 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 battery manufacturing 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 end-of-pipe 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 battery manufacturing 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-4 (Page 616) 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 complete precipitation. The amount of residual dissolved metal depends on the treatment chemicals used and related factors. The effectiveness of this method of removing any specific metal depends on the fraction of the specific metal in the raw waste (and hence in the precipitate) and the effectiveness of suspended solids removal. 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 613), and by plotting effluent zinc concentrations against pH as shown in Figure VII-3 (page 615). 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 592).

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 592) 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 593) shows sampling data from this system, which uses lime and sodium hydroxide for pH adjustment, chemical precipitation, polyelectrolyte flocculant addition, and sedimentation. Samples were taken of the raw waste influent to the system and of the clarifier effluent. Flow through the system is approximately 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.

Sulfide precipitation is sometimes used to precipitate metals resulting in improved metals removals. Most metal sulfides are less soluble than hydroxides, and the precipitates are frequently more dependably removed from water. Solubilities for selected metal hydroxide, carbonate and sulfide precipitates are shown in Table VII-4 (page 593). (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 594). 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:

$$CrO_3 + FeS + 3H_2O \text{ ----> } Fe(OH)_3 + Cr(OH)_3 + S$$

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 595) 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.

<u>Carbonate precipitation</u> 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 614) ("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 596).

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 post treatment. At very high excess sulfide levels and high pH, soluble mercury-sulfide compounds may also be formed. Where excess sulfide is present, aeration of the effluent stream can aid in oxidizing residual sulfide to the less harmful sodium sulfate (Na_2SO_4). The cost of sulfide precipitants is high in comparison 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 and ferricyanide complexes.

Adequate removal of the precipitated cyanide requires that the pH must be kept at 9.0 and an appropriate retention time be maintained. A study has shown that the formation of the complex is very dependent on pH. At 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 596) 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 multimedia 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 626) 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 621).

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

<u>Operational</u> <u>Factors</u>. 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 627) 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 628) 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 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.

<u>Application and Performance</u>. Settling or clarification is used in the battery manufacturing category to remove precipitated metals. Settling can be used to remove most suspended solids in a particular waste stream; thus it is used extensively by many different industrial waste treatment facilities. Because most metal ion pollutants are readily converted to solid metal hydroxide precipitates, settling is of particular use in those industries associated with metal production, metal finishing, metal working, and any other industry with high concentrations of metal ions in their wastewaters. In addition to toxic metals, suitably precipitated materials effectively removed by settling include aluminum, iron, manganese, cobalt, antimony, beryllium, molybdenum, fluoride, phosphate, and many others.

A properly operating settling system can efficiently remove suspended solids, precipitated metal hydroxides, and other impurities from wastewater. The performance of the process depends on a variety of factors, including the density and particle size of the solids, the effective charge on the suspended particles, and the types of chemicals used in pretreatment. The site of flocculant or coagulant addition also may significantly influence the effectiveness of clarification. If the flocculant is subjected to too much mixing before entering the clarifier, the complexes may be sheared and the settling effectiveness diminished. At the same time, the flocculant must have sufficient mixing and reaction time in order for effective set-up and settling to occur. Plant personnel have observed that the line or trough leading into the clarifier is often the most efficient site for flocculant addition. The performance of simple settling is a function of the retention time, particle size and density, and the surface area of the basin.

The data displayed in Table VII-10 (page 597) 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.

Advantages and Limitations. The major advantage of simple settling is its simplicity as demonstrated by the gravitational settling of solid particulate waste in a holding tank or lagoon. The major problem with simple settling is the long retention time necessary to achieve complete settling, especially if the specific gravity of the suspended matter is close to that of water. Some materials cannot be practically removed by simple settling alone.

Settling performed in a clarifier is effective in removing slow-settling suspended matter in a shorter time and in less space than a simple settling system. Also, effluent quality is often better from a clarifier. The cost of installing and maintaining a clarifier, however, is substantially greater than the costs associated with simple settling.

Inclined plate, slant tube, and lamella settlers have even higher removal efficiencies than conventional clarifiers, and greater capacities per unit area are possible. Installed costs for these advanced clarification systems are claimed to be one half the cost of conventional systems of similar capacity.

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.

Application and Performance. Oil skimming is used in battery manufacture to remove free oil used as a preservative or forming lubricant for various metal battery parts. Another source of oil is lubricants for drive mechanisms and other machinery contacted by process water. Skimming is applicable to any waste stream containing pollutants which float to the surface. It is commonly used to remove free oil, grease, and soaps. Skimming is often used in conjunction with air flotation or clarification in order to increase its effectiveness.

The removal efficiency of a skimmer is partly a function of the retention time of the water in the tank. Larger, more buoyant particles require less retention time than smaller particles. Thus, the efficiency also depends on the composition of the waste stream. The retention time required to allow phase separation and subsequent skimming varies from 1 to 15 minutes, depending on the wastewater characteristics.

API or other gravity-type separators tend to be more suitable for use where the amount of surface oil flowing through the system is consistently significant. Drum and belt type skimmers are applicable to waste streams which evidence smaller amounts of floating oil and where surges of floating oil are not a problem. Using an API separator system in conjunction with a drum type skimmer would be a very effective method of removing floating contaminants from nonemulsified oily waste streams. Sampling data shown in Table VII-11 (page 598) 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 599).

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 600).

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.

Plant-Day	Percent Removal 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 616-624). 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 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-20 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 Xij = 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
Ji = 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 S_i^2 = log variance at plant i

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

$\bar{y}_i$ = 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

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

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

where Ψ (.) is a Bessel function and exp is e, the base of the natural logarithms (See Aitchison, J. and J.A.C. Brown, The Lognormal Distribution, 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 600) 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 $\overline{X}_{10}$ denote the mean of 10 consecutive measurements. The following relationships then hold assuming the daily measurements are independent:

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

variance of $\overline{X}_{10} = V(\overline{X}_{10}) = V(X) \div 10$.

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

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

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

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

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

The formulas for $\widehat{E(X)}$ and $\widehat{V(X)}$ 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 601) are reliably attainable with hydroxide precipitation and settling. Treatment effectiveness values were calculated by multiplying the mean performance from Table VII-15 (page 601) 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 606).

In establishing which data were suitable for use in Table VII-14 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 601) and VII-17 (page 602) 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.

Antimony (Sb) - 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.

Arsenic (As) - 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 602) is comparable with the combined data set matrix.

Beryllium (Be) - 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.

Mercury (Hg) - 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.

Selenium (Se) - 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 603 and 604) 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 605) 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 595) 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 605) 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 597) 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 treatment 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 category. 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 629). 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 (page 609), 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 607) summarizes the treatment effectiveness for most of the organic priority pollutants by activated carbon as compiled by EPA. Table VII-23 (page 608) 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 630).

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, nonsettling 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 631).

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 632).

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 633) 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 634) 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 evaproator 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 posttreatment.

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 635) 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 636) 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 637). 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 609). 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 610) 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 610) 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 638) depicts a reverse osmosis system.

As illustrated in Figure VII-27, (page 639), 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 640) shows the construction of a drying bed.

Drying beds are usually divided into sectional areas approximately 7.5 meters (25 ft) wide x 30 to 60 meters (100 to

200 ft) long. The partitions may be earth embankments, but more often are made of planks and supporting grooved posts.

To apply liquid sludge to the sand bed, a closed conduit or a pressure pipeline with valved outlets at each sand bed section is often employed. Another method of application is by means of an open channel with appropriately placed side openings which are controlled by slide gates. With either type of delivery system, a concrete splash slab should be provided to receive the falling sludge and prevent erosion of the sand surface.

Where it is necessary to dewater sludge continuously throughout the year regardless of the weather, sludge beds may be covered with a fiberglass reinforced plastic or other roof. Covered drying beds permit a greater volume of sludge drying per year in most climates because of the protection afforded from rain or snow and because of more efficient control of temperature. Depending on the climate, a combination of open and enclosed beds will provide maximum utilization of the sludge bed drying facilities.

Application and Performance. Sludge drying beds are a means of dewatering sludge from clarifiers and thickeners. They are widely used both in municipal and industrial treatment facilities.

Dewatering of sludge on sand beds occurs by two mechanisms: filtration of water through the bed and evaporation of water as a result of radiation and convection. Filtration is generally complete in one to two days and may result in solids concentrations as high as 15 to 20 percent. The rate of filtration depends on the drainability of the sludge.

The rate of air drying of sludge is related to temperature, relative humidity, and air velocity. Evaporation will proceed at a constant rate to a critical moisture content, then at a falling rate to an equilibrium moisture content. The average evaporation rate for a sludge is about 75 percent of that from a free water surface.

Advantages and Limitations. The main advantage of sludge drying beds over other types of sludge dewatering is the relatively low cost of construction, operation, and maintenance.

Its disadvantages are the large area of land required and long drying times that depend, to a great extent, on climate and weather.

Operational Factors. Reliability: Reliability is high with favorable climactic conditions, proper bed design and care to avoid excessive or unequal sludge application. If climatic conditions in a given area are not favorable for adequate drying, a cover may be necessary.

Maintainability: Maintenance consists basically of periodic removal of the dried sludge. Sand removed from the drying bed with the sludge must be replaced and the sand layer resurfaced.

The resurfacing of sludge beds is the major expense item in sludge bed maintenance, but there are other areas which may require attention. Underdrains occasionally become clogged and have to be cleaned. Valves or sludge gates that control the flow of sludge to the beds must be kept watertight. Provision for drainage of lines in winter should be provided to prevent damage from freezing. The partitions between beds should be tight so that sludge will not flow from one compartment to another. The outer walls or banks around the beds should also be watertight.

Solid Waste Aspects: The full sludge drying bed must either be abandoned or the collected solids must be removed to a landfill. These solids contain whatever metals or other materials were settled 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 641) 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 611) 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 642).

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 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 they can be more completely removed, or by eliminating pollutants which are not readily removed or which interfere with the treatment of other pollutants. They also frequently yield economic benefits 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-30 (page 642) 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 control at these facilities.

Many in-process pollution control techniques are of general significance, 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 cost-effective pollution control. Separation of noncontact cooling water from process wastewater prevents dilution of the process wastes and maintains the character of the non-contact stream for subsequent reuse or discharge. Similarly, the segregation of process wastewater streams differing significantly in their chemical characteristics can reduce treatment costs and increase effectiveness. Segregation of specific process wastewater streams is common at battery manufacturing plants.

Mixing process wastewater with noncontact cooling water increases the total volume of process wastewater. This has an adverse effect on both treatment performance and cost. The resultant waste stream is usually too contaminated for continued reuse in noncontact cooling, and must be treated before discharge. The increased volume of wastewater increases the size and cost of treatment facilities and lowers the mass removal effectiveness. 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.

Battery manufacturing plants commonly produce multiple process wastewater streams having significantly different chemical characteristics; some are high in toxic metals, some may contain primarily suspended solids, and others may be quite dilute.

Wastewater from a specific process operation usually contains only a few of the many pollutants generated at a particular site. Segregation of these individual process waste streams may allow reductions in treatment costs and pollutant discharges.

The segregation of dilute process waste streams from those bearing high pollutant loads often allows further process use of the dilute streams. Sometimes the lightly polluted streams may be cycled to the process from which they were discharged; other wastewater streams may be suitable for use in another process with only minimal treatment; and in selected cases dilute process wastewater streams are suitable for incorporation into the product.

Segregation of wastewater streams may lower the cost of separate treatment of the wastewater stream. 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 allowing increased 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. This technique presently is used to recover materials used in processing pasted, electrodeposited, and impregnated electrodes at battery manufacturing plants.

<u>Wastewater Recycle and Reuse</u> - 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, and wastewater from equipment and area cleaning. Numerous other process wastewater streams from 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 water, 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 for electrode manufacture, pasting area washdown water can be collected in the immediate area of pasting, settled and the supernatant reused for the next 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 sometimes low enough to allow recycle to the process with minimal treatment. A high degree of recycle of wastewater from contact cooling streams may require provisions for neutralization or removal of heat.

The extent of recycle possible in most process water uses is ultimately limited by 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. One example of this condition is 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 adjustments 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 savings 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 later in this section.

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 requirements are 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 Multistage 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.

One cadmium subcategory plant has recently implemented a five-stage countercurrent rinse after electrode impregnation. This change has reduced the rinse discharge from 150,000 to 12,000 gal/day. In addition, the countercurrent rinse discharge is sufficiently concentrated to be sold for its caustic (NaOH) content. The flow rates before and after implementation of the cascade rinse indicate a 12.5 fold reduction in wastewater flow by this technique. Since a substantial increase in production also occurred, the actual flow reduction attributable to countercurrent rinsing must have been greater. These results illustrate the flow reductions which may be achieved by countercurrent rinsing. The transfer of this performance to other process elements and subcategories requires the consideration of rinsing factors which may differ.

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

For a multistage 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. Multistage rinsing uses two or more stages of rinsing each of which is supplied with fresh water and discharges to sewer or treatment.

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 of 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:

$$\frac{Co}{Cf}^{(1/2)} = \frac{Vr}{VD} = \frac{20.9}{0.029} = 720$$

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

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

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.

A corresponding comparison between theoretical and actual countercurrent rinse performance cannot be made for the cadmium subcategory plant because of uncertainties in production level, number of impregnation and rinse cycles performed on each electrode, and electrode pore volume during the early stages of impregnation (a process which fills electrode pores with active material to achieve the final electrode porosity).

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 present 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 production normalizing parameters make up only approximately 45 percent of the total electrode weight in most cases.

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.

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)			
	Multistage	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.

<u>Process Modification</u> - There are numerous process alternatives for the manufacture of batteries in most of the battery manufacturing subcategories, and the alternatives frequently differ significantly in the quantity and quality of wastewater produced. Most process modifications which may be considered as techniques for reducing pollutant discharge are specific to individual subcategories and are discussed in subsequent sections. In general, process modifications considered deal with changes in electrolyte addition techniques as discussed previously and changes in elec-

trode formation processes. In addition, changes in amalgamation procedures and improvements in process control to reduce rework requirements are viable techniques to reduce wastewater discharge at some sites.

One process modification applicable to several subcategories is the substitution of alternative formulations for cell wash materials containing chromate and cyanide. This substitution will eliminate these pollutants from process wastewater at the plants which presently use them.

Plant Maintenance and Good Housekeeping - Housekeeping practices are particularly significant for pollution control at battery manufacturing facilities. Large quantities of toxic materials used as active materials in battery electrodes are handled and may be spilled in production areas. The use of water in cleaning up these materials may contribute significantly to wastewater discharges at some facilities.

Maintenance practices are observed to be important in eliminating unnecessary spills and leaks and in reducing contamination of noncontact cooling water. Examples of the impact of faulty maintenance were observed in the contamination of noncontact cooling water in a leaking ball mill cooling jacket at one lead subcategory facility and in the use of excess water in hosing down a malfunctioning amalgamation blender. In both cases, the volume of wastewater requiring treatment and losses of process materials were increased resulting in increased treatment and manufacturing process costs as well as increased pollutant discharges.

Good housekeeping encompasses a variety of plant design and operating practices which are important for efficient plant operation and worker hygiene and safety as well as for water pollution control. These include:

> Floor maintenance and treatment in areas where toxic materials are handled to minimize cracks and pores in which spilled materials may lodge. This reduces the volume of water required to clean up spills and increases the efficiency of dry cleanup techniques.
>
> Preventing drips and spills and collecting those which cannot be avoided, especially in electrolyte addition areas. Isolating the collected materials rather than letting them run over equipment and floor surfaces can greatly reduce wash-down requirements and also allow the collected materials to be returned for process use instead of being discharged to waste treatment.

Reduction in spillage in bulk handling by provision for dust control and for rapid dry cleanup of spilled materials.

Cadmium Subcategory

Cadmium subcategory manufacturing processes involve a wide variety of process water uses in active material preparation, electrode processing and rinses, cell washing, equipment and area washing, and air pollution control. Consequently, many different in-process control techniques are applicable. These include waste segregation, material recovery, process water recycle and reuse, water use control (reduction), and process modification possibilities.

Waste Segregation - The segregation of wastewater streams from individual process operations is presently practiced by some manufacturers in this subcategory. Segregation of specific waste streams is useful in allowing recycle and reuse and in making the recovery of some process materials feasible. Waste streams segregated for these purposes include wet air pollution control scrubber discharges which are segregated for recycle, formation process solutions which are segregated for reuse in formation or in other process operations and waste streams from impregnation, electrodeposition and wet plate cleaning or brushing which are segregated to allow material recovery. Segregation of process wastes is not practiced for end-of-pipe treatment in this subcategory because all process waste streams are amenable to treatment by the same technologies. The segregation of noncontact cooling and heating water from process wastewater is essential for effective removal of process pollutants in end-of-pipe treatment, and it is presently practiced at most plants in the subcategory. Many plants recirculate noncontact cooling water through cooling towers.

Material Recovery - Cadmium or nickel hydroxide particles, formed during impregnation or electrodeposition, do not adhere to the electrode structure and are removed in rinse or process discharges. If the discharges from cathode and anode processes are segregated, these particles may be recovered by settling or filtering to yield separate sludges rich in cadmium or nickel. The metal values may be recovered from these sludges. This practice, presently employed in the subcategory, yields an economic return from recovered cadmium and nickel; reduces the waste loads flowing to treatment; and reduces the quantities of toxic metal sludge requiring disposal.

Wastewater Recycle and Reuse - Process wastewater streams produced in this subcategory which are presently recycled or suitable for recycle include wet scrubber discharges, wastewater from scrubbing impregnated electrodes or electrode stock, and process solutions used in material deposition and electrode formation. Recycle of these waste streams is presently practiced and is observed to yield large reductions in process wastewater flow.

Air pollution control scrubbers are employed to control emissions of acid fumes and toxic metals (cadmium and nickel) from process solutions used in electrodeposition, impregnation, active material preparation and material recovery operations. Recycle of water used in these scrubbers is common but not universal. Of six wet scrubbers reported in use at plants in this subcategory, five employ extensive recycle of the scrubber water. Discharge flow rates from recirculated scrubber systems were as low as 1.1 l/hr, while the nonrecirculated scrubber had a discharge of 9538 l/hr. In many cases, caustic solutions are used in the scrubbers and recirculated until neutralized by the collected acid fumes. This practice results in the presentation to treatment of a concentrated small volume discharge from which pollutants may be effectively removed.

Wet cleaning of impregnated electrodes or electrode stock results in large volumes of wastewater bearing high concentrations of particulate nickel or cadmium hydroxide. This wastewater may be treated by settling and recycled for continued use in the wet scrubbing operation. Since the primary contaminants in this waste stream are suspended solids, a very high degree of recycle after settling is practical. Recycle of this waste stream following settling to remove suspended solids is practiced at one plant with wastewater discharged only once per month. The volume of wastewater from this process after recycle is only 4.8 l/kg. This may be compared to a discharge volume of 108 l/kg observed at another plant which does not recycle electrode scrubbing wastewater.

Water used in washing process equipment and production floor areas in this subcategory also becomes contaminated primarily with suspended solids. The wastewater may be treated by settling and recycled for further use in floor and equipment wash operations. Recycle of these waste streams will allow effective maintenance of equipment and floor areas with little or no resultant process wastewater discharge.

Process solutions used in material deposition and electrode formation are extensively reused at most plants and represent a minimal contribution to the total wastewater flow. Reuse of these process solutions significantly reduces pollutant loads discharged to waste treatment and also yields economic benefits in reduced consumption of process chemicals.

Water Use Control and Reduction - Large volumes of process water are used in rinsing at cadmium subcategory plants. On site observations at several plants and analysis of flow rate information from other sites indicate that effective control of water use in these operations is not achieved, and that substantial reductions from present discharge rates may be attained by instituting effective water use control. The lack of effective water use control in these operations is demonstrated by the wide range of flow rates among plants and on different days at the same plant. Practices contributing to excessive water use and discharge in rinsing were observed during sampling visits at four cadmium subcategory plants. At one plant for example, measured rinse flow was observed to be about 25 percent greater than the values reported in the dcp, although the production rate was about 50 percent less than that reported. The wastewater discharge per unit of production was approximately three times the value indicated by dcp information. At this site rinsing was practiced on a batch basis, and the rinse cycle included an overflow period after the rinse tank was filled with water. The length of this overflow period was observed to vary arbitrarily and was frequently lengthened considerably when the water was left running through coffee breaks and meals. Similar rinse flow variability was observed at other plants.

Flows reported in dcp for wastewater discharge from process rinses associated with anode and nickel cathode electrodeposition and impregnation are attainable by implementation of rinse flow control at all sites. This can be achieved through the use of automatic shutoffs which will close water supply valves when the process line is not running and adjustment of rinse flow rates when production rates vary.

Further reductions may be achieved by application of multistage countercurrent rinse techniques. While multistage rinses are common in the subcategory, countercurrent rinsing is practiced only sometimes and is not accompanied by effective water use control. Implementation of countercurrent rinses in this subcategory will differ at different plants since rinsing equipment and techniques are observed to vary.

Another technique used to reduce process flow rates is the use of dry air pollution control equipment such as bag houses. Two plants reported using bag houses to control dust emissions caused by processing dry materials.

Wastes from electrolyte preparation and addition to cells result from equipment washing and from drips and spills of electrolyte. Collection of electrolyte drips in filling operations and reusing this material in filling cells can aid in eliminating this waste stream. Wastewater from washing electrolyte preparation and addition equipment is reported by only a few plants. Other plants evidently use dry equipment maintenance procedures or recycle equipment wash water.

Floor cleaning at cadmium subcategory plants may also be accomplished with or without the use of process water, and where water is used, the efficiency of use varies. Efficient use of floor wash water may substantially reduce wastewater discharge at some plants as indicated by the comparison of reported normalized discharge flows for this activity which range from 0.25 to 33.4 liters per kilogram of finished cells produced. Dry floor cleanup is a viable option in this subcategory since most of the materials requiring removal from production floor areas are dry solids. Seven active plants in the subcategory reported no process wastewater from washing floors and apparently employ dry floor cleaning techniques. Only two plants in the subcategory reported wastewater discharge from floor cleaning.

Process Modification - Numerous manufacturing processes for the production of cadmium subcategory batteries are observed. They vary widely in the volume and characteristics of process wastewater produced. Many of the process variations, however, correspond to variations in battery performance characteristics and therefore may not be suitable for use as bases for pollutant discharge reductions throughout the subcategory. For example, the manufacture of pasted and pocket plate powder electrodes is observed to yield significantly lower wastewater discharges than the production of sintered, impregnated electrodes, but the current and power densities attained in pocket plate electrodes are lower than those in sintered, impregnated electrodes. Since the products of these two process alternatives are not equivalent, process modification by substitution of one for the other may not be a viable basis for effluent limitations. There are, however, some observed or potential process modifications which can result in reduced pollutant discharges without significantly affecting product characteristics. These include modifications in electrode formation practices and improvements in process control on active material preparation operations.

In-case formation appears to be feasible without any apparent impact on battery performance characteristics. This practice which eliminates wastewater discharge from spent formation solutions and from post formation rinses could be applied to reduce pollutant discharges.

In the production of cadmium powder for use in battery manufacturing, the product is rinsed after precipitation. Improved process control of the precipitation step and of rinsing would reduce the volume of wastewater from this operation by approximately 40%.

Calcium Subcategory

Process water use in this subcategory is very limited. Consequently, the opportunities for in-process controls significantly reducing water use or wastewater discharge are correspondingly limited. Wastewater generated from heat generation component manufacture, cell testing and scrap disposal can be eliminated.

The manufacture of thermal heat paper produces solids and wastewater from the pasting equipment cleanup which is similar to pasting in the lead subcategory. As is practiced at numerous plants in the lead subcategory the solids can be recycled back to the process and wastewater can be used for past make-up water. This is feasible because wastes generated contain constiuents used in the paste. Water used for cell testing can also be treated when necessary and reused. Water used in the disposal of calcium scrap may be reduced by limiting the amount of scrap produced and by limiting the amount of water used per unit weight of scrap disposed. Alternatively, this waste source may be eliminated altogether by allowing the calcium to react with atmospheric moisture and disposing of the resultant calcium hydroxide as a solid waste.

Leclanche Subcategory

Process water use and wastewater discharge in this subcategory are limited. Many plants presently report no discharge of process wastewater, and most others discharge only limited volumes of wastewater from one or two sources. Almost all of the existing discharges can be eliminated by the implementation of effective in-process control measures, especially wastewater recycle and reuse.

Waste Segregation - At most plants in this subcategory, waste segregation is not required except for the segregation of process wastewater from other wastes. Only one or two battery manufacturing waste sources are typically encountered in this subcategory, and the characteristics of the resultant waste streams are generally similar. One exception to this observation occurs where paste separators are employed or pasted paper separators are produced. In this case, segregation of wastewater from the paste preparation and handling operations from other process waste streams is important for effective treatment as well as wastewater recycle and reuse.

Wastewater Recycle and Reuse - Essentially all of the process wastewater discharge streams reported in this subcateogry result from washing production equipment, fixtures, and utensils. While the specific recycle and reuse techniques differ, waste streams from both paste preparation and application and from other equipment cleanup may be completely recycled and reused eliminating process wastewater discharged from these sources. Process water used to supply heat for setting paste separators in some cells is also amenable to extensive recycle.

Equipment used in the preparation and application of paste to cells containing paste separators or to paper for use as cell separator material, is generally washed down with water periodically as a part of normal maintenance. The resultant wastewater, generally containing paste, ammonium chloride, zinc, and mercury, may be retained and reused in subsequent equipment washing. The buildup of contaminants in the wash water can be controlled by using a portion of the wash stream in paste preparation. The contaminants which are normal constituents of the paste are thereby included in the product, and discharge of process wastewater pollutants from this operation is eliminated. This recycle and reuse practice is demonstrated at plants which report no process wastewater discharge from paste preparation and application.

Water used in washing equipment and utensils for most other production operations serves primarily to remove insoluble materials such as carbon and manganese dioxide particles. Wastewater from these washing operations can be retained, treated by settling to remove the solids, and reused in further equipment washing. The buildup of dissolved materials in this stream may be controlled by using some of the wash water in electrolyte or cathode formulation. For foliar batteries reuse is restricted because of cell failure which can result from small quantities of contaminants in this particular cell design. Since the primary source of dissolved salts in the wash water is electrolyte incorporated in cell cathodes or handled in the process equipment, the contaminants in the wash water after settling are normal electrolyte constituents, and no deleterious effect on cell performance will result from this practice.

Water is used to supply heat for setting paste separators by one manufacturer. As a result of contact with machinery used to convey the cells, and occasional spillage from cells, this water becomes moderately contaminated with oil and grease, paste, manganese dioxide particulates, zinc, ammonium chloride, and mercury. These contaminants, however, do not interfere with the use of this water for heat transfer to the outside of assembled cells. Wastewater discharge from this operation results from manufacturing conveniences, maintenance of the equipment, and from drag-out of water on the cells and conveyors. Discharge from each of these process sources may be reduced or eliminated by recycle and reuse of the water.

The paste processing steps in making mercury containing seperator paper generates a wastewater discharge when the paste mixing equipment is washed. The flow from the wash operation is minimal and can be eliminated either by dry maintenance of the equipment or recycle of the wash water for inclusion in the paste.

Water Use Control and Reduction - Water use in equipment and floor cleaning at some sites in this subcategory may be substantially reduced by the implementation of water use controls or eliminated entirely by the substitution of dry equipment cleanup procedures. Most plants in the subcategory presently employ dry equipment and floor cleaning techniques and discharge no process wastewater. Dry air pollution control devices also serve to reduce water use in this subcategory.

Reduction in water use in cleaning electrolyte handling and delivery equipment and cathode blending equipment may be possible by more effective control of flow rates at several sites in the subcategory. These reductions would decrease the cost of treating wastewater for recycle or of contract removal of the wastes. The potential for such reductions is indicated by the broad range in water use for this purpose within the subcategory. Normalized discharge flows ranging from 0.01 l/kg of cells produced to 6.37 l/kg of cells produced were reported by plants that discharge from this operation. Some of this variation, however, is attributable to variations in the type of cells produced and the nature of the production equipment requiring cleaning. As noted in the previous discussion, this water may be recycled, eliminating all wastewater discharge to the environment from this source. Use of dry maintenance techniques will also serve to eliminate equipment cleaning wastewater discharge. The majority of plants do not report any wastewater discharge from equipment maintenance, indicating that these techniques are widely applied in this subcategory.

For foliar battery production water use is excessive and can be controlled with various flow control practices and limited recycle of wastewater. The present flow of 0.132 l/kg can be reduced to half of its present flow using these in-process techniques discussed above.

Water is used in a washing machine at one plant to clean fixtures used to transport cell cathodes to the assembly. Since the machine is often used with only a partial load, wastewater discharge from this process may be reduced by scheduling washing cycles so that a complete load is washed each time. This may require a somewhat increased inventory of the fixtures, but will reduce waste treatment costs as well as pollutant discharge.

A majority of manufacturers reported no wastewater discharged from floor wash procedures, and it is concluded that dry maintenance techniques are widely applied in the subcategory although not specifically identified by most facilities. Some of these dry techniques include either sweeping or vacuuming floor areas and using desiccant materials in instances of spillage.

Process Modification - Variations in manufacturing processes and products in this subcategory are observed to correspond to variations in process water use and wastewater discharge. Significant differences in wastewater discharge are observed between plants producing cells with paste separators and pasted paper separators. Among plants producing cells with paste separators, differences in wastewater discharge result from differences in assembly technique and in the paste formulation employed. Relatively high water usage and wastewater discharge are also associated with the manufacture of foliar batteries. While cells using pasted paper and paste separators serve the same applications and are directly competitive, the foliar batteries are designed for a unique application.

The manufacture of cells using heat-set paste separators is observed to produce a wastewater discharge from the paste setting operation. This source of discharge may be eliminated by substitution of a paste formulation which sets at a lower temperature or by use of pasted paper separators. Industry personnel report that production of paste separator cells is significantly less costly than the manufacture of cells with pasted paper separators.

Plant Maintenance and Housekeeping - Dry cleanup of production areas is practiced at essentially all sites in this subcategory. In addition, most facilities employ dry cleaning techniques in maintaining process equipment. These practices contribute to the low wastewater discharge rates typical of this subcategory.

Lithium Subcategory

Process water use and wastewater discharges in the lithium subcategory are limited. The cell anode material reacts vigorously with water, necessitating the use of nonaqueous electrolytes and dry processes for most manufacturing operations. Correspondingly, opportunities for in-process control are also limited.

Thermal batteries similar to those produced in the calcium subcategory are manufactured in this subcategory including the production of heat generation component material. As discussed for the calcium subcategory, this waste stream may be recycled after settling, eliminating this source of wastewater discharge.

At some plants in this subcategory, wet scrubbers are used to control emissions from sulfur dioxide and thionyl chloride depolarizer materials. Extensive recycle of the scrubber discharge streams is possible, reducing the volume of wastewater discharge to minimal values.

Magnesium Subcategory

Half of the plants in this subcategory report zero discharge of magnesium battery manufacturing process wastewater. The remaining facilities report process wastewater discharges from eight different process operations to which a variety of in-process control techniques may be applied.

At one plant which produces magnesium anode thermal batteries, process wastewater discharges result from wet scrubbers on dehumidification equipment used to control conditions in process areas and from the production of heating component material. These waste streams may be extensively recycled significantly reducing or eliminating wastewater discharges from these sources.

Significant wastewater discharge from floor washing operations is also reported in this subcategory and may be reduced by the use of water-efficient or dry floor cleaning techniques. Alternatively, the floor wash water may be treated and recycled.

Zinc Subcategory

Manufacturing processes in the zinc subcategory involve a wide variety of process water uses and wastewater discharge sources. Wastewater discharges result from active material preparation, electrode processing and associated rinses, cell washing, and equipment and area cleaning. Consequently a variety of techniques may be applied within the process to reduce the volume of wastewater or mass of pollutants discharged.

Waste Segregation - The segregation of individual process waste streams which differ markedly in character is an important factor in effective water pollution control. The segregation of noncontact cooling and heating water from process wastes is essential for effective removal of process pollutants in end-of-pipe treatment. Waste segregation is presently practiced at most plants in the subcategory, many of which recirculate noncontact cooling water through cooling towers.

Many cell cleaning or electrode preparation operations involve the use of organic reagents such as methanol, methylene chloride, and hydrazine, which ultimately leave the process in organic laden waste streams. The segregation of the organic laden waste streams from waste streams bearing predominantly toxic metals and suspended solids is necessary if these pollutants are to be removed effectively and without incurring excessive costs.

The volume of the organic laden waste streams is quite small at most sites, and contract removal to a central location is generally less costly than wastewater treatment and is predominant in present practice. Efficient segregation therefore also contributes to minimizing the cost of contract disposal.

Silver oxides are used as the depolarizer in some of the cells manufactured in this subcategory and are present at particularly high concentrations in wastewater streams from some active material and cathode preparation operations. The segregation of these waste streams may allow recovery of the silver for use on site or its return to a refinery.

Amalgamation of zinc anodes consumes large quantities of mercury, part of which enters process wastewater. Specific process waste streams, contain substantial concentrations of mercury. Segregation, and separate treatment of these streams can reduce the total mass of mercury released to the environment.

<u>Wastewater Recycle and Reuse</u> - Process operations in this subcategory produce waste streams which may be recycled for use in the same operation or reused at some other point in the process. Waste streams which may be recycled or reused in this subcategory include a variety of process solutions, cell wash and rinse wastewater, electrolyte dripped in battery filling, equipment and area wash water, and wastewater from rinsing amalgamated zinc powder. While most of these streams may be recycled without treatment, a few, notably the floor and equipment wash wastewater, may require some degree of treatment before being recycled.

The opportunity for wastewater recycle and reuse in this subcategory is in general minimal because plants in this subcategory do not employ wet scrubbers and the electrolyte content of many zinc subcategory cells is low. Process solutions in this subcategory are commonly reused extensively until either depleted or heavily contaminated, and consequently represent a minimal contribution to the total wastewater flow. Reuse of process solutions significantly reduces pollutant loads discharged to waste treatment, and also yields economic benefits in reduced consumption of process chemicals.

At several plants, it was observed that the addition of electrolyte to assembled cells resulted in small volumes of dripped or spilled electrolyte which was collected and discarded. With care in maintaining the cleanliness of the drip collection vessels, this electrolyte can be returned for addition to cells eliminating this source of highly concentrated wastes.

At most plants, it was observed that cell washing removed small amounts of contaminants from most cells and that water use was governed by the need to ensure adequate contact of the wash solution and rinse water with the complete cell surface. At two plants, wastewater discharges from these operations are presently reduced by the practice of recycling the cell wash and rinse wastewater and discharging from the recycle system only occasionally, generally once each day. Cell wash operations in which this recycle is practiced result in substantially lower discharge volumes than similar cell washes without recycle.

Water is frequently used to wash production equipment, especially equipment used in mixing slurries for the preparation of pasted electrodes and for the amalgamation of zinc powder. The usual purpose of this equipment wash water is to remove solids from the equipment. Because the concentrations of dissolved materials in the equipment wash water are generally moderate, the wastewater from equipment washing can be recycled for further use with any minor treatment. This practice is employed so effectively at one plant that water from equipment washing is discharged only once every six months.

Water used in washing production floor areas also serves primarily to remove solid materials, and wastewater from this operation may be recycled generally if suspended solids removal is provided; where mercury is used in the production areas being cleaned, the wastewater must be treated by a technique which is effective in removing mercury.

Wastewater from rinsing wet amalgamated zinc powder contains zinc, mercury, and soluble materials used in the amalgamation process. Countercurrent rinsing, if applied to these rinse steps, will result in smaller volume discharge which contain relatively high concentrations of mercury and zinc. These contaminants may readily be reduced to levels acceptable for use in washing floors.

<u>Water Use Control and Reduction</u> - The degree of control of process water use is observed to vary significantly among zinc subcategory plants. Production normalized process water use and wastewater discharge in specific process operations are observed to vary by as much as a factor of twenty between different plants, and by factors of six or more from day to day at a single plant. The most significant area where wastewater discharge may be reduced through more effective flow control and efficient water use is in rinsing active materials, electrodes, and finished cells. These reductions may often be achieved by very

simple actions such as turning off rinse water flows when production stops, by adjusting rinse flow rates to correspond to varying levels of production activity, and by the modification of rinsing techniques to provide multistage or countercurrent rinses.

Other techniques which reduce process flows include the replacement of wet processes with processes that do not use water. For example, floor maintenance can be performed by using dry sweeping or vacuuming techniques. In instances of spillage, desiccant material can be applied with subsequent dry floor cleaning. Since most plants report no wastewater from cleaning, these dry techniques are apparently widely applied in the subcategory although not specifically identified by most plants. Only a few plants discharge significant volumes of floor wash water because of such practices as hosing down floor areas.

Material recovery may also significantly reduce pollutant loadings. Zinc cell manufacturerers practice material recovery for silver and mercury in either process wastewater or reject cells.

Process Modification - Manufacturing processes in this subcategory are widely varied and correspond to differences in product types, physical configuration and performance characteristics. A significant number of manufacturing operations are governed by military specifications. Some of the observed variations, however, do not correspond to discernible differences in the end product, and reflect only differences in plant practices.

Zinc powder for use in anodes is amalgamated by three techniques; "wet" amalgamation in which the zinc powder and mercury are mixed in an aqueous solution which is subsequently drained off and discharged; "gelled" amalgamation in which zinc and mercury are moistened with a small volume of electrolyte and mixed with binders to produce an amalgamated anode gel; and "dry" amalgamation in which zinc and mercury are mixed without the introduction of any aqueous phase. Since amalgamated material produced by all three techniques is used on a competitive basis in many cell types, the substitution of a dry amalgamation technique for wet amalgamation may be considered a viable in-process control technique for the reduction of process wastewater discharges in this subcategory.

Silver peroxide is presently produced by several chemical processes at facilities in this subcategory, and different wastewater discharge volumes are observed to result. Substantially less wastewater per unit of product is discharged from one process, and the process solutions are completely recycled.

Cell wash procedures and materials are highly variable in this subcategory, and the resultant normalized discharge volumes vary over nearly three orders of magnitude, from 0.09 to 34.1 l/kg of cells produced. At some sites, organic solvents are used to remove oils and greases from cell cases, eliminating most water use. At others cells are simply rinsed with water without the use of any chemicals in the cell wash.

Cell wash formulations used sometimes contain toxic pollutants, especially chromium and cyanide not otherwise encountered in battery manufacturing wastewater. Cells are successfully washed at many facilities using formulations which do not contain cyanide or chromate. Therefore substitution of an alternative chemical in the cell wash is a practical method for eliminating these pollutants from wastewater discharges in this subcategory.

Another process modification involves forming electrodes in the battery case. This eliminates the post-formation rinsing step, thereby reducing water usage and pollutant loadings. One plant presently uses this procedure.

<u>Plant Maintenance and Good Housekeeping</u> - As in subcategories previously discussed, plant maintenance and housekeeping practices play a vital role in water pollution control. Because large quantities of mercury are used in this subcategory, good housekeeping practices to control losses of the toxic metal are of particular importance for both water pollution control and industrial hygiene. These include the maintenance of floors in process areas where mercury is used, to eliminate cracks and pits in which mercury could be trapped necessitating excessive water use in cleaning. Most plant maintenance and housekeeping practices applicable in this subcategory are similar to those previously discussed for other subcategories.

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	9.2-9.6	8.3-9.8	9.2	7.6-8.1	9.6	7.8-8.2
(mg/l)						
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

Plant	Skimmer Type	Oil & Grease mg/l In	Oil & Grease mg/l 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-benzo-pyrene)	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
Chlorinated 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	Mercury levels - mg/l 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		Plant 31022		Predicted Performance
		In	Out	In	Out	
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

EPA ID#	EQUIPMENT WASH & PASTE FORMULATION	PROCESS SOLUTION	RINSES	SCRUBBER WASTE	PLAQUE SCRUBBING	COMBINED TREATED WASTE STREAMS IN-PROCESS	WATER USE REDUCTION DRY AIR POLLUTION CONTROL TECHNOLOGY	WATER USE REDUCTION MULTI-STAGE COUNTER-CURRENT RINSE	WATER USE REDUCTION DRY PLAQUE SCRUB TECHNIQUE	PROCESS MODIFICATION BATTERY WASH ELIMI-NATION	PROCESS MODIFICATION CONTACT COOLING ELIMI-NATION	PROCESS MODIFICATION FORMATION IN CASE (EXCEPT LEAD SUB-CATEGORY	PROCESS MODIFICATION DRY AMAL-GAMATION PROCESS	MATERIAL RECOVERY
Cadmium Subcategory														
		X			X									
		X												X
								X						
		X												
		X												
		X		X										
														X
							X							
		X		X										X
							X	X	X			X		X
							X							
Calcium Subcategory														
Leclanche Subcategory														
	X						X							
	X						X							
Lithium Subcategory														
														X
Magnesium Subcategory														
							X							
Zinc Subcategory														
		X												
		X												X
												X		X
								X						
			X											
							X							
			X											
							X							
													X	
							X							
			X										X	X
													X	
		X											X	
							X							
		X											X	
							X	X						
													X	

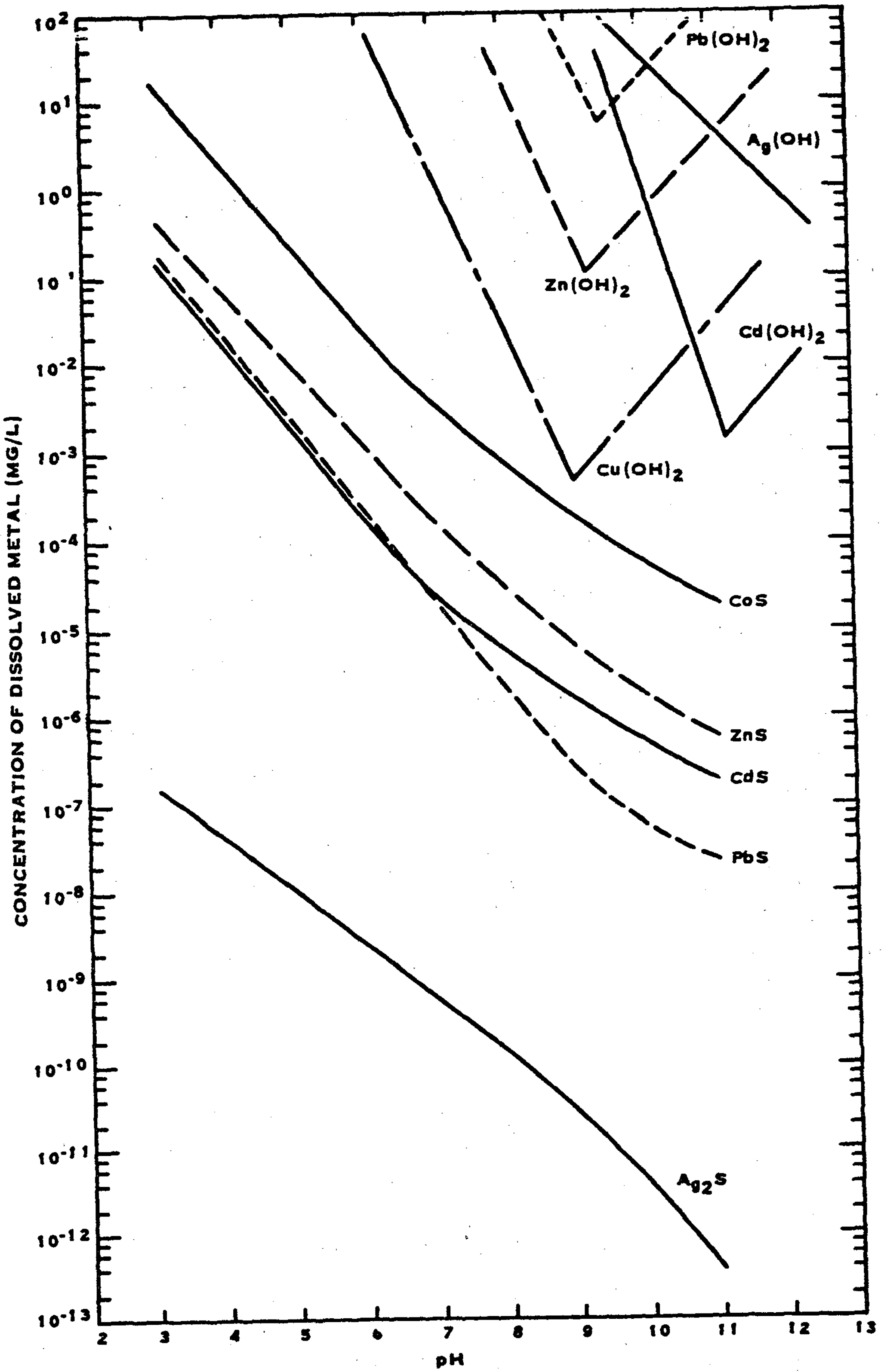


FIGURE VII - 1. COMPARATIVE SOLUBILITIES OF METAL HYDROXIDES AND SULFIDE AS A FUNCTION OF pH

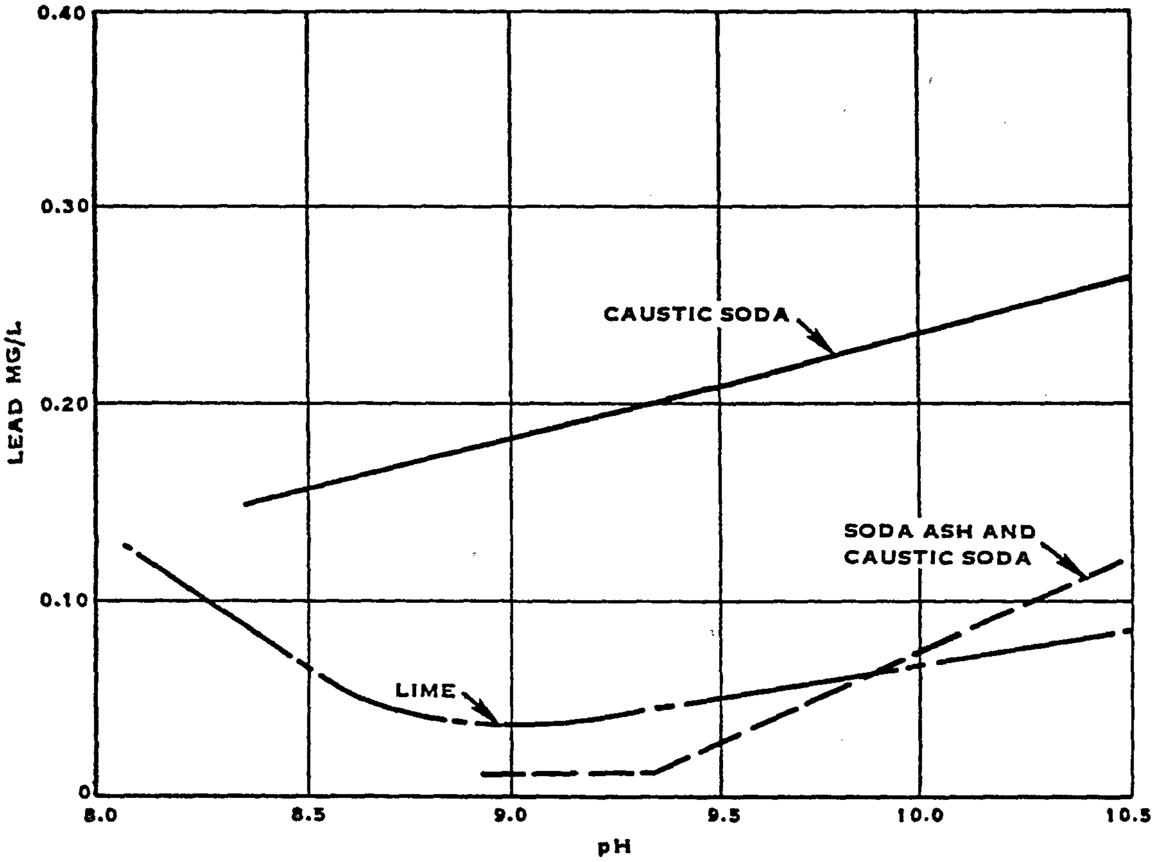


FIGURE VII - 2. LEAD SOLUBILITY IN THREE ALKALIES

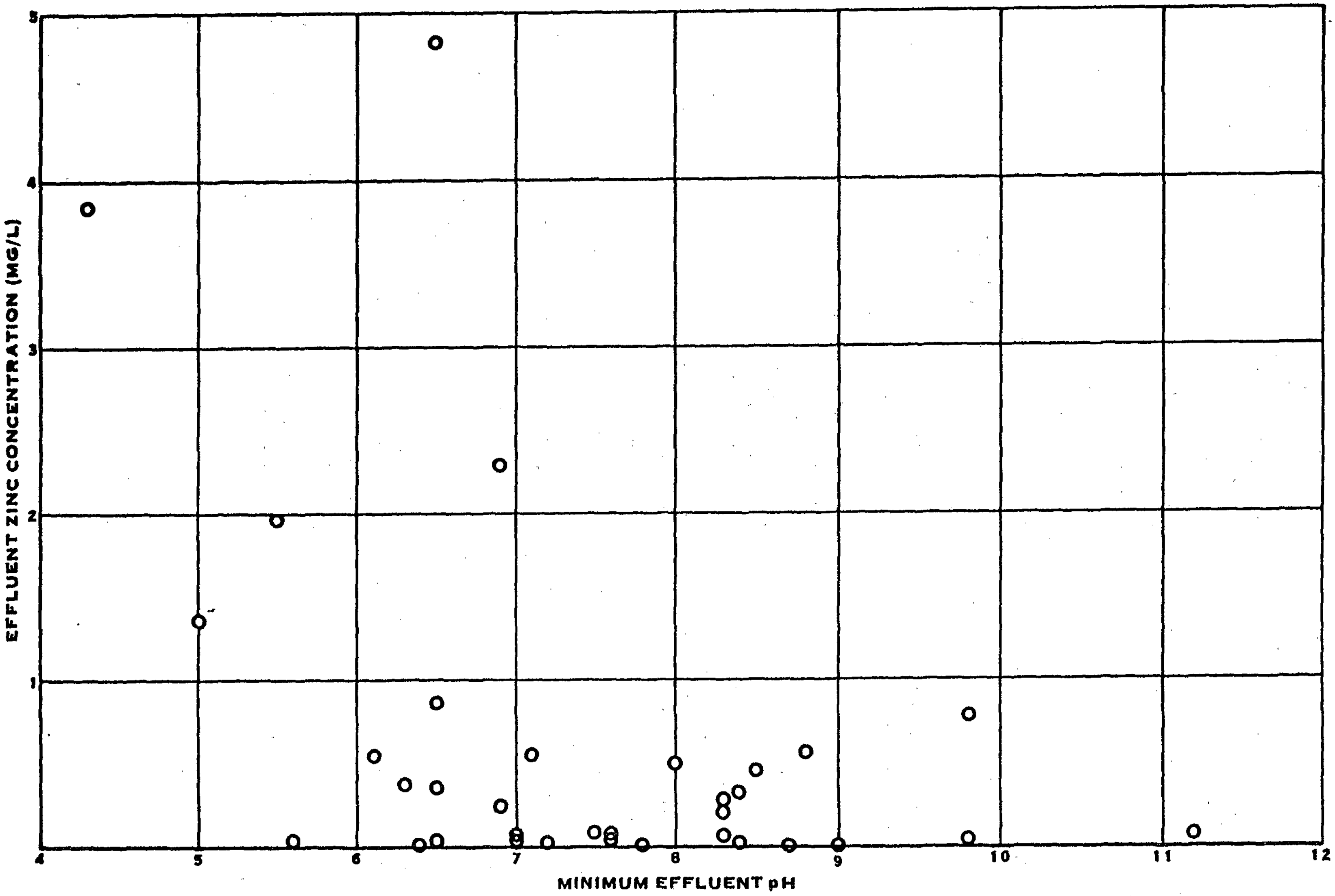
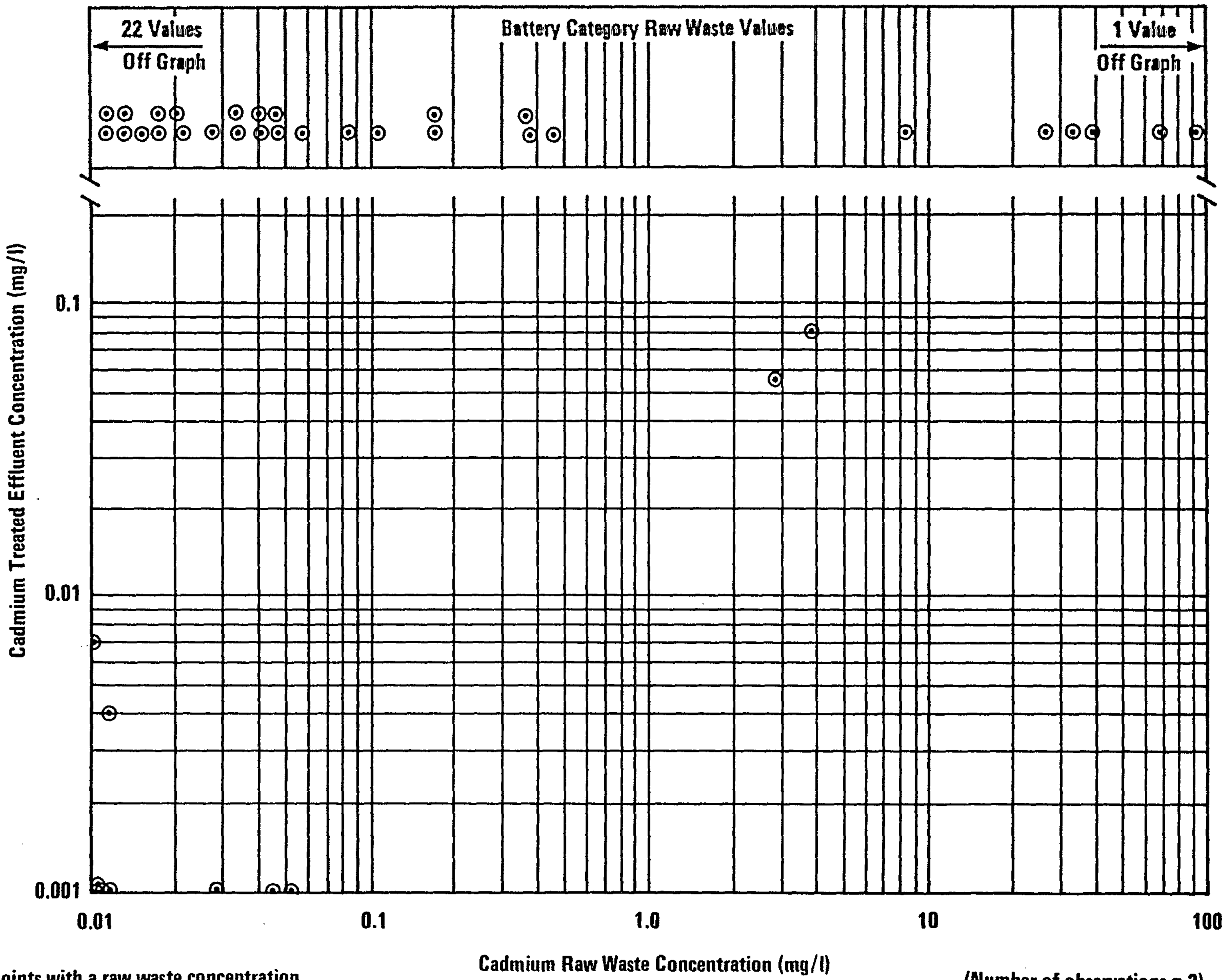


FIGURE VII-3. EFFLUENT ZINC CONCENTRATION VS. MINIMUM EFFLUENT pH



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

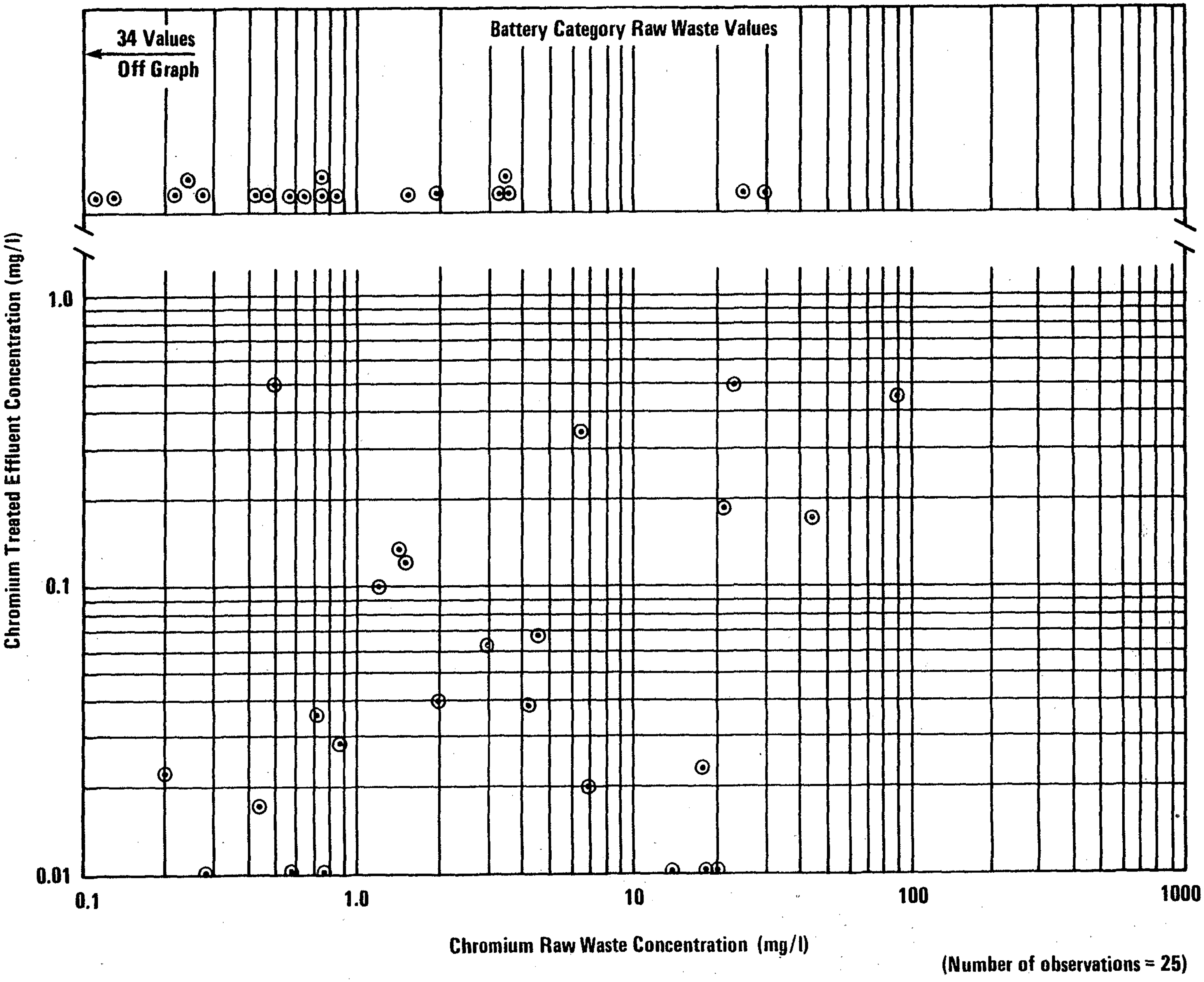
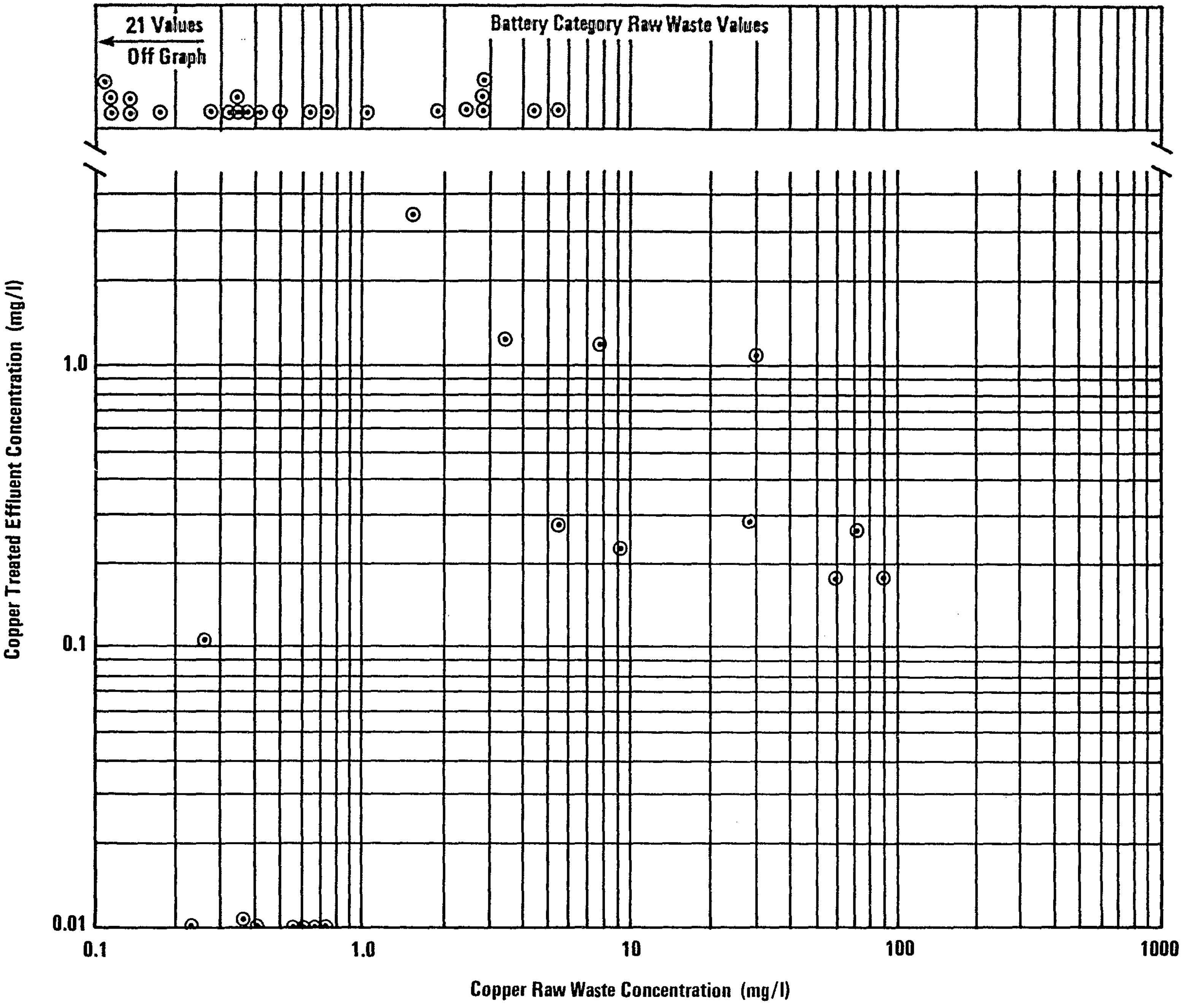


FIGURE VII-5
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CHROMIUM

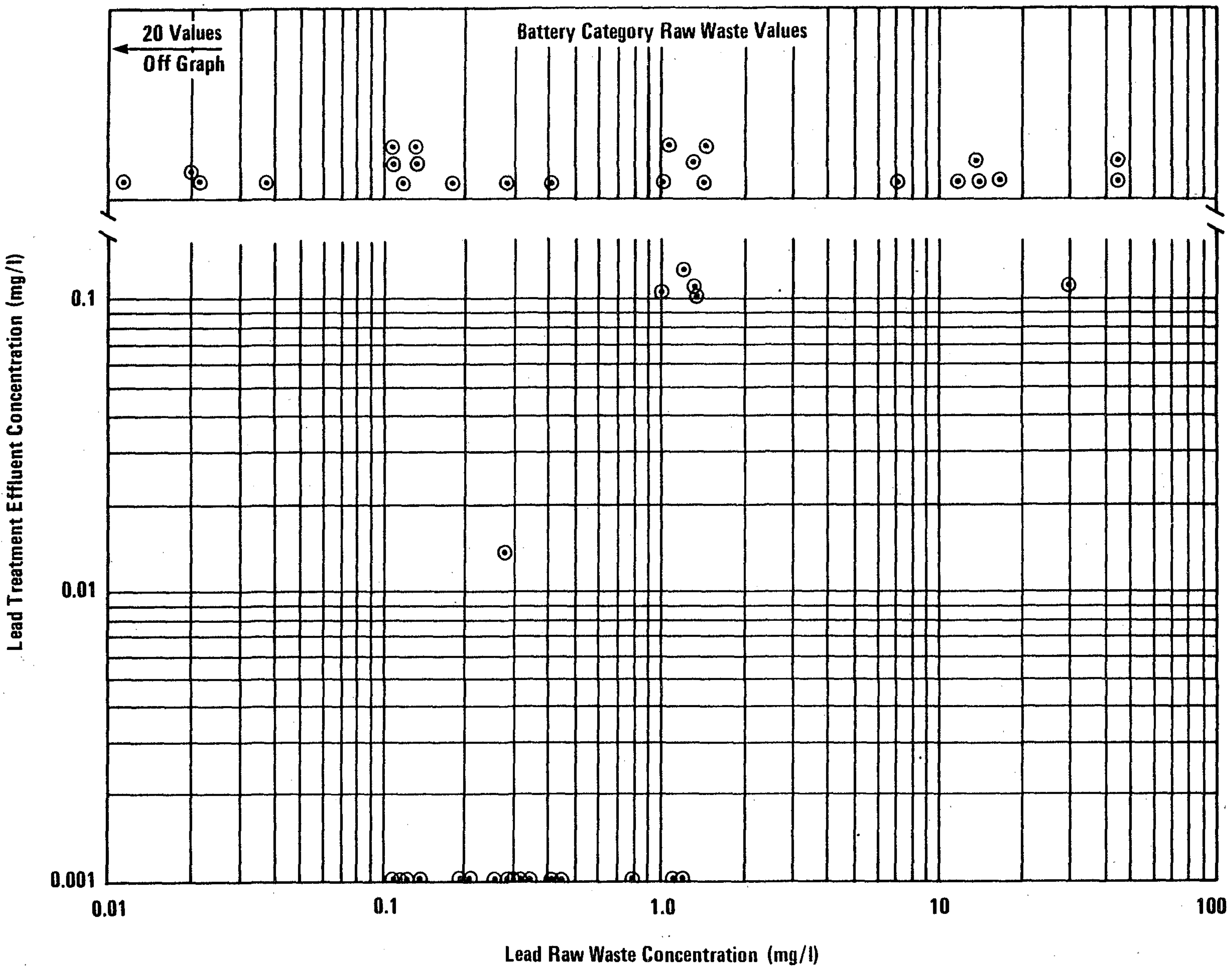


(Number of observations = 18)

FIGURE VII-6

HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS

COPPER



(Number of observations = 22)

FIGURE VII-7
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
LEAD

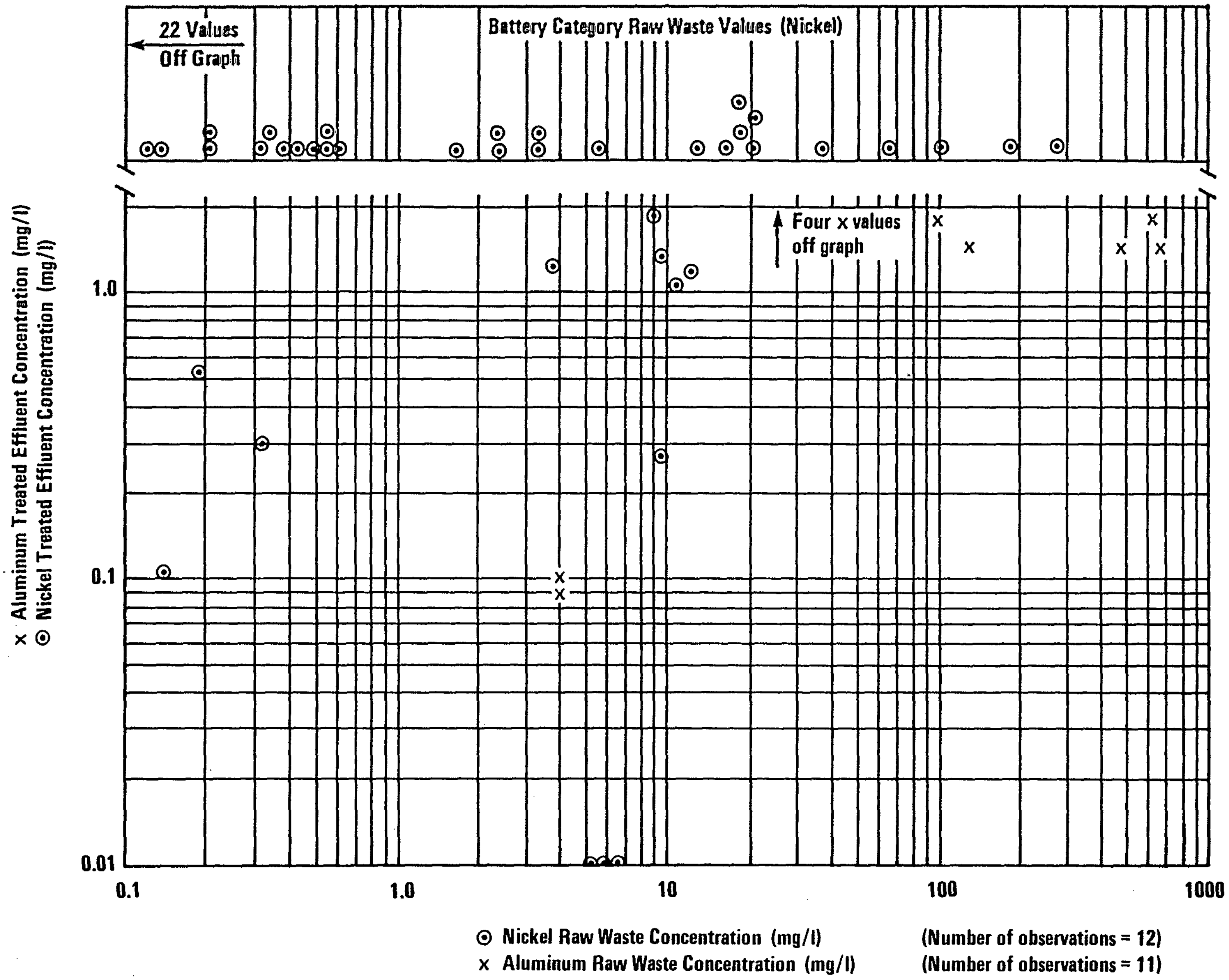
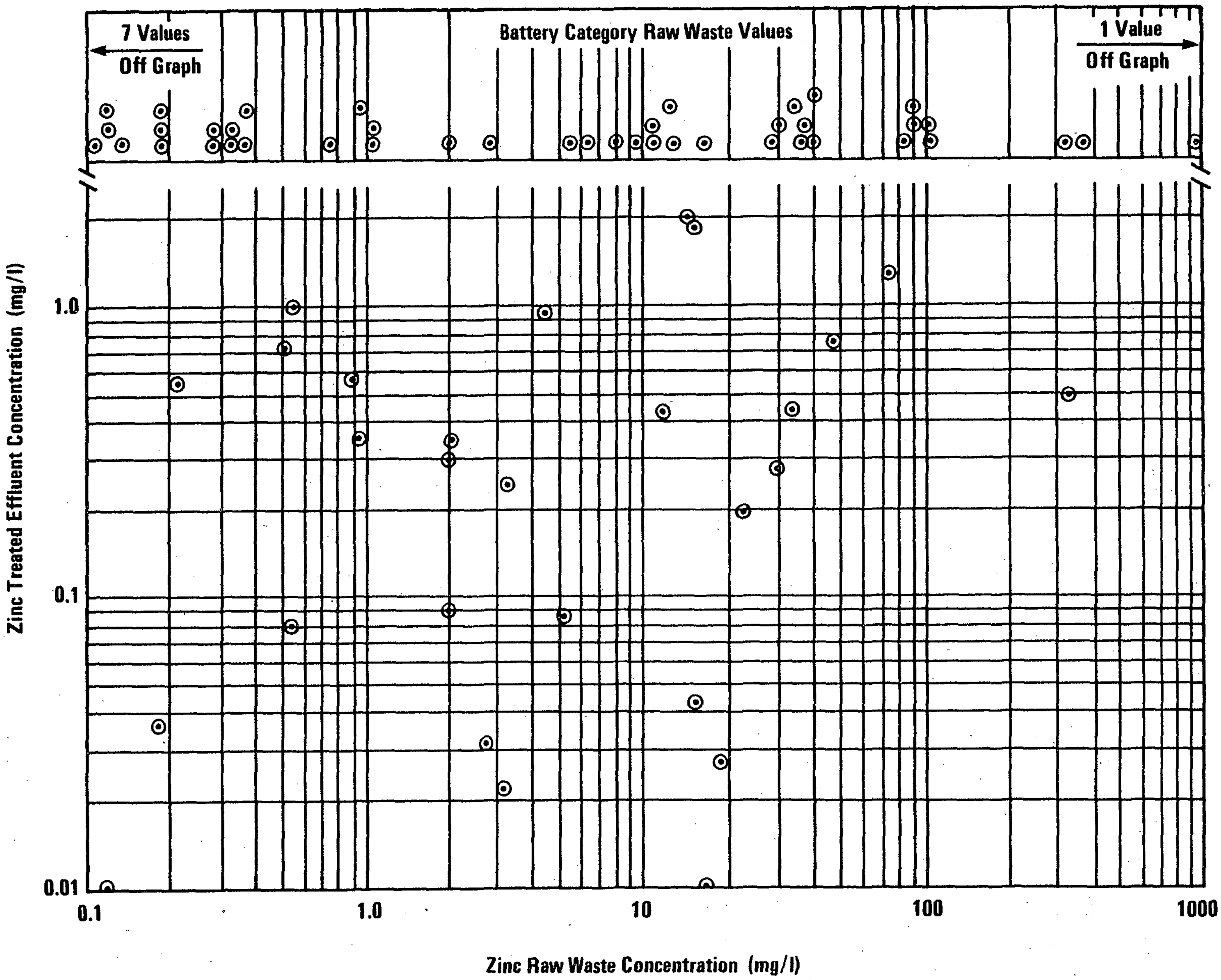
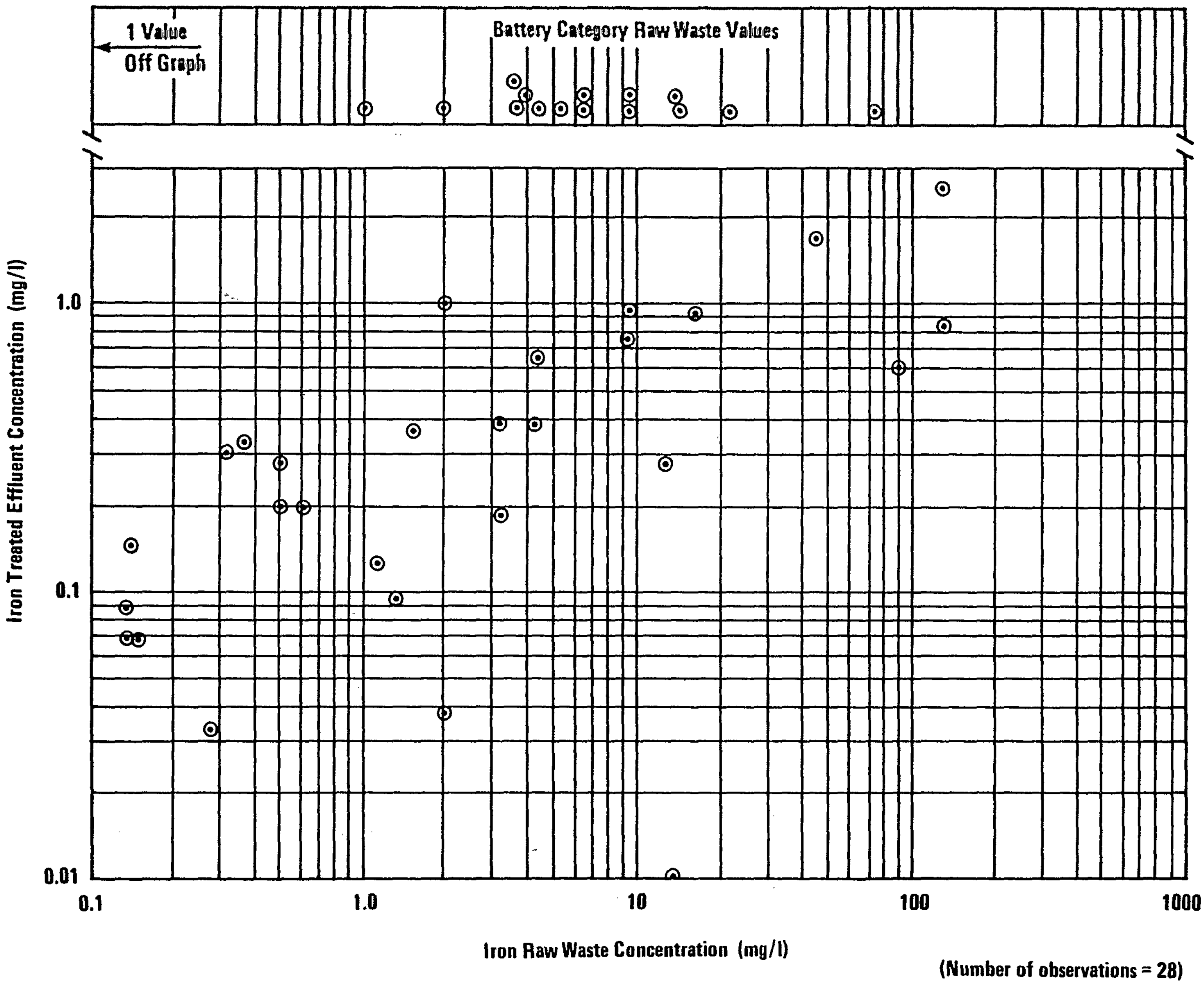


FIGURE VII-8
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
NICKEL AND ALUMINUM



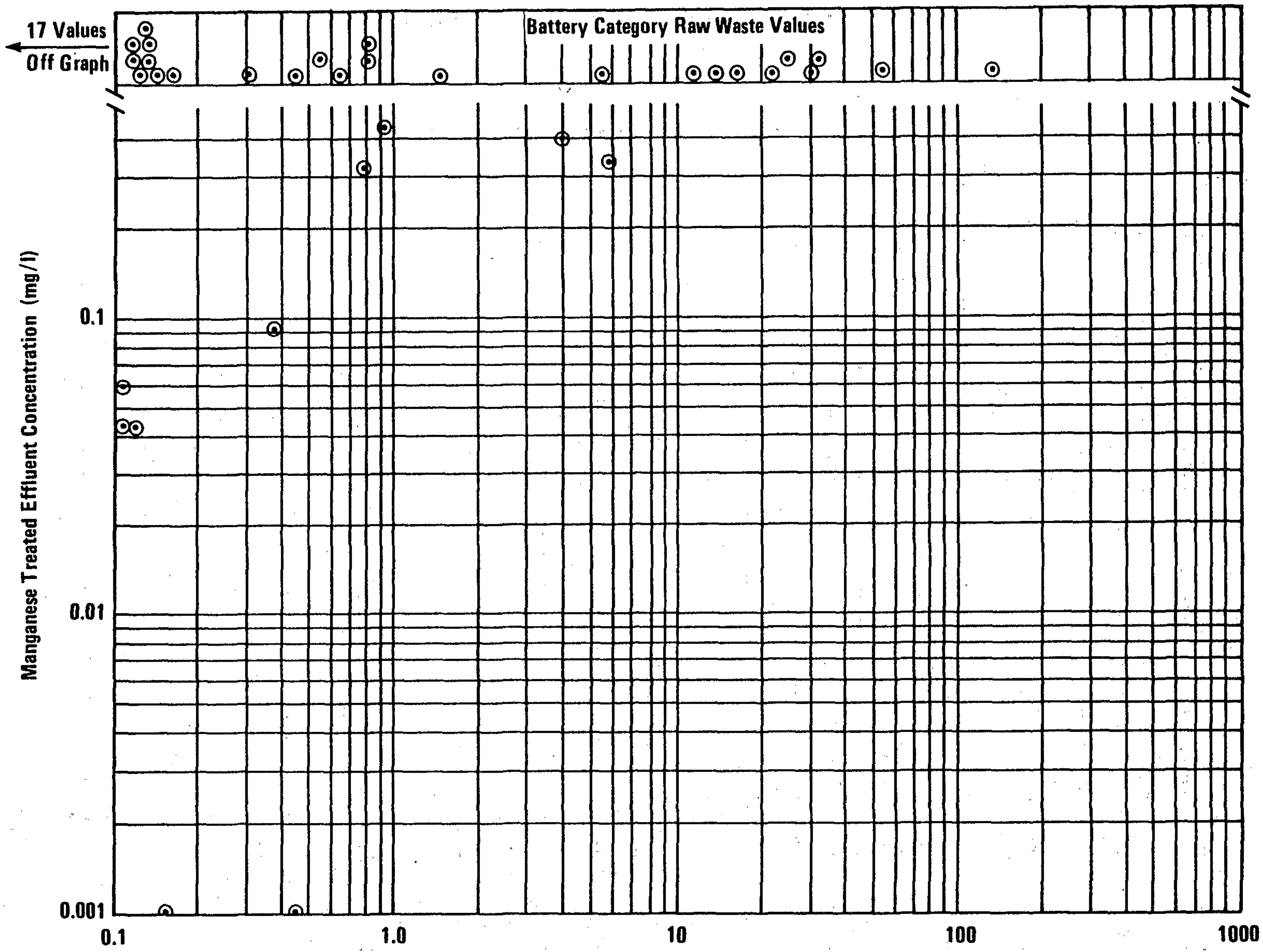
(Number of observations = 28)

FIGURE VII-9
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
ZINC



(Number of observations = 28)

FIGURE VII-10
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
IRON



Manganese Raw Waste Concentration (mg/l)

(Number of observations = 10)

FIGURE VII-11
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
MANGANESE

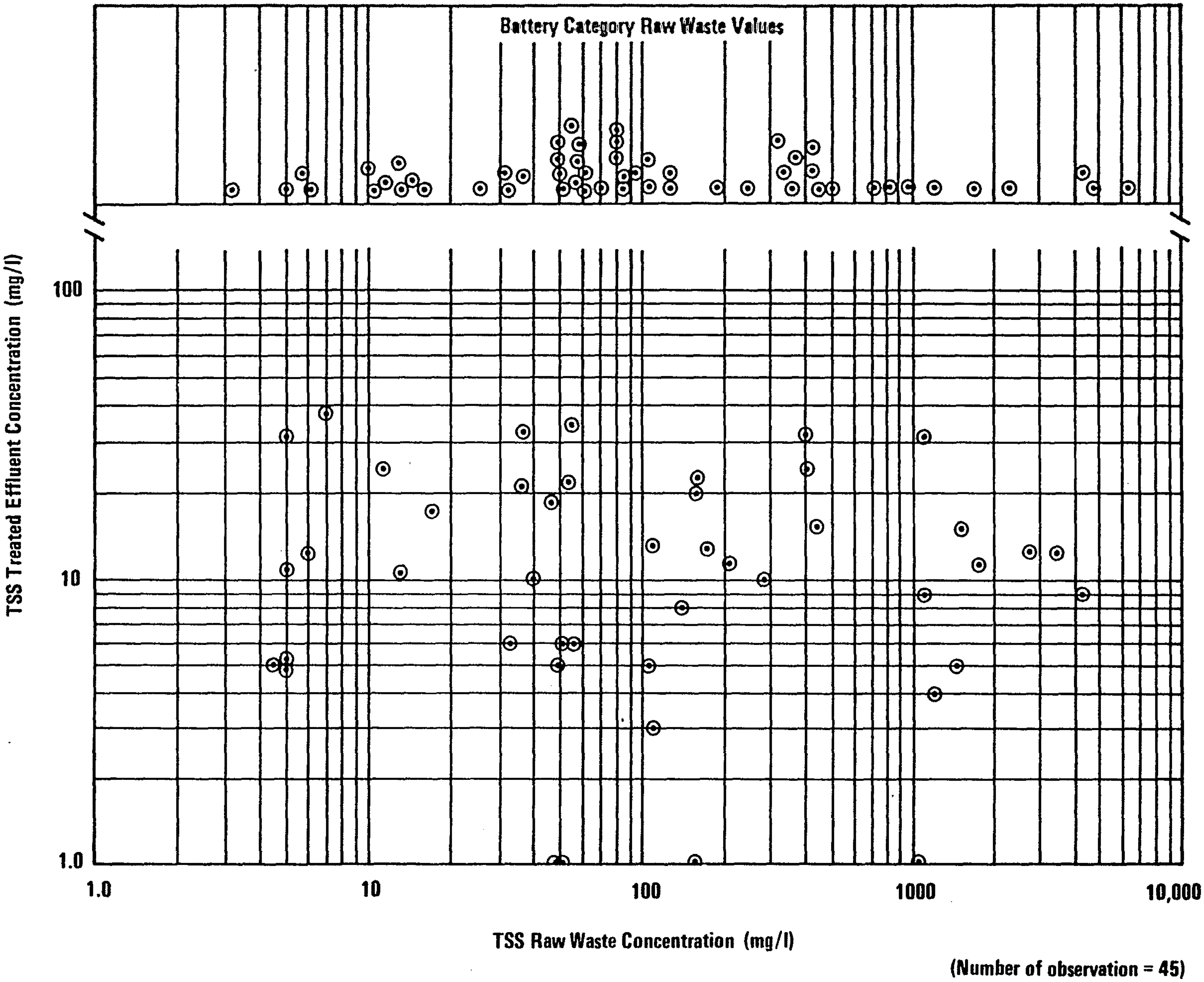


FIGURE VII-12
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
TSS

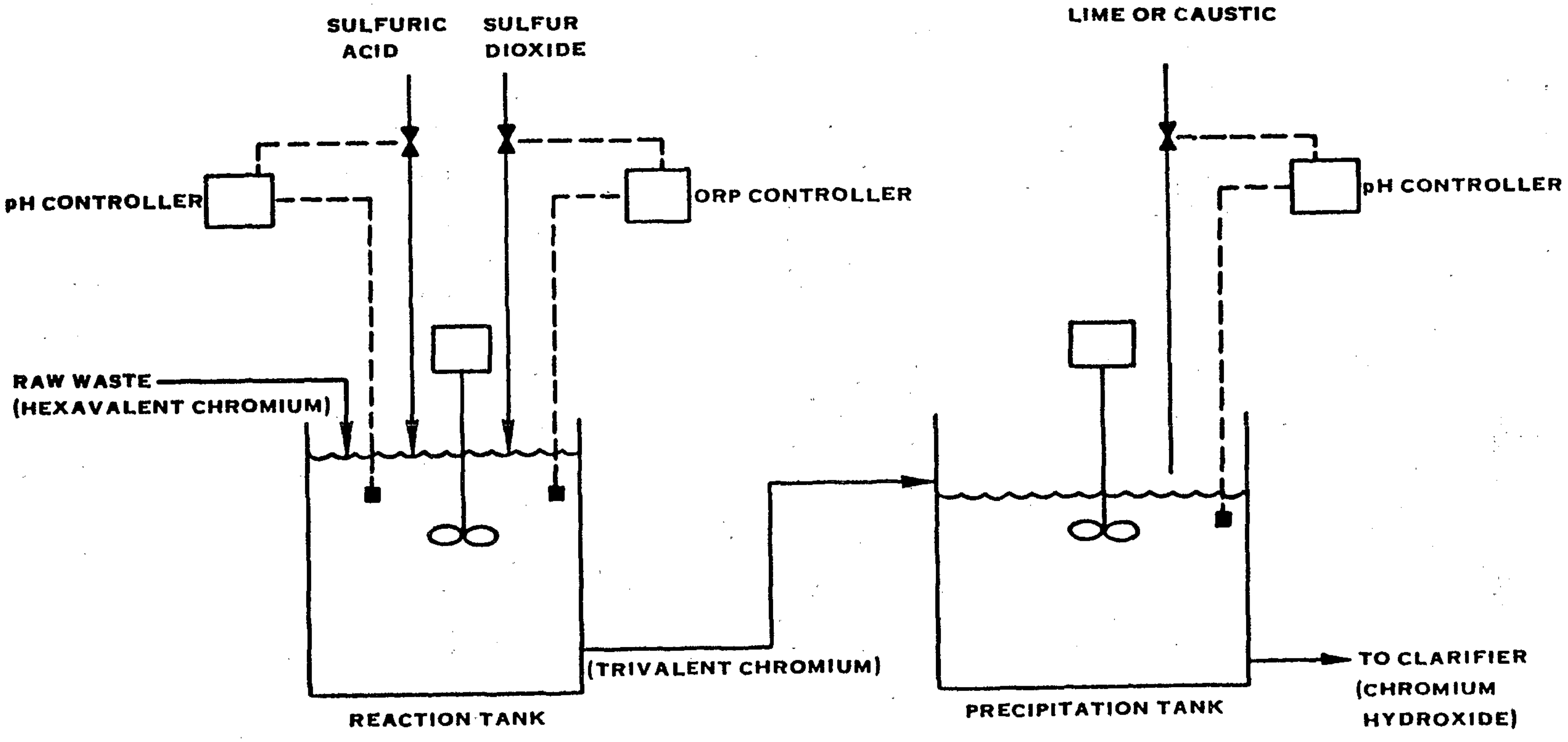


FIGURE VII-13. HEXAVALENT CHROMIUM REDUCTION WITH SULFUR DIOXIDE

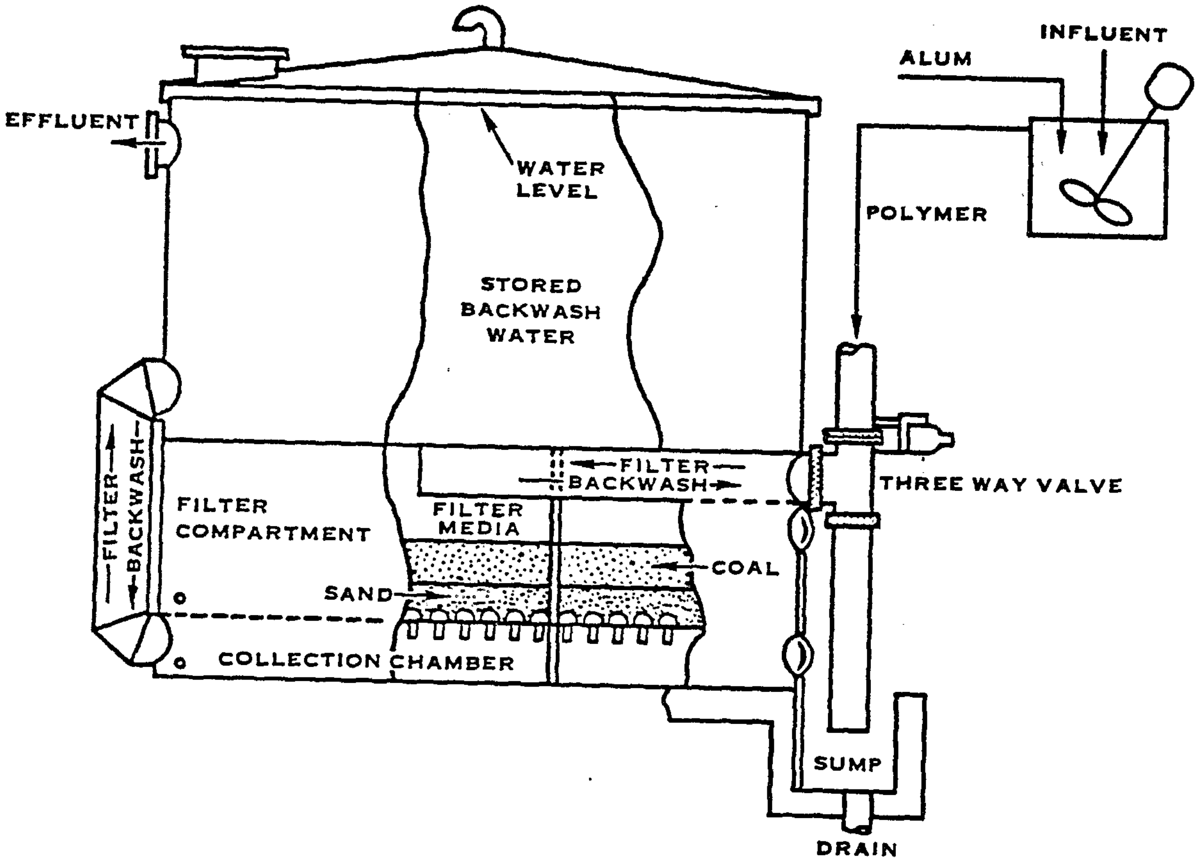


FIGURE VII-14. GRANULAR BED FILTRATION

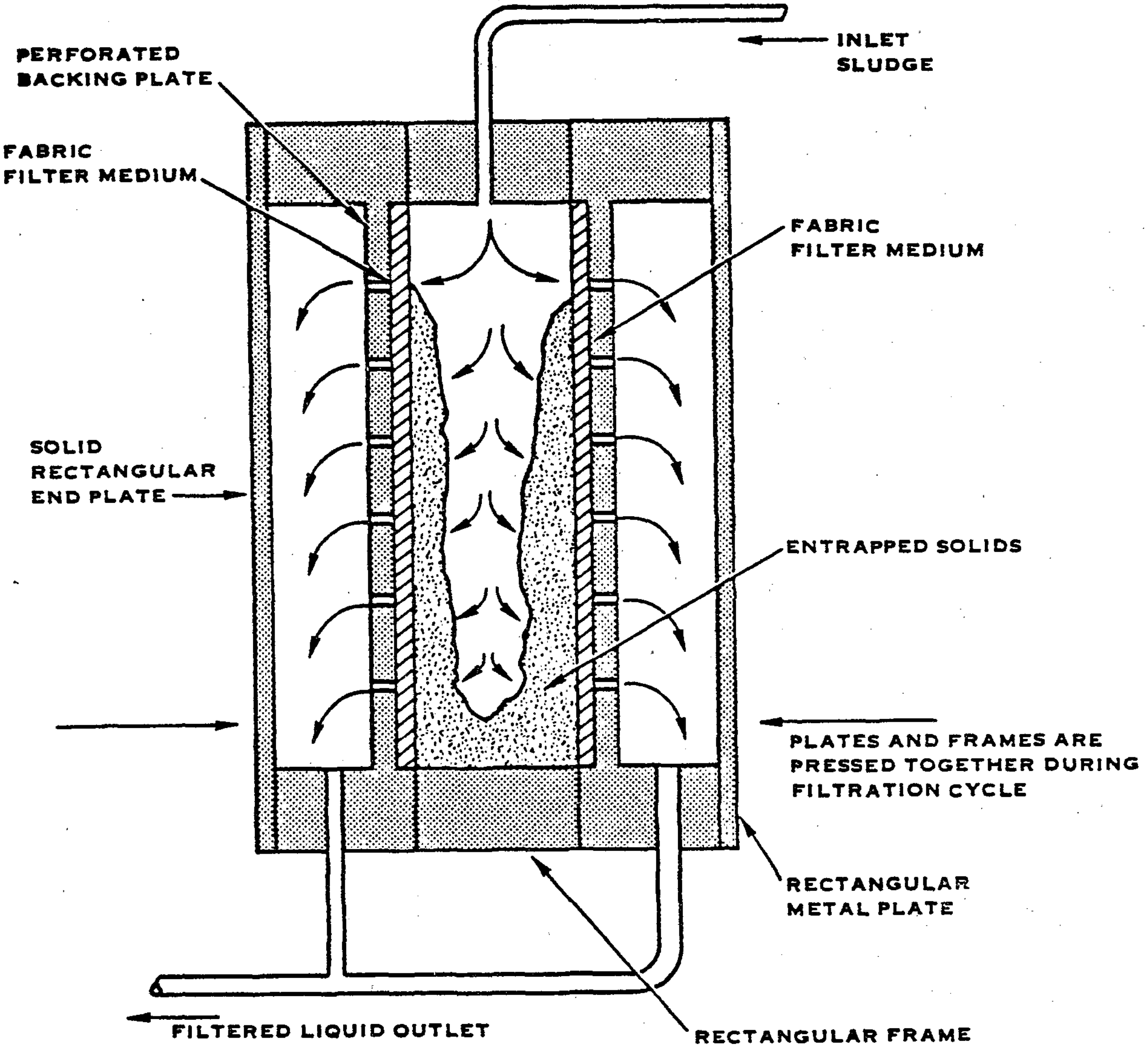
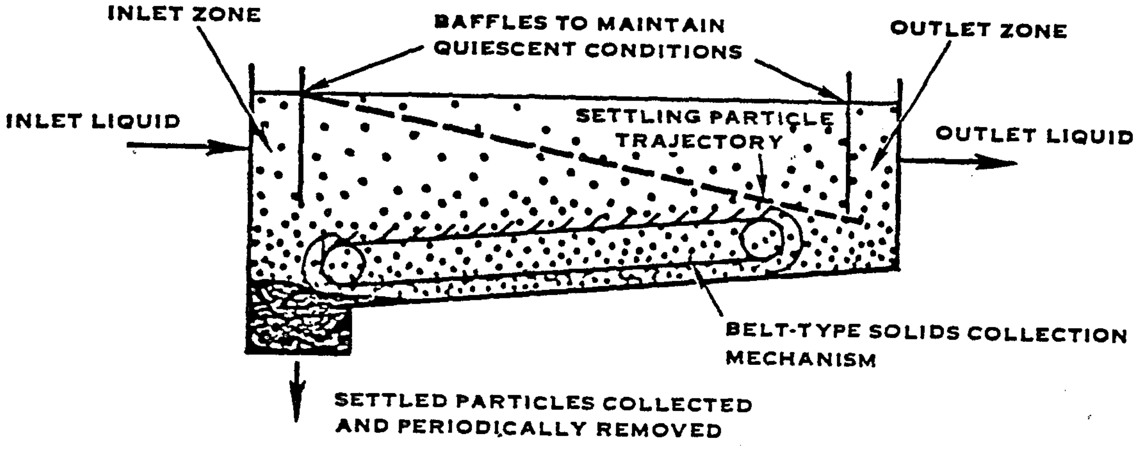


FIGURE VII-15. PRESSURE FILTRATION

SEDIMENTATION BASIN



CIRCULAR CLARIFIER

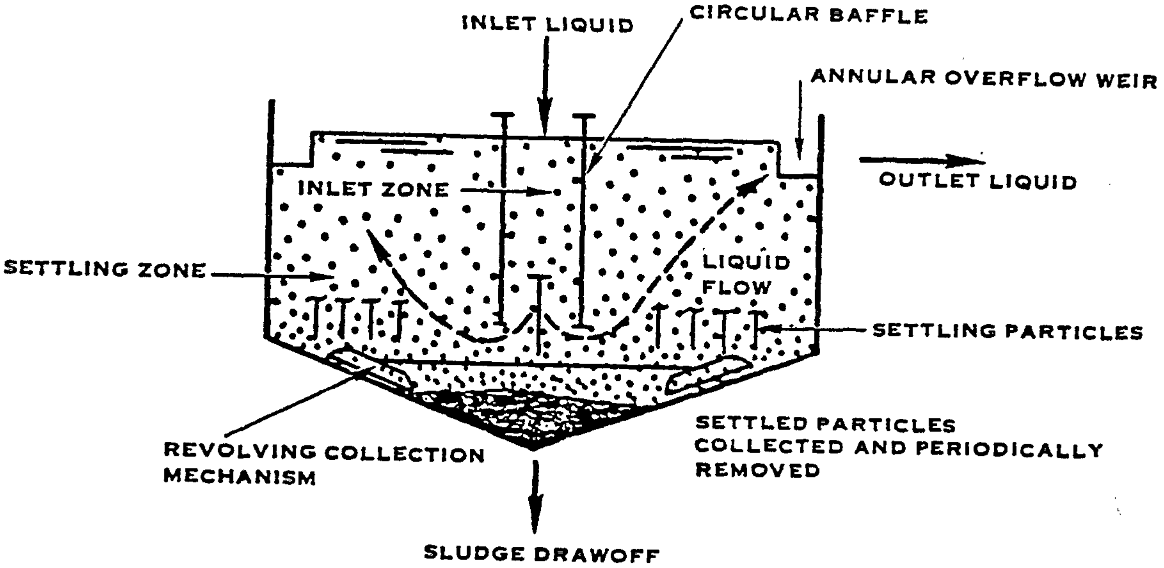


FIGURE VII-16. REPRESENTATIVE TYPES OF SEDIMENTATION

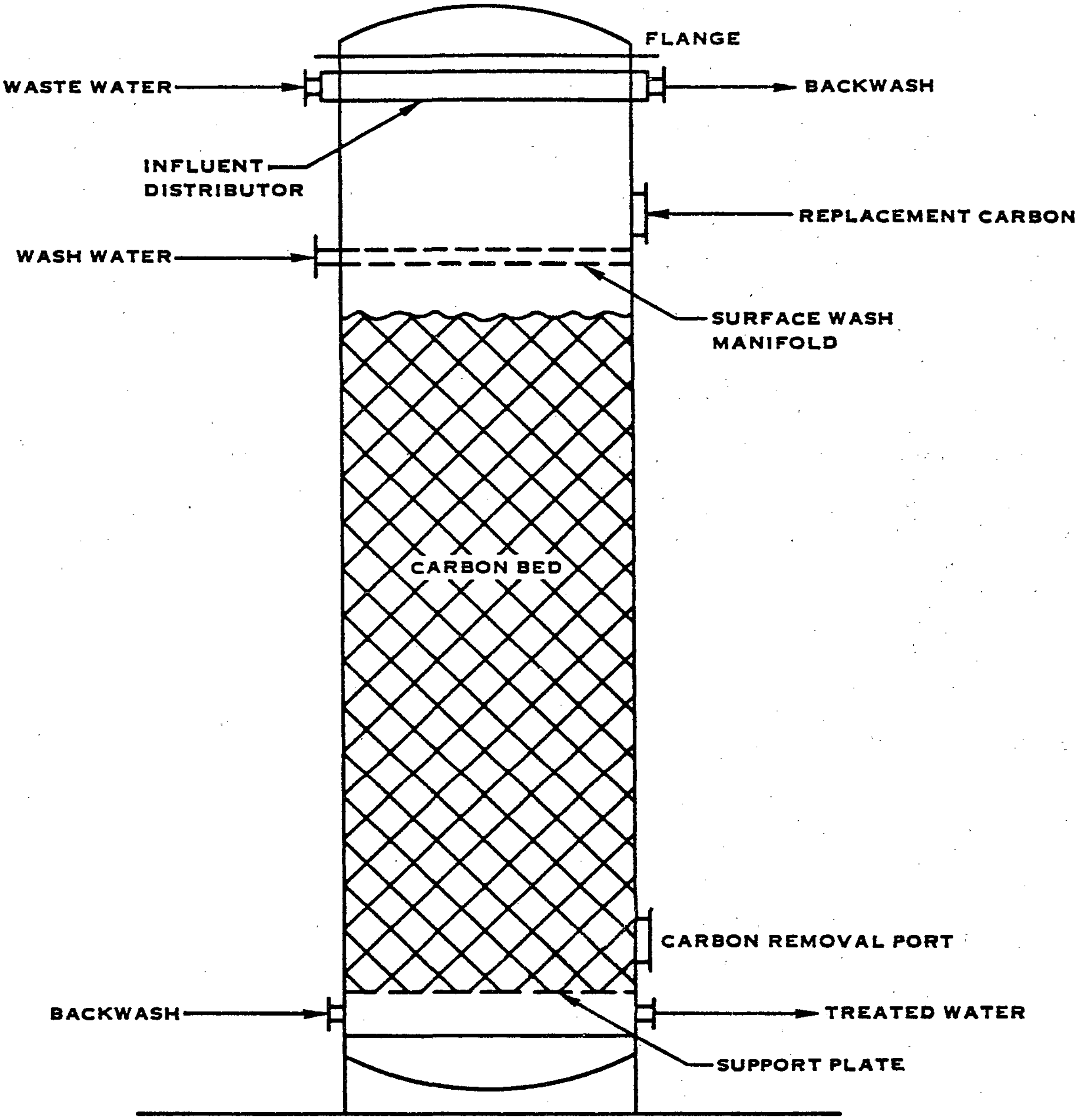


FIGURE VII - 17. ACTIVATED CARBON ADSORPTION COLUMN

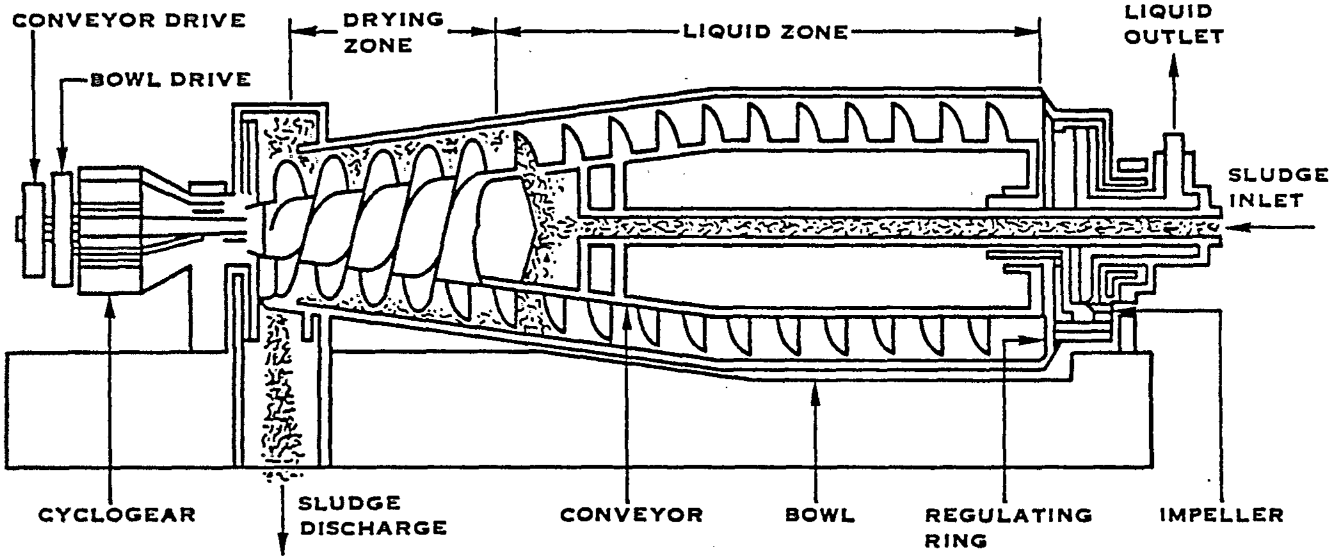


FIGURE VII - 18. CENTRIFUGATION

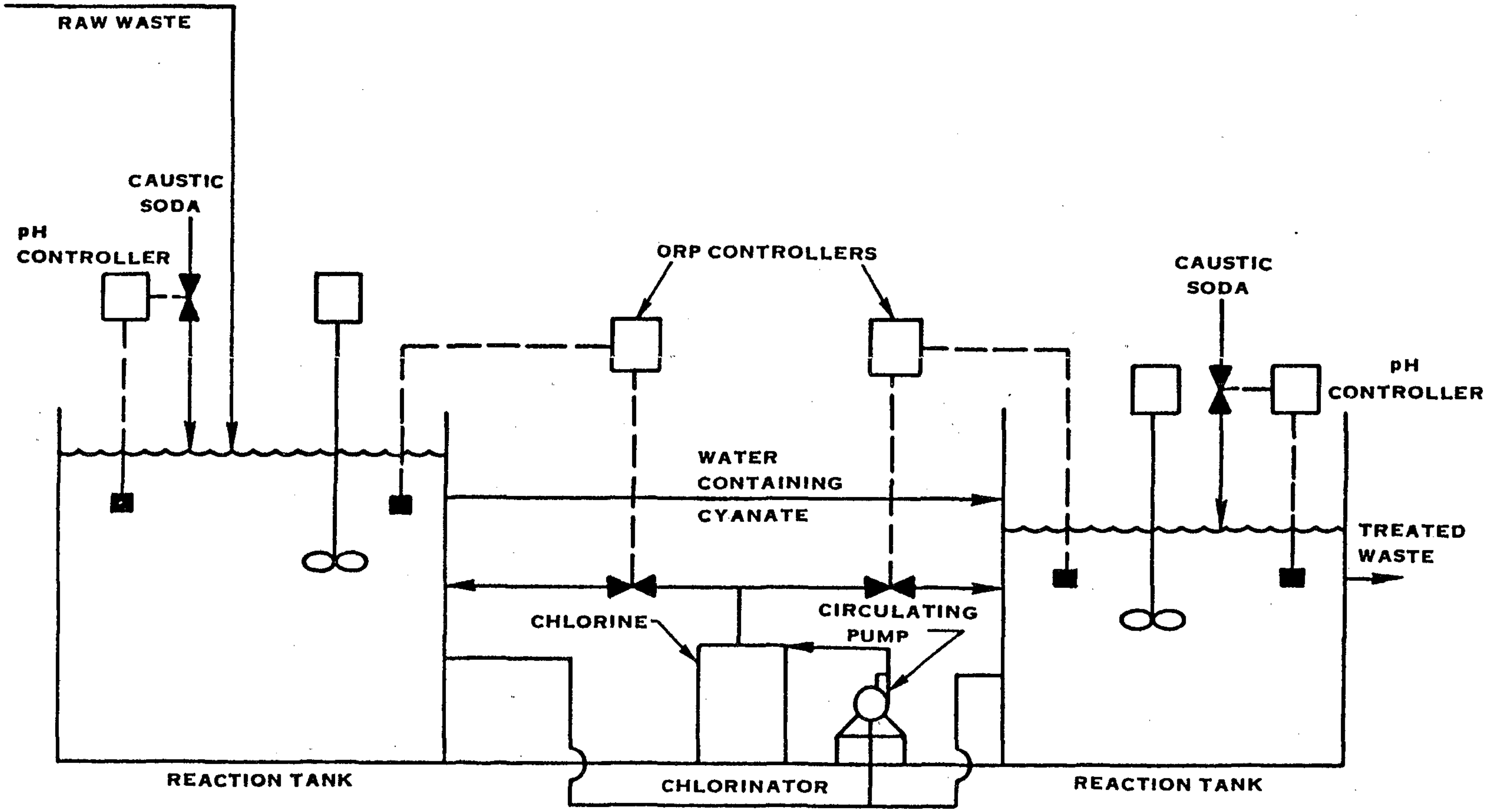


FIGURE VII - 19. TREATMENT OF CYANIDE WASTE BY ALKALINE CHLORINATION

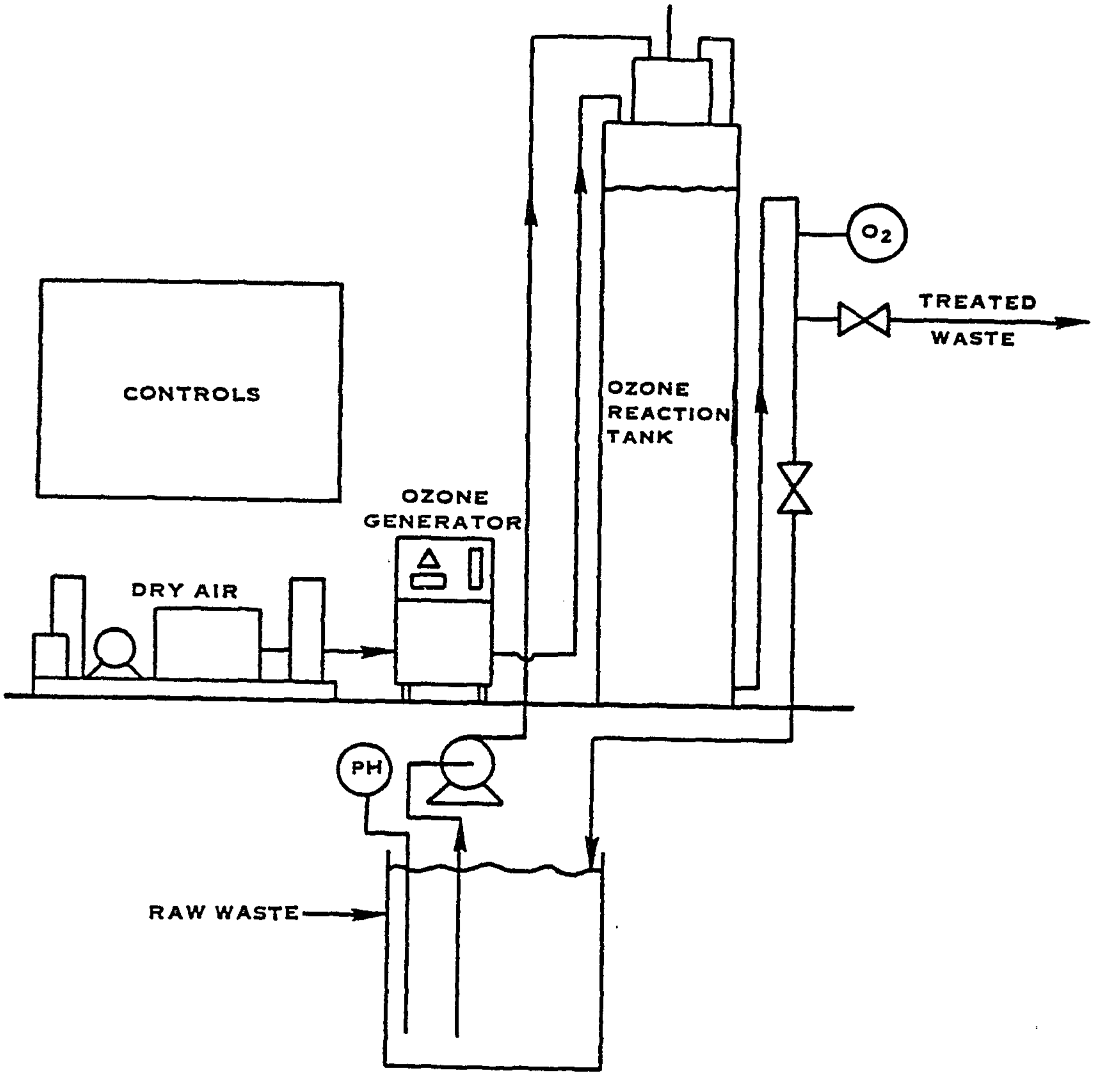


FIGURE VII - 20. TYPICAL OZONE PLANT FOR WASTE TREATMENT

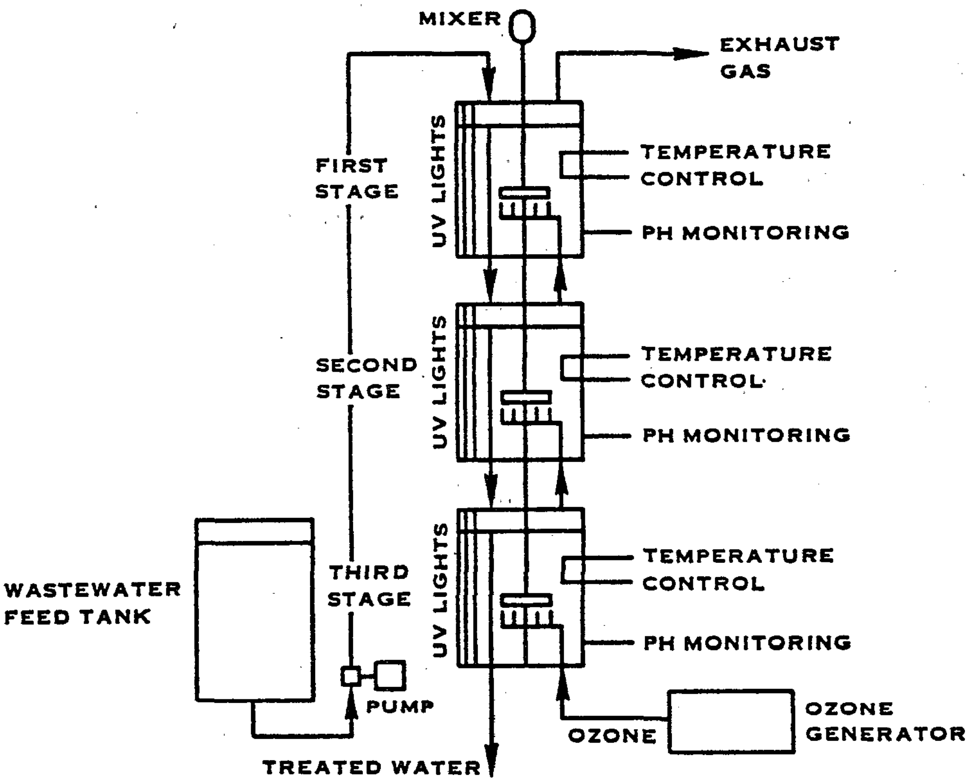
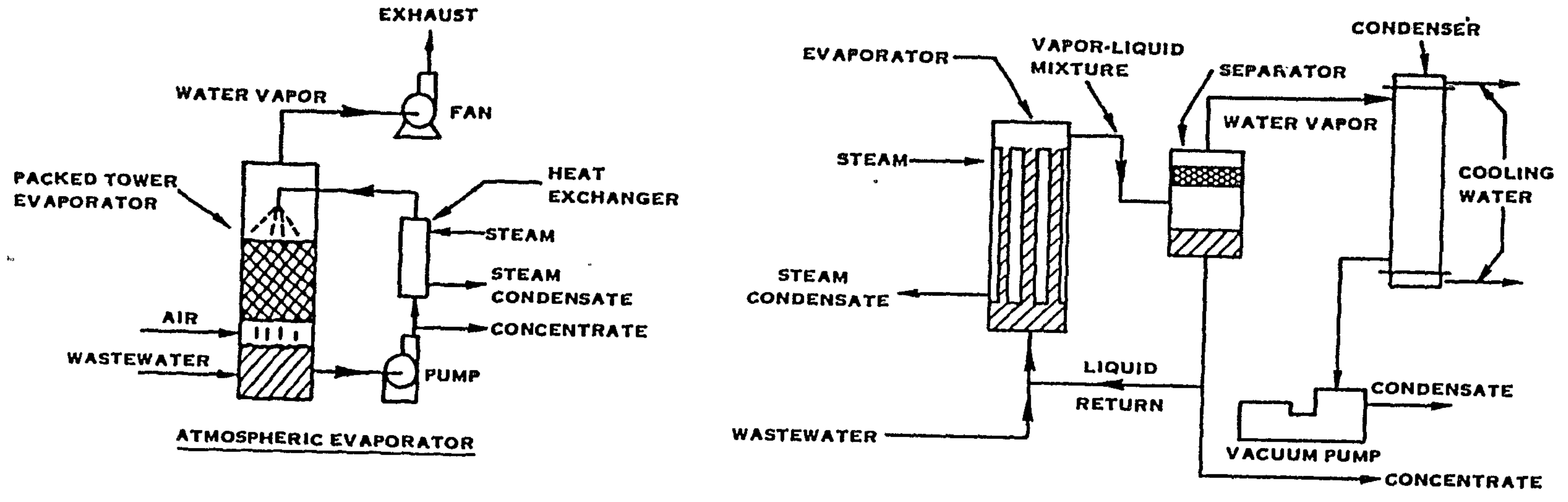
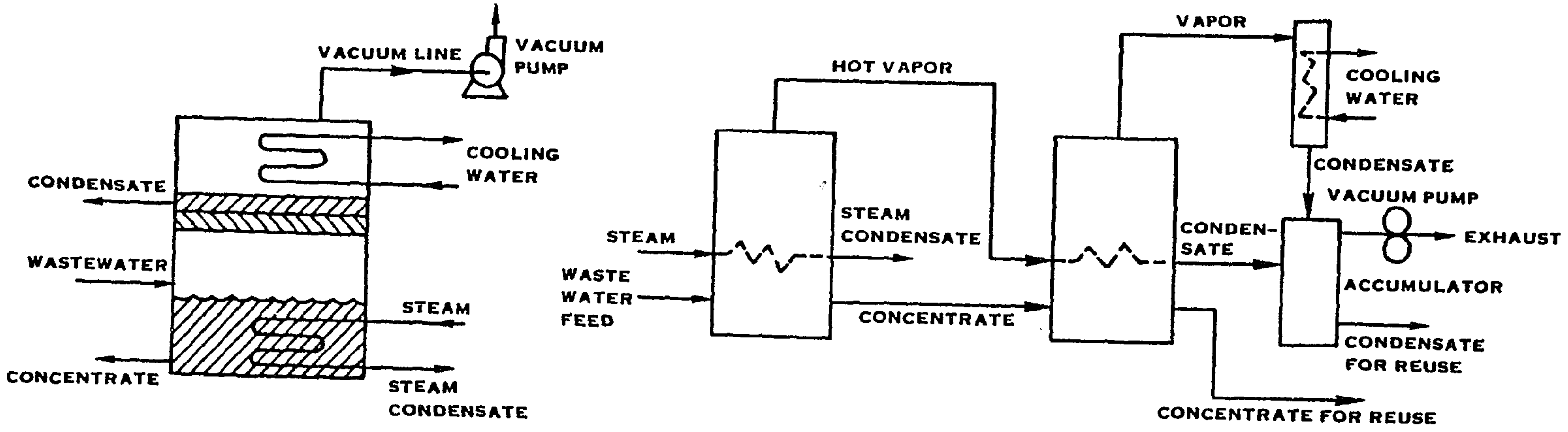


FIGURE VII - 21. UV/OZONATION



ATMOSPHERIC EVAPORATOR

CLIMBING FILM EVAPORATOR



SUBMERGED TUBE EVAPORATOR

DOUBLE-EFFECT EVAPORATOR

FIGURE VII - 22. TYPES OF EVAPORATION EQUIPMENT

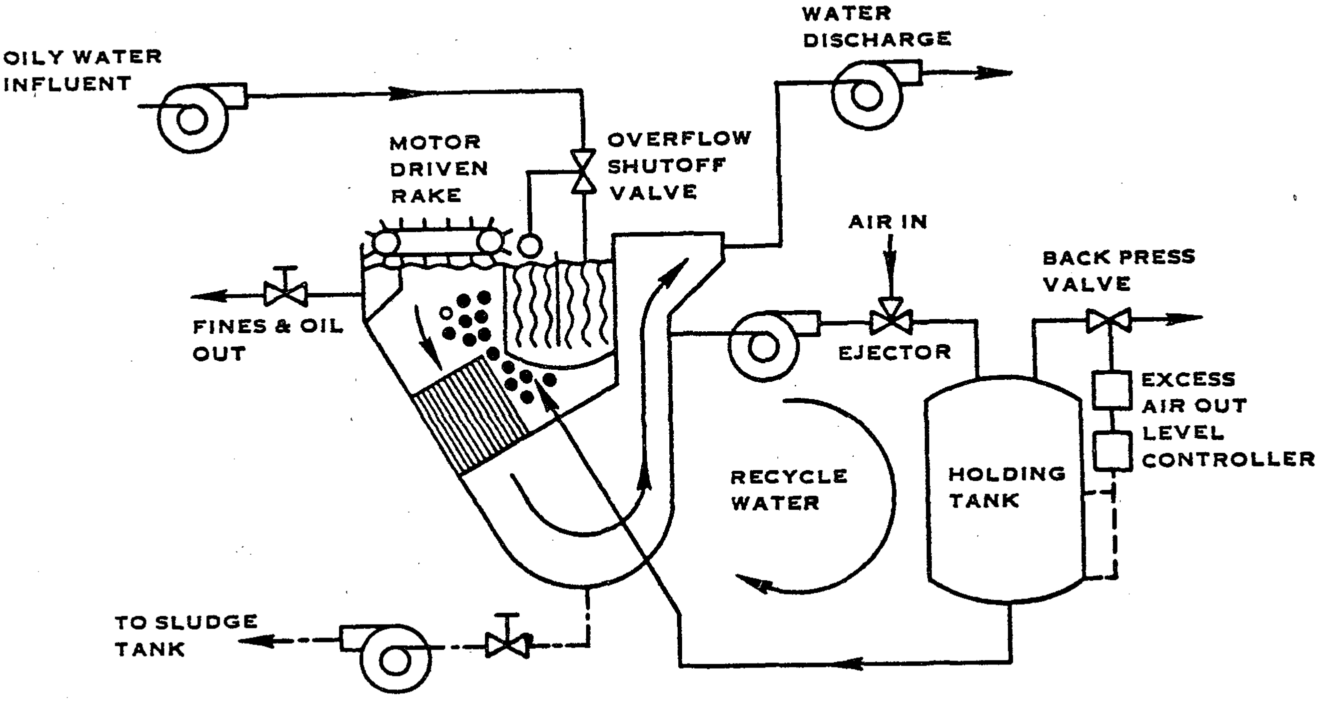
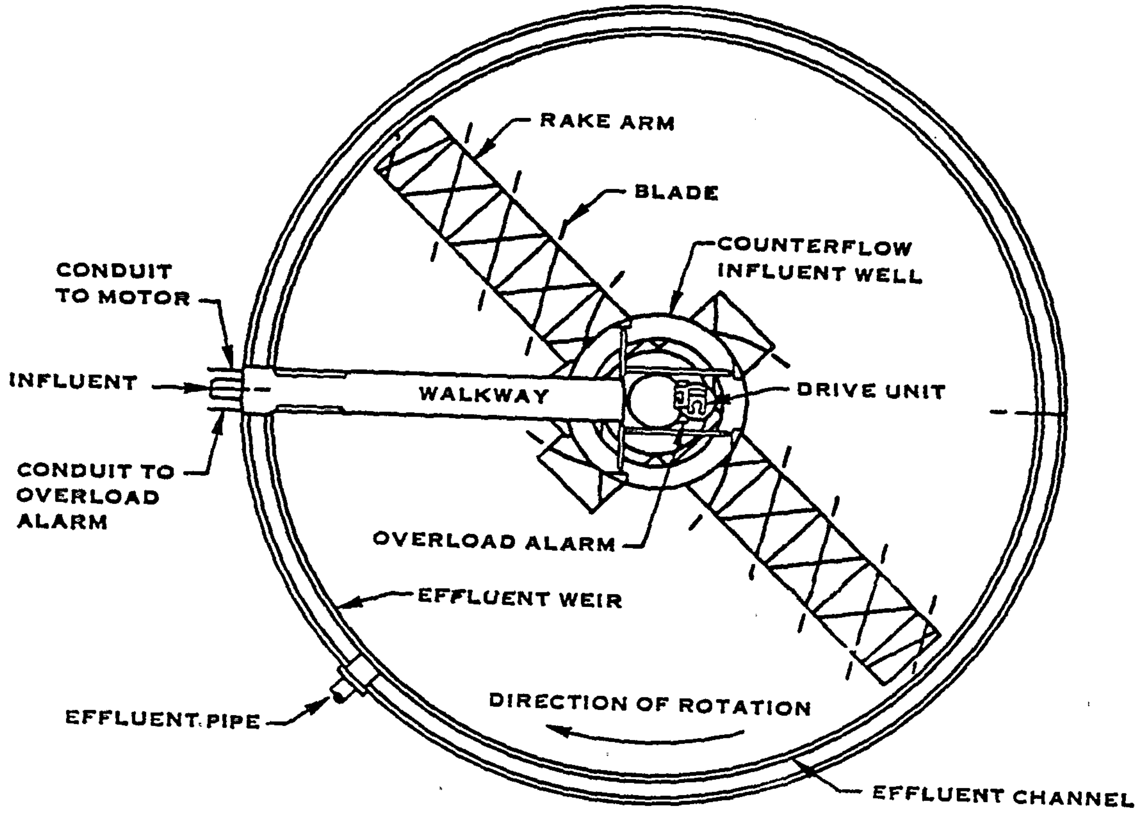


FIGURE VII - 23. DISSOLVED AIR FLOTATION



PLAN

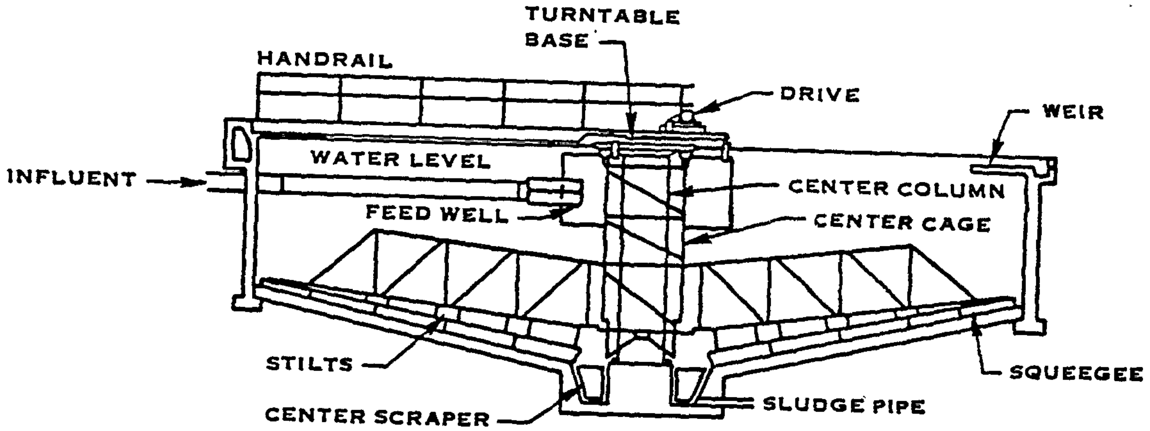


FIGURE VII - 24. GRAVITY THICKENING

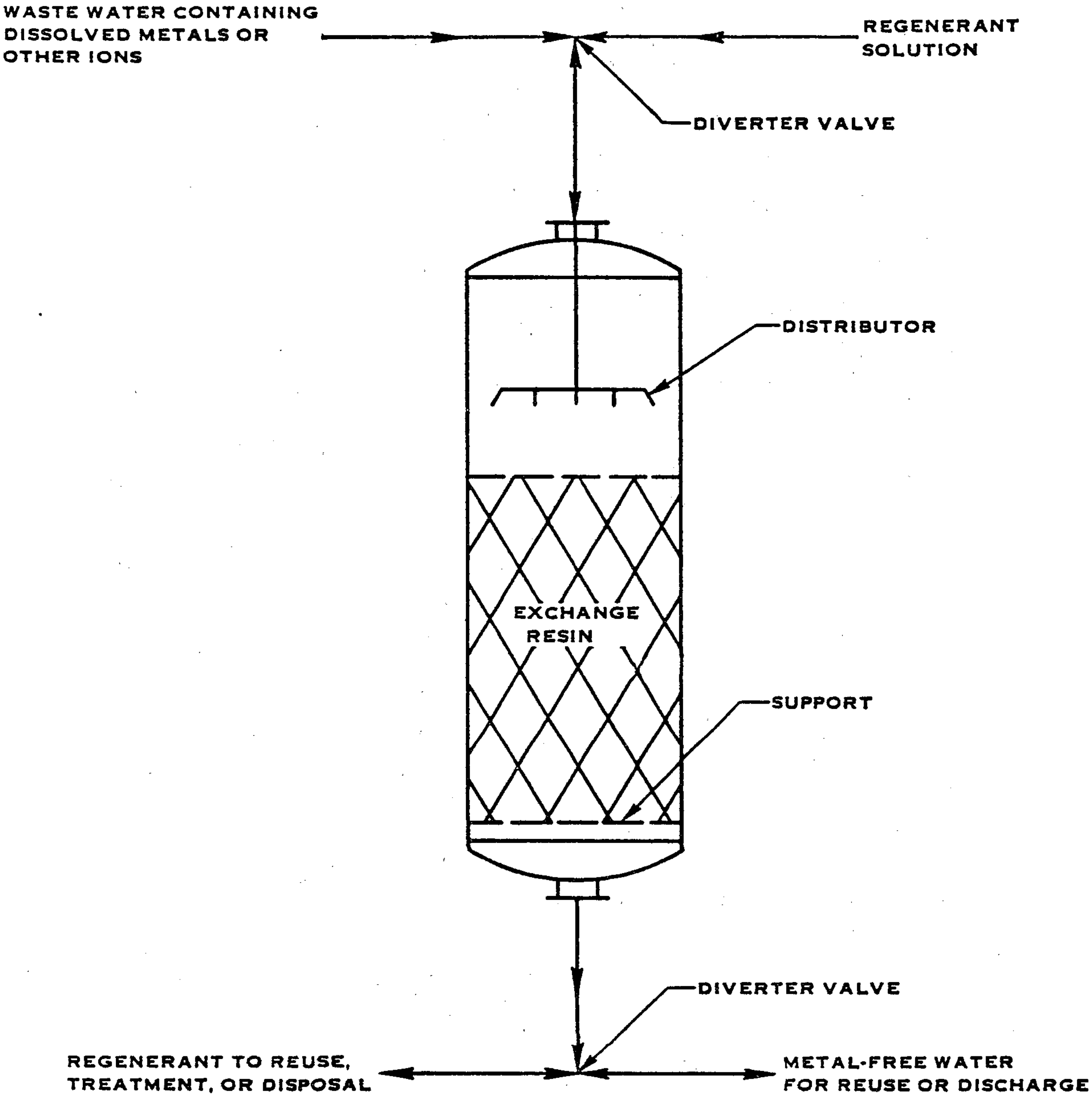


FIGURE VII - 25. ION EXCHANGE WITH REGENERATION

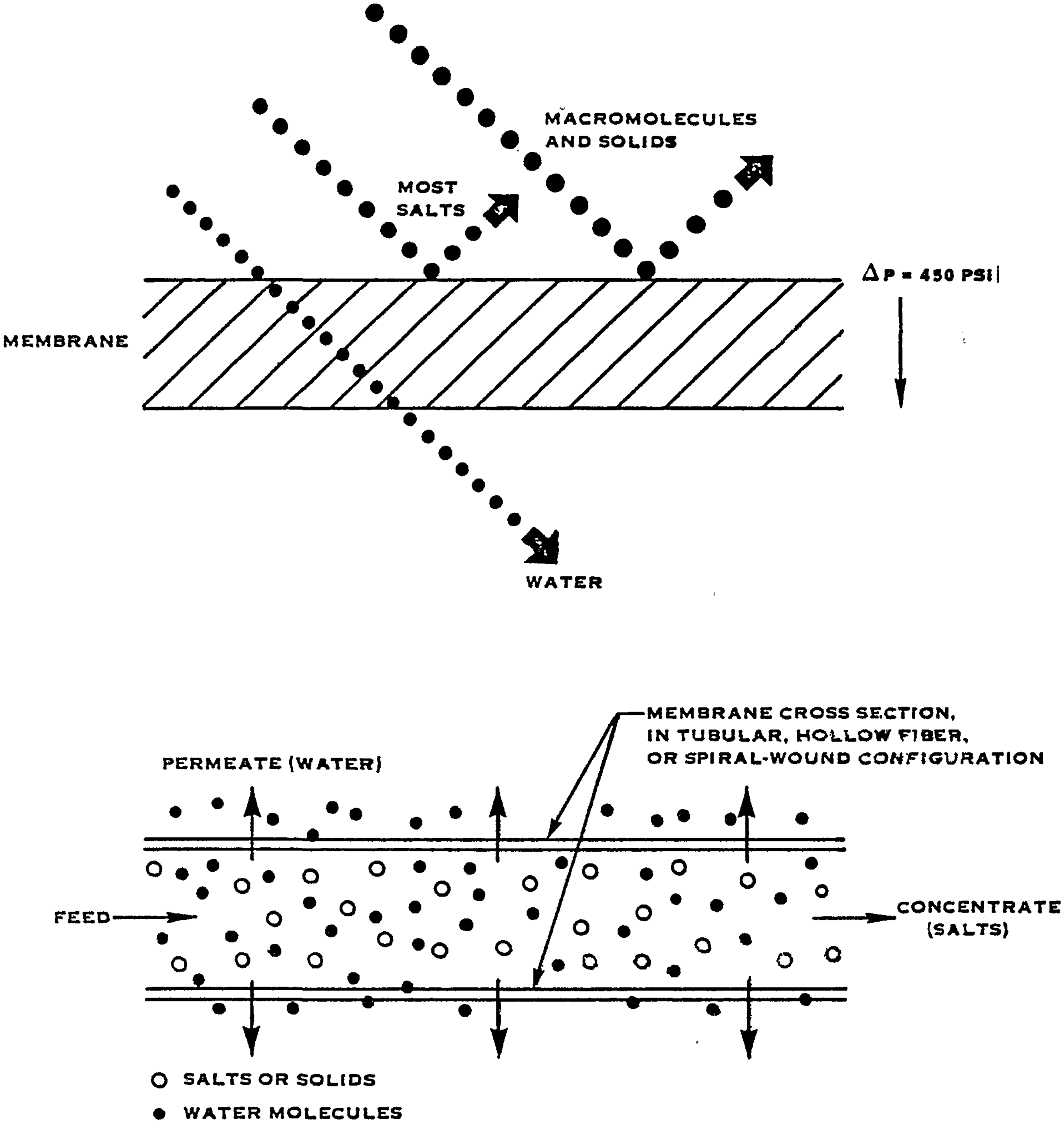
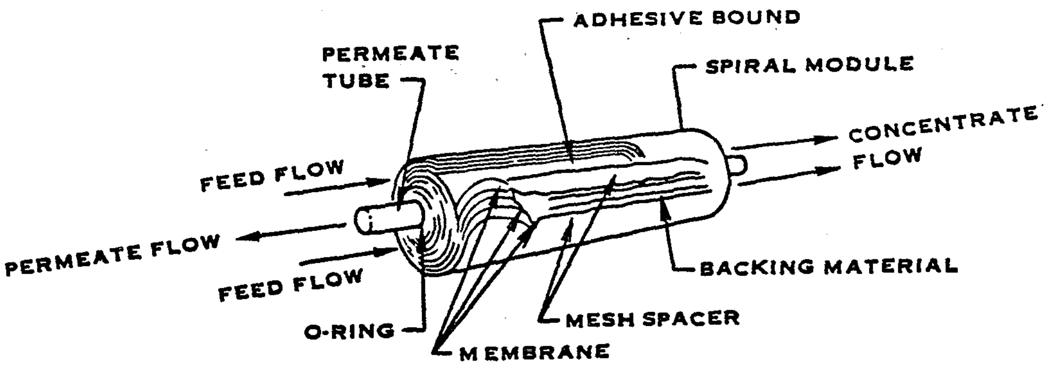
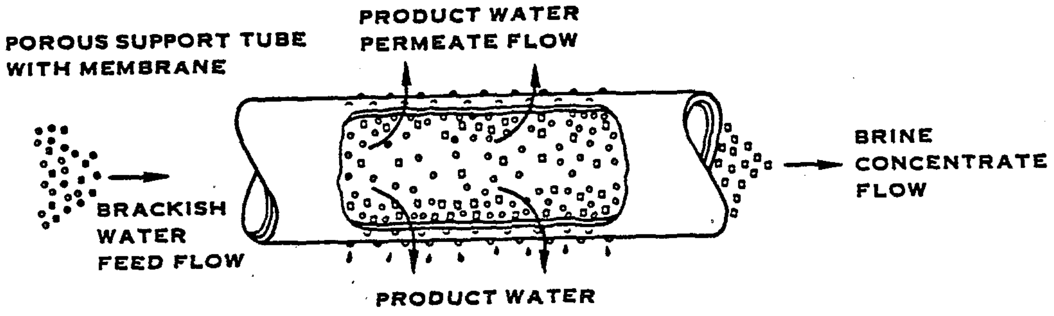


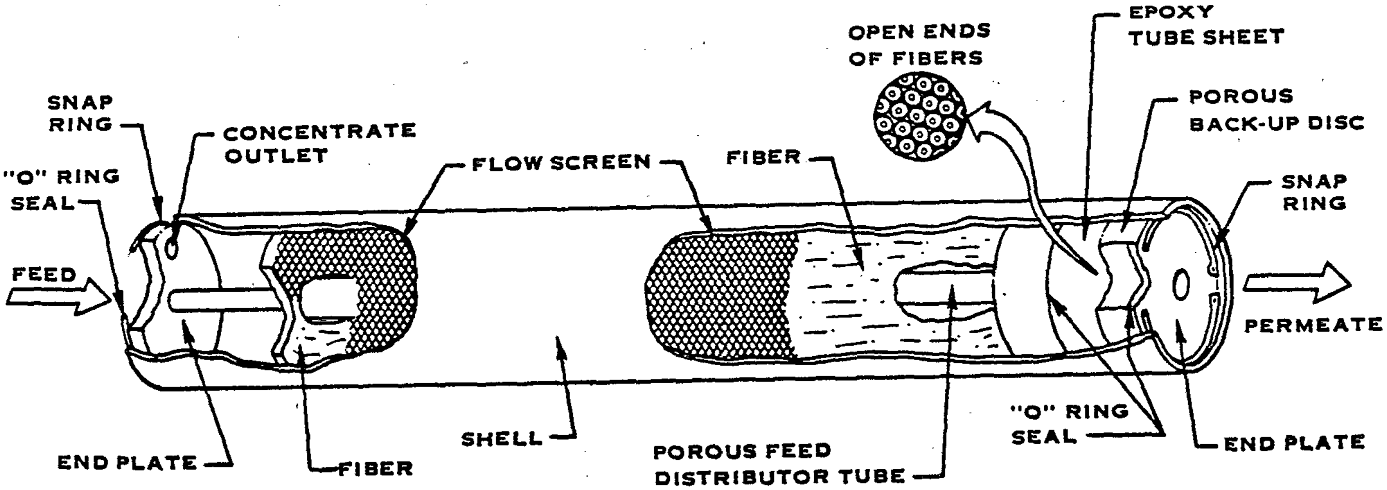
FIGURE VII-26. SIMPLIFIED REVERSE OSMOSIS SCHEMATIC



SPIRAL MEMBRANE MODULE



TUBULAR REVERSE OSMOSIS MODULE



HOLLOW FIBER MODULE

FIGURE VII - 27. REVERSE OSMOSIS MEMBRANE CONFIGURATIONS

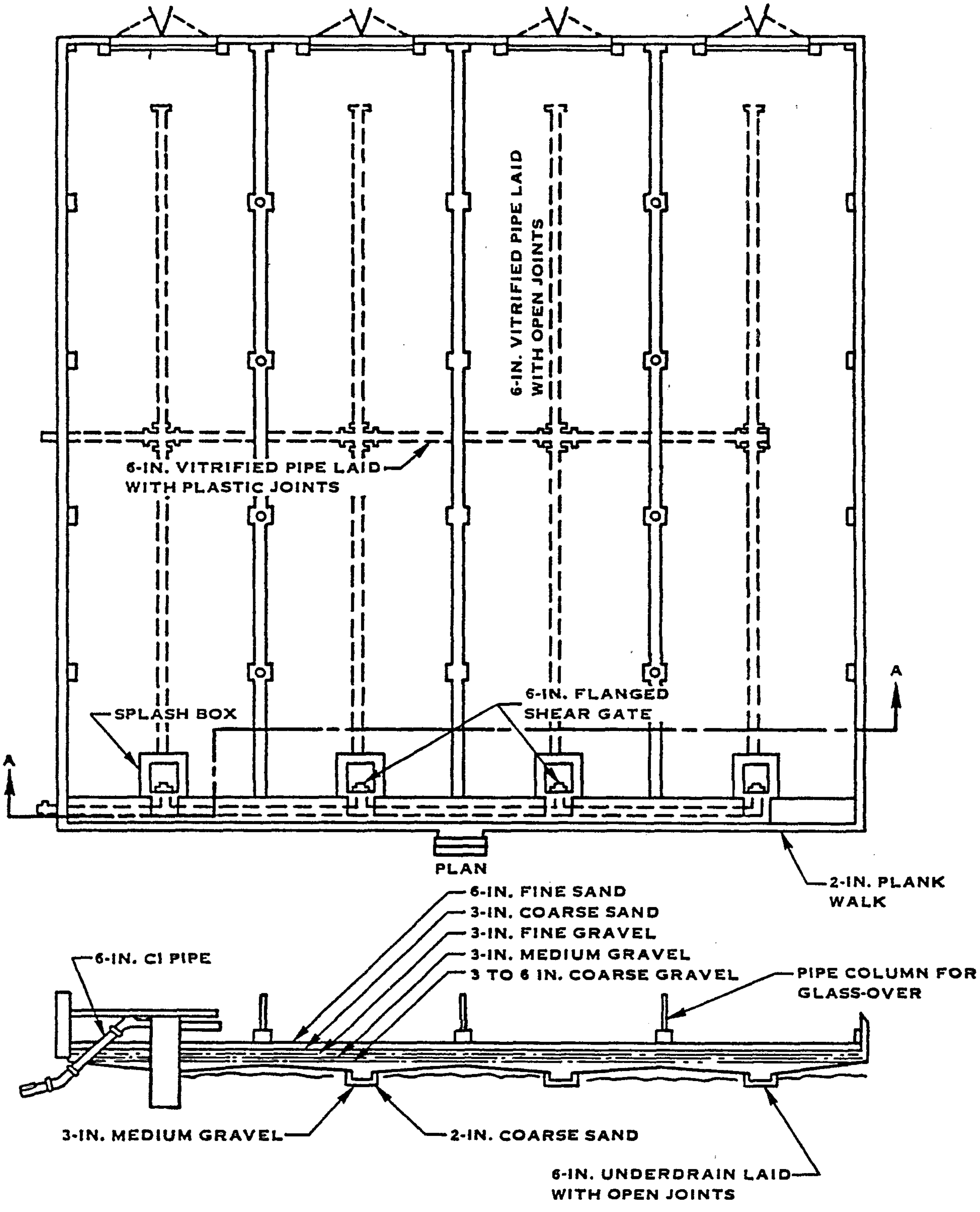


FIGURE VII - 28. SLUDGE DRYING BED

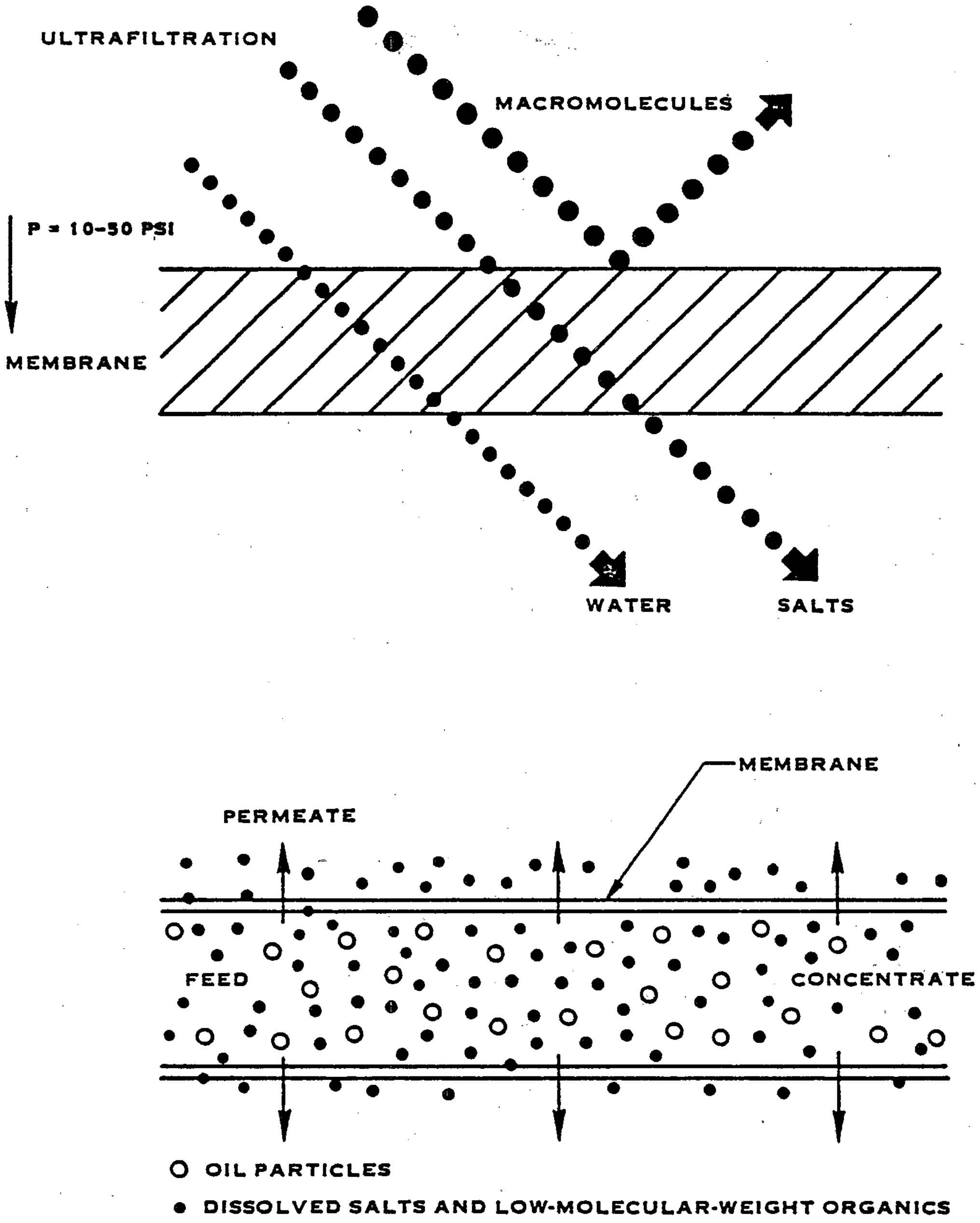


FIGURE VII - 29. SIMPLIFIED ULTRAFILTRATION FLOW SCHEMATIC

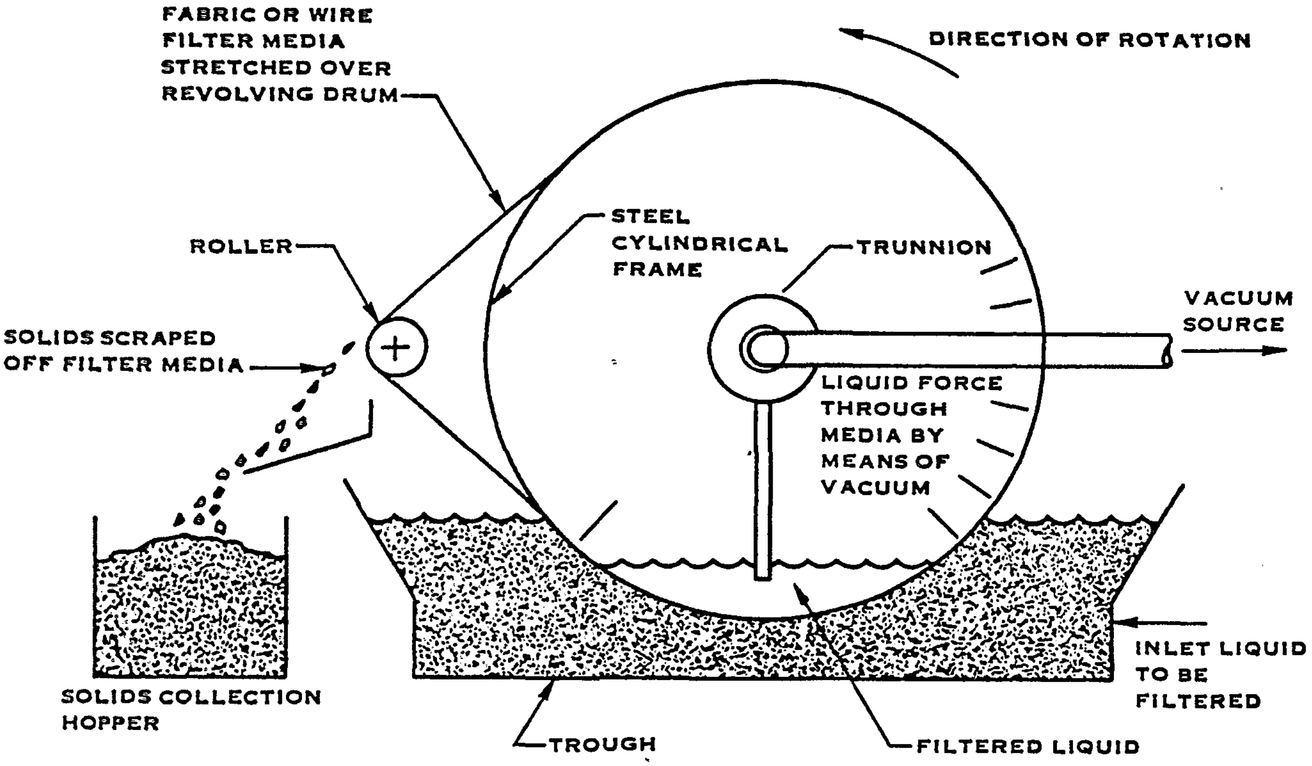


FIGURE VII - 30. VACUUM FILTRATION

SECTION VIII

COST OF WASTEWATER CONTROL AND TREATMENT

This section presents estimates of the cost of implementation of wastewater treatment and control options for each of the subcategories included in this document of the battery manufacturing category. The cost estimates provide the basis for the determination of the probable economic impact of regulation at different pollutant discharge levels on these subcategories. These costs are also among the factors required to be considered in developing effluent limitations for BPT and BAT. In addition, this section addresses other factors which must be considered in developing effluent limitations including nonwater quality environmental impacts of wastewater treatment and control alternatives including air pollution, noise pollution, solid wastes, and energy requirements.

To arrive at the cost estimates presented in this section, specific wastewater treatment technologies and in-process control techniques from among those discussed in Section VII were selected and combined in wastewater treatment and control systems appropriate for each subcategory. Investment and annual costs for each system were estimated based on wastewater flows and raw waste characteristics for each subcategory as presented in Section V. Cost estimates are also presented for individual treatment technologies included in the waste treatment systems.

COST ESTIMATION METHODOLOGY

Cost estimation is accomplished with the aid of a computer program which accepts inputs specifying the treatment system to be estimated, chemical characteristics of the raw waste streams treated, flow rates and operating schedules. The program accesses models for specific treatment components which relate component investment and operating costs, materials and energy requirements, and effluent stream characteristics to influent flow rates and stream characteristics. Component models are exercised sequentially as the components are encountered in the system to determine chemical characteristics and flow rates at each point. Component investment and annual costs are also determined and used in the computation of total system costs. Mass balance calculations are used to determine the characteristics of combined streams resulting from mixing two or more streams and to determine the volume of sludges or liquid wastes resulting from treatment operations such as sedimentation, filtration, flotation, and oil separation.

Cost estimates are broken down into several distinct elements in addition to total investment and annual costs: operation and maintenance costs, energy costs, depreciation, and annual costs of capital. The cost estimation program incorporates provisions for adjustment of all costs to a common dollar base on the basis of economic indices appropriate to capital equipment and operating supplies. Labor and electrical power costs are input variables appropriate to the dollar base year for cost estimates. This section discusses cost breakdown and adjustment factors as well as other aspects of the cost estimation process.

Cost Estimation Input Data

The waste treatment system descriptions input to the cost estimation program include both a specification of the waste treatment components included and a definition of their sequences. For some components such as holding tanks, retention times or other operating parameters are also specified in the input, while for others, such as reagent mix tanks and clarifiers, the parameters are specified within the program based on prevailing design practice in industrial waste treatment. The waste treatment system descriptions may include multiple raw waste stream inputs and multiple treatment trains.

The input data set also includes chemical characteristics for each raw waste stream specified as input to the treatment systems for which costs are to be estimated. These characteristics are derived from the raw waste sampling data presented in Section V. The pollutant parameters which are presently accepted as input by the cost estimation program are shown in Table VIII-1 (page 677). The values of these parameters are used in determining materials consumption, sludge volumes, treatment component sizes and effluent characteristics. The list of input parameters is expanded periodically as additional pollutants are found to be significant in waste streams from industries under study and as additional treatment technology cost and performance data become available. For the battery manufacturing category, individual subcategories commonly encompass a number of widely varying waste streams which are present to varying degrees at different plants. The raw waste characteristics shown as input to waste treatment represent a mix of these streams including all significant pollutants generated in the subcategory and will not in general correspond precisely to process wastewater at any existing plant. The process by which these raw wastes were defined is explained in Sections IX and X.

The final input data set corresponds to the flow rates reported by each plant in the category which were input to the computer to provide cost estimates for use in economic impact analysis.

System Cost Computation

A simplified flow chart for the estimation of wastewater treatment and control costs from the input data described above is presented in Figure VIII-1 (page 700). In the computation, raw waste characteristics and flow rates are used as input to the model for the first treatment technology specified in the system definition. This model is used to determine the size and cost of the component, materials and energy consumed in its operation, and the volume and characteristics of the stream(s) discharged from it. These stream characteristics are then used as input to the next component(s) encountered in the system definition. This procedure is continued until the complete system costs and the volume and characteristics of the final effluent stream(s) and sludge or concentrated oil wastes have been determined. In addition to treatment components, the system may include mixers in which two streams are combined, and splitters in which part of a stream is directed to another destination. These elements are handled by mass balance calculations and allow cost estimation for specific treatment of segregated process wastes such as oxidation of cyanide bearing wastes prior to combination with other process wastes for further treatment, and representation of partial recycle of wastewater.

As an example of this computation process, the sequence of calculations involved in the development of cost estimates for the simple treatment system shown in Figure VIII-2 (page 701) may be described. Initially, input specifications for the treatment system are read to set up the sequence of computations. The subroutine addressing chemical precipitation and clarification is then accessed. The sizes of the mixing tank and clarification basin are calculated based on the raw waste flow rate to provide 45 minute retention in the mix tank and 4 hour retention with 610 $l/hr/m^2$ (159 gph/ft^2) surface loading in the clarifier. Based on these sizes, investment and annual costs for labor, supplies and for the mixing tank and clarifier including mixers, clarifier rakes and other directly related equipment are determined. Fixed investment costs are then added to account for sludge pumps, controls and reagent feed systems.

Based on the input raw waste concentrations and flow rates, the reagent additions (lime, alum, and polyelectrolyte) are calculated to provide fixed concentrations of alum and polyelectrolyte and 10 percent excess lime over that required for stoichiometric reaction with the acidity and metals present in the waste stream. Costs are calculated for these materials, and the suspended solids and flow leaving the mixing tank and entering the clarifier are increased to reflect the lime solids added and precipitates formed. These modified stream characteristics are then used with performance algorithms for the clarifier (as discussed in Section VII) to determine concentrations of each pollutant in the clarifier effluent stream. By mass balance, the amount of each pollutant in the clarifier sludge may be determined. The volume of the sludge stream is determined by the concentration of TSS which is fixed at 4-5 percent based on general operating experience, and concentrations of other pollutants in the sludge stream are determined from their masses and the volume of the stream.

The subroutine describing vacuum filtration is then called, and the mass of suspended solids in the clarifier sludge stream is used to determine the size and investment cost of the vacuum filtration unit. Operating hours for the filter are calculated from the flow rate and TSS concentration and determine manhours required for operation. Maintenance labor requirements are added as a fixed additional cost.

The sludge flow rate and TSS content are then used to determine costs of materials and supplies for vacuum filter operation including iron and alum added as filter aids, and the electrical power costs for operation. Finally, the vacuum filter performance algorithms are used to determine the volume and characteristics of the vacuum filter sludge and filtrate, and the costs of contract disposal of the sludge are calculated. The recycle of vacuum filter filtrate to the chemical precipitation-clarification system is not reflected in the calculations due to the difficulty of iterative solution of such loops and the general observation that the contributions of such streams to the total flow and pollutant levels are in practice, negligibly small. Allowance for such minor contributions is made in the 20 percent excess capacity provided in most components.

The costs determined for all components of the system are summed and subsidiary costs are added to provide output specifying total investment and annual costs for the system and annual costs for capital, depreciation, operation and maintenance, and energy. Costs for specific system components and the characteristics of all streams in the system may also be specified as output from the program.

In-Process Technologies

Costs calculated by the computer estimation procedure are dependent upon discharge flows produced by plants in the category. The use of in-process technology to achieve flow reduction is cost effective because savings result from buying less water, recovering metals in the solids, and selling concentrated process solutions. These savings are not evaluated in the computer program. Reliance on the computer estimation procedure without attention to in-process technologies results in an overstatement of the cost required to achieve various levels of environmental improvement.

For the subcategories sufficient data were available from plant visits and dcp to estimate costs of treatment which include plant-specific in-process controls. Since each plant has a different process flow diagram, these calculations require extensive hand calculations to provide the relevant instrumentation, holding tanks, and process equipment appropriate to individual plants. Flows resulting from in-plant technology were then used as input to the computer.

Treatment Component Models

The cost estimation program presently incorporates subroutines providing cost and performance calculations for the treatment technologies identified in Table VIII-2 (page 678). These subroutines have been developed from the best available information including on-site observations of treatment system performance, costs, and construction practices at a large number of industrial facilities, published data, and information obtained from suppliers of wastewater treatment equipment. The subroutines are modified and new subroutines added as additional data allow improvements in treating technologies presently available, and as additional treatment technologies are required for the industrial wastewater streams under study. Specific discussion of each of the treatment component models used in costing wastewater treatment and control systems for the battery manufacturing category is presented later in this section.

In general terms, cost estimation is provided by mathematical relationships in each subroutine approximating observed correlations between component costs and the most significant operational parameters such as water flow rate, retention times, and pollutant concentrations. In general, flow rate is the primary determinant of investment costs and of most annual costs with the exception of materials costs. In some cases, however, as discussed for the vacuum filter, pollutant concentrations may also significantly influence costs.

Cost Factors and Adjustments

Costs are adjusted to a common dollar base and are generally influenced by a number of factors including: Cost of Labor, Cost of Energy, Capital Recovery Costs and Debt-Equity Ratio.

Dollar Base - A dollar base of January 1978 was used for all costs.

Investment Cost Adjustment - Investment costs were adjusted to the aforementioned dollar base by use of the Sewage Treatment Plant Construction Cost Index. This cost is published monthly by the EPA Division of Facilities Construction and Operation. The national average of the Construction Cost Index for January 1978 was 288.0.

Supply Cost Adjustment - Supply costs such as chemicals were related to the dollar base by the Wholesale Price Index. This figure was obtained from the U.S. Department of Labor, Bureau of Labor Statistics, "Monthly Labor Review". For January 1978 the "Industrial Commodities" Wholesale Price Index was 201.6. Process supply and replacement costs were included in the estimate of the total process operating and maintenance cost.

Cost of Labor - To relate the operating and maintenance labor costs, the hourly wage rate for nonsupervisory workers in water, stream, and sanitary systems was used from the U.S. Department of Labor, Bureau of Labor Statistics Monthly publication, "Employment and Earnings". For January 1978, this wage rate was $6.00 per hour. This wage rate was then applied to estimates of operation and maintenance man-hours within each process to obtain process direct labor charges. To account for indirect labor charges, 10 percent of the direct labor costs was added to the direct labor charge to yield estimated total labor costs. Such items as Social Security, employer contributions to pension or retirement funds, and employer-paid premiums to various forms of insurance programs were considered indirect labor costs.

Cost of Energy - Energy requirements were calculated directly within each process. Estimated costs were then determined by applying an electrical rate of 3.3 cents per kilowatt hour.

The electrical charge for January 1978 was corroborated through consultation with the Energy Consulting Services Department of the Connecticut Light and Power Company. This electrical charge was determined by assuming that any electrical needs of a waste treatment facility or in-process technology would be satisfied by an existing electrical distribution system; i.e., no new meter would be required. This eliminated the formation of any new demand load base for the electrical charge.

Capital Recovery Costs - Capital recovery costs were divided into straight line ten-year depreciation and cost of capital at a ten percent annual interest rate for a period of ten years. The ten-year depreciation period was consistent with the faster write-off (financial life) allowed for these facilities even though the equipment life is in the range of 20 to 25 years. The annual cost of capital was calculated by using the capital recovery factor approach.

The capital recovery factor (CRF) is normally used in industry to help allocate the initial investment and the interest to the total operating cost of the plant. It is equal to:

$$\mathbf{CRF} = i + \frac{i}{(1+i)^N - 1}$$

where i is the annual interest rate and N is the number of years over which the capital is to be recovered. The annual capital recovery was obtained by multiplying the initial investment by the capital recovery factor. The annual depreciation of the capital investment was calculated by dividing the initial investment by the depreciation period N, which was assumed to be ten years. The annual cost of capital is then equal to the annual capital recovery minus the depreciation.

Debt-Equity Ratio - Limitations on new borrowings assume that debt may not exceed a set percentage of the shareholders equity. This defines the breakdown of the capital investment between debt and equity charges. However, due to the lack of information about the financial status of various plants, it was not feasible to estimate typical shareholders equity to obtain debt financing limitations. For these reasons, no attempt was made to break down the capital cost into debt and equity charges. Rather, the annual cost of capital was calculated via the procedure outlined in the Capital Recovery Costs section above.

Subsidiary Costs

The waste treatment and control system costs for end-of-pipe and in-process waste water control and treatment systems include subsidiary costs associated with system construction and operation. These subsidiary costs include:

- administration and laboratory facilities
- garage and shop facilities
- line segregation
- yardwork
- land
- engineering
- legal, fiscal, and administrative
- interest during construction

Administrative and laboratory facility investment is the cost of constructing space for administration, laboratory, and service functions for the wastewater treatment system. For these cost computations, it was assumed that there was already an existing building and space for administration, laboratory, and service functions. Therefore, there was no investment cost for this item.

For laboratory operations, an analytical fee of $90 (January 1978 dollars) was charged for each wastewater sample, regardless of whether the laboratory work was done on or off site. This analytical fee is typical of the charges experienced by EPA contractors during the past several years of sampling programs. The frequency of wastewater sampling is a function of wastewater discharge flow and is presented in Table VIII-3 (page 679). This frequency was suggested by the EPA Water Compliance Division.

For industrial waste treatment facilities being costed, no garage and shop investment cost was included. This cost item was assumed to be part of the normal plant costs and was not allocated to the wastewater treatment system.

Line segregation investment costs account for plant modifications to segregate wastes. The investment costs for line segregation included placing a trench in the existing plant floor and installing the lines in this trench. The same trench was used for all pipes and a gravity feed to the treatment system was assumed. The pipe was assumed to run from the center of the floor to a corner. A rate of 2.04 liters per hour of wastewater discharge per square meter of area (0.05 gallons per hour per square foot) was used to determine floor and trench dimensions from wastewater flow rates for use in this cost estimation process.

The yardwork investment cost item includes the cost of general site clearing, intercomponent piping, valves, overhead and underground electrical wiring, cable, lighting, control structures, manholes, tunnels, conduits, and general site items outside the structural confines of particular individual plant components. This cost is typically 9 to 18 percent of the installed components investment costs. For these cost estimates, an average of 14 percent was utilized. Annual yardwork operation and maintenance costs are considered a part of normal plant maintenance and were not included in these cost estimates.

No new land purchases were required. It was assumed that the land required for the end-of-pipe treatment system was already available at the plant.

Engineering costs include both basic and special services. Basic services include preliminary design reports, detailed design, and certain office and field engineering services during construction of projects. Special services include improvement studies, resident engineering, soils investigations, land surveys, operation and maintenance manuals, and other miscellaneous services. Engineering cost is a function of process installed and yardwork investment costs and ranges between 5.7 and 14 percent depending on the total of these costs.

Legal, fiscal and administrative costs relate to planning and construction of waste water treatment facilities and include such items as preparation of legal documents, preparation of construction contracts, acquisition to land, etc. These costs are a function of process installed, yardwork, engineering, and land investment costs ranging between 1 and 3 percent of the total of these costs.

Interest cost during construction is the interest cost accrued on funds from the time payment is made to the contractor to the end of the construction period. The total of all other project investment costs (process installed; yardwork; land; engineering; and legal, fiscal, and administrative) and the applied interest affect this cost. An interest rate of 10 percent was used to determine the interest cost for these estimates. In general, interest cost during construction varies between 3 and 10 percent of total system costs depending on the total costs.

COST ESTIMATES FOR INDIVIDUAL TREATMENT TECHNOLOGIES

Table VIII-4 (page 680) lists the technologies which are incorporated in the wastewater treatment and control options offered for the battery manufacturing subcategories included in this document and for which cost estimates have been developed. These treatment technologies have been selected from among the larger set of available alternatives discussed in Section VII on the basis of an evaluation of raw waste characteristics, plant characteristics (e.g. location, production schedules, product mix, and land availability), and present treatment practices within the subcategories addressed. Specific rationale for selection is addressed in Sections IX, X, XI and XII. Cost estimates for each technology addressed in this section include capital (investment) costs and annual costs for depreciation, capital, operation and maintenance, and energy.

Investment - Investment is the capital expenditure required to bring the technology into operation. If the installation is a package contract, the investment is the purchase price of the installed equipment. Otherwise, it includes the equipment cost, cost of freight, insurance and taxes, and installation costs.

Total Annual Cost - Total annual cost is the sum of annual costs for depreciation, capital, operation and maintenance (less energy), and energy (as a separate cost item).

Depreciation - Depreciation is an allowance, based on tax regulations, for the recovery of fixed capital from an investment to be considered as a non-cash annual expense. It may be regarded as the decline in value of a capital asset due to wearout and obsolescence.

Capital - The annual cost of capital is the cost, to the plant, of obtaining capital expressed as an interest rate. It is equal to the capital recovery cost (as previously discussed on cost factors) less depreciation.

Operation and Maintenance - Operation and maintenance cost is the annual cost of running the wastewater treatment equipment. It includes labor and materials such as waste treatment chemicals. Operation and maintenance cost does not include energy (power or fuel) costs because these costs are shown separately.

Energy - The annual cost of energy is shown separately, although it is commonly included as part of operation and maintenance cost. Energy cost has been shown separately because energy requirements are a factor considered when developing effluent limitations, and energy is important to the nation's economy and natural resources.

Lime Precipitation and Settling (L&S)

This technology removes dissolved pollutants by the formation of precipitates by reaction with added lime and subsequent removal of the precipitated solids by gravity settling in a clarifier. Several distinct operating modes and construction techniques are costed to provide least cost treatment over a broad range of flow rates. Because of their interrelationships and integration in common equipment in some plants, both the chemical addition and solids removal equipment are addressed in a single subroutine.

Investment Cost - Investment costs are determined for this technology for continuous treatment systems and for batch treatment. The least cost system is selected for each application. Continuous treatment systems include controls, reagent feed equipment, a mix tank for reagent feed addition and a clarification basin with associated sludge rakes and pumps. Batch treatment includes only reaction-settling tanks and sludge pumps.

Controls and reagent feed equipment: costs for continuous treatment systems include a fixed charge of \$9075 covering an immersion pH probe and transmitter, pH monitor, controller, lime slurry pump, 1 hp mixer, and transfer pump. In addition, an agitated storage tank sufficient to hold one days operating requirements of a 30 percent lime slurry is included. Costs for this tank are estimated based on the holding tank costs discussed later in this section and shown in Figure VIII-16 (page 715). Lime feed to the slurry tank is assumed to be manual. Hydrated lime is used and no equipment for lime slaking or handling is included in these cost estimates. At plants with high lime consumption mechanical lime feed may be used resulting in higher investment costs, but reduced manpower requirements in comparison to manual addition.

Mix Tank: Continuous systems also include an agitated tank providing 45 minutes detention for reagent addition and formation of precipitates.

Clarifier: The clarifier size is calculated based on a hydraulic loading of 61, $l/hr/m^2$ (15 gph/ft^2) and a retention time of 4 hours with a 20 percent allowance for excess flow capacity. Costs include both the settling basin or tank and sludge collection mechanism. Investment costs as a function of flow rate are shown in Figure VIII-3 (page 702). The type of construction used is selected internally in the cost estimation program to provide least cost.

Sludge Pumps: A cost of \$3202 is included in the total capital cost estimates regardless of whether steel or concrete construction is used. This cost covers the expense for two centrifugal sludge pumps.

To calculate the total capital cost for continuous lime precipitation and settling, the costs estimated for the controls and reagent feed system, mix tank, clarifier and sludge pump must be summed.

For batch treatment, dual above-ground cylindrical carbon steel tanks sized for 8 hour retention and 20 percent excess capacity are used. If the batch flow rate exceeds 5204 gph, then costs for fabrication are included. The capital cost for the batch system (not including the sludge pump costs) is shown in Figure VIII-4 (page 703). To complete the capital cost estimation for batch treatment, a fixed \$3,202 cost is included for sludge pumps as discussed above.

Operation & Maintenance Costs - The operation and maintenance costs for the chemical precipitation and settling routine include:

1) Cost of chemicals added (lime, alum, and polyelectrolyte)
2) Labor (operation and maintenance)
3) Energy

- CHEMICAL COST

Lime, alum and polyelectrolyte are added for metals and solids removal. The amount of lime required is based on equivalent amounts of various pollutant parameters present in the stream entering the clarifier, or settling, unit. The methods used in determining the lime requirements are shown in Table VIII-5 (page 681). Alum and polyelectrolyte additions are calculated to provide a fixed concentration of 200 mg/l of alum and 1 mg/l of polyelectrolyte.

- LABOR

Figure VIII-5 (page 704) presents the manhour requirements for the continuous clarifier system. For the batch system, maintenance labor is assumed negligible and operation labor is calculated from:

man hours for operation = 390 + (0.975) x (lb. lime added per day)

- ENERGY

The energy costs are calculated from the clarifier and sludge pump horsepower requirements.

Continuous Mode. The clarifier horsepower requirement is assumed constant over the hours of operation of the treatment system at a level of 0.0000265 horsepower per 1 gph of flow influent to the clarifier. The sludge pumps are assumed operational for 5 minutes of each operational hour at a level of 0.00212 horsepower per 1 gph of sludge stream flow.

Batch Mode. The clarifier horsepower requirement is assumed to occur for 7.5 minutes per operation hour at the following levels:

influent flow $<$ 1042 gph; 0.0048 hp/gph
influent flow $\geq$ 1042 gph; 0.0096 hp/gph

The power required for the sludge pumps in the batch system is the same as that required for the sludge pumps in the continuous system.

Given the above requirements, operation and maintenance costs are calculated based on the following:

- $6.00 per man hour + 10 percent indirect labor charge
- $41.26/ton of lime
- $44.91 ton of alum
- $3.59/lb of polyelectrolyte
- $0.033/kilowatt-hour of required electricity

Sulfide Precipitation and Settling

This technology removes dissolved pollutants by the formation of precipitates by reaction with sodium sulfide, sodium bisulfide, or ferrous sulfide and lime, and subsequent removal of the precipitates by settling. As discussed for lime precipitation and settling the addition of chemicals, formation of precipitates, and removal of the precipitated solids from the wastewater stream are addressed together in cost estimation because of their interrelationships and commonality of equipment under some circumstances.

Investment Cost - Capital cost estimation procedures for sulfide precipitation and settling are identical to those for lime precipitation and settling as shown in Figures VIII-3 and VIII-4. Continuous treatment systems using concrete and steel construction and batch treatment systems are costed to provide a least cost system for each flow range and set of raw waste characteristics. Cost factors are also the same as for lime precipitation and settling.

Operation and Maintenance Costs - Costs estimated for the operation and maintenance of a sulfide precipitation and settling system are also identical to those for lime precipitation and settling except for the cost of treatment chemicals. Lime is added prior to sulfide precipitation to achieve an alkaline pH of approximately 8.5-9 and will lead to the precipitation of some pollutants as hydroxides or calcium salts. Lime consumption based on both neutralization and formation of precipitates is calculated to provide a 10 percent excess over stoichiometric requirements. Sulfide costs are based on the addition of ferrous sulfate and sodium bisulfide (NaHS) (on a 2:1 ratio by weight) to form a 10 percent excess of ferrous sulfide over stoichiometric requirements for precipitation. Reagent additions are calculated as shown in Table VIII-6 (page 682). Addition of alum and polyelectrolyte is identical to that shown for lime precipitation and settling as are labor (in Figure VII-5) and energy rates.

The following rates are used in determining operating and maintenance costs for this technology.

- $6.00 per man hour + 10 percent indirect labor charge
- $44.91/ton of alum
- $3.59/lb of polyelectrolyte
- $41.26/ton of lime
- $0.27/lb of sodium bisulfide
- $143.74/ton of ferrous sulfate
- $0.033/kilowatt-hour of electricity

Mixed Media Filtration

This technology provides removal of suspended solids by filtration through a bed of particles of several distinct size ranges. As a polishing treatment after chemical precipitation and settling processes, mixed media filtration provides improved removal of .precipitates and thereby improved removal of the original dissolved pollutants.

Investment Cost - The size of the mixed media filtration unit is based on 20 percent excess flow capacity and a hydraulic loading of 0.5 ft^2/gpm. The capital cost, presented in Figure VIII-6 (page 705) as a function of flow rate, includes a backwash mechanism, pumps, controls, media and installation.

Operation And Maintenance - The costs shown in Figure VIII-6 for annual costs includes contributions of materials, electricity and labor. These curves result from correlations made with data obtained from a major manufacturer. Energy costs are estimated to be 3 percent of total O&M.

Membrane Filtration

Membrane filtration includes addition of sodium hydroxide to form metal precipitates and removal of the resultant solids on a membrane filter. As a polishing treatment, it minimizes solubility of metal and provides highly effective removal of precipitated hydroxides and sulfides.

Investment Cost - Based on manufacturer's data, a factor of $52.60 per 1 gph flow rate to the membrane filter is used to estimate capital cost. Capital cost includes installation.

Operation and Maintenance Cost - The operation and maintenance costs for membrane filtration include:

1) Labor
2) Sodium Hydroxide Added
3) Energy

Each of these contributing factors are discussed below.

- LABOR

2 man-hours per day of operation are included.

- SODIUM HYDROXIDE ADDITION

Sodium hydroxide is added to precipitate metals as hydroxides or to insure a pH favorable to sulfide precipitation. The amount of sodium hydroxide required is based on equivalent amounts of various pollutant parameters present in the stream entering the membrane filter. The method used to determine the sodium hydroxide demand is shown below:

POLLUTANT	ANaOH
Chromium, Total	0.000508
Copper	0.000279
Acidity	0.000175
Iron, DIS	0.000474
Zinc	0.000268
Cadmium	0.000158
Cobalt	0.000301
Manganese	0.000322
Aluminum	0.000076

Sodium Hydroxide Per Pollutant (lb/day) = ANaOH x Flow Rate (GPH) x Pollutant Concentration (mg/l)

- ENERGY

The energy required is as follows:

- two 1/2 horsepower mixers operating 34 minutes per operational hour
- two one horsepower pumps operating 37 minutes per operational hour
- one 20 horsepower pump operating 45 minutes per operational hour

Given the above requirements, operation and maintenance costs are calculated based on the following:

- $6.00 per man-hour + 10 percent indirect labor charge
- $0.11 per pound of sodium hydroxide required
- $0.033 per kilowatt-hour of energy required

Calculated costs in the battery category as a function of flow rate for membrane filtration are presented in Figure VIII-7 (page 706).

Reverse Osmosis (RO)

This technology achieves the concentration of dissolved organic and inorganic pollutants in wastewater by forcing the water through semi-permeable membranes which will not pass the pollutants. The water which permeates the membranes is relatively free of contaminants and suitable for reuse in most manufacturing process operations. A number of different membrane types and constructions are available which are optimized for different wastewater characteristics (especially pH and temperature). Two variations, one suited specifically to recovery of nickel plating solutions, and the other of more general applicability are addressed in cost and performance models.

Investment Cost - Data from several manufacturers of RO equipment is summarized in the cost curve shown in Figure VIII-8 (page 707). The cost shown includes a prefilter, chemical feed system, scale inhibitor tank, high pressure pump, and permeators. Installation is also included. Two different systems, one using cellulose acetate membranes suitable for nickel plating bath recovery, and one using polyamide membranes which are tolerant of a wider pH and temperature range are addressed. The polyamide resin systems are applicable to treatment of battery manufacturing wastewaters.

Operation and Maintenance Cost - Contributions to operation and maintenance costs include:

- LABOR

The annual labor requirement is shown in Figure VIII-9 (page 708). Labor cost is calculated using a $6.00 per hour labor rate plus a 10 percent indirect labor charge.

- MATERIALS

The annual cost of materials used in operation and maintenance of the reverse osmosis unit is shown in Figure VIII-10 (page 709). The major component of the materials cost is the cost of replacement of permeator modules which are assumed to have a 1.5 year service life based on manufacturers' data.

- POWER

The power requirements for reverse osmosis unit is shown in Figure VIII-11 (page 710). This requirement is assumed to be constant over the operating hours of the system being estimated. The energy cost is determined using a charge of $0.033 per kilowatt-hour.

Ion Exchange

This technology achieves the concentration of inorganic pollutants in wastewater by exchanging ions on the surface of the ion exchange resin with ions of similar charge from the waste stream in which the resin is immersed. The contaminants in the waste stream are exchanged for harmless ions of the resin. The water is then suitable for reuse in most manufacturing process operations. A number of different resins are available which are optimized for different wastewater characteristics.

Investment cost, and operation and maintenance cost are comparable to those discussed above under "Reverse Osmosis." The costs are summarized in the cost curve shown in Figure VIII-8.

Vacuum Filtration

Vacuum filtration is widely used to reduce the water content of high solids streams. In the battery manufacturing industry, this technology is applied to dewatering sludge from clarifiers, membrane filters and other waste treatment units.

Investment Cost - The vacuum filter is sized based on a typical loading of 14.6 kilograms of influent solids per hour per square meter of filter area (3 lb/ft^2-hr). The curves of cost versus flow rate at TSS concentrations of 3 percent and 5 percent are shown in Figure VIII-12 (page 711). The capital cost obtained from this curve includes installation costs.

Operation and Maintenance Cost - Contributions to operation and maintenance costs include:

- LABOR

The vacuum filtration labor costs may be determined for off-site sludge disposal or for on-site sludge disposal. The required operating hours per year varies with both flow rate and the total suspended solids concentration in the influent stream. Figure VIII-13 (page 712) shows the variance of operating hours with flow rate and TSS concentration. Maintenance labor for either sludge disposal mode is fixed at 24 man-hours per year.

- MATERIALS

The cost of materials and supplies needed for operation and maintenance includes belts, oil, grease, seals, and chemicals required to raise the total suspended solids to the vacuum filter. The amount of chemicals required (iron and alum) is based on raising the TSS concentration to the filter by 1 mg/l. Costs of materials required as a function of flow rate and unaltered TSS concentrations is presented in Figure VIII-14 (page 713).

- ENERGY

Electrical costs needed to supply power for pumps and controls is presented in Figure VIII-15 (page 714). As the required horsepower of the pumps is dependent on the influent TSS level, the costs are presented as a function of flow rate and TSS level.

Holding Tanks

Tanks serving a variety of purposes in wastewater treatment and in-process control systems are fundamentally similar in design and construction and in cost. They may include equalization tanks, solution holding tanks, slurry or sludge holding tanks, mixing tanks, and settling tanks from which sludge is intermittently removed manually or by sludge pumps. Tanks for all of these purposes are addressed in a single cost estimation subroutine with additional costs for auxilliary equipment such as sludge pumps added as appropriate.

Investment Costs - Costs are estimated for either steel or concrete tanks. Tank construction may be specified as input data, or determined on a least cost basis. Retention time is specified as input data and, together with stream flow rate, determines tank size. Capital costs for concrete and steel tanks sized for 20 percent excess capacity are shown as functions of volume in Figure VIII-16 (page 715).

Operation and Maintenance Costs - For all holding tanks except sludge holding tanks, operation and maintenance costs are minimal in comparison to other system O&M costs. Therefore only energy costs for pump and mixer operation are determined. These energy costs are presented in Figure VIII-17 (page 716).

For sludge holding tanks, additional operation and maintenance labor requirements are reflected in increased O&M costs. The required manhours used in cost estimation are presented in Figure VIII-18 (page 717). Labor costs are determined using a labor rate of $6.00 per manhour plus 10 percent indirect labor charge.

Where tanks are used for settling as in lime precipitation and clarification batch treatment, additional operation and maintenance costs are calculated as discussed specifically for each technology.

pH Adjustment (Neutralization)

The adjustment of pH values is a necessary precursor to a number of treatment operations and is frequently required to return waste streams to a pH value suitable for discharge following metals precipitation. This is typically accomplished by metering an alkaline or acid reagent into a mix tank under automatic feedback control.

Investment Costs - Figure VIII-19 (page 718) presents capital costs for pH adjustment as a function of the flow rate going into the units. The cost calculations are based on steel or concrete tanks with a 15 minute retention time and an excess capacity of 20 percent. Tank construction is selected on a least cost basis. Costs include a pH probe and control system, reagent mix tanks, a mixer in the pH adjustment tank, and system installation.

Operation and Maintenance Costs - Contributions to operation and maintenance costs include:

- LABOR

The annual manhour requirement is presented as a function of flow rate in Figure VIII-20 (page 719). The cost of labor may be calculated using a labor rate of $6.00 per hour plus a 10 percent indirect labor charge.

- MATERIALS

Sodium hydroxide or sulfuric acid is added according to the stream pH, and acidity or alkalinity. The amount of lime or acid required may be calculated by the procedure shown in Table VIII-7 (page 683). The cost of lime or acid added may be determined using the rates of $0.11 per pound of sodium hydroxide and $70.0 per ton of sulfuric acid.

- ENERGY

Power, required for a mixer, is based on a representative installation with 1-turnover per minute. The daily horsepower requirement is 3 hp per 10,000 gph flow rate. The energy cost may be calculated using the rates of 0.8 kilowatts per horsepower and $0.33 per kilowatt-hour.

Contract Removal

Sludge, waste oils, and in some cases concentrated waste solutions frequently result from wastewater treatment processes. These may be disposed of on-site by incineration, landfill or reclamation, but are most often removed on a contract basis for off-site disposal. System cost estimates presented in this report are based on contract removal of sludges and waste oils. In addition, where only small volumes of concentrated wastewater are produced, contract removal for off-site treatment may represent the most cost-effective approach to water pollution abatement. Estimates of solution contract haul costs are also provided by this treatment component and may be selected in place of on-site treatment on a least-cost basis.

Investment Costs - Capital investment for contract removal is zero.

Operating Costs - Annual costs are estimated for contract removal of total waste streams or sludge and oil streams as specified in input data. Sludge and oil removal costs are further divided into wet and dry haulage depending upon whether or not upstream sludge dewatering is provided. The use of wet haulage or of sludge dewatering and dry haulage is based on least cost as determined by annualized system costs over a ten year period. Wet haulage costs are always used in batch treatment systems and when the volume of the sludge stream is less than 100 gallons per day. Both wet sludge haulage and total waste haulage differ in cost depending on the chemical composition of the water removed. Wastes are classified as cyanide bearing, hexavalent chromium bearing, or oily and assigned different haulage costs as shown below.

Waste Composition	Haulage Cost
$\geq .05$ mg/l CN^-	\$0.45/gallon
$\geq .1$ mg/l Cr^{+6}	\$0.20/gallon
Oil & grease $\geq$ TSS	\$0.12/gallon
All others	\$0.16/gallon

Dry sludge haul costs are estimated at \$0.12/gallon and 40 percent dry solids in the sludge.

Carbon Adsorption

This technology removes organic and inorganic pollutants and suspended solids by pore adsorption, surface reactions, physical filtering by carbon grains, and in some cases as part of a biological treatment system. It typically follows other types of treatment as a means of polishing effluent. A variety of carbon adsorption systems exist: upflow, downflow, packed bed, expanded bed, regenerative and throwaway. Regeneration of carbon requires an expensive furnace and fuel. As a general criteria, it is not economically feasible to install a thermal regeneration system unless carbon usage is above 1000 lb per day.

Investment Costs - Capital investment costs estimated for carbon adsorption systems applied to battery manufacturing wastewater are provided in Figure VIII-21 (page 720) and assume a packed bed throwaway system. All equipment costs are based on the EPA Technology Transfer Process Design Manual, Carbon Adsorption and include a contactor system, a pump station, and initial carbon. Costs for carbon adsorption are highly variable and it is usually cost effective to pretreat waste before using carbon adsorption. The high cost of removing a small amount of a given priority pollutant results from the requirement that the system be sized and operated to remove all organics present which are more easily removed than the species of interest. Removal efficiencies depend upon the type of carbon used, and a mixture of carbon types may be cost beneficial. In regenerative systems removal efficiencies achieved by regenerated carbon are vastly different from fresh carbon. Equipment sizing is based on dynamic (as opposed to carbon isotherm) studies.

Operation and Maintenance Costs - The chief operation and maintenance costs are labor, replacement carbon, and electricity for the pump station. Annual costs determined for battery manufacturing applications are shown in Figure VIII-21 (page 720). Carbon usage selected to provide 99 percent removal of each organic priority pollutant is determined from a reciprocal carbon efficiency of an appropriate mix of carbons (bituminous and lignite) estimated at 0.2 ft^3 of fresh unregenerated (virgin) carbon per pound of organics provided by the influent. Carbon is costed at $1.19/lb and electricity at $0.033/kw hr.

Chromium Reduction

This technology provides chemical reduction of hexavalent chromium under acid conditions to allow subsequent removal of the trivalent form by precipitation as the hydroxide. Treatment may be provided in either continuous or batch mode, and cost estimates are developed for both. Operating mode for system cost estimates is selected on a least cost basis.

Investment Costs - Cost estimates include all required equipment for performing this treatment technology including reagent feed, equipment reaction tanks, mixers and controls. Different reagents are provided for batch and continuous treatment resulting in different system design considerations as discussed below.

For both continuous and batch treatment, sulfuric acid is added for pH control. A 90-day supply is stored in the 25 percent aqueous form in an above-ground, covered concrete tank, 0.305 m(1 ft) thick.

For continuous chromium reduction the single chromium reduction tank is sized as an above-ground cylindrical concrete tank with a 0.305 m (1 ft) wall thickness, a 54 minute retention time, and 20 percent excess capacity factor. Sulfur dioxide is added to convert the influent hexavalent chromium to the trivalent form.

The control system for continuous chromium reduction consists of:

1	immersion pH probe and transmitter
1	immersion ORP probe and transmitter
1	pH and ORP monitor
2	slow process controllers
1	sulfonator and associated pressure regulator
1	sulfuric acid pump
1	transfer pump for sulfur dioxide ejector
2	maintenance kits for electrodes, and miscellaneous electrical equipment and piping

For batch chromium reduction, the dual chromium reduction tanks are sized as above-ground cylindrical concrete tanks, 0.305 m (1 ft) thick, with a 4 hour retention time, an excess capacity factor of 0.2. Sodium bisulfite is added to reduce the hexavalent chromium.

A completely manual system is provided for batch operation. Subsidiary equipment includes:

1	sodium bisulfite mixing and feed tank
1	metal stand and agitator collector
1	sodium bisulfite mixer with disconnects
1	sulfuric acid pump
1	sulfuric acid mixer with disconnects
2	immersion pH probes
1	pH monitor, and miscellaneous piping

Capital costs for batch and continuous treatment systems are presented in Figure VIII-22 (page 721).

Operation and Maintenance - Costs for operating and maintaining chromium reduction systems are determined as follows:

- Labor

The labor requirements are plotted in Figure VIII-23 (page 722). Maintenance of the batch system is assumed negligible and so it is not shown.

- Chemical Addition

For the continuous system, sulfur dioxide is added according to the following:

$$(\text{lb } SO_2/\text{day}) = (15.43)\ (\text{flow to unit-MGD})\ (Cr^{+6}\ \text{mg/l})$$

In the batch mode, sodium bisulfite is added in place of sulfur dioxide according to the following:

$$(\text{lbs } NaHSO_3/\text{day}) = (20.06)\ (\text{flow to unit-MGD})\ (Cr^{+6}\ \text{mg/l})$$

- Energy

Two horsepower is required for chemical mixing. The mixers are assumed to operate continuously over the operation time of the treatment system.

Given the above requirements, operation and maintenance costs are calculated based on the following:

- $6.00 per manhour + 10 percent indirect labor charge
- $380/ton of sulfur dioxide
- $20/ton of sodium bisulfite
- $0.033/kilowatt hour of required electricity

Vapor Recompression Evaporation

Vapor recompression evaporation is used to increase energy efficiency by allowing heat to be transferred from the condensing water vapor to the evaporating wastewater. The heat contained in the compressed vapor is used to heat the wastewater, and energy costs for system operation are reduced.

Costs for this treatment component related to flow are displayed in Figure VIII-24 (page 723).

In-Process Treatment and Control Components

A wide variety of in process controls has been identified for application to battery manufacturing wastewaters, and many of these require in process treatment or changes in manufacturing plants and capital equipment for which additional costs must be estimated. For most of these in-process controls, especially recirculation and reuse of specific process streams, the required equipment and resultant costs are identical to end-of-pipe components discussed above. The recirculation of amalgamation area wash water requires the removal of mercury for which costs are estimated based on the sulfide precipitation and settling system previously discussed. Other area wash water costs are based on the holding tank costs associated with sizing assumptions discussed for each treatment technology sequence within each subcategory.

Summary of Treatment and Control Component Costs. Costs for each of the treatment and control components discussed above as applied to process wastewater streams within the battery manufacturing category are presented in Tables VIII-8 to VIII-20 (pages 684-696). Three levels of cost are provided for each technology representative of median, low, and high raw waste flow rates encountered within the category.

TREATMENT SYSTEM COST ESTIMATES

Estimates of the total cost of wastewater treatment and control systems for battery manufacturing process wastewater are made by incorporating the treatment and control components discussed above.

BPT or PSES Option 0 System Cost Estimates

Cadmium Subcategory - The option 0 treatment system for this subcategory, shown in Figure IX-1 (page 810), consists of oil skimming (if necessary) lime precipitation and settling of all process wastewater for the removal of nickel, cadmium and other toxic metals, and includes a vacuum filter for dewatering the clarifier sludge. Rationale for selection of this system is presented in Section IX.

Assumptions used in sizing system components are those discussed for the individual treatment components.

Data from dcp and plant visits were evaluated to determine the existing in-process treatment technologies for wastewater conservation, and the actual and achievable loading levels. These technologies include recycle or reuse of process solutions, segregation of noncontact cooling water from process wastewater and control of electrolyte drips and spills. The in-process costs reflect additional controls required for water use reduction at high flow plants.

Calcium Subcategory - The option 0 treatment system, shown in Figure IX-2 (page 811), consists of the treatment of two streams. The first waste stream is settled to remove asbestos, barium chromate and suspended zirconium powder, reduced to insure that no slightly soluble barium chromate provides hexavalent chromium, and then merged with the second wastewater stream from cell testing. The combined stream is treated with lime to precipitate dissolved metals. The precipitate is removed, and the water is neutralized in the sedimentation tank before being discharged. The sludge from sedimentation is filtered, and the filtrate is recycled to the lime precipitation tank. Contract hauling of the solid wastes from the treatment is more economical than on-site disposal for the low flows encountered in the calcium subcategory.

Leclanche Subcategory - Option 0 for this subcategory achieves zero discharge of process wastewater pollutants by the application of in-process control techniques, for all processes except foliar battery miscellaneous wash discharges. No costs are incurred in most plants in the subcategory because no process wastewater is presently produced. Cost estimates for the remaining plants reflect holding tanks, pumps, piping, and treatment facilities needed to achieve recycle of process wastewater from paste setting and from equipment and tool washing operations. Paste setting wastewater is treated by lime or sulfide (ferrous sulfide) precipitation prior to recycle, and equipment wash wastewater is treated in settling tanks. For the foliar battery plants cost estimates are for holding tanks, pumps, piping and lime, settle and filter wastewater treatment facilities needed to achieve some flow reduction and final treatment of miscellaneous wash waters. The treatment system is illustrated in Figure IX-3 (page 812). In some cases in the subcategory, where the reported volume of process wastewater was small, estimated costs reflect contract removal of the wastes rather than treatment and recycle.

Lithium Subcategory - The option 0 treatment for this subcategory, as shown in Figure IX-4 (page 813), includes grouping of wastes into three streams. Stream A resulting from heat paper production is settled to remove asbestos, barium chromate and zirconium powder suspension. Hexavalent chromium in this stream is then reduced to the trivalent state. Metals are precipitated by lime addition, and the precipitate along with the solid particulates are removed in a clarifier. The resulting sludge is dewatered by vacuum filtration, and the filtrate is recycled to the lime precipitation tank.

Treatment for Stream B resulting from all cathode and ancillary operations except heat paper production and air scrubber wastewaters includes precipitation with lime or acid addition, and settling.

The process wastewater from Stream C, air scrubbers, is first aerated to oxidize sulfur, and then treated with lime to precipitate metals. The precipitates along with solid particulates are removed by settling. Contract hauling of all wastes from this subcategory is used when there are low flows and hauling is less costly than treatment.

Magnesium Subcategory - The option 0 treatment for this subcategory presented in Figure IX-5 (page 814) includes grouping wastes into three streams. Wastewater from heat paper production (Stream A) is settled in a tank to remove asbestos, barium chromate and zirconium, and then treated for the reduction of hexavalent chromium to the trivalent state. The final treatment includes precipitation of chromium and any other metals by lime addition, settling of the precipitate along with suspended solids and vacuum filtration of the sludge following settling. The filtrate is recycled to the chemical precipitation tank.

For Stream B, wastewater from silver chloride cathode production and spent process solution are first oxidized by means of potassium permanganate to reduce the COD level. This stream is then treated along with the wastewater from cell testing, and floor and equipment wash for precipitation of heavy metals (by means of lime or acid addition), followed by settling and vacuum filtration of the sludge. The filtrate is recycled to the chemical precipitation tank.

The process wastewater from Stream C, air scrubbers, is first treated by lime for precipitation of metals, and then settling of the precipitate and solid particulates. Solids are dewatered by means of a vacuum filter. The filtrate is recycled to the precipitation tank. Contract hauling of the solid wastes from this treatment is usually more economical than on-site disposal for the low flows encountered in the magnesium subcategory.

Zinc Subcategory. The option 0 wastewater treatment and control system for this subcategory, as shown in Figure IX-6 (page 815), includes skimming for the removal of oil and grease, lime or acid addition for the precipitation of metals, sedimentation of the precipitate along with solid particulates, and vacuum filtration of the sludge. The filtrate is recycled to the chemical precipitation treatment tank. In the draft development document distributed for comment in 1980, this option included sulfide precipitation and filtration. This option was changed to L&S technology because of the difficulty and expense of retrofitting existing plants so that sulfide precipitation may be used safely, and the fact .that filters are less costly with flow reduction, evaluated as a BAT (PSES) option.

In-process control technologies included at option 0 for this subcategory include the following: reuse of process solutions, segregation of noncontact cooling water, segregation of organic-bearing cell cleaning wastewater, control of electrolyte drips and spills, elimination of chromates in cell washing, and flow controls for rinse waters.

BAT (PSES) Treatment System Cost Estimates - Existing Sources

The following discussion of cost estimates for treatment options is based on data from existing sources. Rationale for the selection of the BAT options are discussed in Section X and the PSES options are discussed in Section XII.

Cadmium Subcategory - Costs were estimated for three options of treatment and control considered appropriate for BAT and PSES.

Option 1

As shown in Figure X-1 (page 908), end-of-pipe treatment for option 1 is the same as the option 0 treatment with the addition of a number of in-process control techniques to limit the volume of process wastewater and pollutant loads to treatment. The in-process control technology recommended for option 1, in addition to that listed for option 0, include: recycle or reuse of pasted and pressed powder anode wastewater, use of dry methods to clean floors and equipment, control of rinse flow rates, recirculation of wastewater from air scrubber, dry cleaning of impregnated electrodes, reduction of the cell wash water use, countercurrent rinse of silver and cadmium powder, and countercurrent rinse for sintered and electrodeposited anodes and cathodes.

Costs for recirculation of scrubber solutions are based on the provision of tanks providing 2 hours retention of the scrubber discharge. No costs are determined for control of rinse flow rates since this can be accomplished with minimum manpower and manual flow control values which are present on most units or available at low cost. Similarly, no costs were estimated for the use of dry brushing processes since these are observed to be used in existing plants on a competitive basis with wet brushing techniques. Estimates include costs for the segregation of two scrubber discharge streams. Cost estimation for multistage countercurrent rinses are based on present rinse flow and production rates and considerations previously discussed for this in-process technique. Costs for reuse of final product wash water after cadmium powder precipitation are based on provision of a tank for retention of final wash water from one batch of product for use in early rinses of the next batch.

. Option 2

As shown in Figure X-2 (page 909), end-of-pipe treatment provided for cadmium subcategory wastes at option 2 is identical to that provided at option 1, except that the effluent from settling is filtered in option 2 and that the backwash from polishing filter is recycled to the precipitation tank. In-process control techniques for option 2 are identical to those recommended for option 1.

- Option 3

End-of-pipe treatment for option 3 includes concentration of process wastewater using reverse osmosis prior to chemical precipitation, settling and filtration for final treatment. Permeate from the reverse osmosis unit is reused in the process. As shown in Figure X-3 (page 910), before reverse osmosis, wastewater is skimmed to remove oil and grease, treated with lime or acid to form metal precipitates, and then filtered to remove precipitates and solids. Initial precipitation and filtration steps protect the permeators. Sludge is dewatered in a vacuum filter. In-process control techniques at option 3 include improved process control on cadmium powder precipitation to eliminate the need for rework of this product in addition to the in-process controls discussed as option 2.

- Option 4

As shown in Figure X-4 (page 911), option 4 end-of-pipe treatment includes oil skimming, chemical precipitation, settling, filtration, and ion exchange (or reverse osmosis) prior to vapor recompression evaporation of the ion exchange regenerant (or reverse osmosis brine). The sludge from settling is dewatered by vacuum filtration, and the filtrate is recycled to the chemical precipitation tank. Distillate or permeate from the evaporation unit is returned to the production process for reuse. In-process control technologies include all those discussed for options 2 and 3 as well as the elimination of discharge from the impregnation rinse.

Calcium Subcategory - Costs were estimated for two options of treatment and control considered appropriate for BAT and PSES.

- Option 1

At option 1, end-of-pipe treatment is identical to that provided for option 0 with the addition of a mixed-media filter prior to discharge. This filter is intended to act as a polishing unit on the treated waste stream. The filter backwash is returned to the treatment system. A schematic of the system is provided in Figure X-5 (page 912).

- Option 2

This level of treatment is similar to option 1 except that the waste stream from heat paper production is recycled back to the process. A schematic of the system is provided in Figure X-6 (page 913).

Leclanche Subcategory - Only one option is considered for BAT (PSES) for this subcategory. This option is identical to BPT (PSES) option 0 and achieves zero discharge of process wastewater pollutants by the application of in-process control technology for all processes except foliar battery miscellaneous wash discharges. For foliar batteries the option is identical to BPT and includes flow reduction and lime, settle and filter end-of-pipe treatment.

Lithium Subcategory - Costs were estimated for three options of treatment and control presented for evaluation as BAT and PSES.

- Option 1

This level of treatment is similar to that prescribed for option 0 except that the wastewaters from Streams A and B are passed through a polishing filter after settling. Stream C is unchanged from option 0. The schematic for this system is provided in Figure X-7 (page 914). The filter backwash is returned to waste treatment.

- Option 2

As shown in Figure X-8 (page 915) option 2 treatment is identical to option 1 treatment except that Stream A wastewater is treated in a settling tank for the removal of solids, and then recycled to the process.

- Option 3

At this level of treatment and control shown in Figure X-9 (page 916), treatment identical to option 2 is provided, except that Stream C process wastewater originating from air scrubbers is filtered following aeration, precipitation and settling.

Magnesium Subcategory - Costs were estimated for three options of treatment and control presented for evaluation as BAT and PSES.

- Option 1

This level of treatment is similar to that prescribed for option 0 except that the effluent originating from Stream A is filtered following precipitation and settling. The backwash from the filter is recycled to the chemical precipitation tank. The schematic for this system is provided in Figure X-10 (page 917). The additional recommended in-process technology includes countercurrent cascade rinsing for silver chloride cathodes in Stream B.

- Option 2

Option 2 treatment is identical to option 1 except that Stream A wastewater is treated in a settling tank for the removal of solids, and then recycled to the process and sedimentation discharge in option 1 treatment of Stream B is filtered. No in-process control technology is recommended. Stream C treatment is unchanged. The schematic for this system is in Figure X-11 (page 918).

- Option 3

Option 3 is identical to option 2 treatment except that on Stream B a carbon adsorption unit is used instead of the oxidizer in option 2 treatment of the silver chloride cathode production wastewater and spent process solution, and sedimentation effluent in option 2 treatment of Stream C wastewaters is filtered before discharge. A schematic of option 3 is shown in Figure X-12 (page 919).

Zinc Subcategory - Costs were estimated for three options of treatment and control presented for evaluation as BAT and PSES.

- Option 1

This level of treatment and control combines end-of-pipe treatment as specified for option 0 with additional in-process control techniques to reduce wastewater flow rates and pollutant loads discharged to treatment. Additional in-process controls include countercurrent cascade rinsing of amalgamated zinc powder, formed zinc electrodes, electrodeposited silver powder, formed silver oxide electrodes, silver peroxide, impregnated nickel cathodes, and silver etching grids; as well as recirculation of amalgamation area floor wash water, elimination of electrolyte preparation spills, and dry cleanup or wash water reuse for floor and equipment. The schematic for the system is shown in Figure X-13 (page 920).

Cost estimates include provision of eight tanks, associated pumps and piping to provide retention of rinse waters from wet amalgamation operations allowing countercurrent rinsing in which water is used in an earlier rinse stage on each batch of amalgam produced, and water from only the first rinse is discharged to treatment. Treatment and recycle costs for amalgamation area wash water are based on batch treatment using lime or ferrous sulfide and are discussed under lime or sulfide precipitation and settling. Cost estimates are also provided for countercurrent rinses as described in the general discussion of that technology. No costs are estimated for dry cleanup of general plant floor areas.

- Option 2

Option 2 is identical to option 1 except that the settled effluent from option 2 is treated by filtration. A schematic of option 2 is shown in Figure X-14 (page 921). No additional in-process control techniques beyond those listed for option 1 are recommended.

- Option 3

Option 3 is identical to option 2, except chemical precipitation is performed by sulfide addition rather than lime addition, and membrane filtration is used instead of mixed media polishing filtration. Additional in-process controls include elimination of wastewater from gelled amalgam. Costs for gelled amalgam equipment wash are estimated based on provision of pumps and piping as discussed for line segregation costs. A schematic for option 3 is provided in Figure X-15 (page 922).

- Option 4

End-of-pipe treatment for option 4 includes concentration of process wastewaters using reverse osmosis prior to sulfide precipitation, settling and filtration. Permeate from the reverse osmosis is reused in the process. As shown in Figure X-16 (page 923), prior to reverse osmosis, wastewater is skimmed to remove oil and grease, treated with lime to form precipitates, and then filtered to remove precipitates and solids. Additional recommended in-process technology includes amalgamation by dry processes which eliminates all wastewater from amalgamation.

NSPS (PSNS) Treatment System Cost Estimates - New Source

The suggested treatment options and estimated costs for new sources are identical to the treatment options for existing sources. Each option is discussed above. Rationale for the selection of new source options is discussed in Sections XI and XII. Cost estimates overstate the actual costs a new source would incur because new sources will be able to plan and implement both in-process modifications and end-of-pipe treatment without any retrofitting costs. Additionally, new sources will be able to plan and implement more cost saving systems such as resource recovery of metal and process solutions.

Use of Cost Estimation Results

The costing methodology and recommended treatment system options were used primarily to estimate compliance costs for the implementation of treatment in the category. Costs for each plant were calculated for what additional equipment would be needed at an existing site for the treatment options. Contract hauling costs were estimated for plants when hauling would be less costly than installing treatment. In this category actual costing is plant specific and is dependent upon what processes a plant is using. The results of estimating compliance costs for the category are tabulated in Table X-56 (page 907). Plants which were known to be closed were eliminated from summation.

The cost results were also used for the economic impact analysis (See "Economic Impact Analysis of Proposed Effluent Standards and Limitations for the Battery Manufacturing Industry"). For this analysis cost estimates were broken down for each facility (location for producing final battery products, i.e., alkaline manganese, silver oxide-zinc) and cost results were expressed in dollars per pound of battery produced.

Finally, this section can be used to estimate costs for alternatives to the options presented by using the component graphs for investment and annual costs based on varying flows.

NONWATER QUALITY ENVIRONMENTAL ASPECTS

Nonwater quality environmental aspects including an evaluation of energy requirements of all of the wastewater treatment technologies described in Section VII are summarized in Tables VIII-20 and VIII-21 (pages 696 and 697). These general energy requirements are listed, the impact on environmental air and noise pollution is noted, and solid waste generation characteristics are summarized. The treatment processes are divided into two groups, wastewater treatment processes on Table VIII-20 and sludge and solids handling processes on Table VIII-21.

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. Table VIII-22 (page 698) summarizes the battery manufacturing category and subcategory energy costs which would result at existing plants with the implementation of the different technology options.

Energy requirements are generally low, although evaporation can be an exception if no waste heat is available at the plant.

Thus, if evaporation is used to avoid discharge of pollutants, the influent water rate should be minimized. For example, an upstream reverse osmosis, ion exchange, or ultrafiltration unit can drastically reduce the flow rate of wastewater to an evaporation device.

Nonwater Quality Environmental Aspects

It is important to consider the impact of each treatment process on water scarcity and air, noise and radiation, and solid waste pollution of the environment to preclude the development of a more adverse environmental impact.

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.

Air - In general, none of the liquid handling processes causes air pollution. With sulfide precipitation, however, the potential exists for evolution of hydrogen sulfide, a toxic gas. Proper control of pH in treatment eliminates this problem. Incineration of sludges or solids can cause significant air pollution which must be controlled by suitable bag houses, scrubbers or stack gas precipitators as well as proper incinerator operation and maintenance. 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, (eg. cadmium and mercury) sludges from battery manufacturing wastewater treatment are not amenable to incineration except in retorts for metals recovery.

Noise and Radiation - None of the wastewater treatment processes causes objectionable noise levels and none of the treatment processes has any potential for radioactive radiation hazards.

Solid Waste - Costs for treatment sludge handling were included in the computer cost program and are included in the compliance cost summary. 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 the lime and settle technology. Only plants which have mercury containing treatment sludges or sulfide treatment sludges were considered as hazardous under RCRA. The RCRA costs for disposing of hazardous wastewater treatment sludges are presented by subcategory, in Table VIII-23 (page 699). Only indirect dischargers are shown because no hazardous waste disposal costs would be incurred by direct dischargers. Many existing plants recover the metals from the sludges. The costs for indirect dischargers can be summarized as follows:

- Only seven plants (all in the Leclanche and zinc subcategories) of the 69 plants in the battery manufacturing subcategories which are included in this document would incur RCRA costs because of the disposal of hazardous sludges from wastewater treatment.
- The annual cost for disposal of hazardous sludges from wastewater treatment for these seven plants is estimated at $34,000.

Lime precipitation and settling produces a sludge with a high solids content, consisting of calcium salts, which in some instances has a potential economic benefit. The recovery potential for the principal toxic metals(s) contained in the wastewater treatment sludge from lime precipitation was also considered. Recovery of nickel and cadmium from the cadmium subcategory sludge has a potential economic benefit. In fact, most cadmium subcategory plants already reclaim wastewater treatment sludges.

The RCRA related costs presented are based on an analysis of lime and settle treatment costs and wastewater loadings provided in this document, on-site disposal costs developed in an EPA report and contact with hazardous waste disposal tranporters and operators. This analysis is in the public record for this category. These costs were developed using the following four-steps process: (1) the total amount of wastes for each battery manufacturing plant and the total subcategory were determined; (2) the waste constituents were then evaluated according to RCRA criteria to determine whether they would be characterized as hazardous; (3) the amount of waste characterized as hazardous was then used to determine whether off-site or on-site disposal was the preferred alternative based on disposal site cost curves; and (4) the disposal cost was calculated on a dollar-per-pound of battery produced basis and presented as the incremental cost resulting from hazardous sludge disposal.

TABLE VIII-1

COST PROGRAM POLLUTANT PARAMETERS

Parameter, Units

Flow, MGD
pH, pH units
Turbidity, Jackson Units
Temperature, degree C
Dissolved Oxygen, mg/l
Residual Chlorine, mg/l
Acidity, mg/l $CaCO_3$
Alkalinity, mg/l $CaCO_3$
Ammonia, mg/l
Biochemical Oxygen Demand mg/l
Color, Chloroplatinate units
Sulfide, mg/l
Cyanides, mg/l
Kjeldahl Nitrogen, mg/l
Phenols, mg/l
Conductance, micromhos/cm
Total Solids, mg/l
Total Suspended Solids, mg/l
Settleable Solids, mg/l
Aluminum, mg/l
Barium, mg/l
Cadmium, mg/l
Calcium, mg/l
Chromium, Total, mg/l
Copper, mg/l
Fluoride, mg/l
Iron, Total, mg/l
Lead, mg/l
Magnesium, mg/l
Molybdenum, mg/l
Total Volatile Solids, mg/l

Parameter, Units

Oil, Grease, mg/l
Hardness, mg/l $CaCO_3$
Chemical Oxygen Demand, mg/l
Algicides, mg/l
Total Phosphates, mg/l
Polychlorobiphenyls, mg/l
Potassium, mg/l
Silica, mg/l
Sodium, mg/l
Sulfate, mg/l
Sulfite, mg/l
Titanium, mg/l
Zinc, mg/l
Arsenic, mg/l
Boron, mg/l
Iron, Dissolved, mg/l
Mercury, mg/l
Nickel, mg/l
Nitrate, mg/l
Selenium, mg/l
Silver, mg/l
Strontium, mg/l
Surfactants, mg/l
Beryllium, mg/l
Plasticizers, mg/l
Antimony, mg/l
Bromide, mg/l
Cobalt, mg/l
Thallium, mg/l
Tin, mg/l
Chromium, Hexavalent, mg/l

TABLE VIII-2

TREATMENT TECHNOLOGY SUBROUTINES

Spray/Fog Rinse
Countercurrent Rinse
Vacuum Filtration
Gravity Thickening
Sludge Drying Beds
Holding Tanks
Centrifugation
Equalization
Contractor Removal
Reverse Osmosis
Chemical Reduction of Chrom.
Chemical Oxidation of Cyanide
Neutralization
Clarification (Settling Tank/Tube Settler)
API Oil Skimming
Emulsion Breaking (Chem/Thermal)
Membrane Filtration
Filtration (Diatomaceous Earth)
Ion Exchange - w/Plant Regeneration
Ion Exchange - Service Regeneration
Flash Evaporation
Climbing Film Evaporation
Atmospheric Evaporation
Cyclic Ion Exchange
Post Aeration
Sludge Pumping
Copper Cementation
Sanitary Sewer Discharge Fee
Ultrafiltration
Submerged Tube Evaporation
Flotation/Separation
Wiped Film Evaporation
Trickling Filter
Activated Carbon Adsorption
Nickel Filter
Sulfide Precipitation
Sand Filter
Pressure Filter
Mixed-media Filter
Sump
Cooling Tower
Ozonation
Activated Sludge
Coalescing Oil Separator
Non Contact Cooling Basin
Raw Wastewater Pumping
Preliminary Treatment
Preliminary Sedimentation
Aerator - Final Settler
Chlorination
Flotation Thickening
Multiple Hearth Incineration
Aerobic Digestion
Lime Precipitation (metals)

TABLE VIII-3

WASTEWATER SAMPLING FREQUENCY

Wastewater Discharge (liters per day)	Sampling Frequency
0 - 37,850	once per month
37,850 - 189,250	twice per month
189,250 - 378,500	once per week
378,500 - 946,250	twice per week
946,250+	thrice per week

TABLE VIII-4

WASTE TREATMENT TECHNOLOGIES FOR BATTERY MANUFACTURING CATEGORY

Hydroxide Precipitation and Settling; Batch Treatment

Hydroxide Precipitation and Settling, Continuous Treatment

Sulfide Precipitation and Settling; Batch Treatment

Sulfide Precipitation and Settling; Continuous Treatment

Mixed-media Filtration

Membrane Filtration

Reverse Osmosis

Ion Exchange

Vacuum Filtration

Holding and Settling Tanks

pH Adjustment (Neutralization)

Contract Removal

Aeration

Carbon Adsorption

Chrome Reduction

Vapor Recompression Evaporator

TABLE VIII-5

LIME ADDITIONS FOR LIME PRECIPITATION

Stream Parameter	Lime Addition kg/kg (lb/lb)
Acidity (as $CaCO_3$)	0.81
Aluminum	4.53
Antimony	1.75
Arsenic	2.84
Cadmium	2.73
Chromium	2.35
Cobalt	1.38
Copper	1.28
Iron (Dissolved)	2.19
Lead	0.205
Magnesium	3.50
Manganese	1.48
Mercury	0.42
Nickel	1.45
Selenium	3.23
Silver	0.39
Zinc	1.25

TABLE VIII-6

REAGENT ADDITIONS FOR SULFIDE PRECIPITATION

Stream Parameter	Ferrous Sulfide Requirement kg/kg (lb/lb)
Cadmium	0.86
Calcium	2.41
Chromium (Hexavalent)	1.86
Chromium (Trivalent)	2.28
Cobalt	1.64
Copper	1.52
Lead	0.47
Mercury	0.24
Nickel	1.65
Silver	0.45
Tin	0.81
Zinc	1.48

Sodium Bisulfide Requirement = 0.65 x Ferrous Sulfide Requirement

Ferrous Sulfate Requirement = 1.5 x Ferrous Sulfide Requirement

Lime Requirement = 0.49 x $FeSO_4$(lb) + 3.96 x NaHS(lb) + 2.19 x lb of Dissolved Iron

TABLE VIII-7

NEUTRALIZATION CHEMICALS REQUIRED

Chemical	Condition	A_o
Lime	pH less than 6.5	.00014
Sulfuric Acid	pH greater than 8.5	.00016

(Chemical demand, lb/day) = A_o x Flow Rate (GPH) x Acidity (Alkalinity, mg$CaCO_3$/l)

TABLE VIII-8

WATER TREATMENT COMPONENT COSTS

	Process:	HYDROXIDE PRECIPITATION AND SETTLING		
	Least cost:	BATCH	BATCH	CONTINUOUS
System flow rate:	l/hr	4	23890	56780
	gal/day	8	101000	360000
Investment:		18090	54630	72620
Annual costs:				
Capital costs		1134	3428	4557
Depreciation		1809	5463	7262
Operating & Maintenance costs (excluding energy)		2706	4491	8815
Energy costs		0.001	17.72	61.29
Total annual costs:		$ 8650	$ 13400	$ 20700

TABLE VIII-9

WATER TREATMENT COMPONENT COSTS

Process:		SULFIDE PRECIPITATION AND SETTLING		
Least cost:		BATCH	BATCH	BATCH
System flow rate:	l/hr	4	95	6529
	gal/day	8	600	13800
Investment:		3722	6101	31060
Annual costs:				
Capital costs		234	383	1949
Depreciation		372	610	3106
Operating & Maintenance costs (excluding energy)		824	2488	3351
Energy Costs		0.031	2.33	107
Total annual costs:		$ 1430	$ 3484	$ 8513

TABLE VIII-10

WATER TREATMENT COMPONENT COSTS

		Process: SULFIDE PRECIPITATION AND SETTLING		
	Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate:	l/hr	5677	10740	19240
	gal/day	24000	45400	122000
Investment:		26820	32300	39030
Annual costs:				
Capital costs		1683	2027	2449
Depreciation		2682	3230	3903
Operating & Maintenance costs (excluding energy)		6615	9780	20331
Energy costs		4.88	8.84	23.36
Total annual costs:		$ 10980	$ 15050	$ 26710

TABLE VIII-11

WATER TREATMENT COMPONENT COSTS

	Process:	MIXED-MEDIA FILTRATION		
	Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate:	1/hr	4	5195	17348
	gal/day	8	10980	110000
Investment:		261	21470	44800
Annual costs:				
Capital costs		16	1347	2811
Depreciation		26	2147	4480
Operating & Maintenance costs (excluding energy)		6065	6065	6065
Energy costs		284	284	284
Total annual costs:		$ 6391	$ 9843	$ 13640

TABLE VIII-12

WATER TREATMENT COMPONENT COSTS

Process:	MEMBRANE FILTRATION		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: 1/hr	26	380	1223
gal/day	112	2412	7755
Investment:	367	5280	16970
Annual costs:			
Capital costs	23	331	1065
Depreciation	37	527	1697
Operating & Maintenance costs (excluding energy)	3128	3300	3406
Energy costs	1650	2610	2694
Total annual costs:	$ 4838	$ 6769	$ 8862

TABLE VIII-13

WATER TREATMENT COMPONENT COSTS

Process:	REVERSE OSMOSIS		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: l/hr	4	182	16180
gal/day	8	768	102600
Investment:	2707	15080	145100
Annual costs:			
Capital costs	170	946	9102
Depreciation	270	1508	14510
Operating & Maintenance costs (excluding energy)	419	799	40080
Energy costs	75	335	5895
Total annual costs:	$ 934	$ 3587	$ 69580

TABLE VIII-14

WATER TREATMENT COMPONENT COSTS

Process:	VACUUM FILTRATION		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: l/hr	25	168	326
gal/day	106	210	1377
Investment:	25220	25220	25220
Annual costs:			
Capital costs	1582	1582	1582
Depreciation	2522	2522	2522
Operating & Maintenance costs (excluding energy)	3990	5179	5940
Energy costs	0	0	0
Total annual costs:	$ 8094	$ 9283	$ 10040

TABLE VIII-15

WATER TREATMENT COMPONENT COSTS

	Process:	HOLDING AND SETTLING TANKS		
	Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate:	l/hr	4	151	3406
	gal/day	8	640	7200
Investment:		700	1180	3592
Annual costs:				
Capital costs		44	74	225
Depreciation		70	118	359
Operating & Maintenance costs (excluding energy)		0	0	0
Energy costs		50	107	75
Total annual costs:		$ 164	$ 300	$ 660

TABLE VIII-16

WATER TREATMENT COMPONENT COSTS

Process:	pH ADJUSTMENT (NEUTRALIZATION)		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: l/hr	4	261	5267
gal/day	8	552	33400
Investment:	106	891	4144
Annual costs:			
Capital costs	7	56	260
Depreciation	11	89	414
Operating & Maintenance costs (excluding energy)	11	120	1190
Energy costs	0.008	0.536	34
Total annual costs:	$ 29	$ 266	$ 1898

TABLE VIII-17

WATER TREATMENT COMPONENT COSTS

	Process:	AERATION		
	Least cost:	CONTINUOUS	CONTINUOUS	
System flow rate:	l/hr	53	466	
	gal/day	223	984	
Investment:		800	1191	
Annual costs:				
Capital costs		50	75	
Depreciation		80	119	
Operating & Maintenance costs (excluding energy)		0	0	
Energy costs		101	52	
Total annual costs:		$ 231	$ 245	$

TABLE VIII-18

WATER TREATMENT COMPONENT COSTS

	Process:	CARBON ADSORPTION		
	Least cost:			
System flow rate:	l/hr	45	466	
	gal/day	192	984	
Investment:		14630	26180	
Annual costs:				
Capital costs		918	1643	
Depreciation		1463	2618	
Operating & Maintenance costs (excluding energy)		491	1767	
Energy costs		0.88	4.49	
Total annual costs:		$ 2873	$ 6033	$

TABLE VIII-19

WATER TREATMENT COMPONENT COSTS

Process:	CHROME REDUCTION		
Least cost:	BATCH	BATCH	BATCH
System flow rate: 1/hr	26	61	3406
gal/day	56	128	7200
Investment:	7853	8355	19970
Annual costs:			
Capital costs	423	524	1253
Depreciation	785	835	1997
Operating & Maintenance costs (excluding energy)	7	16	891
Energy costs	108	103	103
Total annual costs:	$ 1393	$ 1479	$ 4244

TABLE VIII-20

NON-WATER QUALITY ASPECTS OF WASTEWATER TREATMENT

PROCESS	ENERGY REQUIREMENTS			NON-WATER QUALITY IMPACT			
	Power kwh/1000 liters	Fuel	Energy Use	Air Pollution Impact	Noise Pollution Impact	Solid Waste	Solid Waste Concentration % Dry Solids
Chemical Reduction	1.0	—	Mixing	None	None	None	—
Skimming	0.01-.3	—	Skimmer Drive	None	None	Concentrated	5-50 (oil)
Clarification	0.1-3.2	—	Sludge Collector Drive	None	None	Concentrated	1-10
Flotation	1.0	—	Recirculation Pump, Compressor, Skim	None	None	Concentrated	3-5
Chemical Oxidation by Chlorine	0.3	—	Mixing	None	None	None	—
Oxidation by Ozone	0.5-5.0	—	Mixing Ozone Generation	None	None	None	—
Chemical Precipitation	1.02	—	Flocculation Paddles, Mixers	None	None	Concentrated	1-10
Sedimentation	0.1-3.2	—	Sludge Collector Drive	None, Possible H_2S Evolution	None	Concentrated	1-3
Deep Bed	0.10	—	Head, Backwash Pumps	None	None	Concentrated	Variable
Ion Exchange	0.5	—	Pumps	None	Not Objectionable	None	N/A
Adsorption	0.1	—	Pumps, Evaporate During Regeneration	None	None	None/Waste Carbon	40
Evaporation	—	2.5*	Evaporate Water	None	None	Concentrated/ Dewatered	50-100
Reverse Osmosis	3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Ultrafiltration	1.25-3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Membrane Filtration	1.25-3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Electrochemical Chromium Reduction	0.2-0.8	—	Rectifier, Pump	None	None	Concentrated	1-3
Electrochemical Chromium Regeneration	2.0	—	Regeneration, Pump	None	None	None	—

* 10^6 BTU/1000 liters

TABLE VIII-21

NONWATER QUALITY ASPECTS OF SLUDGE AND SOLIDS HANDLING

PROCESS	ENERGY REQUIREMENTS			NONWATER QUALITY IMPACT			
	Power kwh / ton dry solids	Fuel kwh / ton dry solids	Energy Use	Air Pollution Impact	Noise Pollution Impact	Solid Waste	Solid Waste Concentration % Dry Solids
Sludge Thickening	29-930	—	Skimmer, Sludge Rake Drive	None	None	Concentrated	4-27
Pressure Filtration	21	—	High Pressure Pumps	None	None	Dewatered	25-50
Sand Bed Drying	—	35	Removal Equipment	None	None	Dewatered	15-40
Vacuum Filter	16.7-66.8	—	Vacuum Pump, Rotation	None	Not Objectionable	Dewatered	20-40
Centrifugation	0.2-98.5	—	Rotation	None	Not Objectionable	Dewatered	15-50
Landfill	—	20-980	Haul, Landfill 1-10 Mile Trip	None	None	Dewatered	N/A
Lagooning	—	36	Removal Equipment	None	None	Dewatered	3-5

TABLE VIII-22
BATTERY CATEGORY ENERGY COSTS AND REQUIREMENTS

	BPT/PSES-0 COSTS ($)	BPT/PSES-0 REQUIREMENTS (kwh)	BAT-1/PSES-1 COSTS ($)	BAT-1/PSES-1 REQUIREMENTS (kwh)	BAT-2/PSES-2 COSTS ($)	BAT-2/PSES-2 REQUIREMENTS (kwh)	BAT-3/PSES-3 COSTS ($)	BAT-3/PSES-3 REQUIREMENTS (kwh)	BAT-4/PSES-4 COSTS ($)	BAT-4/PSES-4 REQUIREMENTS (kwh)
Cadmium Subcategory										
Direct	46.3	1,403.0	596.0	18,060.6	944.1	28,608.5	3,265.0	98,939.4		
Indirect	1,998.7	60,566.7	1,644.0	49,818.2	1,863.0	56,454.5	7,292.0	220,969.7		
Total	2,045.0	61,969.7	2,240.0	67,878.8	2,807.1	85,063.0	10,557.0	319,999.1		
Calcium Subcategory										
Direct	---	---	---	---	---	---	---	---		
Indirect	316.0	9,575.8	884.0	26,787.9	208.0	6,303.0	208.0	6,303.0		
Total	316.0	9,575.8	884.0	26,787.9	208.0	6,303.0	208.0	6,303.0		
Leclanche Subcategory										
Direct	---	---								
Indirect	2,584.0	78,303.0								
Total	2,584.0	78,303.0								
Lithium Subcategory										
Direct	100.0	3,030.3	100.0	3,030.0	100.0	3,030.3	100.0	3,030.3		
Indirect	372.0	11,272.7	656.0	19,878.8	603.0	18,272.7	603.0	18,272.7		
Total	472.0	14,303.0	756.0	22,909.1	703.0	21,303.0	703.0	21,303.0		
Magnesium Subcategory										
Direct	202.0	6,724.2	486.0	14,727.3	486.0	14,727.3	386.0	11,697.0		
Indirect	383.0	11,606.1	951.0	28,818.2	770.0	23,333.3	798.0	24,181.8		
Total	585.0	17,727.3	1,437.0	43,545.5	1,256.0	38,060.6	1,184.0	35,878.8		
Zinc										
Direct	655.0	19,848.5	871.0	26,393.9	4,497.0	136,272.7	4,497.0	136,272.7	2,312.9	70,087.9
Indirect	3,705.0	112,272.7	4,347.0	131,727.3	19,290.0	584,545.5	19,290.0	584,545.5	10,293.4	311,921.2
Total	4,360.0	132,121.2	5,218.0	158,121.2	23,787.0	720,818.2	23,787.0	720,818.2	12,606.3	382,009.1
Category										
Direct	8,465.8	257,142.4	6,342.0	192,181.5	37,221.1	1,127,911.5	39,442.0	1,195,212.1	43,733.9	1,325,269.7
Indirect	61,808.7	1,872,990.9	32,248.3	977,221.3	232,244.0	7,037,696.9	237,701.0	7,203,060.6	213,393.4	6,465,466.7
Total	70,274.5	2,129,530.3	38,590.3	669,403.1	269,465.1	8,165,608.4	277,143.0	8,398,362.7	257,127.3	7,791,736.4

TABLE VIII- 23

INDIRECT DISCHARGERS - L & S TREATMENT

WASTEWATER TREATMENT SLUDGE RCRA DISPOSAL COSTS

SUBCATEGORY	TOTAL ANNUAL COST PSES-0	TOTAL ANNUAL COST PSES	$/lb of BATTERY PSES-0	$/lb of BATTERY PSES
Cadmium	0	0	0	0
Calcium	0	0	0	0
Leclanche	14,450	14,450	0.00011	0.00011
Lithium	0	0	0	0
Magnesium	0	0	0	0
Zinc	2,400	2,700	0.00006	0.00007

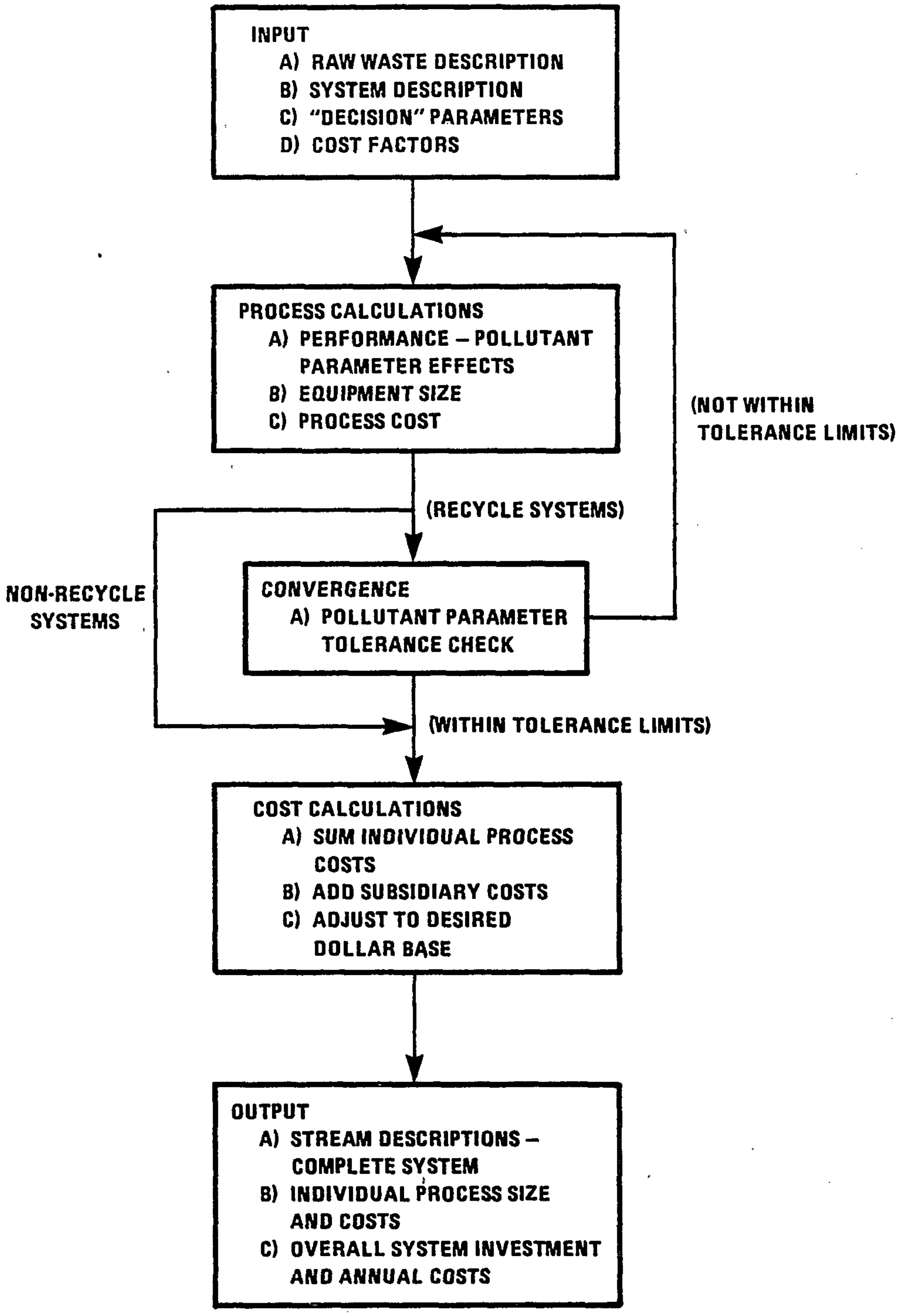


FIGURE VIII-1
SIMPLIFIED LOGIC DIAGRAM
SYSTEM COST ESTIMATION PROGRAM

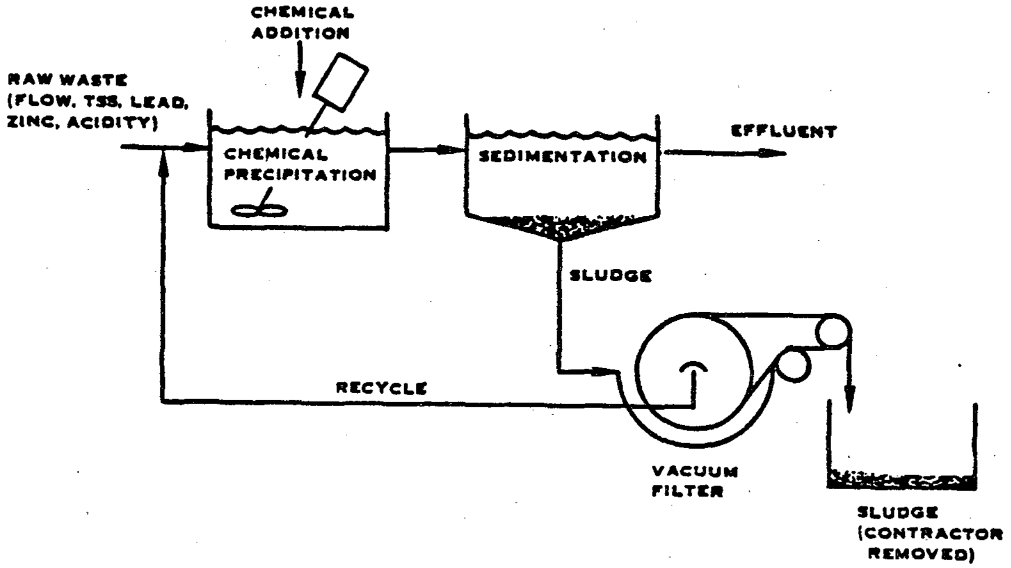
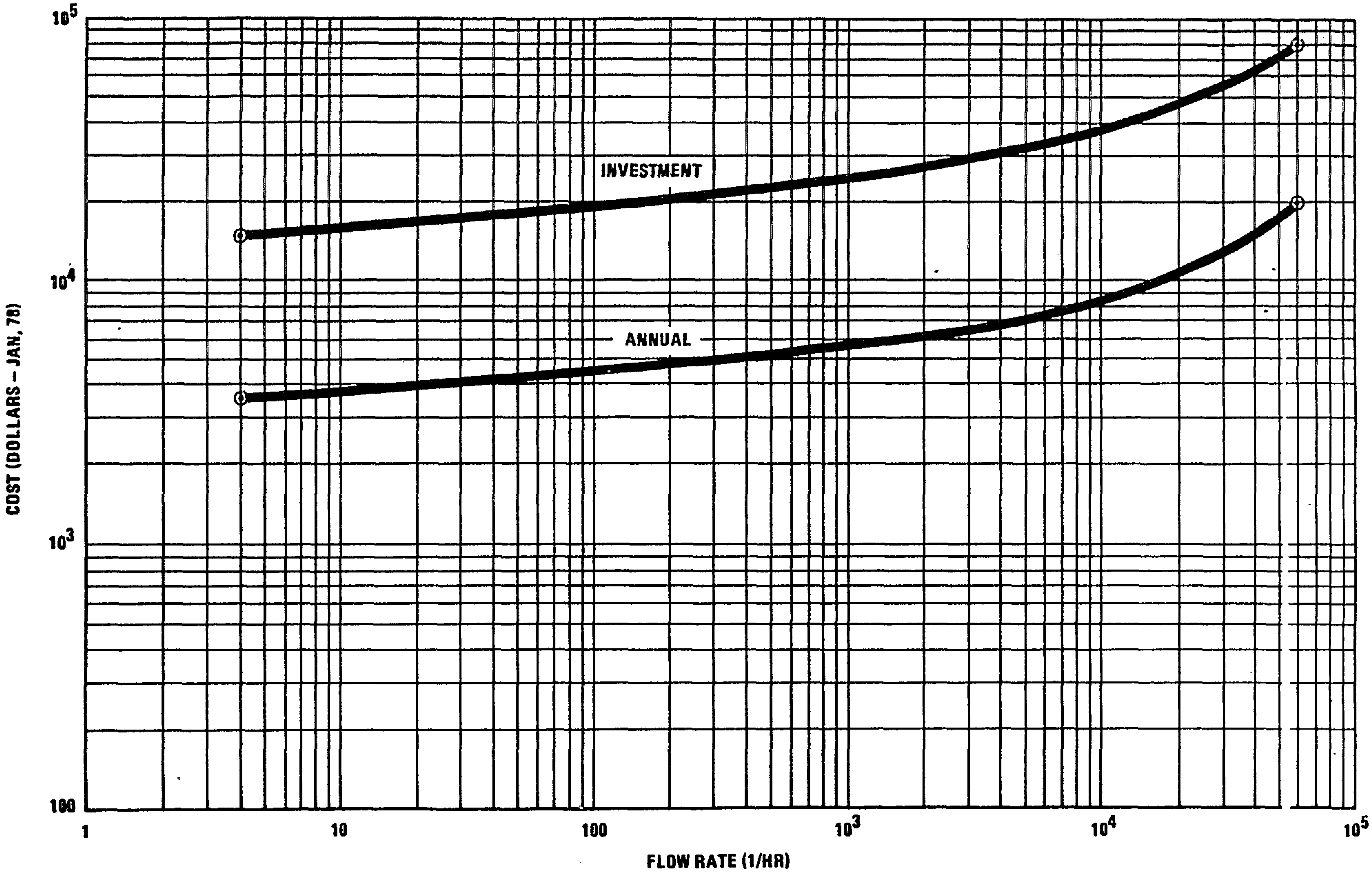
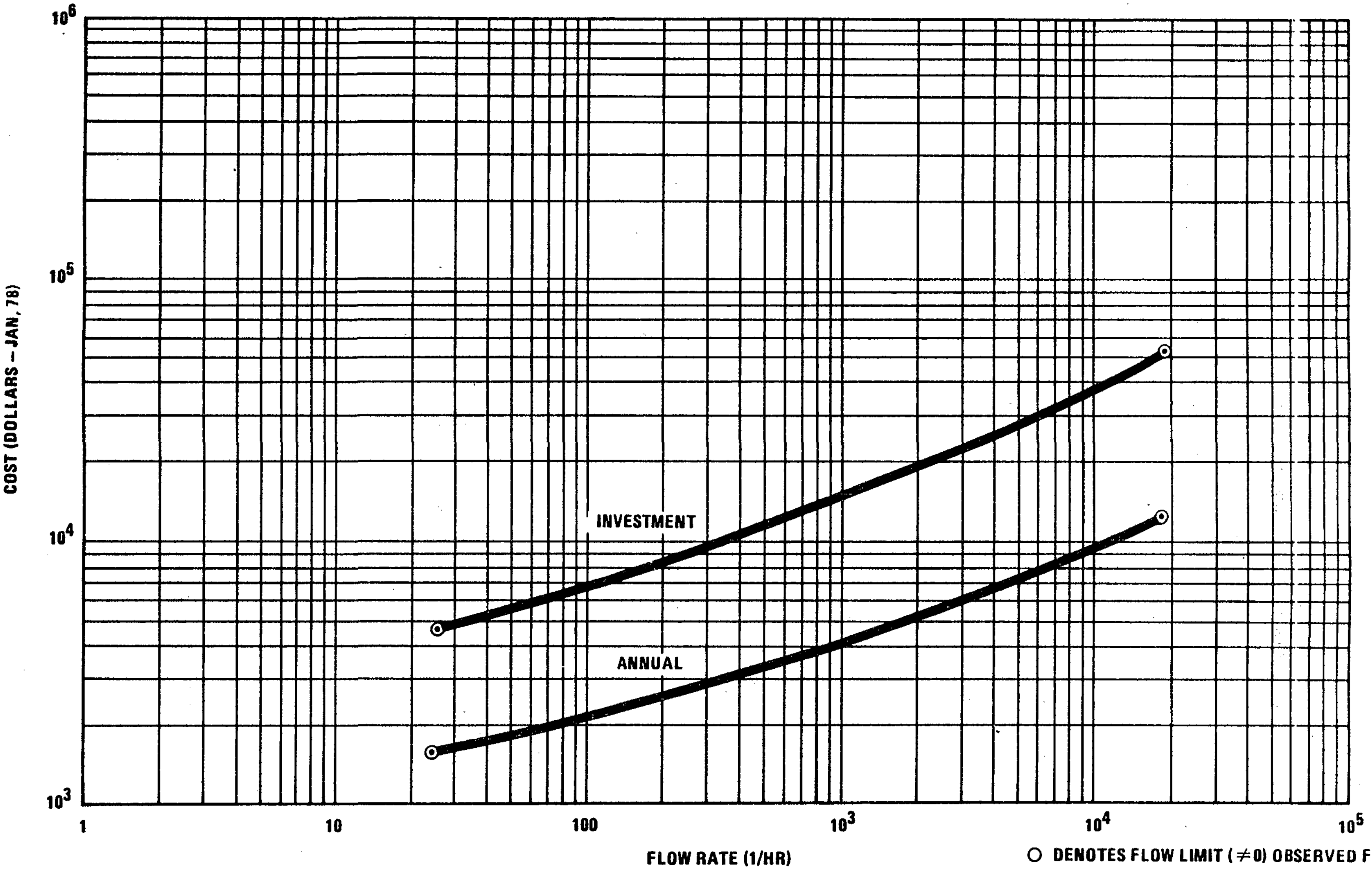


FIGURE VIII - 2. SIMPLE WASTE TREATMENT SYSTEM



○ DENOTES FLOW LIMITS OBSERVED FOR THIS TREATMENT FOR THE LEAD SUBCATEGORY

FIGURE VIII-3
PREDICTED PRECIPITATION AND SETTLING COSTS
CONTINUOUS



○ DENOTES FLOW LIMIT (≠0) OBSERVED FOR THIS TREATMENT IN THE BATTERY INDUSTRY (NON-LEAD SUBCATEGORY).

INDIVIDUAL PLANTS MAY DIFFER BECAUSE OF VARIATION IN OPERATING HOURS.

ALL COMPUTER SELECTED TREATMENT WAS BATCH.

FIGURE VIII-4
PREDICTED COSTS FOR PRECIPITATION AND SETTLING
BATCH

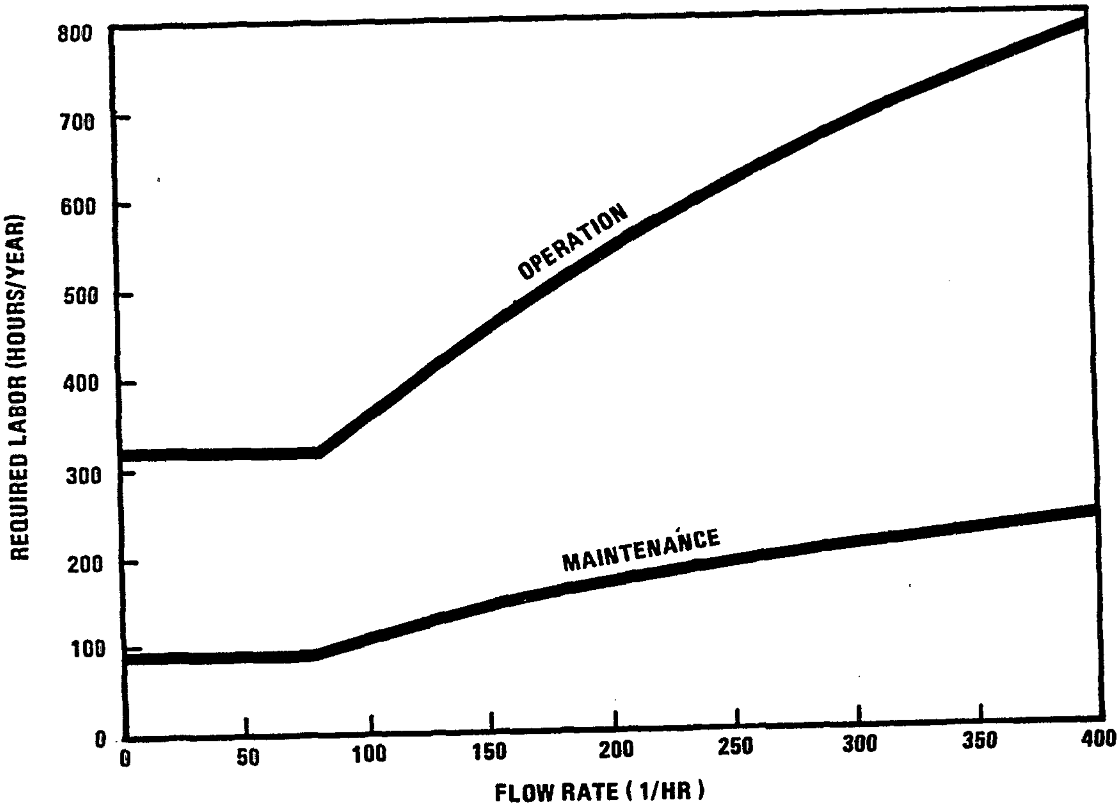
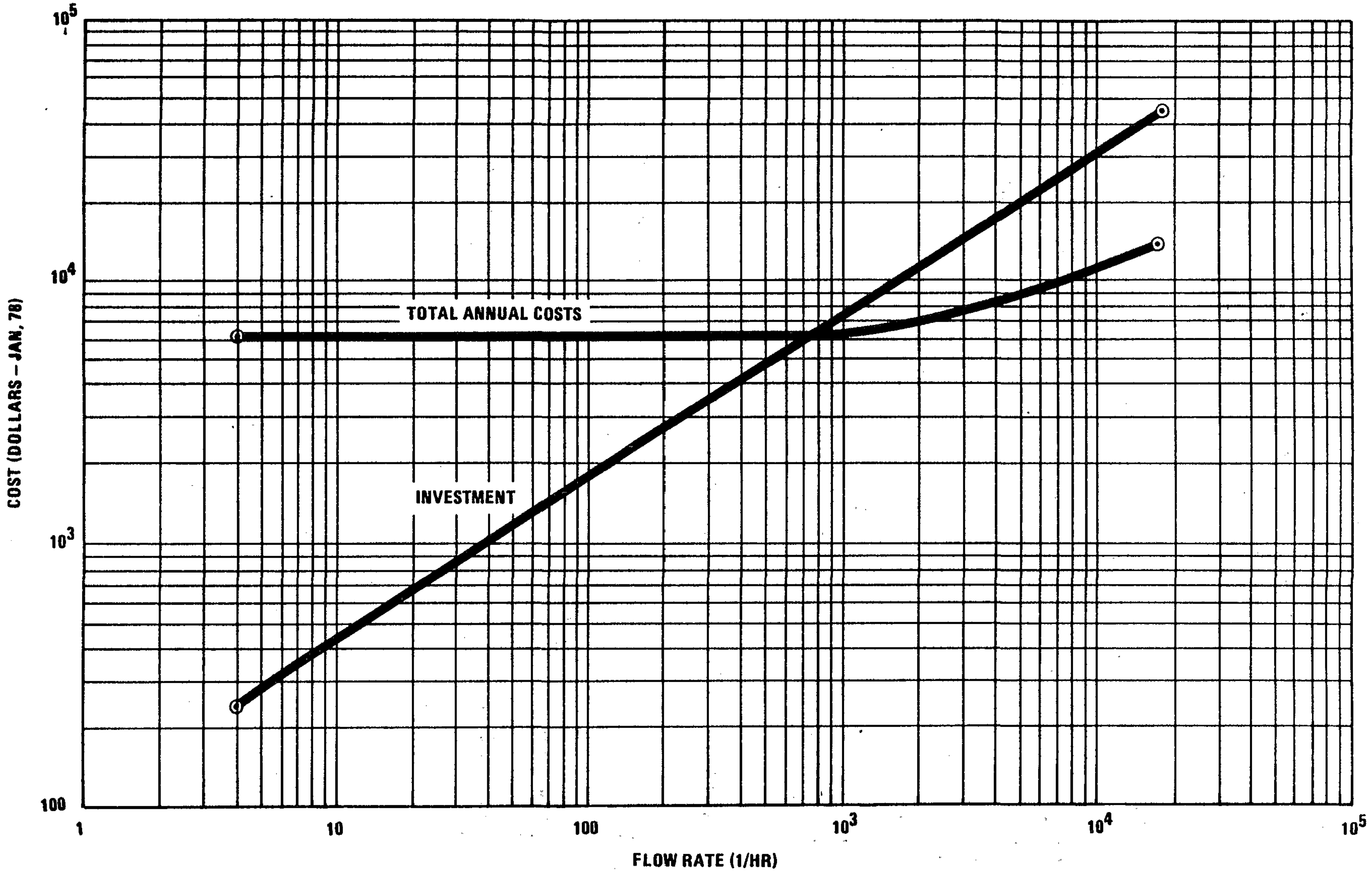


FIGURE VIII - 5
CHEMICAL PRECIPITATION AND SETTLING COSTS



○ DENOTES FLOW LIMIT (≠ 0) OBSERVED FOR THIS TREATMENT IN THE BATTERY INDUSTRY.

FIGURE VIII–6
PREDICTED COSTS OF MIXED-MEDIA FILTRATION

INDIVIDUAL PLANTS MAY DIFFER BECAUSE OF VARIATION IN OPERATING HOURS.

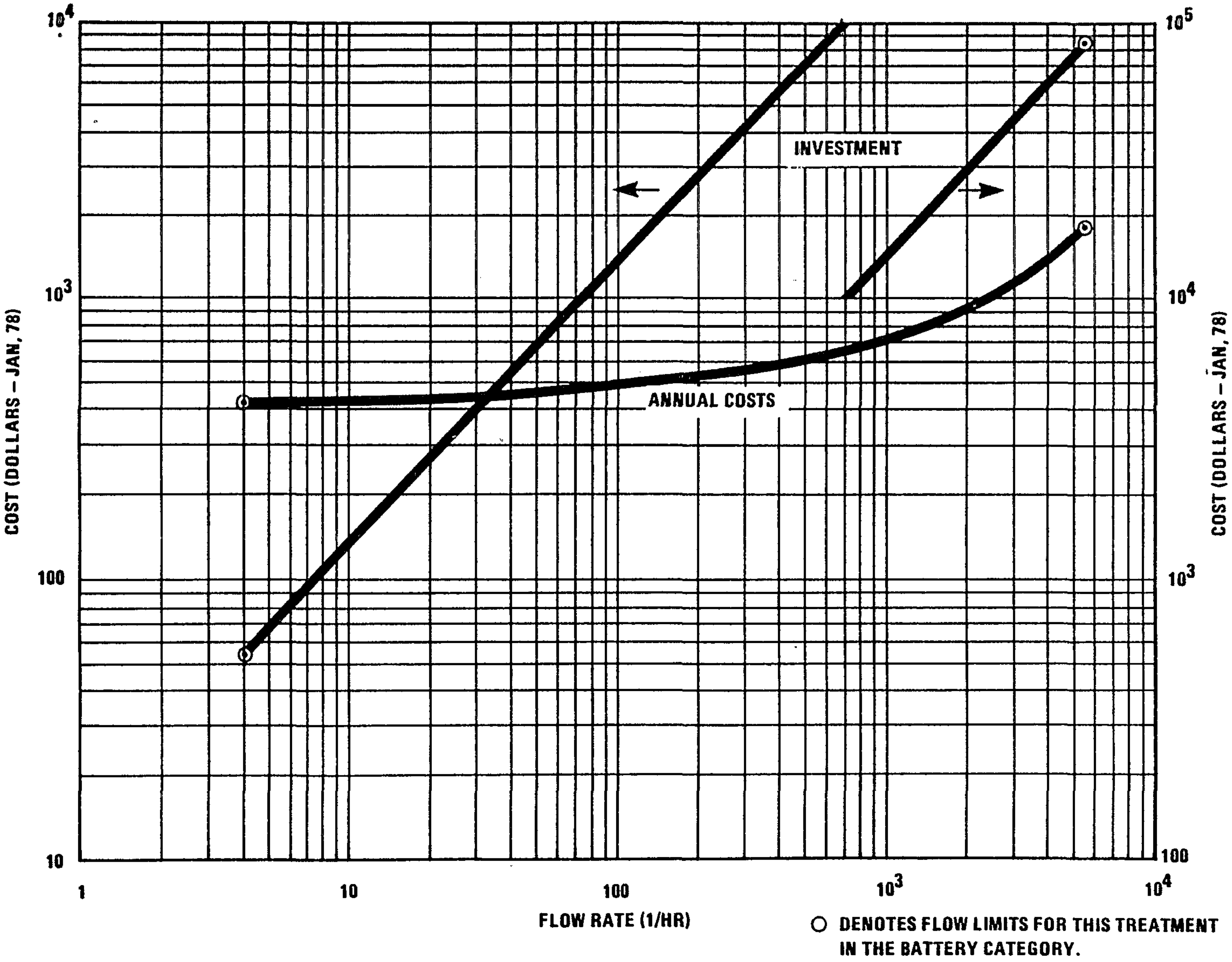


FIGURE VIII–7
MEMBRANE FILTRATION COSTS

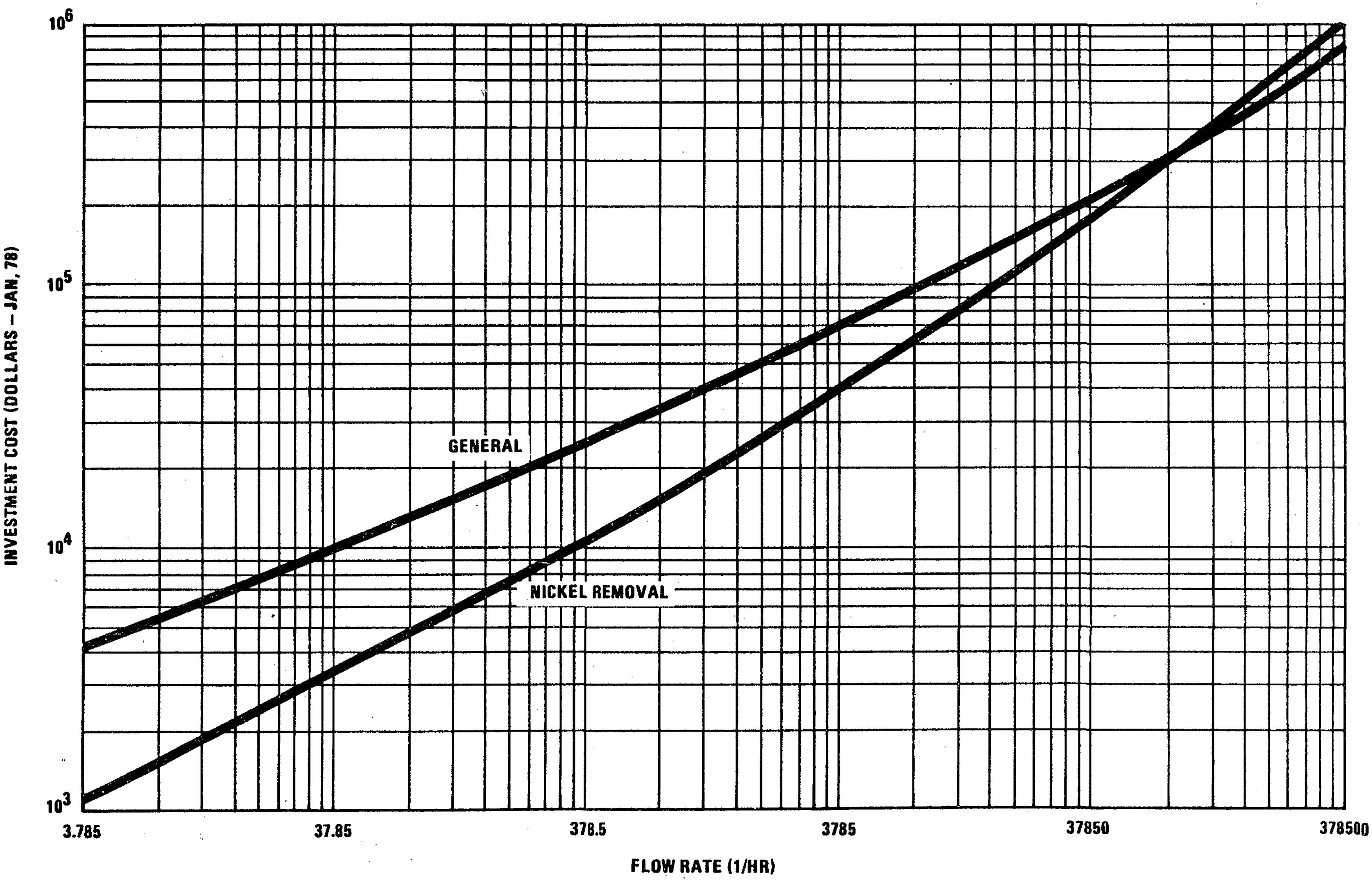


FIGURE VIII–8
REVERSE OSMOSIS OR ION EXCHANGE INVESTMENT COSTS

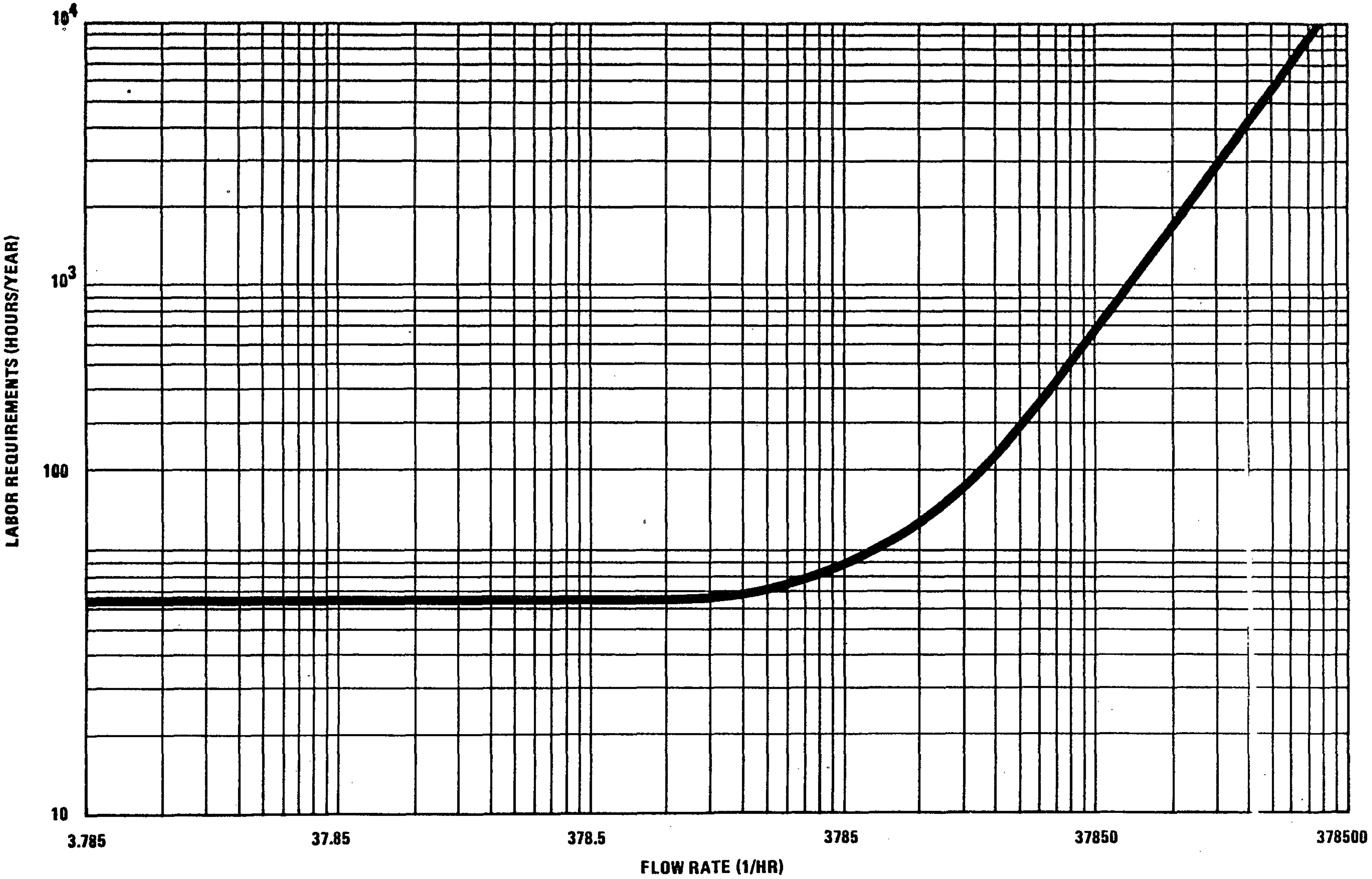


FIGURE VIII–9
REVERSE OSMOSIS OR ION EXCHANGE LABOR REQUIREMENTS

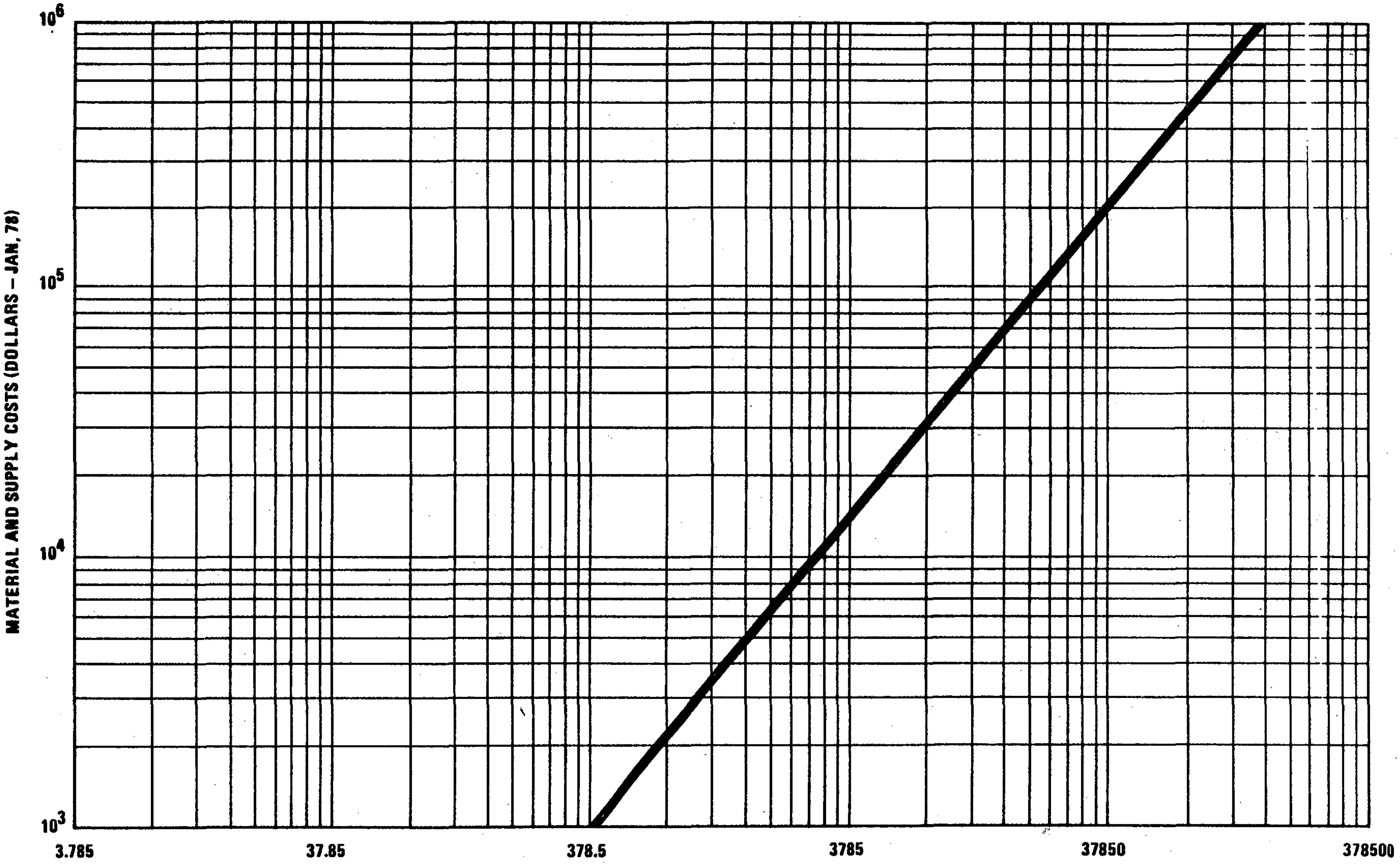


FIGURE VIII–10
REVERSE OSMOSIS OR ION EXCHANGE MATERIAL COSTS

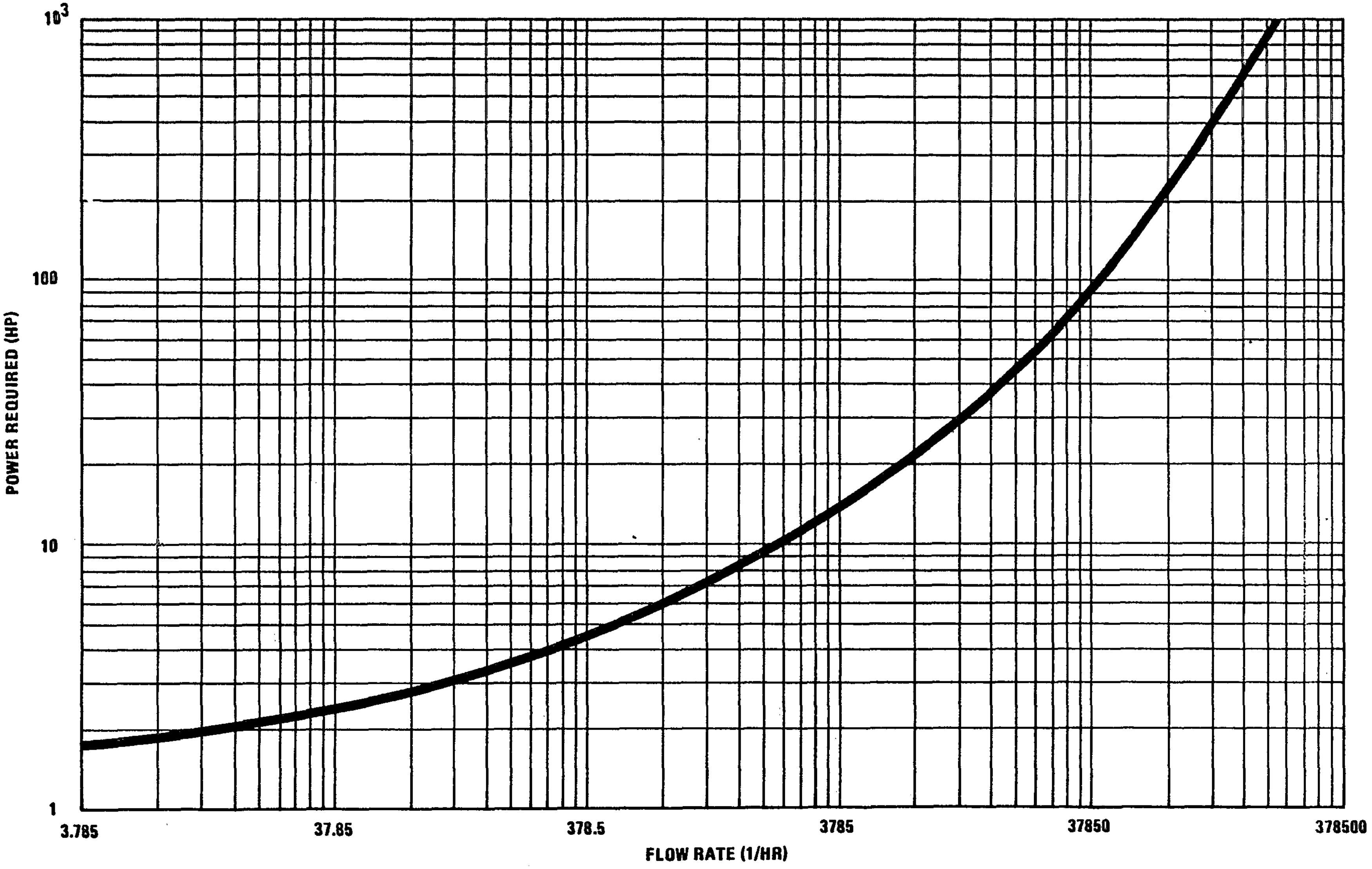


FIGURE VIII–11
REVERSE OSMOSIS OR ION EXCHANGE POWER REQUIREMENTS

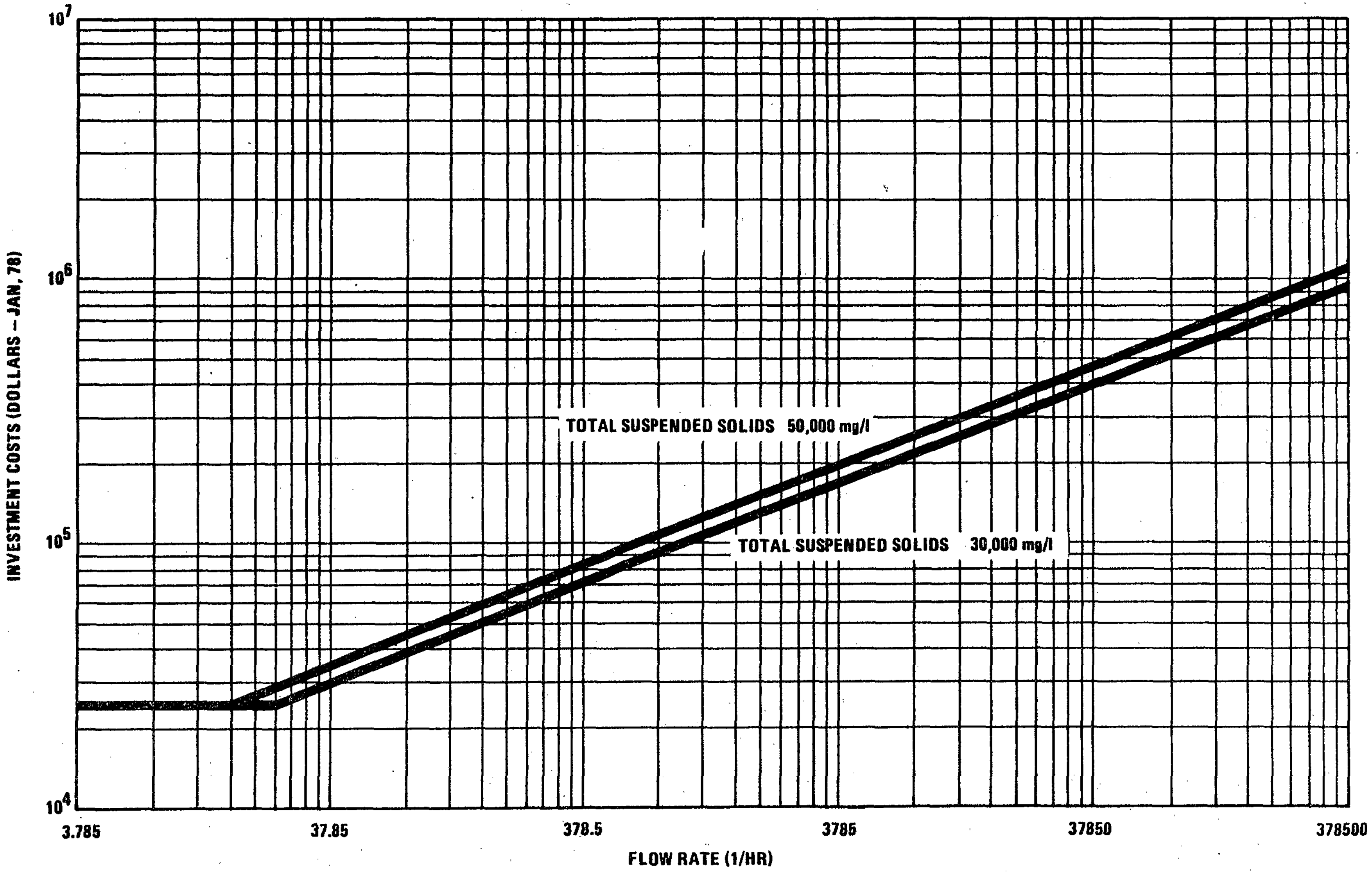


FIGURE VIII–12
VACUUM FILTRATION INVESTMENT COSTS

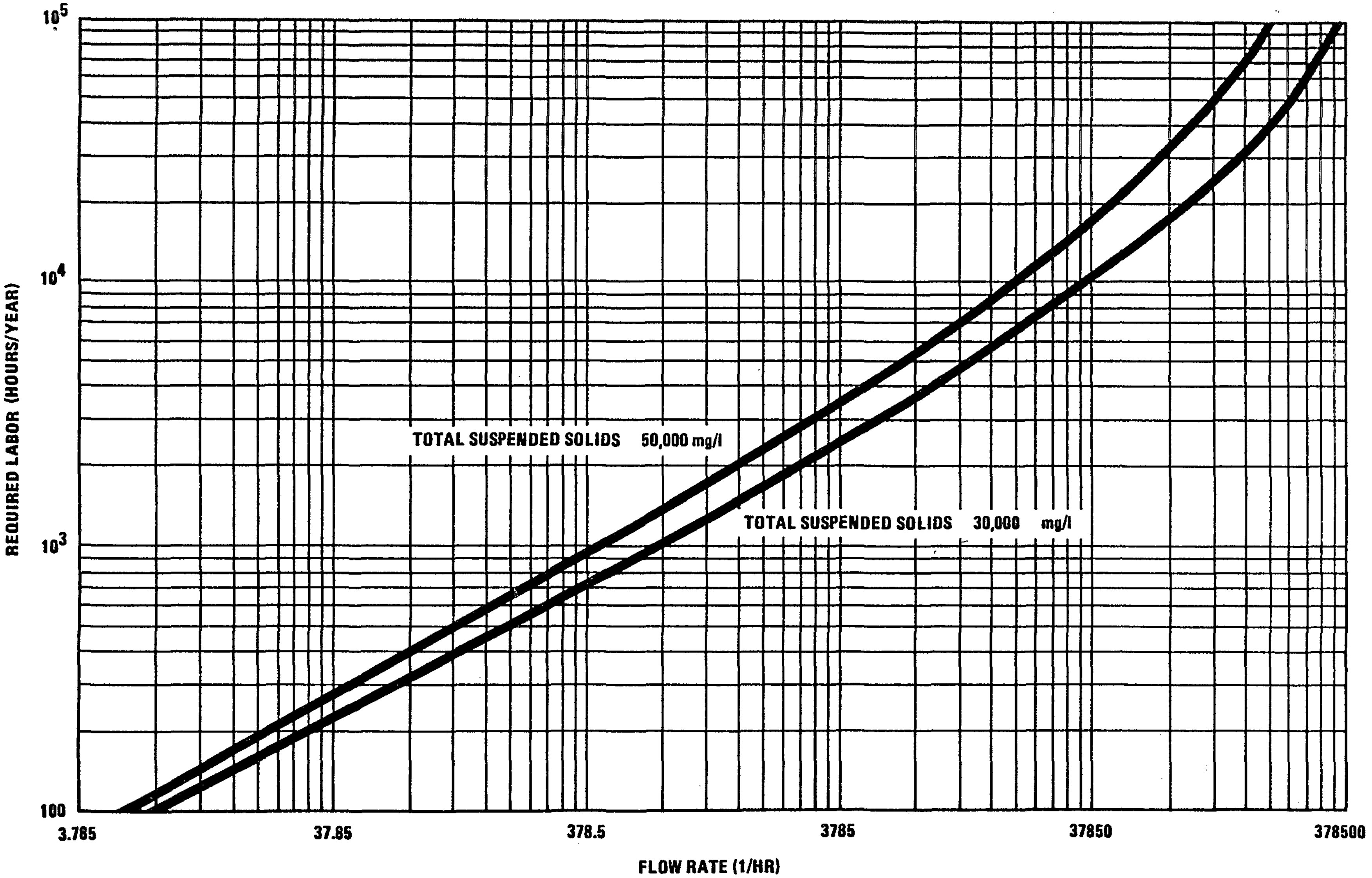


FIGURE VIII–13
VACUUM FILTRATION LABOR REQUIREMENTS

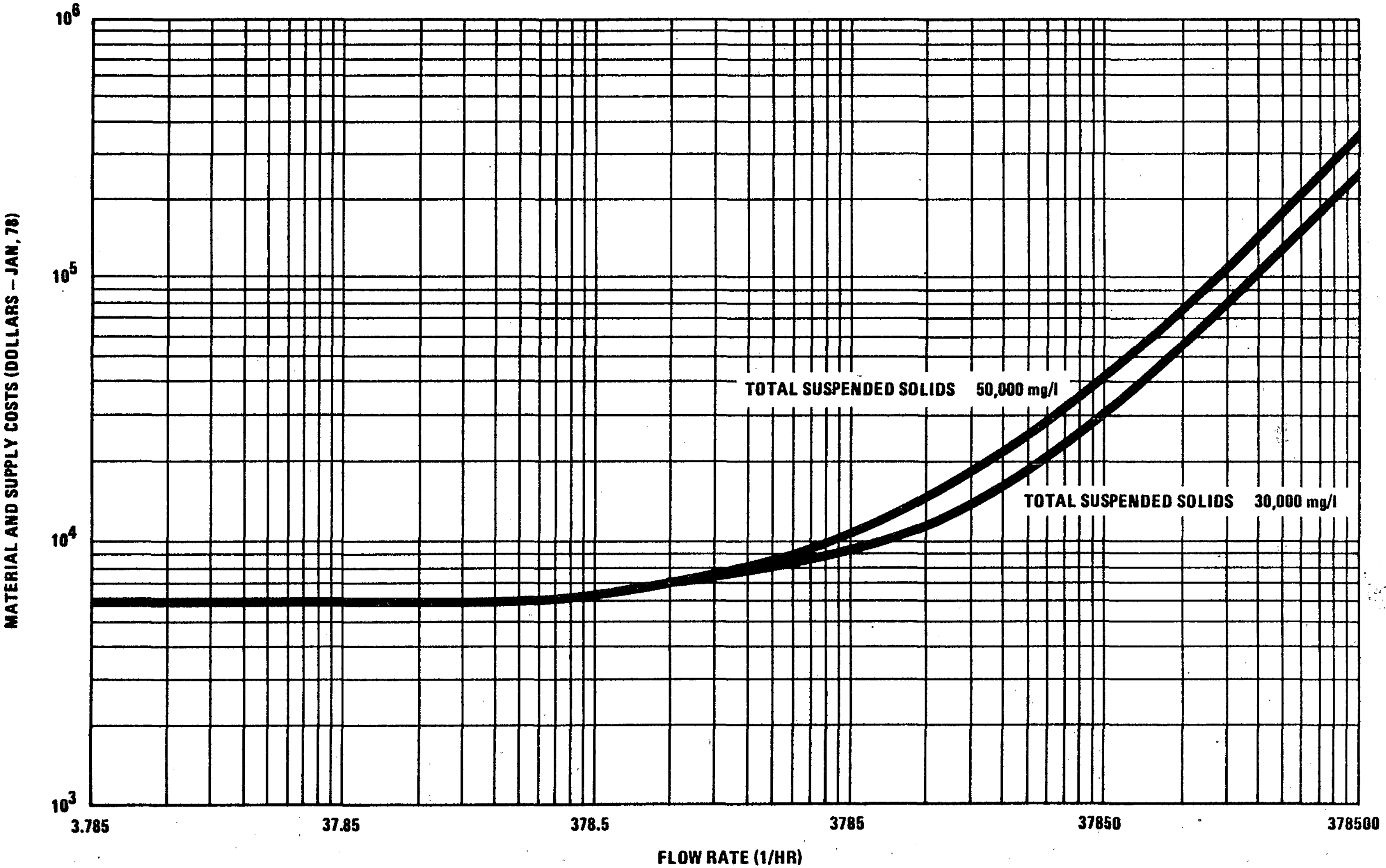


FIGURE VIII–14
VACUUM FILTRATION MATERIAL COSTS

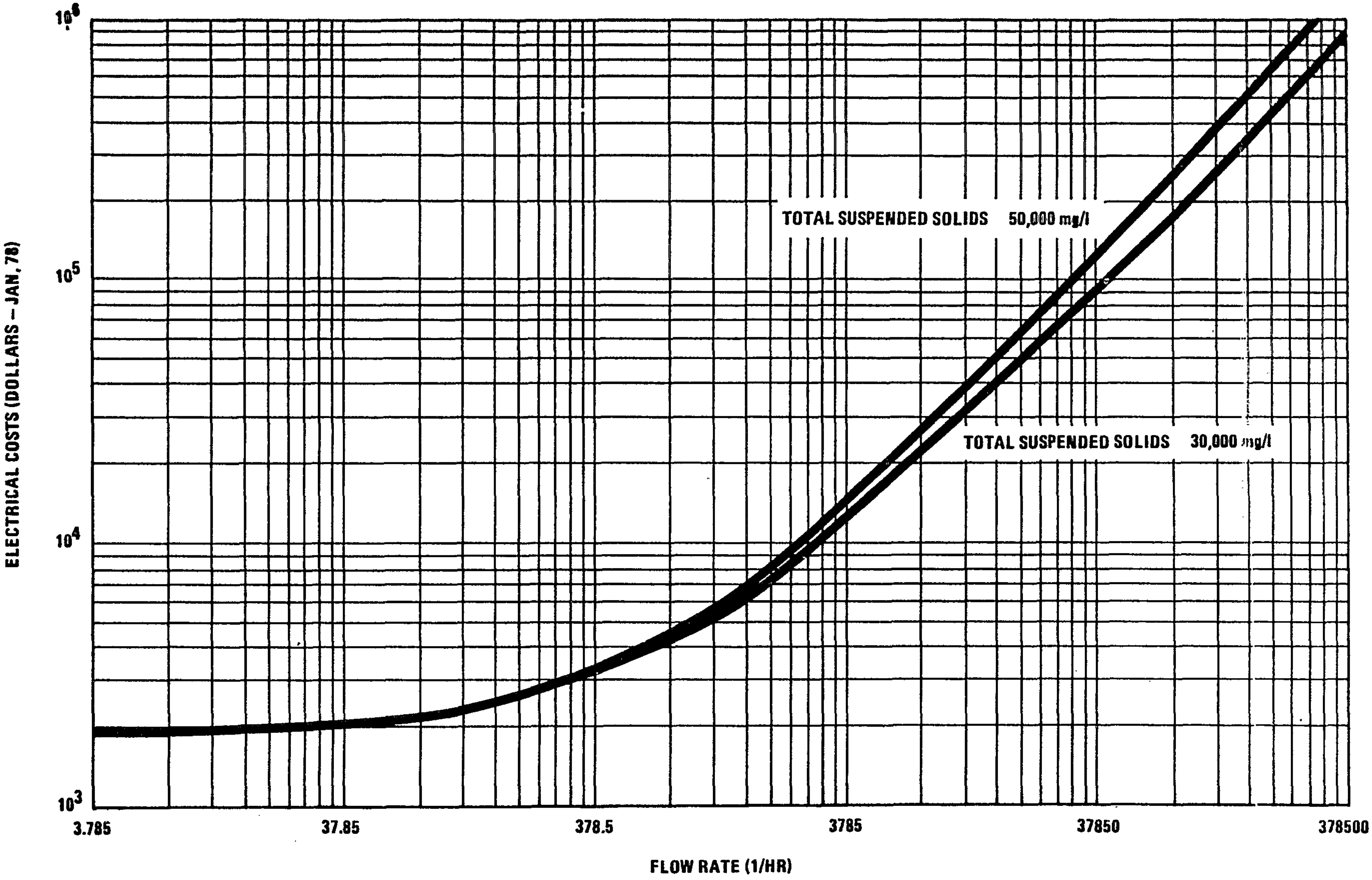
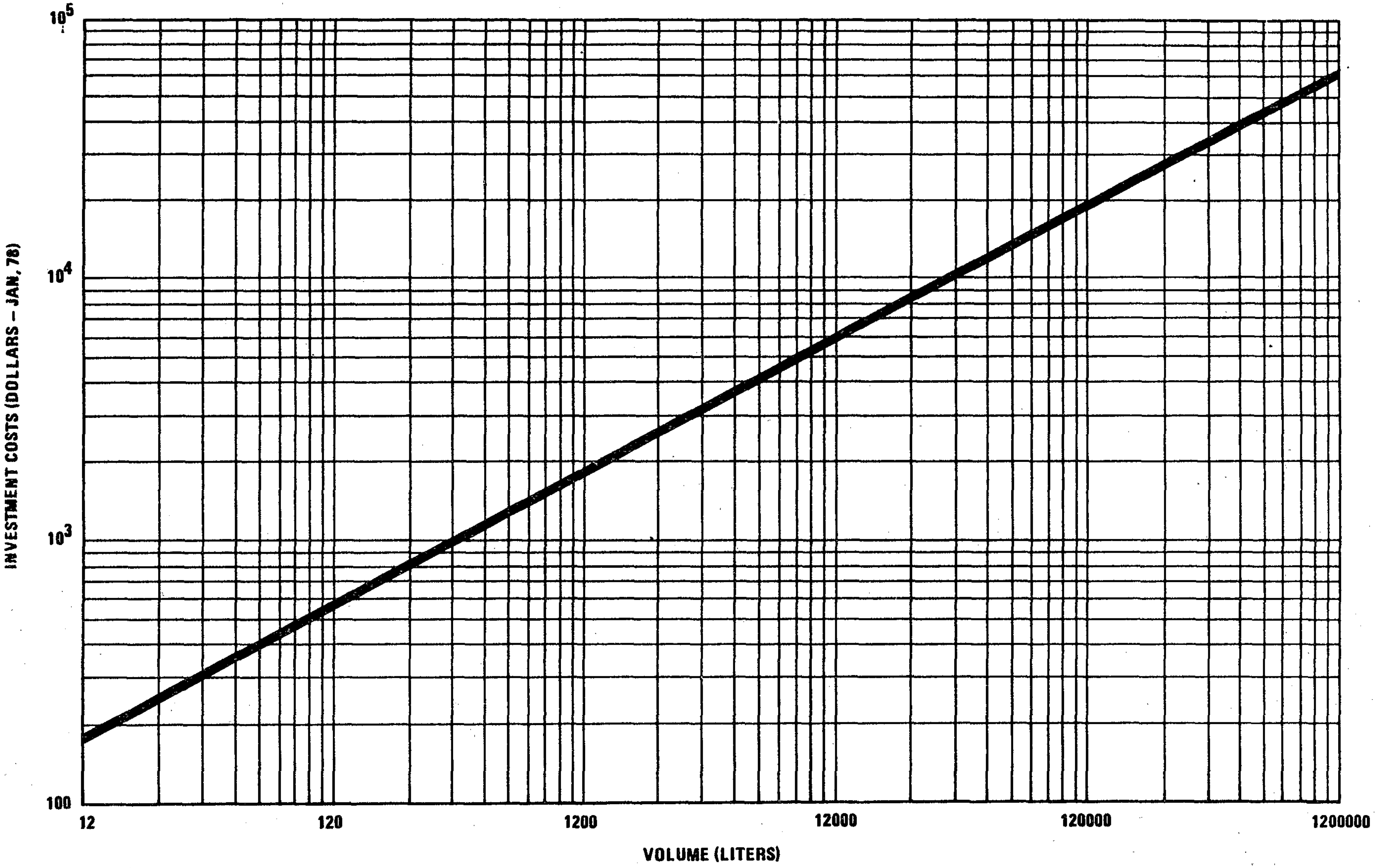


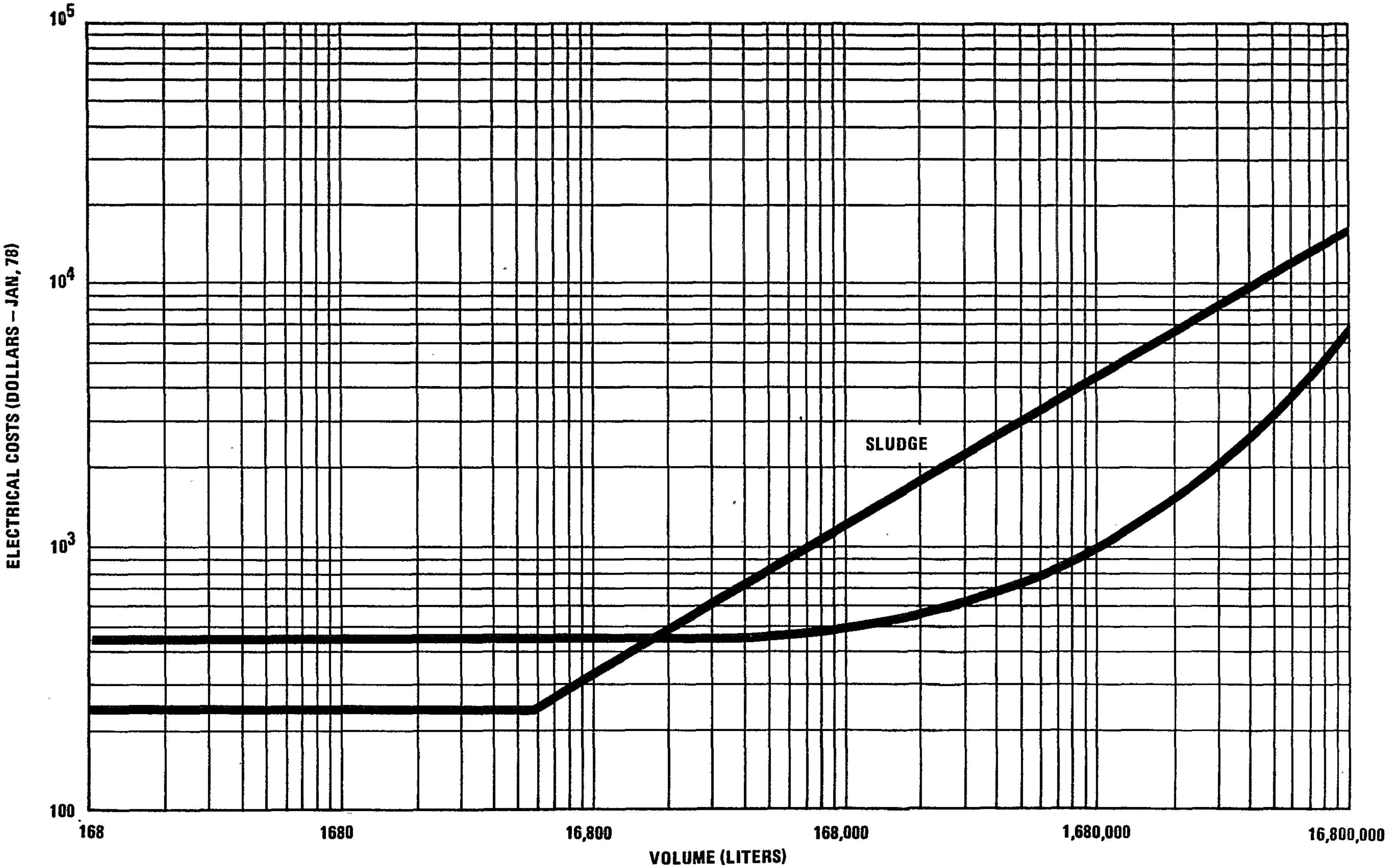
FIGURE VIII–15
VACUUM FILTRATION ELECTRICAL COSTS



COST = 41.93 x VOLUME (LITERS) $^{0.5344}$

RETENTION TIME = 12 HOURS

FIGURE VIII–16
HOLDING TANK INVESTMENT COSTS



RETENTION TIME = 7 DAYS

FIGURE VIII–17
HOLDING TANK ELECTRICAL COSTS

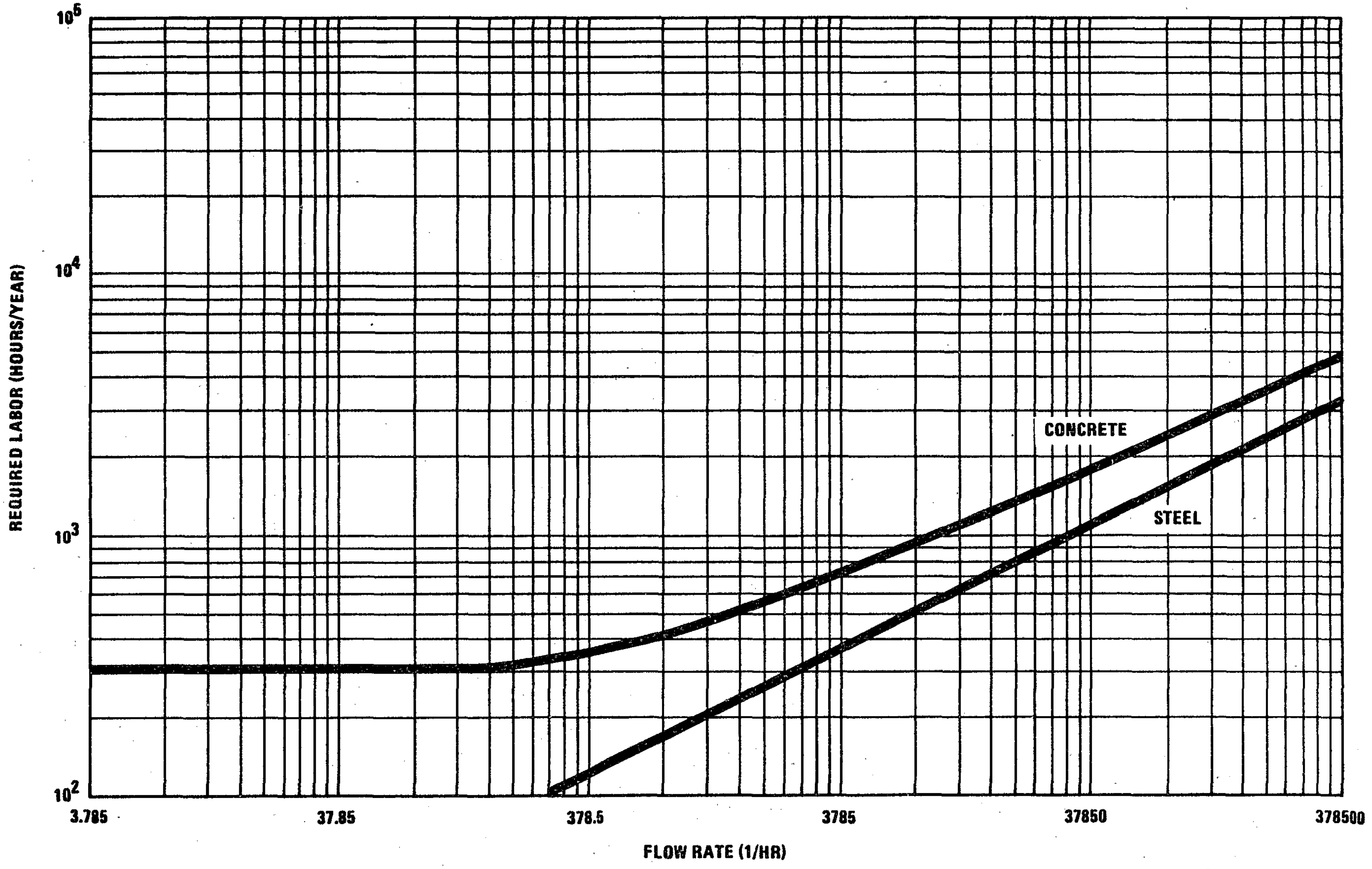
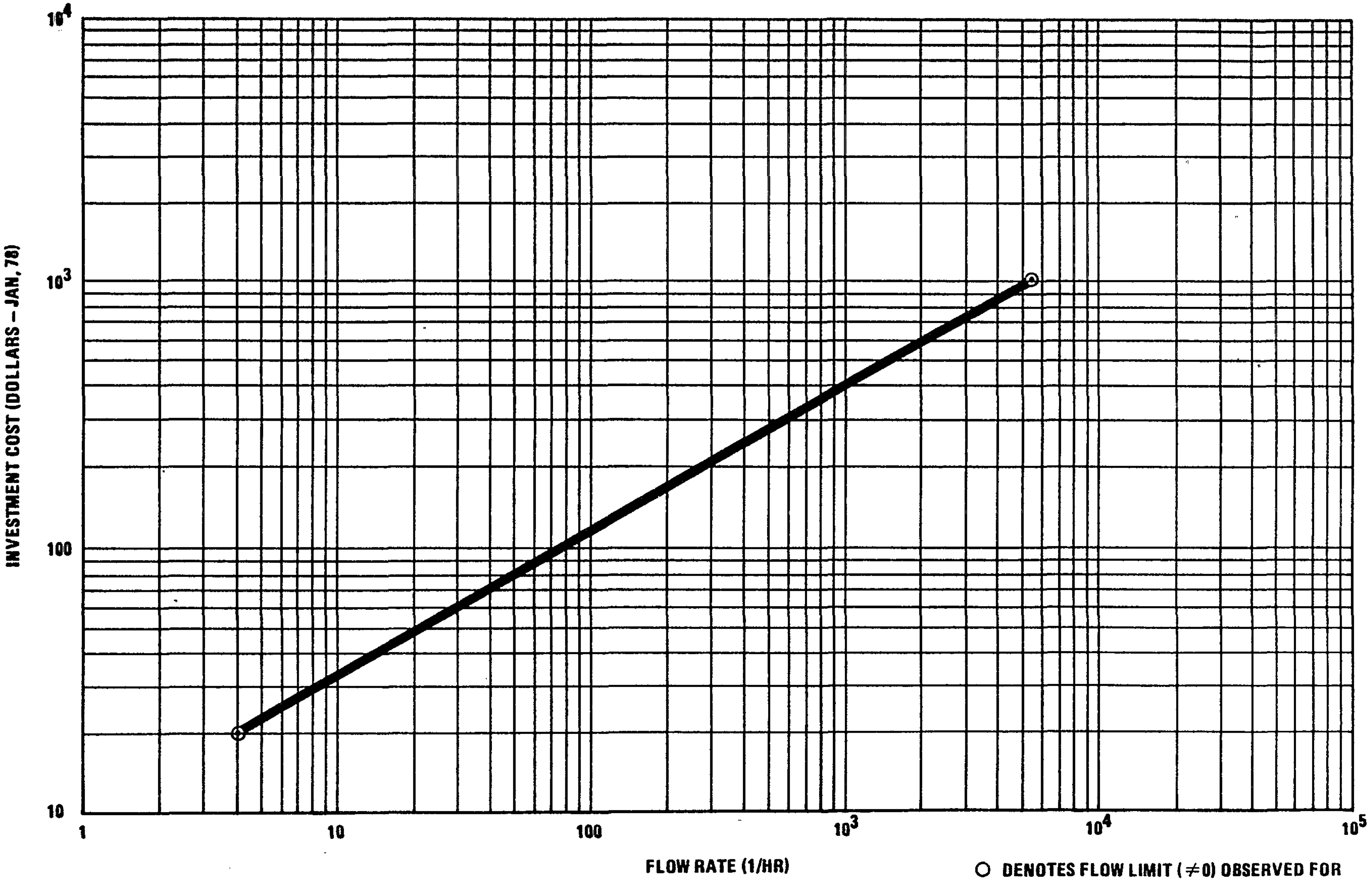


FIGURE VIII–18
HOLDING TANK LABOR REQUIREMENTS



○ DENOTES FLOW LIMIT (≠0) OBSERVED FOR THIS TREATMENT IN THE NON-LEAD SUBCATEGORIES OF THE BATTERY INDUSTRY.

INDIVIDUAL PLANTS MAY DIFFER BECAUSE OF VARIATION IN OPERATING COSTS.

FIGURE VIII–19
NEUTRALIZATION INVESTMENT COSTS

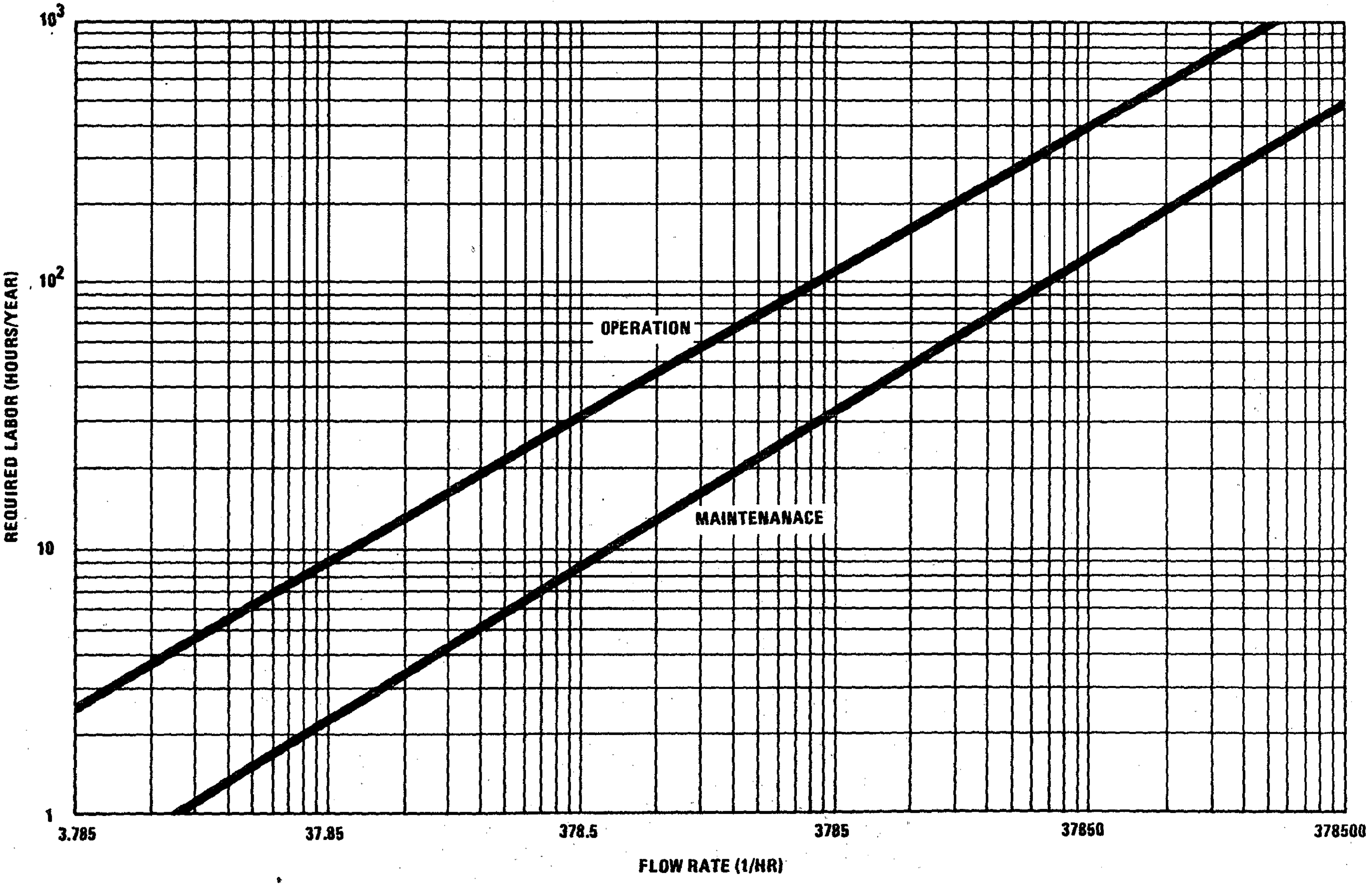


FIGURE VIII-20
NEUTRALIZATION LABOR REQUIREMENTS

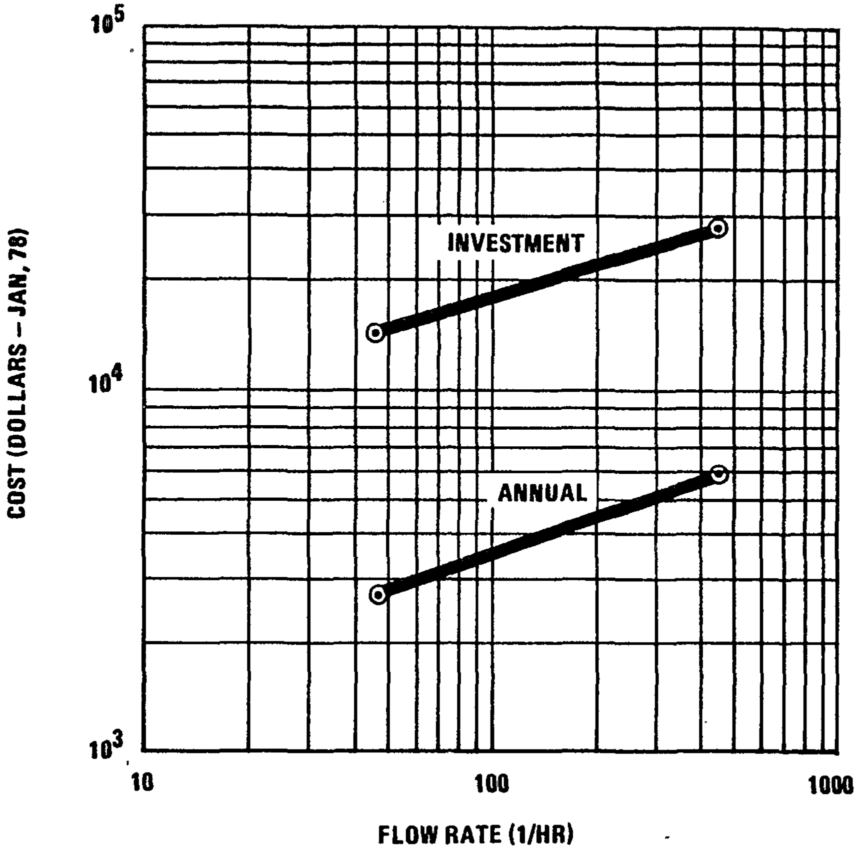


FIGURE VIII–21
CARBON ADSORPTION COSTS

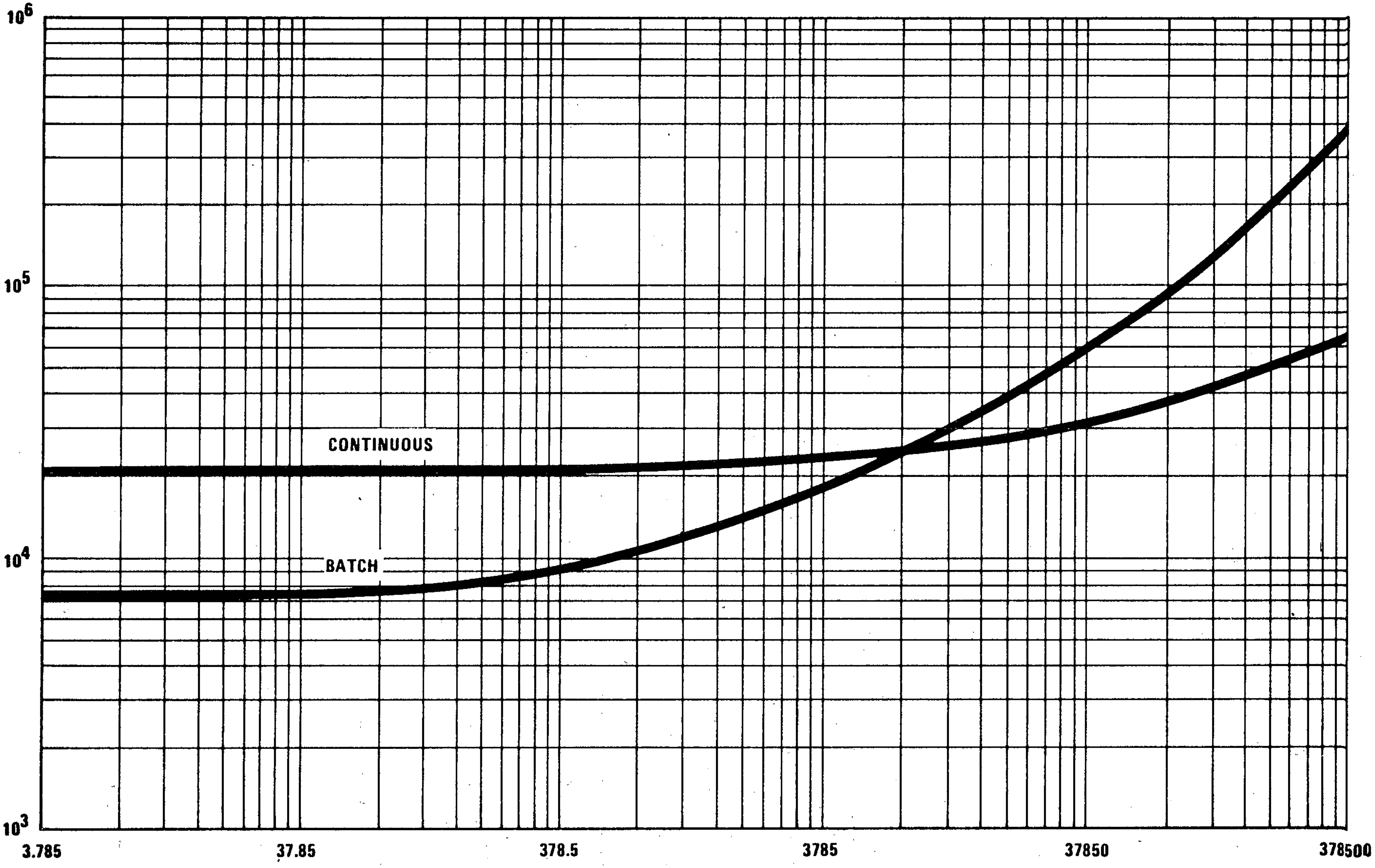
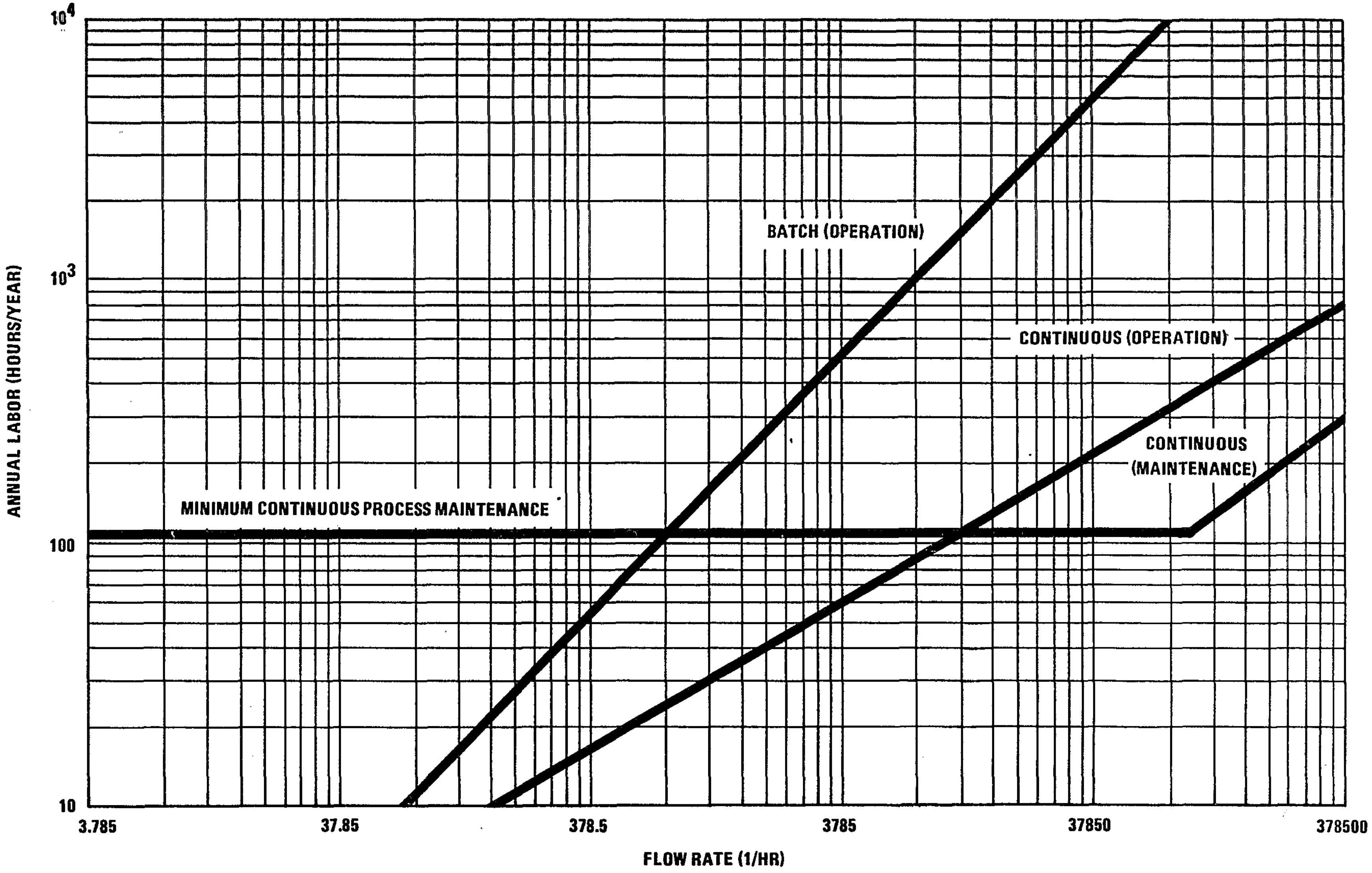


FIGURE VIII–22
CHEMICAL REDUCTION OF CHROMIUM
INVESTMENT COSTS



BATCH MAINTENANCE EQUALS 0 HOURS

FIGURE VIII–23
ANNUAL LABOR FOR CHEMICAL REDUCTION OF CHROMIUM

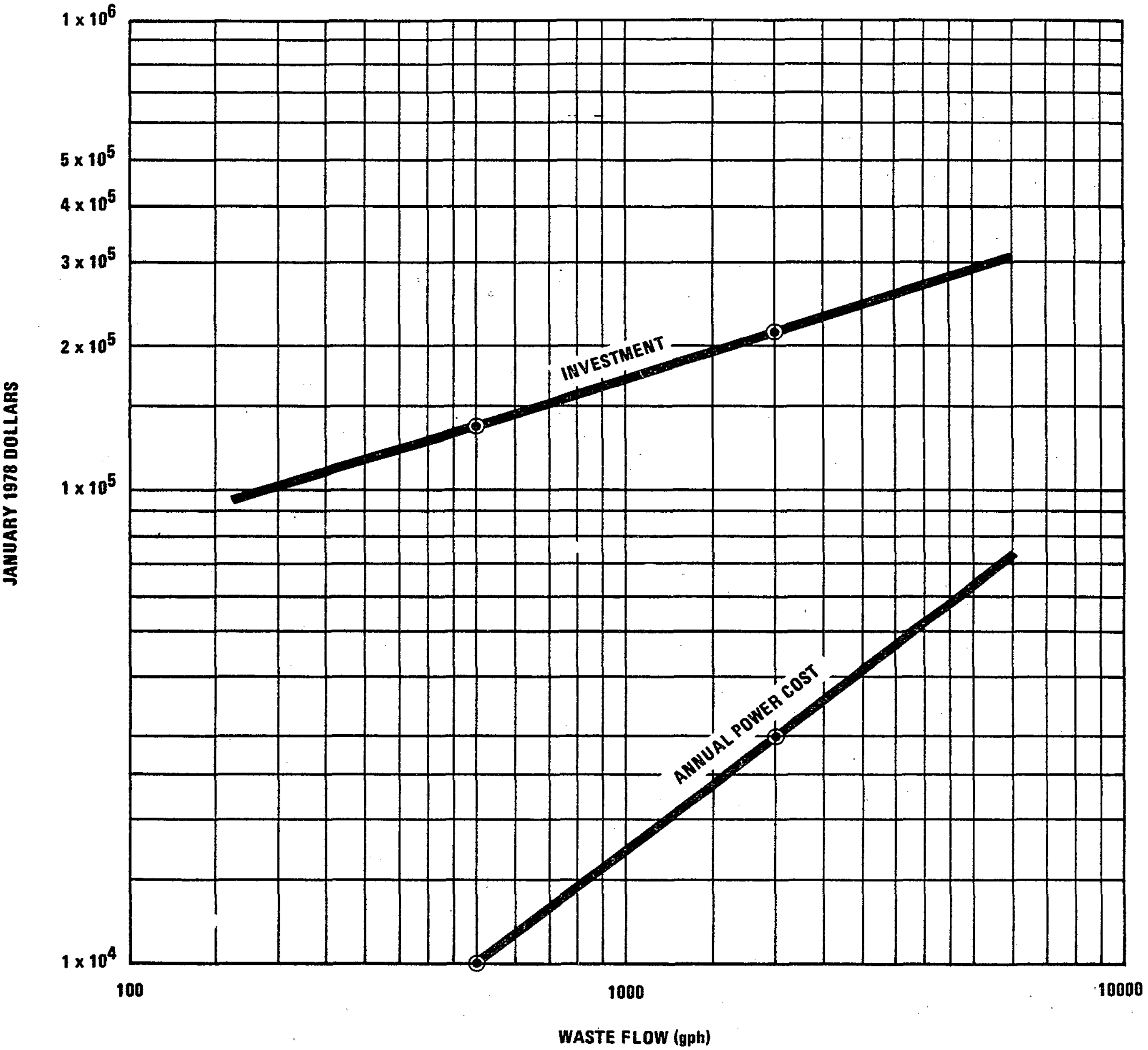


FIGURE VIII - 24
COSTS FOR VAPOR RECOMPRESSION EVAPORATION

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 each subcategory within the battery manufacturing category. BPT reflects the performance of existing treatment and control practices at battery manufacturing plants of various sizes, ages, and various manufacturing processes. Particular consideration is given to the treatment in place at plants within each subcategory.

The factors considered in defining BPT include the total cost of the application of technology in relation to the effluent reduction benefits from such application, the age of equipment and facilities involved, the processes employed, nonwater 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 the anode materials, since specific anode metals can be combined with many cathode materials, and the electrolytes used in battery manufacturing. Each subcategory was further subdivided into discrete manufacturing process elements as shown in Table IV-1 (page 154). 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:

- Each subcategory encompasses several manufacturing 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 each subcategory usually share similar pollutant characteristics, have similar treatment requirements and are often treated in combined systems.

- The most significant pollutants present in battery process wastewater are generally different in each subcategory. Combined treatment or discharge of wastewater from different subcategories occurs quite infrequently.

- Most wastewater streams generated in this category are characterized by high levels of toxic metals.

- Treatment practices vary extensively in the category and also within the subcategories. Observed category practices include: chemical precipitation of metals as hydroxides, carbonates, and sulfides; amalgamation; sedimentation; filtration; ion exchange; and carbon adsorption.

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, processes and treatment technology both indirect and direct dischargers have been considered as a single group. An examination of plants and processes did not indicate any process or product differences based on wastewater destination. This has also been followed in describing applicable technology options with initial description made for direct dischargers, and indirect discharger applications largely described by reference to the direct discharge descriptions. Hence, treatment technologies for BPT (and BAT) are described in substantial detail for all subcategories even though there may be no direct discharge plants in that subcategory.

For each subcategory included in this document, a specific approach was followed for the development of BPT mass limitations. To account for production and flow variability from plant to plant, a unit of production or production normalizing parameter (pnp) was determined for each element which could then be related to the flow from the element to determine a production normalized flow. Selection of the pnp for each process element is discussed in Section IV and summarized in Table IV-1 (page 154). 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) for each process element. This analysis is discussed in general and summarized for each subcategory 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 and plant visit data. Significant differences between the mean and median reflect a data set which has skewed or biased a wide range of points. When 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 category practice. In cases where there was evidence that data was 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 mean or average production normalized flow is used as a part of the basis for BPT mass limitations. In those cases where the median rather than mean normalized flow was used as the BPT flow, specific rationale for its use is presented in the subcategory 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.

The general assumption was made that all wastewaters generated within a subcategory were 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. 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 each subcategory is reasonable. Both treatment in place at battery plants and treatment in other categories having similar wastewaters were evaluated. The BPT treatment systems considered require 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 606).

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 the category or subcategory and which reduce flows to meet the production normalized flow for each process element.

For the development of effluent limitations, mass loadings were calculated for each process element within each subcategory. This calculation was made on an element by element basis primarily because plants in this category are active in various process elements, process element production varies within the plants, and pollutants generated and flow rates can vary for each process element. The mass loadings (milligrams of pollutant per kilogram of production unit - mg/kg) were calculated by multiplying the BPT normalized flow (l/kg) by the concentration achievable using the BPT treatment system (mg/l) for each pollutant parameter considered for regulation at BPT. The BPT normalized flow is based on the average of all applicable data rather than the average of the best plants. This was done to provide a measure of operating safety for BPT treatment operations.

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.

Reasonableness of the limitations was determined in several ways. The approach generally used to determine reasonableness was to evaluate the treatment effectiveness numbers for lime and settle systems (already discussed in Section VII) and the reported discharge flows for each plant as compared with the flow the plant would need to comply with the BPT mass limitations. BPT treatment effectiveness numbers were determined to be reasonable based upon engineering and statistical analysis, as discussed in Section VII. When operating hours and plant processes varied throughout the year, the annual flow, as opposed to hourly flow, was used as the rate for comparison. The actual annual flow for each plant was then compared with the calculated annual flow necessary for BPT compliance. BPT flows were considered reasonable if most of the plants in the subcategory were meeting their BPT flow.

SELECTION OF POLLUTANT PARAMETERS FOR REGULATION

The pollutant parameters selected for regulation in each subcategory were selected because of their frequent presence at treatable concentrations in wastewaters from the process elements. In general, pollutant parameters selected are primarily metals and suspended solids. No organic pollutants (except for cyanide) are considered for BPT regulation in this category. 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.

CADMIUM SUBCATEGORY

The cadmium subcategory includes the manufacture of cadmium anode batteries such as nickel-cadmium, silver-cadmium, and mercury-cadmium batteries. Of these, nickel-cadmium batteries account for almost all of the production in the subcategory. Sixteen process elements identified in Table IV-1 (page 154) are manufacturing activities included within this subcategory. Thirteen of these process elements, as shown in Figure V-2 (page 392), generate a wastewater discharge; the other three do not. Normalized flows and production normalizing parameters for these elements are summarized in Table V-10 (page 274).

Model Treatment Technology

BPT end-of-pipe treatment for this subcategory is illustrated in Figure IX-1 (page 810). The treatment system consists of oil skimming, pH adjustment (chemical precipitation) followed by settling. Lime, sodium hydroxide, or acid is used to adjust the pH to a level that promotes adequate precipitation. The optimum pH for precipitation of metals from cadmium subcategory waste streams is typically about 9.3; however, higher values may prove to be appropriate for some waste streams. Proper pH control will enhance the settling of both metal precipitates and suspended solids. Treatment system performance for some wastewater streams in this subcategory may be significantly improved by the addition of iron salts as an aid in the removal of toxic metals, particularly nickel. This technology, sometimes called iron co-precipitation, is described in Section VII. Where required for acceptable effluent this technique is included in BPT. An effective settling device for use in the BPT system is a clarifier; however, similar results can be achieved using other settling devices or by filtration. In some cases, provisions of an oil skimmer may also be required to achieve acceptable effluent quality.

The lime and settle technology set forth as BPT for this subcategory was selected primarily because the treatment system components are generally used in the subcategory. Process wastewaters from the cadmium subcategory are predominantly alkaline, and seven presently operating plants reported settling treatment (see Table V-29 page 293). Four of these plants also reported subsequent filtration. On-site observations, however, indicated that the settling was often inadequate and that filtration was used as a primary solids removal device, rather than as polishing filtration where it is most effective. Consequently alkaline precipitation and settling without polishing filtration corresponds more closely to the actual present practice in the cadmium subcategory.

BPT water flow controls do not require any significant modification of the manufacturing process or process equipment for their implementation. The in-process technologies practiced in the subcategory and recommended at BPT include:

- Recycle or reuse of process solutions (already practiced by 6 plants).
- Segregation of noncontact cooling water from process water (necessary for effective treatment).
- Control of electrolyte drips and spills (observed at various plants visited).

Table IX-1 (page 758) presents the normalized discharge flows which form part of the basis for mass discharge limitations for each process element. These normalized flows are equal to the mean normalized flows presented in Table V-10 and represent the average level of water use presently achieved by plants active in each process element. They therefore correspond to internal controls which are common industry practice.

Pollutant characteristics of process wastewater from the process elements in this subcategory are essentially similar because all contain toxic metals especially cadmium and nickel. The raw wastewater characteristics from nine process elements are presented in Tables V-11 through V-26 (pages 275-290) and Tables V-113 and V-114 (pages 379-380). The remaining four process elements (cell washing, electrolyte preparation, cadmium hydroxide production, and nickel hydroxide production) were not characterized by sampling. Based on raw materials used and the nature of these process operations, their process wastewaters are expected to be similar to those resulting from other process elements. Cell washing wastewaters are not expected to contain high concentrations of pollutants other than the ones already considered for regulation. Flows from electrolyte preparation are minimal (normalized mean flow of 0.08 l/kg) and are not expected to contain unusually high concentrations of any toxic pollutants. Any contaminants in the wastewater from this process element would likely be similar to others found within the subcategory. Process wastewaters from cadmium hydroxide production and nickel hydroxide production are expected to be similar to process wastewaters from cadmium impregnation and nickel impregnation, respectively, because of the similarity in raw materials involved, the chemical reactions occurring, and the nature of the water use.

Specific manufacturing process elements at each plant will affect the overall pollutant characteristics of the combined process wastewater flowing to one end-of-pipe treatment system. Some loss in pollutant removal effectiveness may 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. Although process wastewater streams with different raw waste concentrations will be combined for end-of-pipe treatment, the treatment effectiveness concentrations can be achieved with the recommended treatment technologies as discussed in Section VIII.

Total subcategory raw waste characteristics are needed to evaluate the pollutant removals which would be achieved by implementing the recommended treatment technologies. Total raw waste characteristics from sampled plants alone do not represent the total subcategory. To present raw waste for the total subcategory the following methodology was used. For pollutants in each process element the mean raw waste concentration (from sampling data in Section V) was multiplied by the total wastewater flow for the process. The annual mass of pollutants generated by each process was summed and divided by the total subcategory flow to obtain the subcategory raw waste concentrations. The results of these calculations are shown in Table X-2 (page 851).

Selection of Pollutant Parameters for Regulation

All process element raw wastewater samples and calculated total raw waste concentrations were evaluated to determine which pollutants should be considered for regulation. Tables VI-1 and VI-2 (pages 488 and 493) summarize this analysis and list the pollutants that should be considered. Pollutant parameters which were found frequently or at high concentrations in process element waste streams in this subcategory, and are regulated at BPT are cadmium, nickel, silver, zinc, cobalt, oil and grease, and TSS. Silver is regulated for the process elements associated with silver cathode production only. pH is also selected for regulation as a control parameter. Other pollutants which appeared at lower concentrations and were considered, but not selected for regulation at BPT, are expected to be incidentally removed by the application of BPT technology. With the application of lime and settle technology, combined with oil skimming when necessary, the concentration of regulated pollutants should be reduced to the concentration levels presented in Table VII-21 (page 606).

Effluent Limitations

Pollutant mass discharge limitations based on BPT are determined by multiplying the process element BPT flows summarized in Table IX-1 by the achievable effluent concentration levels for lime and settle technology from Table VII-21 For process elements relating to silver cathodes, waste streams will generally need to be treated separately to comply with the BPT mass limitations for the silver processes because the silver limitation cannot be achieved when these wastewaters are combined with other process wastewaters. Separate treatment is presently practiced by plants within the subcategory who recover and reuse the silver. The results of this computation for all process elements and regulated pollutants in the cadmium subcategory are summarized in Tables IX-2 to IX-15 (page 759-772). To alleviate some of the monitoring burden, several process elements which occur at most plants and have the same pnp are combined in one regulatory table. Table IX-11 (page 768) is the combined table for Tables IX-7 to IX-10. These limitation tables list all the pollutants which were considered for regulation and those regulated are indicated by "*".

Reasonableness of the Limitations

The mass discharge limitations are reasonable based on the demonstrated ability of the selected BPT to achieve the effluent concentrations presented. As discussed in Section VII, the effluent concentrations shown are, in fact, achieved by many plants with wastewater characteristics similar to those from the cadmium subcategory by the application of lime and settle technology with a reasonable degree of control over treatment system operating parameters.

To confirm the reasonableness of these limitations for this subcategory, the Agency compared them to actual performance at cadmium subcategory plants. Since plants presently discharge wastewaters from various process elements and BPT is projected on a single end-of-pipe treatment from multiple process elements, this comparison must be made on the basis of the total plant rather than a process element. This was accomplished by calculating total process wastewater discharge flow rates for each plant in the subcategory based on available production information and the normalized process element flows shown in Table IX-1. These calculated effluent flow rates were then compared to flow rates actually reported or measured. Effluent concentrations were also compared to those attainable by lime and settle technology as presented in Table VII-21. Finally total plant mass discharges were compared to BPT limitations for plants which, on the basis of effluent flows and concentrations, were potentially meeting BPT mass discharge limitations.

As a first step in this comparison, cadmium subcategory process wastewater flow rates from each plant were compared to the flow rates upon which mass limitations for the plant would be based. In order to minimize the effects of irregular operating schedules for some process operations, this comparison was made on the basis of annual flows. To calculate actual annual process wastewater discharge flows, the discharge flow rate (l/hr) from each process element at the plant was multiplied by the hours of production activity reported for the process element. The resultant process element annual discharge flows were summed to determine the total plant discharge flow. In some cases, the only available data were combined flow rates for several process elements as reported in dcp; these combined flow rates were then multiplied by plant production hours to determine the total contribution from these process elements to the plant's annual process wastewater discharge. Production information from each plant was used to determine an annual calculated BPT flow for comparison to the actual values. The total annual production (in terms of pnp) for each process element was determined and multiplied by the normalized flow shown for that process element in Table IX-1 to determine the BPT flow for the process element at the plant. Flows for each process element were summed to obtain a total plant BPT flow. Table IX-16 (page 773) presents a comparison of these values.

Nine of thirteen cadmium subcategory plants in the data base (6 of 10 currently active plants) were found to produce annual process wastewater volumes equal to or lower than those upon which BPT pollutant mass discharge limitations would be based. Two other plants produced process wastewater discharges only one percent larger than those used in calculating BPT mass discharge limitations. This analysis supports the thesis that the flow basis for BPT mass discharge limitations is reasonable and reflects techniques widely practiced in the subcategory.

Most plants have BPT equivalent or more sophisticated treatment systems in place, but few plants in the cadmium subcategory presently apply BPT effectively. Two plants which produce wastewater and discharge treat cadmium subcategory process wastewater and achieve effluent concentrations equivalent to those used to determine mass discharge limitations for BPT technology. Three plants which treat wastewater and discharge can readily comply with the BPT technology by some upgrading and by properly operating their treatment systems. Two additional plants comply with this technology by process selection and are not generating a wastewater discharge. Treatment performance at the three remaining active cadmium subcategory plants could not be evaluated because of the limited amount of data submitted, however all three of these plants have the BPT equivalent or better technology in place.

On-site observations (discussed in Section V) have shown that existing systems in the subcategory are inadequately maintained and operated. Consequently, it is necessary to base BPT mass discharge limitations on the transfer of demonstrated technology performance from other industrial categories. The limitations based on this transfer are reasonable based on the general attainment of the flow levels used as the basis for BPT within the cadmium subcategory and on the basis of effluent concentrations achieved at many industrial plants treating similar process wastewater streams containing primarily metals, oil and grease, and TSS.

Pollutant Removals and Costs

In the establishment of BPT, the cost of application of technology must be considered in relation to the effluent reduction benefit from such application. The quantity of pollutants removed by BPT and the total costs of application of BPT were determined by consideration of wastewater flow rates and treatment costs for each plant in the cadmium subcategory. Pollutant reduction quantities are shown in Table X-4 (page 854) for the total subcategory and Table X-5 (page 855) for direct dischargers. Treatment costs (1978 dollars) are shown in Table X-56 (page 906). The capital cost of BPT as an increment above the cost of in place treatment is estimated to be $390,562 for the cadmium subcategory ($60,472 for direct dischargers only). Annual cost of BPT for the subcategory is estimated to be $98,690 ($23,065 for direct dischargers only). The quantity of pollutants removed by the lime and settle system for this subcategory is estimated to be 474,910 kg/yr (341,700 for direct dischargers) including 193,500 kg/yr of toxic pollutants (139,200 for direct dischargers only). The pollutant reduction benefit is worth the dollar cost of required BPT.

CALCIUM SUBCATEGORY

Currently there are no direct discharging plants in this subcategory and therefore no BPT (or BAT) will be established. This discussion of the BPT technology option is presented here for consistency and completeness and will form the basis for new source discussions in Section XI, and pretreatment discussions in Section XII.

This subcategory encompasses the manufacture of calcium anode batteries, such as thermal batteries, which are used primarily for military applications. Three plants presently manufacture this type of battery and the total production volume is limited. Eight process elements identifed in Table IV-1 (page 154) are manufacturing activities included within this subcategory. Since the cell anode material, calcium, reacts vigorously with water, water use and discharge in this subcategory is limited. Only two of the process elements, as shown in Figure V-8 (page 399), generate a wastewater discharge; the other six do not. Normalized flows for these elements are summarized in Table V-33 (page 297).

Model Treatment Technology

The end-of-pipe treatment technology for the calcium subcategory was selected after a review of the manufacturing processes involved and the wastewaters generated. This review showed that the construction of calcium anode cells generates two distinct wastewater streams which differ in their initial treatment requirements. The first step in treatment technology for the calcium subcategory is the segregation of the two waste streams for separate treatment. A schematic diagram of the end-of-pipe treatment system selected to treat these wastewaters is presented in Figure IX-2 (page 811). The chromium-bearing wastewater from heat paper production is first settled to remove undissolved constituents including zirconium metal, asbestos and barium chromate. After settling, chemical reduction is provided to convert the hexavalent chromium in the waste stream to the trivalent form which may be effectively removed by precipitation as the hydroxide.

Following pretreatment of the heat paper production waste stream, the wastewater is combined with wastewater from cell leak testing. The combined stream is treated with lime and then clarified by settling. 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 lime and settle treatment 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 disposed in a secure landfill.

The chromium reduction and lime and settle technology set forth for heat paper production in this subcategory has been transferred from other categories with chromium wastes, because treatment in this subcategory is universally inadequate or lacking. Chromium-containing heat paper production wastewaters are not treated at one plant, and are only pH adjusted and settled at another. (See Table V-36, page 300). Hence, transfer of technology from another category is necessary and reasonable. Chromium reduction followed by lime and settle technology is a widely used treatment system of proven effectiveness on essentialy similar wastewaters. No in-process technologies are recommended at the BPT treatment level since no in-process control is practiced within the subcategory.

Table IX-17 (page 774) presents the normalized discharge flows which form part of the basis for mass discharge limitations for each process element. For heat paper production and cell testing associated with thermal battery production, data were combined from the calcium, lithium and magnesium subcategories since manufacturing processes and wastewaters generated from these elements are identical. The normalized flow used for mass limitations is equal to the median flow for heat paper manufacture because one plant (which was not visited, but contacted twice) had a normalized flow more than fifty times (more recently reduced to thirty times) greater than the flows achieved by other plants for this process element. In this case, the median flow is believed to more accurately represent what is common practice for this process element and is used as the basis for mass limitations for the heat paper production and cell testing elements.

Pollutant characteristics of the process wastewater from heat paper production (Table V-34, page 298) in the three subcategories are essentially similar and can include asbestos, chromium and iron. No sampling data are available on the cell testing waste stream because testing which is done intermittently was not being done at the time of sampling. As cell testing exposes water to the same materials as are inside the cell, all testing water is assumed to be the same as heat paper wastewater. The volume of water generated by this process is minimal in comparison to heat paper production (about 0.2 percent) and has a negligible contribution to the overall raw wastewater characteristics of the calcium subcategory. Total raw wastewater characteristics calculated from process element raw waste characteristics and total wastewater flow from each process element are shown in Table X-18 (page 868).

Selection of Pollutants

For the purpose of selecting pollutant parameters for limitations with lime and settle technology the raw wastewaters were examined for pollutants found frequently at treatable concentrations. Only chromium and TSS were noted at levels great enough for effluent limitations. Chromium appears in high concentrations due to the use of barium chromates in the manufacture of heat paper. TSS is selected because of its high concentrations in heat paper manufacture wastewater. Proper pH control is also specified to ensure the efficient performance of the lime and settle treatment.

Effluent Limitations

The effluent concentrations of the pollutants considered for regulation attainable through the use of lime and settle technology are listed in Table VII-21 (page 606). When these concentrations are combined with the BPT technology flows from each process element as shown in Table IX-17, the mass of pollutant allowed to be discharged per unit of production normalizing parameter can be calculated. Table IX-18 (page 775) shows the effluent limitations derived from this calculation, and is presented as guidance for state or local pollution control agencies because effluent limitations for the discharges from this subcategory are not established for national regulation at BPT.

LECLANCHE SUBCATEGORY

Currently, there are no direct discharging plants in this subcategory and therefore no BPT (or BAT) will be established. This discussion is presented here for consistency and completeness and will form the basis for new source discussions in Section XI and pretreatment discussions in Section XII.

The Leclanche subcategory includes the manufacture of the zinc anode, acid electrolyte batteries such as the conventional carbon-zinc Leclanche cell or "dry cell" (cylindrical, rectangular, and flat), silver chloride-zinc cells, carbon-zinc air cells, and foliar batteries. Ten process elements identified in Table IV-1 (page 154) are manufacturing activities included within the Leclanche subcategory. Five of these process elements, as shown in Figure V-10 (page 401), generate a wastewater discharge; the other five do not. Normalized flows for these elements are summarized in Table V-39 (page 303).

Model Treatment Technology

Treatment technology for this subcategory for all battery types except foliar is the implementation of in-process treatment and controls to eliminate process wastewater discharge. For foliar batteries the model treatment technology is in-process recycle and lime, settle and filter end-of-pipe treatment. Information collected to characterize manufacturing practices, wastewater sources, and present treatment and control practices was carefully reviewed to define treatment options. Table V-50 (page 314) summarizes present treatment practices which indicate that zero discharge is presently common practice within the subcategory.

The elimination of most wastewater discharges does not require significant modification of the manufacturing process or process equipment. In-process technologies practiced in the subcategory and recommended for zero discharge include:

- Wastewater recycle and reuse
- Water use control
- Good housekeeping
- Process modifications for some waste streams

For wastewater recycle and reuse, wastewater sources which are encountered in this subcategory can be segregated into two groups: those that are related to mercury use and those that are related to other metals use (manganese and zinc). Paste separators, both cooked and uncooked, pasted paper separators, and equipment and utensils which are used to mix or transport mercury-containing materials are included in the mercury use group. The other group includes paste separators and equipment and utensils which are not related to mercury use. Segregation of streams in the mercury use group is important for effective treatment as well as wastewater recycle and reuse. Since wastewater would contain only the constituents used in these processes (primarily mercury) recycle is practical. When all process wastewaters are combined, the contaminants from other processes, primarily zinc and manganese, prevent recycle. All waste streams in this subcategory can be recycled and reused, whether with or without treatment, as deemed necessary by the individual plant. This in-process technology is presently implemented at plants within the subcategory.

Water use within plants can be controlled and good housekeeping techniques can be practiced to substantially reduce the amount of water used. Water use can be eliminated by using dry cleanup procedures or by minimizing spills and keeping production areas clean. These techniques are presently practiced, especially for equipment and floor cleaning processes.

Mechanical and production practices vary from plant to plant, and in some instances within the subcategory, wastewater is discharged from equipment and area cleanup. If all other in-process techniques cannot be implemented at a plant, another alternative is to consider implementation for process modifications. The final alternative is to implement all available in-process practices and contract haul the wastes to a secure landfill or sell for metals reclamation.

Wastewater characteristics of Leclanche subcategory process elements are similar in that they contain metals (primarily mercury and zinc), oil and grease, and TSS. These characteristics are presented for all process elements in Tables V-40 to V-43 (pages 304 - 307) and Tables V-45 to V-48 (pages 308 - 311).

Total subcategory raw waste characteristics are needed to evaluate the pollutant removals which would be achieved by implementing the recommended treatment technology. To present raw waste for the subcategory, the mean raw waste concentration for each process from the sampling data in Section V was multiplied by the wastewater flow for the process. The annual mass of pollutants generated by each process was summed and divided by the total subcategory flow to obtain the subcategory raw waste calculations. Although not specifically sampled, foliar battery miscellaneous wash raw wastewater characteristics are similar to the average for the subcategory. Raw waste characteristics for the subcategory are in Table X-20 (page 870).

All process element raw wastewater samples and plant data were evaluated to determine which pollutants should be considered for regulation. Tables VI-1 and VI-2 (pages 488 and 493) summarize this analysis and list the pollutants that should be considered. Pollutant parameters found frequently or at high concentrations, in process element waste streams in this subcategory include mercury, zinc, manganese, oil and grease, and TSS. These parameters along, with pH, should be regulated for the Leclanche subcategory wastewaters.

Other pollutants which appeared at lower concentrations and were considered, but not recommended or selected for regulation should be incidentally removed by the application of lime, settle and filter (LS&F) technology. With the application of the LS&F technology, the concentration of pollutants should be reduced to the concentration levels presented in Table VII-21 (page 606)

No discharge was selected for most plants primarily because 12 of the 19 existing plants are presently achieving no discharge. Most of these plants achieve zero discharge by employing manufacturing processes, operating practices, and maintenance procedures which do not result in the generation of process wastewater. The remaining plants which presently discharge wastewater, except for the foliar battery plants, could accomplish zero discharge by using in-process treatment and technology practices. Plants with foliar battery production can recycle and reuse some process wastewater and use their existing treatment equipment to achieve LS&F technology effectiveness for the water that is discharged.

At plants where paste is prepared and applied to cells containing paste separators or to paper for use as cell separator material, equipment is periodically washed down with water as part of normal maintenance. Wastewater from equipment cleaning usually contains the paste constituents, including ammonium chloride, zinc and mercury. This water is retained and reused in subsequent paste equipment washing. The build-up of contaminants in the wash water is controlled by using a portion of the wash stream in paste preparation. Of the six plants supplying data for paste preparation, three plants which use mercury in the mix have reported no process wastewater discharge. One plant has recently discontinued this process, but before changing processes was practicing segregation, recycle and reuse. The second plant is presently practicing segregation, recycle and reuse, and the third plant does not generate any process wastewater since its equipment is not washed. The other three plants do not practice recycle or reuse. Two of these plants use less than 10 gallons a day of process water and do not have mercury in their paste processes. The third plant presently uses mercury and discharges water from paste equipment washing.

Water is used at one plant in the cooked paste separator process element, to supply heat for setting paste separators. As a result of contact with machinery used to convey the cells and occasional spillage from cells, this water becomes contaminated with oil and grease, paste constituents (zinc, ammonium chloride and mercury) and manganese dioxide particulates. These contaminants do not interfere with the use of this water for heat transfer to the outside of assembled cells. Wastewater discharge from this operation results from manufacturing conveniences, maintenance of the equipment, and from dragout of water on the cells and conveyors. Discharge from each of these process sources can be eliminated by recycle and reuse of the water. Water drawdown from the paste setting tanks during breaks in production serves to prevent overcooking of the paste separators in cells left in the tanks during these periods. Discharge resulting from the tank drawdown and from emptying tanks for maintenance can be eliminated without loss of productivity by providing a tank to hold the drawdown water during the break. The water can later be pumped back into the process tanks. These practices will eliminate the wastewater discharge and the energy requirement for heating water used in the paste setting tanks. Dragout from paste setting tanks which is presently treated and discharged can be collected and returned to the process tank for recycle. This practice will eliminate wastewater discharge and reduce the amounts of oil and grease (from the process machinery) in wastewater from the paste setting process.

Process wastewater generated by cooking to "set" the paste separator may be eliminated entirely by substitution of a low temperature setting paste. This is presently practiced by one plant. Alternatively, paper separators can be used in accordance with prevailing practice at other Leclanche subcategory plants.

Water used for equipment and floor cleaning in assembly as well as electrolyte preparation areas was reported at seven Leclanche subcategory plants. One plant which was recycling equipment cleaning water has discontinued production. The six remaining plants presently do not practice any substantial in-process technologies to completely eliminate wastewater discharge. Water use and subsequent discharge can be substantially reduced by the implementation of water use controls or eliminated by the substitution of dry equipment cleanup procedures. Eight plants which were visited, presently employ some dry equipment and floor cleaning techniques. The assumption is made that other plants not visited and reporting zero discharge of process wastewater are also practicing dry equipment and floor cleaning techniques. One plant which was visited and is presently discharging substantial volumes of equipment cleaning water, claimed that zero discharge could be achieved through in-process controls, treatment and recycle. Where the quality of the water is essential for final product performance, wastewater can be segregated, treated and reused. Existing treatment at the four plants which treat and discharge wastewater can be used for this purpose. In the unlikely event that all process water cannot be reused after in-process technologies are implemented, resulting wastewaters can be contractor hauled to an approved landfill or sold for metals reclamation if appropriate.

As shown in the above discussion, zero discharge for almost all of the processes in the Leclanche subcategory is reasonable. This level of control is presently achieved by 12 plants and is viable for the remaining seven plants, except for foliar battery production which was reevaluated after proposal.

Comments on the proposal were received which stated that a separate subcategory was needed for foliar batteries and that a discharge was necessary. Separate subcategorization of foliar batteries was rejected because the battery chemistry is classic Leclanche chemistry. However, the nature of the manufacturing process and the sensitivity of the thin layers of active materials in the battery to minute particles of impurities make the reuse of wastewater in the product undesirable. Therefore, a flow allowance was established for foliar battery miscellaneous wash based on data presented in Section V. The in-process technology for reduction of wastewater volume is wastewater segregation, water reuse and improved tool cleaning processes. Application of these technologies will reduce wastewater discharge to one-half of the present discharge level or 0.066 l/kg of cells produced.

The effluent concentrations of the pollutants considered for regulation attainable through the use of this technology are listed in Table VII-21 (page 606). These concentrations are multiplied by the production normalized discharge flow to obtain the mass limitations listed in Table IX-19 (page 776). These limitations for foliar batteries are presented as guidance only, since there are no direct discharging plants in this subcategory. Pollutant reduction benefits are listed in Table X-20 (page 870).

LITHIUM SUBCATEGORY

Currently, the discharge by direct dischargers of process wastewater from this subcategory is small (less than 4 million l/yr) and the quantity of toxic pollutants is also small (less than 220 kg/yr). Because of the small quantities, the Agency has elected not to establish national BPT (and BAT) limitations for this subcategory. Applicable technologies, and potential limitations are set forth as guidance should a state or local pollution control agency desire to establish such limitations. Detailed discussions on technology presented here will form the basis for new source discussions in Section XI and XII.

The lithium subcategory includes the manufacture of lithium anode batteries, including thermal batteries and other high cost, low volume special purpose batteries, such as those used in heart pacemakers, lanterns, watches, and for military applications. Fifteen process elements identified in Table IV-I (page 154) are manufacturing activities included within this subcategory. Since the cell anode material, lithium, reacts vigorously with water, water use and discharge in this subcategory is limited. Eight of these process elements, as shown in Figure V-12 (page 403), generate a wastewater discharge; the other seven do not. Normalized flows for these elements are summarized in Table V-53 (page 317).

Model Treatment Technology

End-of-pipe treatment for this subcategory is illustrated in Figure IX-4 (page 813). Since no lithium subcategory plants presently have adequate treatment systems in place (See Table V-57, page 321), treatment technology is transferred from other similar industrial categories. Three separate treatment systems are shown to account for the processes and waste streams currently encountered. Lithium cell manufacturers do not use processes at any one plant which produce waste streams for all three treatment systems.

The first treatment system is for plants producing lithium anode thermal batteries and generating process wastewater from heat paper production only. This waste stream is treated separately because of the chromium and large quantities of suspended solids present in the raw waste stream, as is discussed in the calcium subcategory on page 736.

The second treatment system is for plants generating process wastewater from lead iodide cathode production, iron disulfide cathode production, cell testing, lithium scrap disposal, and floor and equipment wash. Treatment includes chemical precipitation with lime and settling. A clarifier can be used as a settling device. This treatment system is identical to the first except for the chromium reduction steps. Settled solids are treated identically as the first treatment system, by dewatering in a vacuum filtration unit. As an alternative, for the plants with heat paper production and one or more of the second system process elements, wastewaters can be combined following chromium pretreatment; however, additional pollutant parameters would be regulated.

The third treatment system is for plants generating process wastewater from air scrubbers located in various production areas, such as sulfur dioxide preparation, thionyl chloride preparation, electrolyte preparation, battery filling, and assembly areas. Initially these wastewaters are aerated to reduce the oxygen demand, then neutralized since thionyl chloride and sulfur dioxide streams form hydrochloric and sulfuric acid, respectively. The neutralized waste stream is settled prior to discharge because of the formation of precipitates and suspended solids. Settled solids are removed and contractor hauled to a secure landfill. These solids are not expected to be hazardous.

BPT water flow controls do not require any significant modification of the manufacturing process or process equipment for their implementation. There are no in-process technologies recommended at BPT.

Table IX-20 (page 777) presents the normalized discharge flows which form part of the basis for mass discharge limitations for each process element. These normalized flows are equal to the mean normalized flows presented in Table V-53 (page 317) (except for heat paper production which was discussed under the calcium subcategroy) and represent the average level of water use presently achieved by plants active in each process element. These flows correspond to internal controls which are common industry practices. -

Pollutant characteristics of process wastewater from the process elements in this subcategory are related to the three separate treatment systems. Heat paper production wastewaters, which were described under the calcium subcategory and characterized in Table V-34 (page 298), contain treatable levels of chromium as well as TSS. This element was separated for separate treatment because of the presence of chromium in the wastewater.

The lead iodide cathode production, iron disulfide cathode production, lithium scrap disposal, cell testing and floor and equipment wash process elements contain pollutants such as iron, lead and TSS. These pollutants can be treated by chemical precipitation and settling technology, which is the second treatment system. The iron disulfide cathode production element was sampled since it was expected to contain the most pollutants and comprised a large percentage of the wastes streams considered for this treatment system. The raw waste characteristics are shown in Table V-54 (page 318). The lithium scrap disposal area was also sampled and characteristics are summarized in Table V-56 (page 320). The second largest contributing waste stream, the lead iodide cathode production element was not sampled, but one plant reported that it contained lead. The wastewater was contractor hauled. For the lead iodide, cell testing and floor and equipment wash process elements, no pollutants in addition to those detected in the iron disulfide stream are expected to be present in the wastewaters.

The cell wash wastewater stream which was characterized by plant supplied data, contains high levels of COD. This is expected since acetonitrile, used as a raw material, contains cyanide. Because the flow from this process is low (less than 55 gallons per week) and the waste stream contains organics, this waste stream is contractor hauled for disposal and zero discharge is promulgated.

The wastewater from the air scrubbers process element, which are treated by the third treatment system, are expected to be acidic and contain some suspended solids. These streams were not sampled, however by evaluating raw materials and plant data, the conclusions reached concerning the raw waste characteristics are reasonable.

Specific manufacturing process elements at each plant will affect the pollutant characteristics and the treatment system used. Total subcategory raw waste characteristics and total wastewater flow from each process element are summarized in Table X-23 (page 873).

All process element raw wastewater samples and plant data were evaluated to determine which pollutants should be considered for regulation. Tables VI-1 and VI-2 (pages 488 and 493) summarize this analysis and list the pollutants that should be considered. Pollutant parameters found frequently, or at high concentrations, in process element waste streams in this subcategory include chromium, lead, iron, and TSS. These parameters, along with pH, should be regulated as appropriate for the process elements included in the separate treatment systems. Chromium, TSS and pH should be regulated when only heat paper production wastewater is treated. When cathode and all ancillary operations except scrubber wastewater are treated, chromium, lead, iron, TSS and pH should be regulated. Air scrubber wastewater is segregated from other process wastewater and treated for TSS and pH only.

Other pollutants which appeared at lower concentrations and were considered, but not recommended or selected for regulation should be incidentally removed by the application of lime and settle technology. With the application of chromium reduction and chemical precipitation and settling technology, the concentration of regulated pollutants should be reduced to the concentration levels presented in Table VII-21 (page 606). Pollutant mass discharge limitations based on lime and settle technology are determined by multiplying the process element normalized flows, summarized in Table IX-20, by the achievable effluent concentration levels for lime and settle technology. One limitation is presented for floor and equipment wash, cell testing, and lithium scrap disposal because of the small amounts of wastewater generated. The results of this computation for all process elements and selected pollutants for specific process elements in the lithium subcategory are summarized in Table IX-21 to IX-25 (pages 778-782). These tables are presented as guidance for state or local pollution control agencies agencies because effluent limitations for the discharges from this subcategory are not established for national regulation at BPT.

The pollutant mass discharge limitations are reasonable based on the demonstrated ability of the selected BPT technologies to achieve the effluent concentrations presented. As discussed in Section VII, the effluent concentrations shown are achieved by many plants with wastewater characteristics (metals, TSS) similar to those from the lithium subcategory by the application of lime and settle technology with a reasonable degree of control over treatment system operating parameters.

To determine the reasonableness of these mass limitations, the Agency examined the available effluent data, the treatment systems in place, and the processes conducted at each plant in the subcategory. As discussed in the calcium subcategory, no plants have lime and settle treatment in place for the heat paper production process element. Therefore, for the one lithium subcategory plant active in this process element, reasonableness is based upon the proven effectiveness of lime and settle technology in other industrial categories with similar wastewater characteristics. Of the two plants active in the lead iodide cathode production, iron disulfide cathode production, cell washing, cell testing, floor and equipment wash, and lithium scrap disposal process elements, one plant does not have a complete, effective treatment system in place for all of these elements, and the other contractor hauls their wastes. The first plant does not pH adjust and settle all process element streams, and the second only settles the wastewater before contractor removal. Two plants, active in the air scrubber element, treat process wastewaters by pH adjustment only. This treatment alone is not considered to represent the selected treatment technology, since pH adjustment causes precipitates to form in the wastewater which should be settled before discharge. The reasonableness of this technology is again based on proven effectiveness in other industrial categories with similar wastewater characteristics.

The data collected indicates that plants active in the subcategory do not have adequate treatment in place. Therefore, treatment technology is transferred from other industrial categories which treat wastewaters containing such pollutants as chromium, lead, iron and TSS.

If the application of lime and settle technology at a specific plant does not result in sufficiently low effluent concentrations to meet mass discharge regulations, there are alternative technologies available, such as sulfide precipitation, carbonate precipitation and ferrite co-precipitation (with hydroxide precipitation) which may achieve lower effluent concentrations than hydroxide precipitation. A more simple way of meeting the discharge limitations would be to reduce the discharge flow either through process modification or in-process flow controls. Alternatively, plants with significantly small volumes of wastewater (less than 50 gallons per week) can consider contractor removal to a secure, approved landfill.

MAGNESIUM SUBCATEGORY

Currently, the discharge by direct dischargers of process wastewater from this subcategory is small (less than 4 million l/yr) and the quantity of toxic pollutants is also small (less than 220 kg/yr). Because of the small quantities, the Agency has elected not to establish national BPT (and BAT) limitations for this subcategory. Applicable technologies, and potential limitations are set forth as guidance should a state or local pollution control agency desire to establish such limitations. Detailed discussions on technology presented here will form the basis for new source discussion in Section XI and pretreatment discussions in Section XII.

The magnesium subcategory includes the manufacture of magnesium anode batteries, such as magnesium carbon batteries, and reserve and thermal batteries, which are activated by electrolyte addition or by initiation of a chemical reaction to raise the cell temperature to operating levels. Of these, magnesium carbon batteries account for 85 percent of the production in the subcategory. Sixteen process elements identified in Table IV-I (page 154) are manufacturing activities included within this subcategory. Seven of these process elements, as shown in Figure V-14 (page 405), generate a wastewater discharge; the other nine do not. Normalized flows for these elements are summarized in Table V-59 (page 323).

Model Treatment Technology

End-of-pipe treatment for this subcategory is illustrated in Figure IX-5 (page 814). Since no plants in the subcategory are effectively treating the wastewater (See Table V-62, page 626), technology is transferred from other industrial categories with similar pollutants. Three separate treatment systems are shown to account for the processes and waste streams currently combined and encountered in the subcategory at present. Magnesium cell manufacturers at any one plant do not conduct manufacturing processes which produce all of the identified wastewater streams for all three treatment systems.

The first treatment system is for wastewaters from the silver chloride cathode processes in which silver or silver chloride is treated in process solutions. The batch dumps of the solutions are bled into the rinsewaters from the operations and sent to treatment. In order to reduce the oxygen demand of the organic laden wastes, the wastewater is pretreated with potassium permanganate. When this oxidation process is complete, the water is subjected to chemical precipitation with lime or acid and settling. As in the second system, settled solids are removed and dewatered in a vacuum filtration unit. For plants with silver chloride production and cell testing, or floor and equipment washing process elements, wastewaters are combined following permanganate pretreatment. For plants with only cell testing or floor and equipment wash, pretreatment is not necessary.

The second treatment system is for plants producing magnesium anode thermal batteries and generating process wastewater from heat paper production. The system is identical to the system discussed and described in the calcium subcategory on page 736.

The third treatment system is for plants generating process wastewater from air scrubbers. Treatment includes chemical precipitation with lime or acid, and settling to remove metals and suspended solids. A clarifier can be used as a settling device. Settled solids are removed and dewatered in a vacuum filtration unit. Solids are removed for disposal, and the filtrate is recycled back to the chemical precipitation tank. For plants with heat paper production and air scrubbers, the wastewater streams are segregated.

BPT water flow controls do not require any significant modification of the manufacturing process or process equipment for their implementation. In-process flow control is recommended for the silver chloride cathodes surface reduced process element. On-site visits indicated that rinse water was left flowing continuously in two tanks regardless of whether the process used two rinses or not. Consequently, twice the amount of water was used than was necessary and fifty percent of the observed flow is believed to represent the average process flow.

Table IX-26 (page 783) presents the normalized discharge flows which form part of the basis for pollutant mass discharge limitations for each process element. These normalized flows are equal to the mean normalized flows presented in Table V-59 (except for heat paper production, which was discussed under the calcium subcategory and the silver chloride cathode surface reduced process discussed above) and represent the average level of water use presently achieved by plants active in each process element. These flows correspond to internal controls which are common industry practice.

Pollutant characteristics of process wastewater from the process elements in this subcategory are related to the three separate treatment systems. Heat paper wastewaters and treatment characteristics were discussed in the calcium subcategory. Air scrubber wastewater is expected to only contain treatable levels of TSS. The cell testing and floor and equipment wash process elements should contain pollutants such as metals and TSS which can be treated by chemical precipitation and settling technology. These process elements were not characterized by sampling. However, by evaluating raw materials and plant data, no pollutants, other than those detected in other waste streams sampled in this subcategory, are expected to be present. The characteristics for the silver chloride cathode processes are presented in Table V-6 (page 261), and Table V-60 (page 324). These elements were separated for pretreatment because of the presence of COD in the wastewaters.

Specific manufacturing process elements at each plant will affect the pollutant characteristics and the treatment system used. Total subcategory raw waste characteristics and total wastewater flow from all process elements are summarized in Table X-29 (page 879).

All process element raw wastewater samples and plant data were evaluated to determine which pollutants should be considered for regulation. Table VI-1 and VI-2 (pages 154 and 155) summarize this analysis and list the pollutants that should be considered. Pollutant parameters which were found at high concentrations in process element waste streams from this subcategory and should be regulated include chromium, lead, silver, iron, COD, and TSS. These parameters, along with pH, are considered for regulation. Specific pollutants considered depend on processes practiced at each plant. Other pollutants which appeared at lower concentrations and were considered, but not selected for regulation should be incidentally removed by the application of the selected treatment technology. With the application of chromium reduction, oxidation, chemical precipitation and settling technology, the concentration of the selected pollutants should be reduced to the concentration levels presented in Table VII-21 (page 606). Mass discharge limitations based on the discussed lime and settle treatment are determined by multiplying the process element normalized flows summarized in Table IX-26 , with the achievable effluent concentration levels for lime and settle technology from Table VII-21. The results of this computation for all process elements and considered pollutants and pollutant parameters in the magnesium subcategory are summarized in Tables IX-27 to IX-32 (pages 784-789). These tables are presented as guidance for state or local pollution control agencies because effluent limitations for the discharges from this subcategory are not established for national regulation at BPT.

As discussed in Section VII, the effluent concentrations shown are achieved by many plants with wastewater characteristics (metals, TSS) similar to those from the magnesium subcategory, by the application of lime and settle technology with a reasonable degree of control over treatment system operating parameters.

To determine the reasonableness of these mass limitations, the Agency examined the processes conducted, the available effluent data, and the treatment systems in place at each plant in the subcategory. As discussed in the calcium subcategory, no plants have BPT in place for the heat paper production process element. Therefore, for the one magnesium subcategory plant active in this process element, reasonableness is based upon the proven effectiveness of BPT technology in other industrial categories with similar wastewater characteristics. For the silver chloride cathode production wastewater streams, no plant has BPT in place. Neither the one plant that produces silver chloride cathodes nor the other that is capable of producing them oxidizes the solution waste stream prior to treatment. Therefore, reasonableness is based on the proven effectiveness of the BPT technology in other industrial categories with similar (high COD, metals and TSS) wastewater characteristics. Air scrubber wastewater is generated at a plant which does not treat the process wastewater. Cell testing is also generated at a plant which does not treat process wastewateer;however, the plant does have a BPT system in place which can be used for treatment. Reasonableness for these technologies is based on the proven effectiveness of the technologies in other industrial categories with similar wastewater characteristics. All but one plant, which reported a discharge from floor and equipment wash, have a treatment system in place, but do not treat the wastewater. Proven effectiveness for the technology is transferred from other industrial categories.

Although the effluent limitations are based on the application of chemical precipitation and settling technology, there are alternative technologies available, such as sulfide precipitation, carbonate precipitation and ferrite co-precipitation (with hydroxide precipitation), which may achieve lower effluent concentrations than lime precipitation. A simpler way of meeting the mass limitations would be to reduce the discharge flow either through process modification or in-process flow controls. Alternatively, plants with significantly small volumes of wastewater (less than 50 gallons per week) can consider contractor removal to a secure, approved landfill.

ZINC SUBCATEGORY

The zinc subcategory includes the manufacture of a variety of zinc anode batteries such as alkaline manganese, silver oxide-zinc, mercury-zinc, carbon zinc-air depolarized, and nickel-zinc. Twenty-five process elements identified in Table IV-I (page 154) are manufacturing activities included within this subcategory. Sixteen of these elements, as shown in Figure V-16 (page 407), generate a wastewater discharge, the other nine do not. Normalized flows for these elements are summarized in Table V-64 (page 329).

Model Treatment Technology

BPT end-of-pipe treatment for the zinc subcategory, as shown in Figure IX-6 (page 815) consists of chemical precipitation and sedimentation. Wastewaters are skimmed for oil and grease removal and have hexavalent chromium reduced as necessary. Sludges are dewatered in a vacuum filter. This system was selected following a review of data submitted by plants in the subcategory, observations at plants which were visited, analytical results, and industry comments on the draft development document circulated in September, 1980. As shown in Table V-118 (page 384), plants in the subcategory reported various treatment systems in place, ranging from pH adjustment only, to innovative carbon adsorption and ion exchange systems. Observations at plants indicated, however, that these treatment systems were either rudimentary, improperly operated, or installed during or after data collection activities before performance could be evaluated completely. Most plants can, at present, comply with the limitations based on this technology with little or no treatment system modification. Treatment effectiveness, however, is transferred from other industrial categories with similar wastewater (toxic metals, TSS, oil and grease) because of inadequate treatment system control and operation.

Sulfide precipitation, sedimentation and filtration was initially selected for BPT as being the average technology already in place. Also, zinc subcategory wastewaters contain metals, particularly mercury. Mercury is less soluble as a sulfide than as a hydroxide. Consequently, lower concentrations of mercury could be achieved by using sulfide rather than hydroxide precipitation. The system was not selected primarily because (1) sulfide precipitation may produce a toxic and reactive sludge which would cause significant difficulties with disposal and (2) lime precipitation is a more widely applied technology at the present time, and that its effectiveness has consequently been more thoroughly demonstrated in industrial wastewater treatment.

In addition to end-of-pipe technology for the removal of wastewater pollutants, BPT includes the application of controls within the process to limit the volume of wastewater requiring treatment. Those controls which are included in BPT are generally applied in the subcategory at the present time, and do not require any significant modification of the manufacturing process, process equipment or product for their implementation. They are discussed in detail in Section VII. In-process control technologies upon which BPT limitations are based include:

- Recycle or reuse of process solutions used for material deposition, electrode formation, and cell washing (already practiced by 4 plants)
- Segregation of noncontact cooling and heating water from process wastewater streams (necessary for effective treatment)
- Control of electrolyte drips and spills (observed at various plants visited)
- Segregation of organic-bearing cell cleaning wastewater (at various plants visited, these wastewaters were segregated and contractor hauled)
- Elimination of chromate cell cleaning wastewater (common industry practice as reported and observed is the use of nonchromium cell cleaning solutions)
- Control of process water use in rinsing to correspond to production requirements (already practiced by 5 plants).

As discussed in Section VII, a large number of in-process control techniques could be used in addition to the water use controls specifically identified as BPT. Many of these, including multistage and countercurrent cascade rinses, are presently practiced at plants in this subcategory.

Table IX-33 (page 790) presents the normalized discharge flows which form part of the basis for mass discharge limitations for each process element. These flows are in most cases equal to the mean normalized flows presented in Table V-64 and represent the average level of water use presently achieved by plants active in each process element. Specific discussion follows when the median rather than mean was used as the BPT flow. All flows correspond to internal controls which are common industry practice.

Pollutant characteristics of process wastewater from the process elements in this subcategory are essentially similar because they contain toxic metals especially mercury, and also nickel, silver and zinc. Raw wastewater characteristics for all sixteen process elements are presented in Tables V-18 to V-21 (pages 282 - 285), and in Tables V-66 to V-117 (pages 332 - 383). Specific manufacturing process elements at each plant will affect the overall pollutant characteristics of the combined process wastewater flowing to one end-of-pipe treatment system. Some loss in pollutant removal effectiveness will result where waste streams containing specific pollutants at treatable levels are combined with others in which these same pollutants are absent or present at very low concentrations. Although process wastewater streams with different raw waste concentrations will be combined for end-of-pipe treatment, the treatment effectiveness concentrations can be achieved with the recommended treatment technologies as discussed in Section VII.

Total subcategory raw waste characteristcs are needed to evaluate the pollutant removals which would be achieved by implementing the recommended treatment technologies. Total raw waste characteristics from sampled plants alone do not represent the total subcategory. To present raw waste from the total subcategory the following methodology was used. For pollutants in each process element the mean raw waste concentration (from sampling data in Section V) was multiplied by the total wastewater flow for the process. The annual mass of pollutants generated by each process was summed and divided by the total subcategory flow to obtain the subcategory raw waste concentrations. The results of these calculations are shown in Table X-36 (page 885). For the total subcategory mercury raw waste concentration all total raw wastewater sampling data from both screening and verification was used to obtain an average concentration and loading. This was done because one-fourth of the mercury values from individual samples and combined process element streams were not obtained and reported from the lab as analytical interference.

Selection of Pollutants for Regulation

All process element raw wastewater samples and calculated total raw waste concentrations were evaluated to determine which pollutants should be considered for regulation. Tables VI-1 and VI-2 (pages 488 and 493) summarize this analysis and lists the pollutants that should be considered. Pollutant parameters which were found frequently or at high concentrations in process element waste streams in this subcategory include chromium, mercury, nickel, silver, zinc, cyanide, manganese, oil and grease, and TSS. Nickel is regulated only for the nickel impregnated cathode and cell wash process elements. Cyanide is regulated only for the cell wash process element. Chromium, mercury, nickel, silver, zinc, manganese, oil and grease, and TSS, are selected for regulation at BPT. pH is regulated as a control parameter. Other pollutants which appeared at lower concentrations and were considered, but not selected for regulation at BPT, should be incidentally removed by the application of BPT technology.

Effluent Limitations

With the application of lime and settle technology, combined with oil skimming and chromium reduction when necessary, the concentration of regulated pollutants should be reduced to the concentration levels presented in Table VII-21 (page 606). Pollutant mass discharge limitations based on BPT are determined by multiplying the process element BPT flows summarized in Table IX-33, with the achievable effluent concentration levels for lime and settle technology from Table VII-21. The results of this computation for all process elements and regulated pollutants in the zinc subcategory are summarized in Tables IX-34 to IX-50 (pages 791-807). To alleviate some of the monitoring burden, several process elements which occur at most plants and have the same pnp are combined in one regulatory table. Table IX-48 (page 805) is the combined table for Tables IX-42 to IX-43 and Tables IX-45 to IX-47. These limitation tables list all the pollutants which were considered for regulation and those regulated are *'d.

Reasonableness of the Limitations

These mass discharge limitations are substantiated by the demonstrated ability of the selected BPT to achieve the effluent concentrations presented. As discussed in Section VII, the effluent concentrations shown are in fact achieved by plants with wastewater characteristics (toxic metals, oil and grease, TSS) similar to those from the zinc subcategory by the application of lime and settle technology. Long-term, self-monitoring data have demonstrated the feasibility of maintaining these levels reliably over extended periods of time with a reasonable degree of control over treatment system operating parameters. At least half of all plants active in each process element presently produce production normalized process wastewater volumes equal to or less than the volume upon which pollutant discharge limitations are based.

To confirm the reasonableness of these limitations, the Agency compared them with actual results at zinc subcategory plants. Since plants presently discharge wastewaters from various battery process elements, and BPT is a single end-of-pipe treatment, this comparison is best made on a total plant rather than a process element basis. This was accomplished by calculating total wastewater discharge flow rates for each plant in the subcategory based on available production information and the normalized process element flows shown in Table IX-33. These flow rates were then compared to calculated effluent flow rates actually reported or measured. Effluent concentrations were also compared with those attainable by lime and settle technology as presented in Table VII-21. Finally, total plant 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.

Zinc subcategory process wastewater flow from each plant was compared with the calculated flow upon which pollutant discharge limitations for the plant would be based. In order to minimize the effects of irregular operating schedules for some process operations, this comparison was made on the basis of annual flows. To calculate the actual annual process wastewater discharge flows, the discharge flow rate (l/hr) from each process element was multiplied by the hours of production activity in the process element, and the resultant process element annual discharge flows were summed to determine the plant total. In some cases, process element flow rates were not available, and reported total process wastewater flows or estimated flows for specific process elements were used. Production information from each plant was used to determine a calculated BPT flow for comparison to the actual values. The total annual production (in terms of pnp) for each process element was determined and multiplied by the normalized flow shown for the process element in Table IX-33 to determine this BPT flow for the process element at the plant. Flows for each process element were summed to obtain a total plant BPT flow. Table IX-51 (page 808) presents a comparision of the actual and BPT calculated flows for each zinc subcategory plant.

As shown in Table IX-51 eight of sixteen zinc subcategory plants were found to produce process wastewater discharge equal to or less than those upon which BPT pollutant discharge limitations would be based. In addition, five of the remaining eight plants had flows less than two times the BPT flow. The achievement of BPT flows in present practice at the plants in the subcategory confirms the thesis that the flow basis for BPT limitations is reasonable and reflects control techniques widely practiced in the subcategory at the present time.

Treatment reported to be applied to zinc subcategory process wastewaters and summarized in Table V-119 (page 385) shows that present treatment practice in the subcategory is highly diverse. Many of the technologies practiced (e.g., amalgamation and carbon adsorption) are aimed specifically at the removal of mercury. Effluent data and on-site observations at plants in the zinc subcategory (discussed in Section V) reveal that most of the technologies employed are not effectively applied for the reduction of pollutant discharges. In some cases, such as amalgamation, this is due to the inherent limitations of the technologies employed. In other cases, such as sulfide precipitation, failure to achieve effective pollutant removal results from specific design, operation, and maintenance factors at the plants employing the technologies. Despite these adverse factors and observations, plants in this subcategory can comply with the limitations achieved by lime and settle, the selected BPT technology.

Present treatment and control practices in the zinc subcategory are not only diverse, but are uniformly inadequate either in their design or in their operation and maintenance (See Section V discussion). Consequently, a treatment technology is selected which can be related uniformly to the subcategory. The simplest treatment system technology (lime and settle), and its demonstrated effectiveness, is transferred from other industrial categories with similar waste characteristics (toxic metals, oil and grease, and TSS). By re-evaluating all the flow and effluent data collected based on the selected BPT equivalent technology flows and lime and settle treatment effectiveness, eight plants in the subcategory meet the flows and can readily comply with the mass limitations with some or no treatment modification to their existing treatment systems. Of these eight plants, two plants comply by having no process wastewater flows; one plant can comply by segregating nonprocess wastewater streams; four plants can comply by providing adequate maintenance (adequate solids removal) and control (pH monitoring) of existing waste treatment facilities; and the eighth plant can comply by upgrading design and properly maintaining the existing waste treatment system. The remaining eight plants, in addition to evaluating existing treatment, would have to improve control of process wastewater flow rates by implementing flow normalization to comply with BPT mass limitations.

If the application of BPT technology at specific plants does not result in effluent concentrations sufficiently low to meet mass discharge limitations, there are other available treatment alternatives, such as sulfide precipitation, carbonate precipitation and ferrite co-precipitation, especially for mercury removal (see Section VII, page 495) which could achieve lower effluent concentrations than hydroxide precipitation. Another way of meeting the mass discharge limits is to reduce the discharge flow either through process modification, in-process controls or reuse of water.

Pollutant Removals and Costs

In the establishment of BPT, the cost of application of technology must be considered in relation to the pollutant reduction benefits from such application. The quantity of pollutants removed by BPT treatment are displayed in Table X-38 (page 889) and for direct dischargers in Table X-39 (page 890). Total treatment costs are displayed in Table X-56 (page 907). The capital cost of BPT treatment as an increment above the cost of in place treatment equipment is estimated to be $308,768 ($50294 for direct dischargers) for the zinc subcategory. Annual cost of lime and settle technology for the zinc subcategory is estimated to be $102,462 ($18219 for direct dischargers). The quantity of pollutants removed by the BPT system for this subcategory is estimated to be 9,887 kg/yr (2,274 for direct dischargers) including 5,572 kg/yr (1,282 for direct dischargers) of toxic metals. The pollutant reduction benefit is worth the dollar cost of required BPT.

APPLICATION OF REGULATION 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 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.

Example. Plant Y manufactures nickel cadmium batteries using pressed powder anodes and nickel impregnated cathodes. The plant operates for 250 days during the year. The plant uses 55,800 kg cadmium/yr in anode manufacture; 61,300 kg nickel/yr in cathode manufacture; and produces 404,000 kg/yr of finished cells.

Table IX-52 (page 809) illustrates the calculation of the allowable daily discharge of cadmium.

TABLE IX-1

FLOW BASIS FOR BPT MASS DISCHARGE LIMITATIONS - CADMIUM SUBCATEGORY

Process Element	BPT Flow (l/kg)	Mean Normalized Discharge Flow (l/kg)
Anodes		
Pasted & Pressed Powder	2.7	2.7
Electrodeposited	697.0	697.0
Impregnated	998.0	998.0
Cathodes		
Nickel Electrodeposited	569.0	569.0
Nickel Impregnated	1640.0	1640.0
Ancillary Operations		
Cell Wash	4.93	4.93
Electrolyte Preparation	0.08	0.08
Floor and Equipment Wash	12.0	12.0
Employee Wash	1.5	1.5
Cadmium Powder Production	65.7	65.7
Silver Powder Production	21.2	21.2
Cadmium Hydroxide Production	0.9	0.9
Nickel Hydroxide Production	110.0	110.0

TABLE IX-2

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Pasted and Pressed Powder Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	0.92	0.41
Chromium	1.19	0.49
Cyanide	0.78	0.32
Lead	1.13	0.54
Mercury	0.68	0.27
*Nickel	5.18	3.43
Silver	1.11	0.46
*Zinc	3.94	1.65
*Cobalt	0.57	0.24
*Oil and Grease	54.0	32.4
*TSS	111.0	52.65
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-3

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	237.0	104.6
Chromium	306.7	125.5
Cyanide	202.1	83.6
Lead	292.7	139.4
Mercury	174.3	69.7
*Nickel	1338.2	885.2
Silver	285.8	118.5
*Zinc	1017.6	425.2
*Cobalt	146.4	62.7
*Oil and Grease	13940.0	8364.0
*TSS	28577.0	13592.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-4

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Impregnated Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	339.3	149.7
Chromium	439.1	179.6
Cyanide	289.4	119.8
Lead	419.2	199.6
Mercury	249.5	99.8
*Nickel	1916.2	1267.5
Silver	409.2	169.7
*Zinc	1457.1	608.8
*Cobalt	209.6	89.8
*Oil and Grease	19960.0	11976.0
*TSS	40918.0	19461.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-5

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Nickel Electrodeposited Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	193.5	85.4
Chromium	250.4	102.4
Cyanide	165.0	68.3
Lead	239.0	113.8
Mercury	142.3	56.9
*Nickel	1092.5	722.6
Silver	233.3	96.7
*Zinc	830.7	347.1
*Cobalt	119.5	51.2
*Oil and Grease	11380.0	6828.0
*TSS	23329.0	11095.5
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-6

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Nickel Impregnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	557.6	246.0
Chromium	721.6	295.2
Cyanide	475.6	196.8
Lead	688.8	328.0
Mercury	410.0	164.0
*Nickel	3148.8	2082.8
Silver	672.4	278.8
*Zinc	2394.4	1000.4
*Cobalt	344.4	147.6
*Oil and grease	32800.0	19680.0
*TSS	67240.0	31980.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-7

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	1.68	0.74
Chromium	2.17	0.89
Cyanide	1.43	0.59
Lead	2.07	0.99
Mercury	1.23	0.49
*Nickel	9.47	6.26
Silver	2.02	0.84
*Zinc	7.20	3.01
*Cobalt	1.04	0.44
*Oil and Grease	98.6	59.2
*TSS	202.1	96.1
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-8

CADMIUM SUBCATEGORY BPT EFFLUENT LIMITATIONS

Electrolyte Preparation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.027	0.012
Chromium	0.035	0.014
Cyanide	0.023	0.009
Lead	0.033	0.016
Mercury	0.020	0.008
*Nickel	0.153	0.101
Silver	0.032	0.013
*Zinc	0.116	0.048
*Cobalt	0.016	0.007
*Oil and Grease	1.60	0.960
*TSS	3.28	1.56
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-9

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cell produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	4.08	1.80
Chromium	5.28	2.16
Cyanide	3.48	1.44
Lead	5.04	2.40
Mercury	3.00	1.20
*Nickel	23.1	15.2
Silver	4.92	2.04
*Zinc	17.5	7.32
*Cobalt	2.52	1.08
*Oil and Grease	240.0	144.0
*TSS	492.0	234.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-10

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.510	0.225
Chromium	0.660	0.270
Cyanide	0.435	0.180
Lead	0.630	0.300
Mercury	0.375	0.150
*Nickel	2.88	1.91
Silver	0.615	0.255
*Zinc	2.19	0.915
*Cobalt	0.315	0.135
*Oil and Grease	30.0	18.0
*TSS	61.5	29.3
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-11

CADMIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	6.29	2.77
Chromium	8.14	3.33
Cyanide	5.37	2.22
Lead	7.77	3.70
Mercury	4.63	1.85
*Nickel	35.54	23.50
Silver	7.59	3.15
*Zinc	27.02	11.29
*Cobalt	3.89	1.66
*Oil and Grease	370.20	222.12
*TSS	758.91	360.94
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-12

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Cadmium Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
*Cadmium	22.34	9.86
Chromium	28.91	11.83
Cyanide	19.05	7.88
Lead	27.59	13.14
Mercury	16.43	6.57
*Nickel	126.14	83.44
Silver	26.94	11.17
*Zinc	95.92	40.08
*Cobalt	13.80	5.91
*Oil and Grease	1314.0	788.4
*TSS	2693.0	1281.2
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-13

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
*Cadmium	7.21	3.18
Chromium	9.33	3.82
Cyanide	6.15	2.54
Lead	8.91	4.24
Mercury	5.30	2.12
*Nickel	40.70	26.92
*Silver	8.69	3.61
*Zinc	30.95	12.93
*Cobalt	4.45	1.91
*Oil and Grease	424.0	254.4
*TSS	869.2	413.4
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-14

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Cadmium Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
*Cadmium	0.31	0.14
Chromium	0.40	0.16
Cyanide	0.26	0.11
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
*Cobalt	0.19	0.08
*Oil and Grease	18.0	10.8
*TSS	36.9	17.6
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-15

CADMIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Nickel Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used English Units - lb/1,000,000 lb of nickel used		
*Cadmium	37.4	16.5
Chromium	48.4	19.8
Cyanide	31.9	13.2
Lead	46.2	22.0
Mercury	27.5	11.0
*Nickel	211.2	139.7
Silver	45.1	18.7
*Zinc	160.6	67.1
*Cobalt	23.1	9.9
*Oil and Grease	2200.0	1320.0
*TSS	4510.0	2145.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-16

COMPARISON OF ACTUAL TO BPT ANNUAL FLOW AT CADMIUM SUBCATEGORY PLANTS

Plant ID	Actual Flow (l/yr) (10^6)	BPT Annual Flow (l/yr) (10^6)
A	0.17	0.909 1/
B	3.0	1.44
C	156.0	153.0
D	13.5	102.0 1/
E	48.1	189.0
F	321.0	315.0
G	0.0	0.188
H	10.5	10.6
I	50.5	59.0
J	0.0	<.00005
K	1.72	1.34
L	22.1	39.9
M	0.0	2/

1/ No longer active in the cadmium subcategory

2/ Since actual flow rate was zero, and plant is now closed, the calculation of BPT annual flow is insignificant.

TABLE IX-17

FLOW BASIS FOR BPT MASS DISCHARGE LIMITATIONS - CALCIUM SUBCATEGORY

Process Element	BPT Flow (l/kg)	Mean Normalized Discharge Flow (l/kg)
Ancillary Operations		
Heat Paper Production	24.1	115.4
Cell Testing	0.014	0.014

TABLE IX-18

CALCIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Heat Paper Production and Cell Testing

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of reactants English Units - lb/1,000,000 lb of reactants		
Chromium	10.61	4.34
TSS	988.7	470.2
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-19

LECLANCHE SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Foliar Battery Miscellaneous Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.092	0.038
Cadmium	0.013	0.005
Chromium	0.024	0.010
Copper	0.084	0.040
Lead	0.018	0.009
Mercury	0.010	0.004
Nickel	0.036	0.024
Selenium	0.054	0.024
Zinc	0.067	0.030
Manganese	0.019	0.015
Oil and Grease	0.66	0.66
TSS	0.99	0.79
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-20

FLOW BASIS FOR BPT MASS DISCHARGE LIMITATIONS - LITHIUM SUBCATEGORY

Process Element	BPT FLOW (l/kg)	Mean Normalized Discharge Flow (l/kg)
Cathodes		
Iron Disulfide	7.54	7.54
Lead Iodide	63.08	63.08
Ancillary Operation		
Heat Paper Production	24.1 1/	115.4
Lithium Scrap Disposal	*	*
Cell Testing	0.014 1/	0.014
Cell Wash	0.0	0.929
Air Scrubbers	10.59	10.59
Floor and Equipment Wash	0.094 2/	0.094

* Cannot be calculated at present time.

1/ Same as for calcium subcategory

2/ Same as for magnesium subcategory

TABLE IX-21

LITHIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Iron Disulfide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of iron disulfide English Units - lb/1,000,000 lb iron disulfide		
Chromium	3.32	1.36
Lead	3.17	1.51
Zinc	11.01	4.60
Cobalt	1.58	0.68
Iron	9.05	4.60
TSS	309.1	147.0
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-22

LITHIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Lead Iodide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead English Units - lb/1,000,000 lb of lead		
Chromium	27.8	11.4
Lead	26.5	12.6
Zinc	92.1	38.5
Cobalt	13.3	5.68
Iron	75.7	38.5
TSS	2586.3	1230.1
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-23

LITHIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Heat Paper Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of reactants English Units - lb/1,000,000 lb of reactants		
Chromium	10.6	4.34
Lead	10.1	4.82
Zinc	35.2	14.7
Cobalt	5.06	2.17
Iron	28.9	14.7
TSS	988.1	470.0
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-24

LITHIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.047	0.019
Lead	0.045	0.021
Zinc	0.16	0.065
Cobalt	0.022	0.009
Iron	0.13	0.065
TSS	4.43	2.11
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-25

LITHIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Air Scrubbers

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	4.66	1.91
Lead	4.45	2.12
Zinc	15.46	6.46
Cobalt	2.22	0.95
Iron	12.71	6.46
TSS	434.2	206.5
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-26

FLOWS BASIS FOR BPT MASS DISCHARGE LIMITATIONS - MAGNESIUM SUBCATEGORY

Process Element	Mean Normalized Discharge (l/kg)	BPT Flow (l/kg)
Cathodes		
Silver Chloride-Chemically Reduced	4915.0	2458.0
Silver Chloride-Electrolytic Oxidation	145.0	145.0
Ancillary Operations		
Air Scrubbers	206.5	206.5
Cell Testing	52.6	52.6
Floor and Equipment Wash	0.094	0.094
Heat Paper Production	115.4 1/	24.1 1/

1/ Same as for calcium subcategory

TABLE IX-27

MAGNESIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Chloride Cathodes - Chemically Reduced

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	1081.5	442.4
Lead	1032.4	491.6
Nickel	4719.4	3121.7
Silver	1007.8	417.9
Iron	2949.6	1499.4
TSS	100700.0	47931.0
COD	122900.0	59975.0
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-28

MAGNESIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Chloride Cathodes - Electrolytic

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	63.8	26.1
Lead	60.9	29.0
Nickel	278.4	184.2
Silver	59.5	24.7
Iron	174.0	88.5
TSS	5945.0	2828.0
COD	7250.0	3538.0
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-29

MAGNESIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.041	0.016
Lead	0.039	0.018
Nickel	0.180	0.119
Silver	0.038	0.015
Iron	0.112	0.057
TSS	3.85	1.83
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-30

MAFNESIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Cell Testing

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	23.2	9.47
Lead	22.1	10.5
Nickel	101.0	66.8
Silver	21.6	8.94
Iron	63.1	32.1
TSS	2157.0	1026.0
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-31

MAGNESIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Heat Paper Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of reactants English Units - lb/1,000,000 lb of reactants		
Chromium	10.6	4.34
Lead	10.1	4.82
Nickel	46.3	30.6
Silver	9.88	4.10
Iron	29.9	14.7
TSS	988.1	470.0
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-32

MAGNESIUM SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Air Scrubbers

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced		
English Units - lb/1,000,000 lb of cells produced		
Chromium	90.9	37.2
Lead	86.7	41.3
Nickel	396.5	262.3
Silver	84.7	35.1
Iron	247.8	126.0
TSS	8467.0	4027.0
pH	Within the range of 7.5 - 10.0 at all times	

TABLE IX-33

FLOWS BASIS FOR BPT MASS DISCHARGE LIMITATIONS - ZINC SUBCATEGORY

Process Element	BPT Flow (l/kg)	Mean Normalized Flow (l/kg)
Anodes		
Zinc Powder-Wet Amalgamated	3.8	3.8
Zinc Powder-Gelled Amalgam	0.68	0.68
Zinc Oxide Powder-Pasted or Pressed, Reduced (Zinc Oxide, Formed)	143.0	143.0
Zinc Electrodeposited	3190.0	3190.0
Cathodes		
Silver Powder Pressed and Electrolytically Oxidized (Silver Powder, Formed)	196.0	196.0
Silver Oxide Powder-Thermally Reduced or Sintered, Electrolytically formed (Silver Oxide Powder, Formed)	131.0	131.0
Silver Peroxide Powder	31.4	31.4
Nickel Impregnated	1640.0	1640.0
Ancillary Operations		
Cell Wash	1.13	1.13
Electrolyte Preparation	0.12	0.12
Silver Etch	49.1	49.1
Mandatory Employee Wash	0.27	0.27
Reject Cell Handling	0.01	0.01
Floor and Equipment Wash	7.23	7.23
Silver Peroxide Production	52.2	52.2
Silver Powder Production	21.2	21.2

TABLE IX-34

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Wet Amalgamated Powder Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	10.9	4.86
Cadmium	1.29	0.57
*Chromium	1.67	0.68
Copper	7.22	3.80
Lead	1.60	0.76
*Mercury	0.95	0.38
Nickel	7.30	4.83
Selenium	4.67	2.09
*Silver	1.56	0.65
*Zinc	5.55	2.32
Aluminum	24.4	12.2
Iron	4.56	2.32
*Manganese	2.58	1.10
*Oil and Grease	76.0	45.6
*TSS	155.8	74.1
*pH	Within the range 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-35

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Gelled Amalgam Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc		
English Units - lb/1,000,000 lb of zinc		
Arsenic	1.95	0.87
Cadmium	0.23	0.10
*Chromium	0.30	0.12
Copper	1.29	0.68
Lead	0.29	0.14
*Mercury	0.17	0.07
Nickel	1.31	0.86
Selenium	0.84	0.37
*Silver	0.28	0.12
*Zinc	0.99	0.42
Aluminum	4.37	2.18
Iron	0.82	0.42
*Manganese	0.46	0.20
*Oil and Grease	13.6	8.16
*TSS	27.9	13.26
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-36

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Zinc Oxide Anodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	410.4	183.1
Cadmium	48.6	21.5
*Chromium	62.9	25.7
Copper	271.7	143.0
Lead	60.1	28.6
*Mercury	35.8	14.3
Nickel	274.6	181.6
Selenium	175.9	78.7
*Silver	58.7	24.3
*Zinc	208.8	87.2
Aluminum	919.5	457.6
Iron	171.6	87.2
*Manganese	208.8	87.2
*Oil and Grease	2860.0	1716.0
*TSS	5863.0	2789.0
*pH	Within the range 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-37

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Arsenic	9155.0	4083.0
Cadmium	1085.0	478.5
*Chromium	1404.0	574.0
Copper	6061.0	3190.0
Lead	1340.0	638.0
*Mercury	798.0	319.0
Nickel	6125.0	4051.0
Selenium	3924.0	1755.0
*Silver	1308.0	543.0
*Zinc	4657.0	1946.0
Aluminum	20510.0	10208.0
Iron	3828.0	1946.0
*Manganese	2169.0	925.0
*Oil and Grease	63800.0	38280.0
*TSS	130700.00	62210.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-38

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Powder Cathodes,Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	562.5	250.9
Cadmium	66.7	29.4
*Chromium	86.2	35.3
Copper	372.4	196.0
Lead	82.3	39.2
*Mercury	49.0	19.6
Nickel	376.3	248.9
Selenium	241.1	107.8
*Silver	80.4	33.3
*Zinc	286.2	119.6
Aluminum	1260.0	627.2
Iron	235.2	119.6
*Manganese	133.3	56.8
*Oil and Grease	3920.0	2350.0
*TSS	8036.0	3822.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-39

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Oxide Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	376.0	167.7
Cadmium	44.6	19.7
*Chromium	57.7	23.6
Copper	248.9	131.0
Lead	55.0	26.2
*Mercury	32.8	13.1
Nickel	251.5	166.4
Selenium	161.1	72.1
*Silver	53.7	22.3
*Zinc	191.3	79.9
Aluminum	842.3	419.2
Iron	157.2	79.9
*Manganese	89.1	38.0
*Oil and Grease	2620.0	1570.0
*TSS	5370.0	2554.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-40

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Peroxide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	90.1	40.2
Cadmium	10.7	4.71
*Chromium	13.8	5.65
Copper	59.7	31.4
Lead	13.2	6.28
*Mercury	7.85	3.14
Nickel	60.3	39.9
Selenium	38.6	17.3
*Silver	12.9	5.34
*Zinc	45.8	19.2
Aluminum	202.0	101.0
Iron	37.7	19.2
*Manganese	21.4	9.11
*Oil and Grease	628.0	377.0
*TSS	1287.0	612.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-41

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Nickel Impregnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Arsenic	4707.0	2099.0
Cadmium	557.6	246.0
*Chromium	721.6	295.2
Copper	3116.0	1640.0
Lead	688.8	328.0
*Mercury	410.0	164.0
*Nickel	3149.0	2083.0
Selenium	2017.0	902.0
*Silver	672.4	279.0
*Zinc	2394.4	1000.4
Aluminum	10545.0	5248.0
Iron	1968.0	1001.0
*Manganese	1115.2	475.6
*Oil and Grease	32800.0	19680.0
*TSS	67240.0	31980.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-42

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	3.24	1.45
Cadmium	0.38	0.17
*Chromium	0.50	0.20
Copper	2.15	1.13
*Cyanide	0.33	0.14
Lead	0.48	0.23
*Mercury	0.28	0.11
*Nickel	2.17	1.44
Selenium	1.39	0.62
*Silver	0.46	0.19
*Zinc	1.65	0.69
Aluminum	7.27	3.62
Iron	1.36	0.69
*Manganese	0.77	0.33
*Oil and Grease	22.6	13.6
*TSS	46.3	22.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-43

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Electrolyte Preparation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.344	0.153
Cadmium	0.040	0.018
*Chromium	0.052	0.021
Copper	0.228	0.120
*Cyanide	0.035	0.015
Lead	0.050	0.024
*Mercury	0.030	0.012
*Nickel	0.230	0.152
Selenium	0.147	0.066
*Silver	0.049	0.020
*Zinc	0.175	0.073
Aluminum	0.771	0.384
Iron	0.144	0.073
*Manganese	0.081	0.034
*Oil and Grease	2.40	1.44
*TSS	4.92	2.34
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-44

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Etch

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Arsenic	141.0	62.9
Cadmium	16.7	7.37
*Chromium	21.6	8.84
Copper	93.3	49.1
Lead	20.6	9.82
*Mercury	12.3	4.91
Nickel	94.3	62.4
Selenium	60.4	27.0
*Silver	20.2	8.35
*Zinc	71.7	30.0
Aluminum	315.7	157.1
Iron	58.9	30.0
*Manganese	33.4	14.3
*Oil and Grease	982.0	589.2
*TSS	2013.1	957.5
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-45

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Arsenic	0.774	0.345
Cadmium	0.091	0.040
*Chromium	0.118	0.048
Copper	0.513	0.270
*Cyanide	0.078	0.033
Lead	0.113	0.054
*Mercury	0.067	0.027
*Nickel	0.518	0.342
Selenium	0.332	0.148
*Silver	0.110	0.045
*Zinc	0.394	0.164
Aluminum	1.74	0.864
Iron	0.324	0.164
*Manganese	0.183	0.078
*Oil and Grease	5.40	3:24
*TSS	11.1	5.27
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-46

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Reject Cell Handling

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Arsenic	0.028	0.012
Cadmium	0.003	0.001
*Chromium	0.004	0.001
Copper	0.019	0.010
*Cyanide	0.003	0.001
Lead	0.004	0.002
*Mercury	0.002	0.001
*Nickel	0.019	0.012
Selenium	0.012	0.005
*Silver	0.004	0.001
*Zinc	0.014	0.006
Aluminum	0.064	0.032
Iron	0.012	0.006
*Manganese	0.006	0.002
*Oil and Grease	0.200	0.120
*TSS	0.416	0.195
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-47

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	20.8	9.26
Cadmium	2.46	1.09
*Chromium	3.18	1.30
Copper	13.7	7.23
*Cyanide	2.10	0.87
Lead	3.04	1.45
*Mercury	1.81	0.72
*Nickel	13.9	9.18
Selenium	8.89	3.98
*Silver	2.96	1.23
*Zinc	10.6	4.41
Aluminum	46.5	23.1
Iron	8.68	4.41
*Manganese	4.92	2.10
*Oil and Grease	145.0	86.8
*TSS	297.0	141.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-48

ZINC 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 cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	25.14	11.21
Cadmium	2.98	1.32
*Chromium	3.85	1.58
Copper	16.65	8.76
*Cyanide	2.54	1.05
Lead	3.68	1.75
*Mercury	2.19	0.88
*Nickel	16.82	11.12
Selenium	10.78	4.82
*Silver	3.59	1.49
*Zinc	12.79	5.34
Aluminum	56.33	28.03
Iron	10.51	5.34
*Manganese	5.96	2.54
*Oil and Grease	175.20	105.12
*TSS	359.16	170.82
*pH	Within the limits of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-49

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Peroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Arsenic	150.0	66.8
Cadminum	17.8	7.83
*Chromium	23.0	9.40
Copper	99.2	52.2
Lead	21.9	10.5
*Mercury	13.1	5.22
Nickel	100.0	66.3
Selenium	64.2	28.7
*Silver	21.4	8.88
*Zinc	76.2	31.8
Aluminum	336.0	167.1
Iron	62.7	31.9
*Manganese	35.5	15.1
*Oil and Grease	1044.0	627.0
*TSS	2140.0	1018.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-50

ZINC SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Arsenic	60.85	27.14
Cadmium	7.21	3.18
*Chromium	9.33	3.82
Copper	40.28	21.20
Lead	8.91	4.24
*Mercury	5.30	2.12
Nickel	40.71	26.93
Selenium	26.08	11.66
*Silver	8.69	3.61
*Zinc	30.95	12.93
Aluminum	136.3	67.84
Iron	25.44	12.93
*Manganese	14.42	6.15
*Oil and Grease	424.0	254.4
*TSS	869.0	413.4
*pH	Within the range 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE IX-51

COMPARISON OF ACTUAL TO BPT ANNUAL FLOW AT ZINC SUBCATEGORY PLANTS

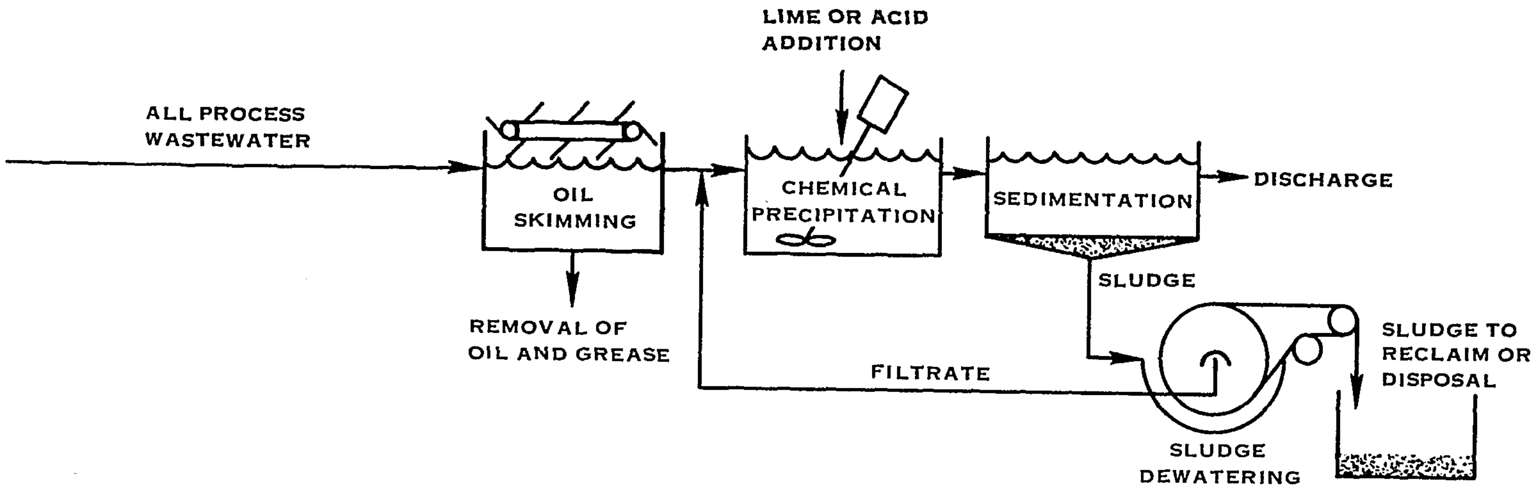
Plant ID	Actual Flow (l/yr) (10^6)	BPT Annual Flow (l/yr) (10^6)
A	1.69	0.826
B	32.5	3.21
C	0.787	0.530
D	39.4	2.94
E	10.6	6.77
F	2.22	12.6
G	15.3	0.184
H	0.266	1.84
I	0.0	0.0
J	0.0032	0.0154
K	10.4	21.0
L	2.70	2.47
M	0.0	0.0
N	4.71	2.71
O	1.14	1.96
P	1.72	3.67

TABLE IX-52
SAMPLE DERIVATION OF THE BPT 1-DAY CADMIUM LIMITATION FOR PLANT Y

Process Elements	PNP	PNP kg/yr	Avg. PNP (kg/day)	1-Day Limits (mg/kg)1/	Cadmium Mass Discharge(mg/day)2/
1. Pasted & Pressed Powder Anode	Wgt. of Cadmium Used	55800	223	0.864	193
2. Nickel Impregnated Cathode	Wgt. of Nickel Applied	61300	245	524.8	128576
3. Electrolyte Preparation	Wgt. of Cells Produced	404000	1616	5.923	9572
4. Floor Equipment Wash					
Total Plant Y Discharge (1-Day Value for Cadmium):					138341 mg/day (0.3 lb/day)

1/ 1/kg values used from Table IX-1 multiplied by lime and settle treatment concentrations (mg/1) from Table VII-20.

2/ Average PNP multiplied by the 1-day limits in Table IX-2, Table IX-6 , and IX-10A.



RECOMMENDED IN-PROCESS TECHNOLOGY:
RECYCLE OR REUSE OF PROCESS SOLUTIONS
SEGREGATION OF NON-CONTACT COOLING WATER FROM PROCESS WATER
CONTROL ELECTROLYTE DRIPS AND SPILLS

FIGURE IX-1. CADMIUM SUBCATEGORY BPT TREATMENT

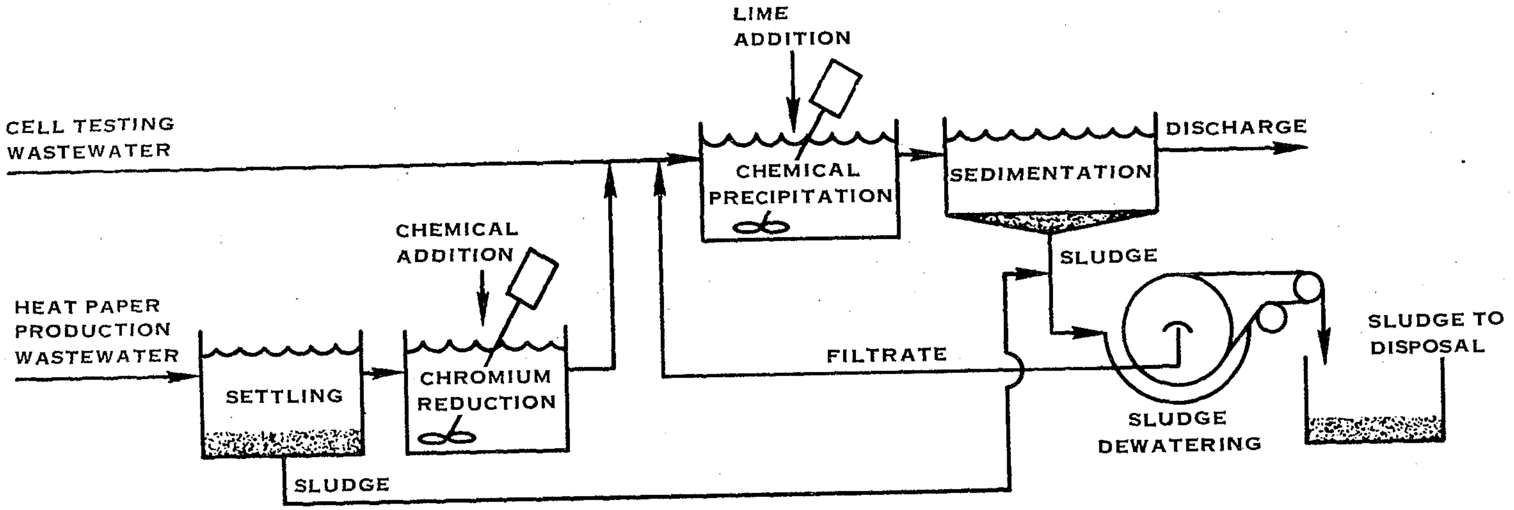
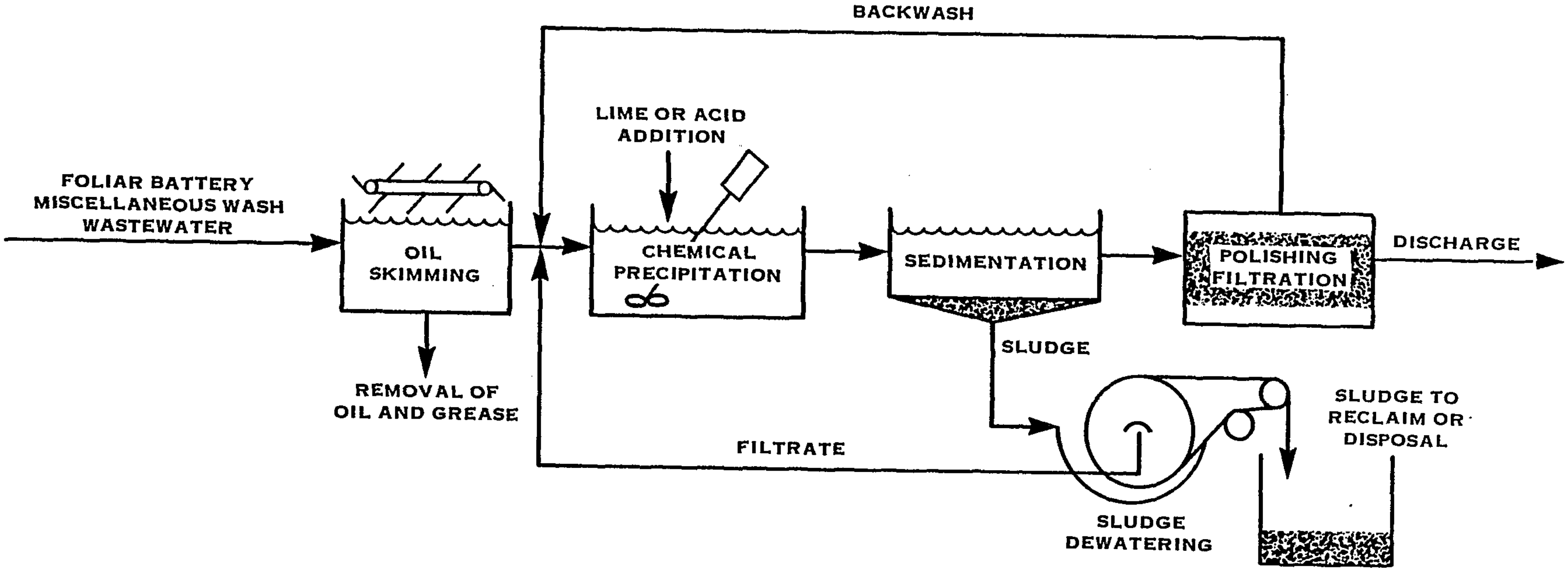


FIGURE IX-2. CALCIUM SUBCATEGORY BPT TREATMENT



OTHER WASTEWATERS: RECYCLE AND REUSE EITHER WITHIN THE PROCESS OR FOLLOWING CHEMICAL PRECIPITATION AND SETTLING END-OF-PIPE TREATMENT.

FIGURE IX-3. LECLANCHE SUBCATEGORY BPT TREATMENT

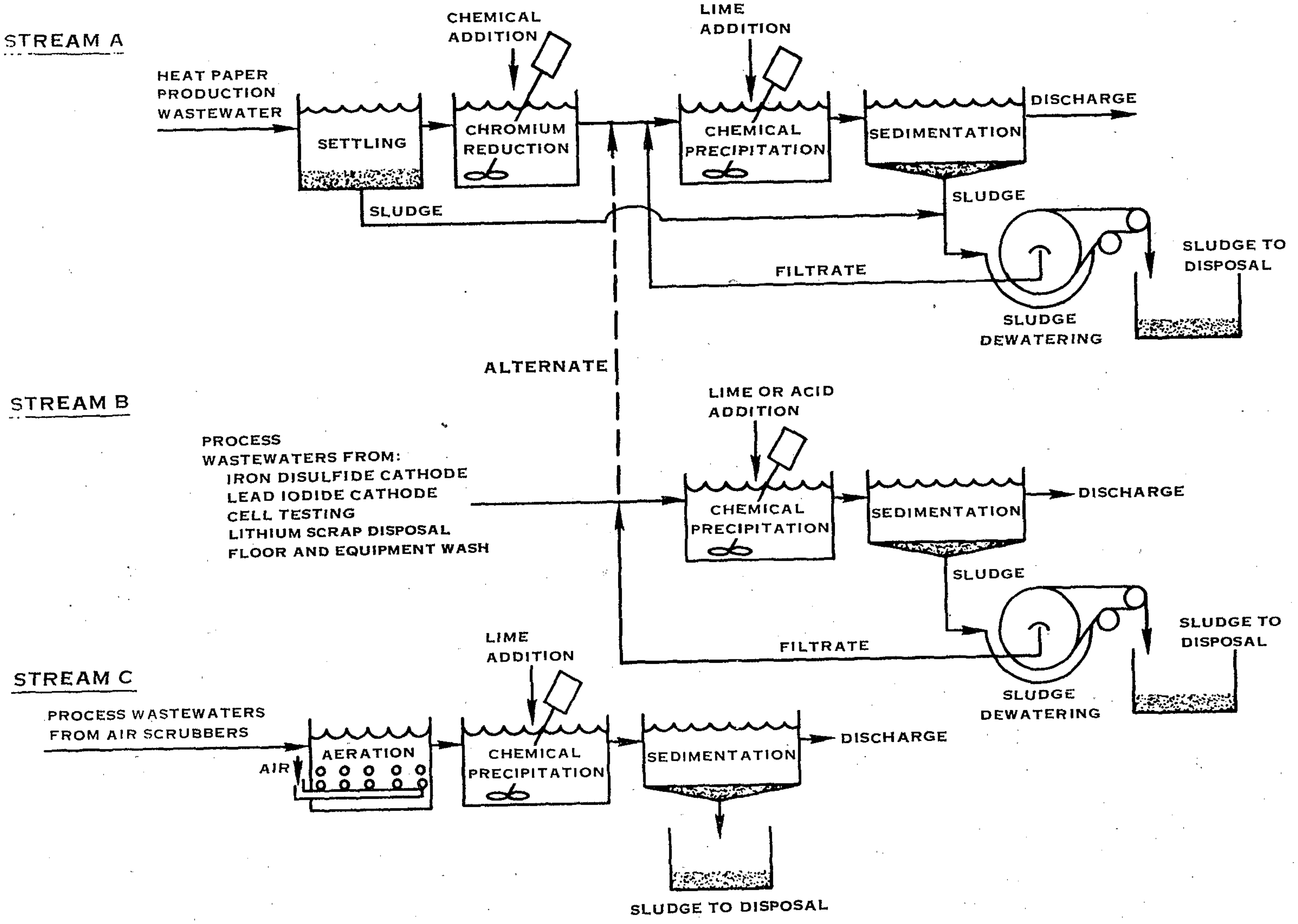


FIGURE IX-4. LITHIUM SUBCATEGORY BPT TREATMENT

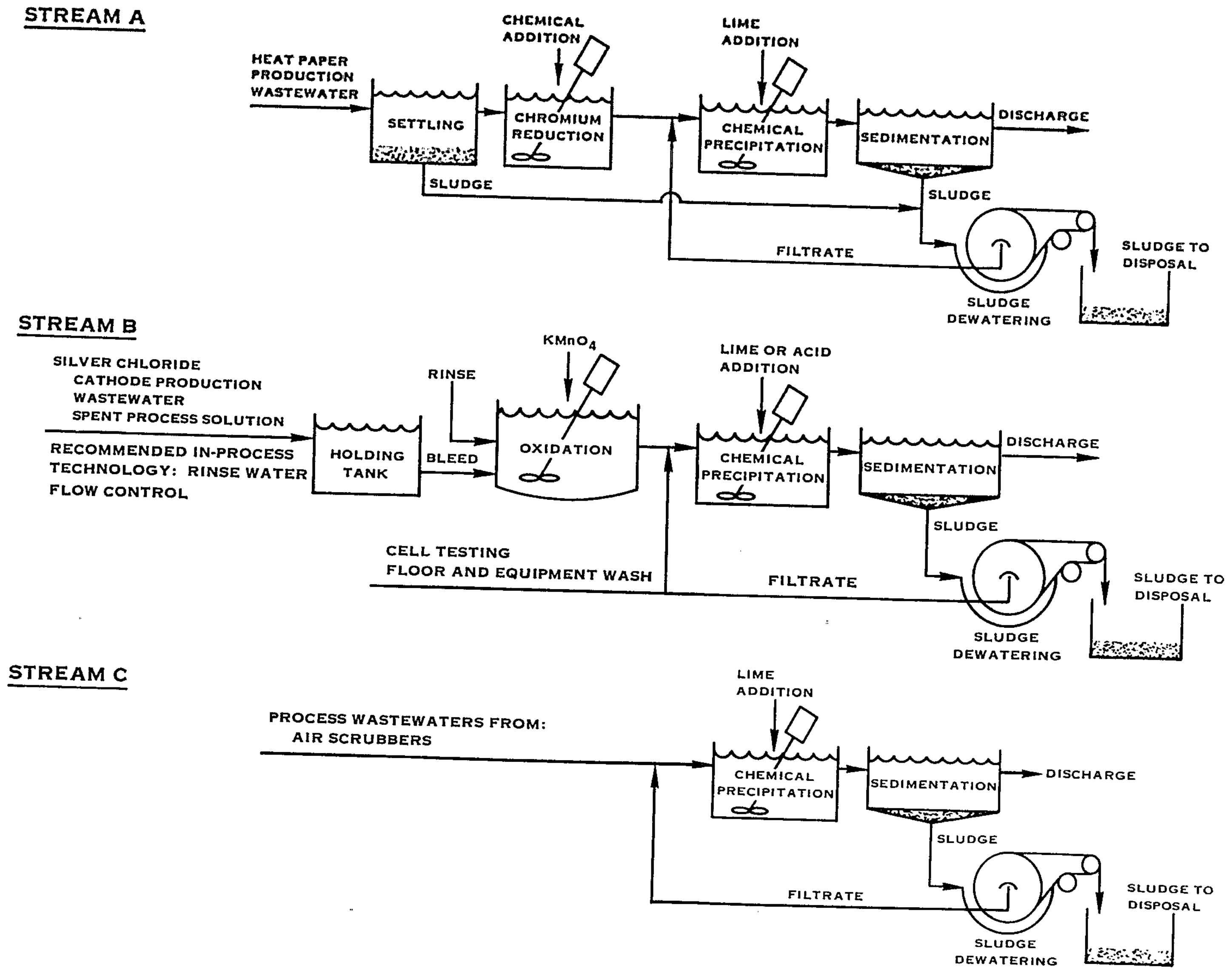
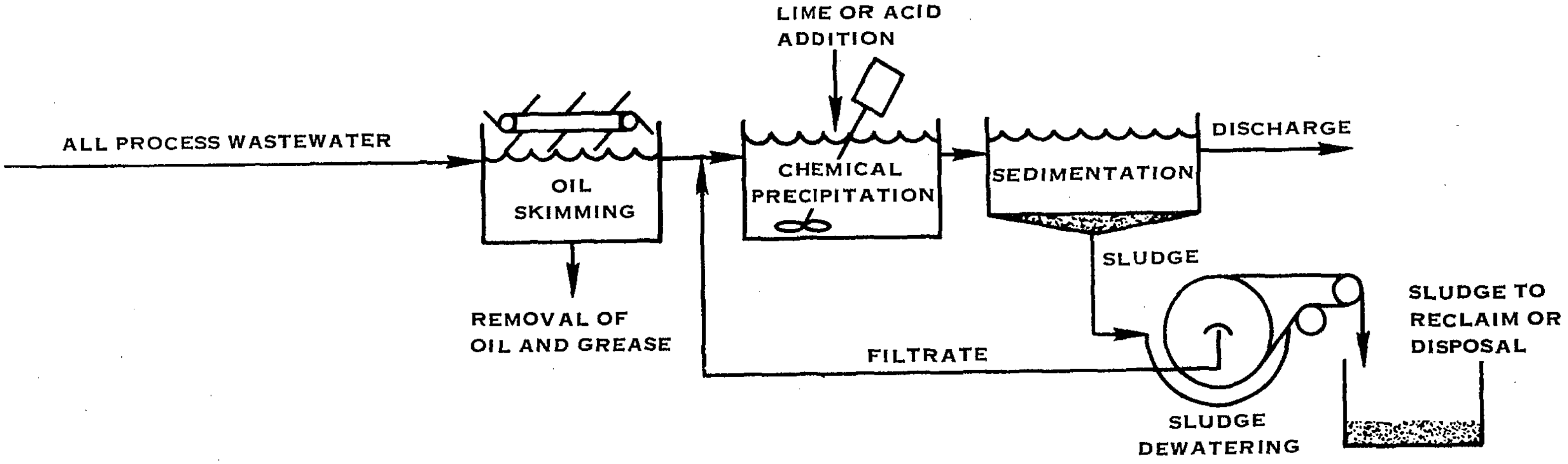


FIGURE IX-5. MAGNESIUM SUBCATEGORY BPT TREATMENT



RECOMMENDED
IN-PROCESS TECHNOLOGY: REUSE OF PROCESS SOLUTIONS
SEGREGATION OF NON-CONTACT COOLING WATER
SEGREGATION OF ORGANIC-BEARING CELL CLEANING WASTEWATER
CONTROL ELECTROLYTE DRIPS AND SPILLS
ELIMINATE CHROMATES IN CELL WASHING
FLOW CONTROLS FOR RINSE WATERS

FIGURE IX-6. ZINC 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 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 plants 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 statuatory 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 each 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 each 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 prior to the final selection of BAT options.

At proposal, generally favorable comments were received on the subcategories included in this volume of the development document. The Leclanche subcategory was reevaluated after receiving comments on foliar battery production.

As discussed in Section IX treatment technology options are described in detail for all subcategories even though there may be no direct discharge plants in that subcategory. In general, three levels of treatment technologies, or options, were evaluated for each subcategory. The technology options considered build on BPT (also referred to as option 0, as described in Section IX), generally providing improved in-process control to reduce or eliminate wastewater and improved end-of-pipe treatment to reduce the pollutant concentration in treated wastewaters. For one subcategory, the selected technology option provides for no discharge of process wastewater pollutants from all process elements. Other subcategory selected options provide reduced pollutant discharge by reducing both the volume of process wastewater and the concentrations of pollutants, and may include the elimination of wastewater discharge from specific process elements. The wastewater treatment technology options considered vary among subcategories. This variation stems from differences in wastewater flow and process characteristics. As a general case - with variations already noted in each subcategory - BPT (option 0) relied upon lime and settle technology applied to the average flow from each manufacturing process element. The BAT options build upon this base using greater wastewater flow reduction gained from in-process controls; lime, settle and filter technology to reduce effluent concentrations of pollutants; augmented filtration; and increased recycle to achieve lower discharge levels of toxic and other pollutants. Waste segregation and separate treatment are also considered where recycle can be substantially improved or where separate treatment has other obvious environmental benefits.

REGULATED POLLUTANT PARAMETERS

The toxic pollutants listed in Tables VI-1 and VI-2 (pages 488 and 493) for regulatory consideration were used to select the specific pollutants regulated in each subcategory. The selection of toxic pollutants for regulation was based primarily upon the presence of the pollutant at high concentrations throughout a subcategory and secondly on the pollutant concentrations in specific process elements. 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 a indicator, but are generally considered under BCT. In the limitation tables all the pollutants which were considered for regulation are listed and those selected for regulation are *'d.

CADMIUM SUBCATEGORY

EPA has considered four technology options for the cadmium subcategory. The first three build upon BPT (option 0) and represent incremental improvements in pollutant discharge reduction from the lime and settle technology level. The fourth, based on a system recently implemented at one cadmium subcategory plant, provides no discharge of process wastewater pollutants.

BAT Options Summary

Option 0 for this subcategory (Figure IX-1, Page 810) consists of the following technology:

a) In-process technology:
  - recycle or reuse of process solutions
  - segregation of noncontact cooling water
  - control of electrolyte drips and spills

b) End-of-pipe treatment:
  - oil skimming
  - chemical precipitation
  - sedimentation
  - sludge dewatering

Option 1 (Figure X-1, page 908) includes all aspects of option 0 and builds on it by adding the following:

a) In-process technology:
  - recycle or reuse pasted and pressed powder anode wastewater
  - use dry methods to clean floors and equipment

- control rinse flow rates
- recirculate water in air scrubbers
- dry clean impregnated electrodes
- reduce cell wash water use
- apply countercurrent rinse to silver powder and cadmium powder
- apply countercurrent rinse for sintered and electrodeposited anodes and cathodes

b) End-of-pipe treatment remains unchanged from option 0.

Option 2 (Figure X-2, page 909) builds on and includes all of the technology and treatment of option 1:

a) In-process technology is identical to option 1.
b) End-of-pipe treatment in addition to option 1:
    - polishing filtration (mixed media)

Option 3 (Figure X-3, page 910) is based on further improvement in both in-process control and end-of-pipe treatment.

a) In-process technology:
    - continue all option 1 in-process technology
    - reduce rework of cadmium powder
b) End-of-pipe treatment:
    - oil skimming
    - chemical precipitation
    - filtration
    - reverse osmosis (alternate, ion exchange) with recycle of permeate
    - chemical precipitation of brine
    - sedimentation
    - polishing filtration (mixed media)
    - sludge dewatering

Option 4 (Figure X-4, page 911) builds on option 3 by improving the treatment of brine or regenerate to achieve no discharge of process wastewater pollutant:

a) In-process technology:
    - continue all in-process technology from option 3
    - eliminate impregnation rinse discharge by recovering used caustic.
b) End-of-pipe treatment:
    - oil skimming
    - chemical precipitation
    - sedimentation
    - filtration
    - sludge dewatering
    - reverse osmosis (alternate, ion exchange) with recycle of permeate

- evaporation with recycle of distillate
- centrifugation of concentrate liquor solids
- landfill dry solids.

Option 1

Option 1 builds on BPT by modifying processes to reduce the amount of wastewater which is generated and must be treated. The in-process technology and its application to specific process elements to achieve the wastewater flow reductions for option 1 are discussed individually.

Countercurrent rinsing is applied for the removal of soluble contaminants from metal powders and from sintered and electrodeposited electrodes. Countercurrent cascade rinsing is most frequently considered as a technique to more efficiently use rinse water in metal finishing. It is equally effective in many battery manufacturing operations. Almost any level of rinsing efficiency can be obtained by providing enough countercurrent cascading steps. In practice, more than ten cascade steps are only rarely seen; two to three are usually adequate. Industrywide, the lowest water use in rinsing sintered plaques is achieved at one plant using three-stage countercurrent cascade rinsing; another achieved a water use reduction of more than an order of magnitude after instituting six-stage countercurrent rinsing. A water reduction ratio of 6.6 is used as a conservative estimate of the benefit of countercurrent cascade rinsing. This can generally be achieved with two or three rinse stages. A theoretical discussion of countercurrent rinsing is included in Section VII.

Controlling rinse flow rates can substantially reduce excess and unnecessary water use. Technology (actually techniques) includes limited or controlled rinse flow, water shut off when not actually being used, proper sizing of rinse tanks to parts being rinsed, and other common sense types of water control.

Pasted and pressed powder anodes generate a small amount of wastewater from tool cleaning, floor washing and related activities. This small volume of wastes can be introduced into the product paste mix after gravity filtering through a paper filter to remove suspended solids. This practice for dealing with small amounts of tool cleaning and related wastes is commonly practiced throughout many battery manufacturing subcategories and is the basis for achieving zero discharge of wastewater pollutants as is required at BAT.

Electrodeposited anodes and electrodeposited cathodes are extensively rinsed and cleaned. Controlling reuse water flow rates to correspond to production rather than allowing excessive flows at low or no production will reduce the mean water use to 232 l/kg for the anodes and 218 l/kg for the cathodes. Applying countercurrent cascade rinsing at a conservative water use reduction will further reduce the water generation by a factor of 6.6 reducing the wastewater generation to 35.15 l/kg for the anodes and 33.0 l/kg for the cathodes.

Impregnated anodes and impregnated cathodes are extensively rinsed and cleaned, and also require extensive air scrubbing of the process area vent gases. Both anode and cathode manufacture have similar manufacturing and water use requirements. When data from both electrodes at BPT is combined and averaged, the normalized flow is 1320 l/kg. Recirculating water to air scrubbers is a widely used mechanism to reduce the amount of water used. Varying degrees of recirculation are frequently used. In-stream treatment to remove unwanted materials often allows air scrubbers to be operated without discharging process wastewaters. Using dry cleaning techniques, recirculating scrubber water, and applying countercurrent cascade rinsing reduces the wastewater from these two process elements to 200 l/kg.

Dry floor and equipment cleaning methods can be used to clean process area floors and equipment. Floor and equipment cleaning methods have been observed to vary from water flushing using high pressure hoses and large quantities of water to dry vacuuming in which no water is used. Even when wet floor and equipment cleaning methods are used, the wastewater can be treated and reused, thereby achieving zero discharge of wastewater pollutants. Applying these techniques will eliminate the generation of floor and equipment wastewater.

Cell wash water reduction can be achieved by using recirculated washing solution and countercurrent cascade rinsing of cells. A conservative water reduction rate of 6.6 is used to reduce wastewater flow to 0.75 l/kg.

Cadmium powder production requires adherence to quality control procedures and also requires substantial washing of the powder to remove impurities. Where observed, quality control was inadequate and water flow control was nonexistent. This production process can be made more efficient by providing adequate quality control, by controlling rinse flows, and by applying countercurrent cascade rinsing. Applying these techniques will reduce the wastewater flow to 6.57 l/kg.

Silver powder, cadmium hydroxide and nickel hydroxide production require substantial washing to remove impurities. This washing process can be made more water efficient by applying countercurrent cascade rinsing. If a conservative water reduction of 6.6 is used the wastewater flows for these elements become 3.21 l/kg, 0.14 l/kg and 16.5 l/kg, respectively.

Reduction in wastewater generation achieved using these in-process technologies are detailed for this and other options in Table X-1 (page 850).

Option 2

Option 2 builds on option 1 and includes all of the in-process technologies and end-of-pipe treatment used in option 1. In addition, a polishing filter of the mixed media type is added to reduce the discharge of toxic metals and incidentally to reduce the discharge of suspended solids.

Option 3

Option 3 generally builds on option 2 with substantial changes in the end-of-pipe treatment. Additional in-process technology is suggested for cadmium powder production to reduce wastewater generation. By using more precise process controls, the amount of off-specification powder produced will be reduced and the reprocessing or rework which is necessary to recover the off-specification powder and the attendent generation of wastewater will also be reduced. Based on sampling and plant visit information from one plant, this will reduce the wastewater flow from cadmium powder production by a factor of 2 from option 1.

End-of-pipe treatment is restructured by using reverse osmosis (or alternatively ion exchange) to recover 85 percent of the wastewater for reuse in the process. Brine (or regenerant) is treated using lime, settle and filtration technology before discharge. Figure X-3 (page 910) details this technology train and the technology performance is detailed in Section VII.

Option 4

Option 4 builds on option 3 by replacing the brine or regenerant treatment system with vapor recompression evaporation and crystalized solids centrifugation. This combination of technologies provides for zero discharge of process wastewater and allows the wastewater pollutants to be disposed as solid waste.

To reduce the hydraulic load on this treatment system (and to provide some economic return) it is suggested that impregnation caustic be recovered and sold or concentrated for reuse in the process. One major producer has converted to this option 4 technology and is achieving zero discharge of process wastewater pollutants.

These options are relatively similar to options depicted in the draft development document. The principal changes are: (1) sulfide precipitation to remove toxic metals has been deleted; (2) flow reduction is considered mainly in option 1; (3) a polishing filter is applied as part of option 2; (4) reverse osmosis has been included as an alternative to ion exchange in option 4; and (5) the option 4 diagram has been simplified to show only major treatment steps.

BAT Option Selection

The four BAT options were carefully evaluated, and the technical merits and disadvantages of each were compared. All of the BAT options are considered to be technologically suitable for cost and performance comparison. All of the options are compatible with the operating requirements of cadmium anode battery manufacturing operations. No comments were received indicating a need to revise the in-process controls applicable to any option. Therefore, selection is based on pollutant removals and economic factors.

The Agency developed quantitative estimates of the total cost and pollutant removal benefits of each technology option. These estimates are based on all available data for each plant in the subcategory. As a first step, an estimate of total raw wastewater pollutant loads and wastewater flows from each manufacturing process element was developed from data presented in Section V. This forms the basis for estimating the mean raw waste used to calculate the pollutant reduction benefits and is shown in Table X-2, (page 851). All plants and process elements in the subcategory are taken into account in this calculation.

Total kg/yr for each pollutant within each process element were summed and divided by the total subcategory flow to obtain a total subcategory mean raw waste concentration. Table X-3 (page 853) displays the pollutant concentrations - both mg/l and mg/kg of total subcategory anode weight for the raw waste and after applying each treatment option. Effluent flow after application of each treatment option was estimated based on wastewater reduction achieved by the option. The mass of pollutant discharged after each treatment option was calculated by using the appropriate mean effluent concentrations for each pollutant shown in Table VII-21 and multiplying them by the treatment option annualized flow. The mass of pollutants discharged after application of treatment was subtracted from the total subcategory raw waste to determine the mass of pollutants removed by each level of control and treatment. The results of these calculations for the total subcategory are shown in Table X-4 (page 854), to display the pollutant reduction of each technology option. Results for direct dischargers only, based on reported flow and production data are shown in Table X-5 (page 855).

An estimate of total annual compliance costs of each technology option for the cadmium subcategory was also prepared and is displayed in Table X-56 (page 907). BAT compliance estimates were developed by estimating costs for each existing direct discharge plant in the subcategory based on reported production and wastewater flows, and summing individual plant costs for each level of treatment and control. Since, the cost estimates for option 4 do not include credits for recovered process materials (cadmium, nickel, and caustic), it is likely that the true costs for this option will be lower than shown. An economic impact analysis based on estimated costs for each treatment and control option at each plant in the subcategory indicates that there are no potential plant closures projected for any option for direct dischargers.

Option 1 is the selected BAT option because limitations are achievable using technologies and practices that are currently in use at plants in the subcategory. Also, the result of implementing this technology is a significant reduction of toxic pollutant discharges. For this option flow is reduced to 102.3 million l/yr for the subcategory and to 73.6 million l/yr for direct dischargers. The annual toxic pollutant removal is 194,149 kg/yr for the subcategory and 139,693 kg/yr for the direct dischargers. For plants to comply direcly with this option, the estimated compliance capital cost is $441,000 for the subcategory ($123,000 for direct dischargers), and annual cost is $147,000 for the subcategory ($38,000 for direct dischargers).

Option 2 was rejected because the technology yields small incremental pollutant removals when compared with option 1. For this option flow is the same as for option 1, but the annual toxic pollutant removal is 194,204 kg/yr for the subcategory and 139,733 kg/yr for the direct dischargers. For plants to comply directly with this option, the estimated compliance capital cost is $563,000 for the subcategory ($147,000 for direct dischargers), and annual cost is $189,000 for the subcategory ($49,000 for direct dischargers).

Options 3 and 4 were rejected because the technology yields small incremental pollutant removals when compared with option 2. The BAT limitations will remove approximately 99.81 percent of current toxic pollutant discharges. Given the results achieved by the technologies used as a basis for the promulgated limitations, further treatment would result only in de minimis, insignificant reductions in annual national discharges. Accordingly, EPA has determined that the total amount of each pollutant in the remaining discharges after compliance with BAT does not justify establishment of a national requirement based on additional end-of-pipe technology.

Regulated Pollutant Parameters

In selecting pollutant parameters for BAT regulation for the cadmium subcategory, all pollutants considered for regulation in Section VI for the subcategory (Table VI-1, page 488) were evaluated. The choice of pollutants selected for regulation was dependent upon the toxicity of the pollutants, their use within the subcategory, and their presence in the raw waste streams at treatable concentrations. The pollutants do not have to appear in every process element or necessarily at high concentrations in the total raw waste streams of the plants which were sampled. Since plants in the cadmium subcategory have a variety of different combinations of process elements, the appearance of a particular pollutant at significant concentrations in a single process element is sufficient reason for selection.

Pollutant parameters regulated at BAT for this subcategory are cadmium, nickel, silver, zinc and cobalt. As discussed in Section IX, silver is regulated for the silver cathode and associated process elements only. Other pollutants 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.

BAT Effluent Limitations

The effluent concentrations attainable through the effectiveness of BAT technology is displayed in Table VII-21 under L&S technology. The BAT mass discharge limitations are calculated by multiplying these concentrations by the applicable BAT flow listed in Table X-1 (page 850). These limitations are expressed in terms of mg of pollutant per kg of production normalizing parameter for each process element and are presented in Tables X-6 to X-17 (pages 856-867). To alleviate some of the monitoring burden, several process elements which occur at most plants and have the same pnp are combined in one table. Table X-13 (page 863) is the combined table for Tables X-10 to X-12. 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.

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 cadmium subcategory plants. By process substitution or in-process controls, cadmium battery manufacturing plants can meet the option 1 flow levels.

The effluent concentrations which are used to calculate BAT mass discharge limitations are based upon the demonstrated performance L&S technology upon waste streams from other industries which have wastewater characteristics similar to those of waste streams in the cadmium subcategory. The details of this performance are documented in Section VII of this document. There are other treatment alternatives available for implementation at existing plants such as sulfide precipitation or iron co-precipitation which are reported to achieve even lower effluent concentrations than those achieved by L&S technology.

CALCIUM SUBCATEGORY

There are no direct dischargers in the calcium subcategory and therefore no BAT regulation is promulgated at this time. However, technology options were analyzed for treating the raw wastewater streams in the subcategory and are discussed here for use in Section XI and XII for pretreatment and new source standards.

Two technology options beyond option 0 were considered for the calcium subcategory. The first provided improved end-of-pipe treatment technology by implementing lime, settle and filter technology. The second included segregation, treatment, and recycle of the major process waste stream (from heat paper production) produced in the subcategory and total reuse or recycle of treated wastewater using the same end-of-pipe system specified for option 1. No significant in-process control technologies were identified for inclusion in these options.

Technology Options Summary

Option 0 for this subcategory (Figure IX-2, page 812) consists of the following technology:

a) In-process technology
   - No water use reduction technology identified
b) End-of-pipe treatment

- Settling
- Chromium reduction
- Chemical precipitation
- Sedimentation
- Sludge dewatering

Option 1 (Figure X-5, page 912) includes all aspects of option 0 and builds on it by adding additional end-of-pipe treatment.

a) In-process technology is identical to option 0.

b) End-of-pipe treatment:

- All option 0 end-of-pipe treatment
- Polishing filtration (mixed media)

Option 2 (Figure X-6, page 913) provides end-of-pipe treatment for two separated wastewater streams, allowing recycle and reuse of wastewater.

a) End-of-pipe treatment for heat paper production wastewater includes:
  - Settling
  - Holding tank
  - Recycle to process

b) End-of-pipe treatment for cell testing wastewater includes:
  - Chemical precipitation
  - Sedimentation
  - Polishing filtration
  - Sludge dewatering
  - Recycle treated water to process

The calcium subcategory technology options are unchanged from the options set forth in a draft development document. There were no comments on this part of the draft development document.

Option 1

The option 1 treatment system for the calcium subcategory is shown in Figure X-5 (page 912). Two distinct process wastewater streams are treated. Prior to combination in the chemical precipitation system, wastewater from heat paper production is passed through a settling tank where the suspended material is allowed to settle. The settled sludge is removed periodically and disposed. Effluent from the settling device is treated chemically to reduce hexavalent chromium to the trivalent state prior to chemical precipitation and clarification. After chromium reduction, it may be combined with the wastewater from cell leak testing to remove dissolved metals using chemical precipitation (with lime) followed by clarification and filtration.

Settled solids are removed from the clarifier and dewatered in a vacuum filter. Filter cake is disposed as a solid waste. The filtrate from the vacuum filter is returned to the treatment system for further treatment.

To further reduce the discharge of metals and suspended solids in the effluent, the waste stream is passed through a multimedia filter. This filter is intended to act as a polishing unit on the treated wastewater stream. Periodic backwashes from the filter are returned to the treatment system.

Option 2

The option 2 treatment begins with segregation of heat paper and cell testing wastewater. Treatment of the cell test wastewater is identical to option 1 treatment, except that following treatment the wastewater is recycled or reused, with makeup water added as required. For the heat paper wastewater stream option 2 treatment consists of settling to remove particulate contaminants. The clarified effluent from the settling unit is discharged to a holding tank, from which it is recycled back to the process operation as required. It is intended that all of this wastewater stream be recycled with makeup water added to the system as required. Recycle of this wastewater stream eliminates asbestos and chromium from the effluent discharged from plants in this subcategory.

Option Selection

In selecting an option for the calcium subcategory, the Agency compared the pollutant reduction benefits of applying each technology option. This comparison is presented in Table X-19, (page 869) which shows the pollutant removal performance for each of the treatment options. Costs for the options at existing plants (all indirect dischargers) are displayed in Table X-56 (page 907). The performance shown is based on the effluent concentrations achievable by the technology being used (as discussed in Section VII and shown in Table X-18 (page 868)), and the normalized discharge flows from each process element. The raw waste is based on wastewater characteristics shown in Section V (from sampled streams) and on the total flow for the heat paper process element. Pollutant removals are for indirect dischargers only.

Option 2 achieves greater pollutant removal than option 1 and achieves zero discharge of process wastewater pollutants. Since option 2 eliminates the need for chromium reduction and chemical precipitation on the heat paper waste stream, it reduces the consumption of chemicals and the generation of toxic sludges requiring disposal, making this option the least costly for the removal of hexavalent chromium. Option 2 is technically achievable since the role of water in heat paper production is as a solids carrier. This water can therefore be recycled without adversely affecting the production process. Similarly, the use of cell testing water does not preclude recycle of this treated effluent.

Pollutant Parameters Selected for Effluent Limitations

Because the selected treatment system achieves zero discharge of process wastewater, no specific pollutants have been selected for limitation. The limitation for the calcium subcategory is no discharge of process wastewater pollutants.

LECLANCHE SUBCATEGORY

There are no direct dischargers in the Leclanche subcategory, and therefore no BAT regulation is recommended at this time. However, technology options were analyzed for treating the raw waste streams in the subcategory.

Technology Summary

The technology considered and selected for this subcategory is identical to option 0 which is presented in Figure IX-3 (page 812). This technology option consists of recycle and reuse for all plants which generate wastewater and lime, settle and filter technology for foliar battery producing plants.

Table X-20 (page 870) shows the pollutant reduction benefits of this option. The corresponding compliance costs are displayed in Table X-56 (page 907).

Pollutant Parameters Selected for Effluent Limitations

Pollutant parameters selected for limitation for this subcategory are those selected and discussed for BPT in Section IX, except that the conventional pollutants would be considered under BCT.

Effluent Limitations

The effluent concentrations attainable through the application of the recommended technology are displayed in Table VII-21. The mass discharge limitation can be calculated by multiplying the concentration by the foliar battery miscellaneous wash flow (0.066 l/kg of cells produced). These limitations are expressed in terms of mg of pollutant per kilogram of cells produced and are displayed in Table X-21 (page 871). This table is presented as guidance for state or local pollution control agencies because a national regulation is not established at BAT.

LITHIUM SUBCATEGORY

As discussed in Section IX for the lithium subcategory, no BAT regulation is recommended at this time. However, technology options were analyzed for treating the raw waste streams in the subcategory and are discussed here for use in Sections XI and XII. Plants in the lithium subcategory generate three distinct wastewaters: wastewater Stream A is generated by heat paper production; wastewater Stream B is generated by the manufacture of iron disulfide cathodes, lead iodide cathodes, cell testing, lithium scrap disposal, floor and equipment wash, and cleanup; and wastewater Stream C is generated by air scrubbers on various plant operations. As discussed in Section IX, these wastewater streams are most usually generated and treated separately.

Three alternative levels of treatment and control technology beyond option 0 were considered for technology options for this subcategory. Each of these options builds upon option 0, and provides different treatment for one or more of the wastewater streams generated in this subcategory. All three options incorporate improvements in end-of-pipe treatment or recycle of treated wastewater. In-process controls providing substantial reductions in process wastewater volumes or pollutant loads have not been identified.

Technology Options Summary

Because there are three wastwater streams the technology options will be outlined for each wastewater stream. Technology options for waste Stream A are identical to heat paper in the calcium subcategory.

Option 0 for this subcategory (Figure IX-4, page 813) consists of the following technology.

A. Wastewater Stream A
    a) In-process technology:
        - None identified
    b) End-of-pipe treatment:
        - Settling
        - Chromium reduction
        - Chemical precipitation
        - Sedimentation
        - Sludge dewatering

B. Wastewater Stream B

- a) In-process technology:
  - None identified
- b) End-of-pipe treatment:
  - Chemical precipitation
  - Sedimentation
  - Sludge dewatering

C. Wastewater Stream C

- a) In-process technology:
  - None identified
- b) End-of-pipe treatment:
  - Aeration
  - Chemical precipitation
  - Sedimentation

Option 1 (Figure X-7, page 914) for this subcategory builds upon BPT.

A. Wastewater Stream A

- a) In-process technology is identical to BPT.
- b) End-of-pipe treatment:
  - All BPT end-of-pipe treatment
  - Polishing filtration (mixed media)

B. Wastewater Stream B

- a) In-process technology is unchanged from BPT.
- b) End-of-pipe treatment is changed by adding:
  - Polishing filtration

C. Wastewater Stream C treatment is unchanged from BPT.

Option 2 (Figure X-8, Page 915) includes the following changes.

A. Wastewater Stream A

- a) In-process technology is identical to BPT.
- b) End-of-pipe treatment for heat paper production wastewater includes:
  - Settling
  - Holding tank
  - Recycle to process

B. Wastewater Streams B and C treatment is unchanged from option 1.

Option 3 (Figure X-9, Page 916) builds upon option 2.

A. Wastewater Streams A and B treatment is unchanged from Option 2.

B. Wastewater Stream C treatment is upgraded by adding polishing filtration.

Option 1

The Option 1 treatment system for the lithium subcategory, shown in Figure X-7, consists of three distinct treatment systems, each of which is directly associated with one of three major wastewater streams generated by this subcategory. These wastewater streams result from: A) heat paper production; B) iron disulfide cathode and lead iodide cathode manufacture, lithium scrap disposal, cell testing, and floor and equipment wash; and C) air scrubber blowdown.

Wastewater Stream A, from heat paper production, is passed through a clarifier or settling tank where the suspended material is allowed to settle. The settled sludge is removed periodically and disposed of on a contract basis. The effluent from the initial clarifier is treated by chemical reduction to reduce hexavalent chromium to the trivalent state. Once the heat paper wastewater stream has undergone chemical reduction of chromium, it may be combined with the wastewater associated with wastewater stream B prior to further treatment.

The combined wastewaters from wastewater Streams A and B are treated to remove dissolved metals using chemical precipitation (with lime) followed by settling in a clarifier. The settled solids are removed from the clarifier, and dewatered in a vacuum filter. The sludge filter cake is disposed on a contract haul basis, along with any oil and grease removed by the skimming mechanism on the clarifier. The filtrate from the vacuum filter is sent back to the treatment system to undergo further treatment.

In order to provide improved removal of metals and suspended solids, the clarified wastewater stream is passed through a multimedia filter prior to discharge. This filter is intended to act as a polishing unit on the treated wastewater stream. Periodic backwashes from the filter are sent back to the treatment system.

Wastewater Stream C is initially aerated to decrease the oxygen demand. In the process, sulfuric acid is formed from the sulfurous acid originally present. Subsequently, the low pH wastewater is neutralized and settled prior to discharge. Lime used to neutralize the waste stream may precipitate calcium sulfate and calcium chloride. The clarifier also removes miscellaneous suspended solids contained in the wastewater streams. It is expected that solids removed in settling will be disposed on a contract haul basis.

Option 2

The option 2 treatment for the heat paper wastewater stream consists of settling after which the clarified effluent is discharged to a holding tank. This wastewater stream is recycled with makeup water added to the system as required. Solids are recovered or contractor hauled.

Because of the recycle of the treated heat paper wastewater to the process, further treatment will not be required to remove hexavalent chromium from solution.

Stream B is identical to the system described for this wastewater stream in option 1.

The option 2 treatment system for Stream C is identical to the system described in option 1.

Option 3

The option 3 treatment system for Streams A and B is identical to the system described in option 2. A polishing filter is added to remove additional solids from the air scrubber blowdown water.

Option Selection

These three treatment and control options were studied carefully and the technical merits and disadvantages of each were compared. In the selection of a technology option from among these alternatives, the Agency considered pollutant reduction benefits, costs, and the status of demonstration of each technical alternative. Tables X-23 and X-24 (pages 873 and 874) provide a quantitative comparison of polluant reduction benefits of the different options and compliance costs are displayed in Table X-56. In this subcategory, contract hauling is the least costly method for compliance at existing plants.

Because there are three distinct wastewater streams in this subcategory, it is necessary to consider and evaluate each of them separately in determining the most appropriate technology option for treatment and control of pollutants. The wastewater generated by heat paper manufacture is identical to the heat paper manufacturing operation discussed in detail in the calcium subcategory. Employing the same logic as detailed in the calcium subcategory is appropriate to arrive at the same conclusion about treatment options for this operation. The technically preferred option for this segment of the subcategory is option 2. This option results in the maximum reduction in the discharge of toxic pollutants.

Technology options 1-3 contain only one change from option 0 for wastewater Stream B which contains wastewaters from iron disulfide or lead iodide cathodes, cell testing, lithium scrap disposal, and floor and equipment wash. This improved technology is the addition of a polishing filter after sedimentation to improve removal of toxic metals and suspended solids. The operability of lime, settle and filter technology is detailed in Section VII. For this segment of the subcategory the technically preferred option is option 1.

Option 3 adds a filter to improve removal of TSS from the wastewater for Stream C. Since this wastewater stream is believed to be essentially free from toxic metals, the filter would only remove TSS. It is therefore not the technically preferred option, and the selected technology for this segment of the subcategory is lime and settle technology.

Pollutant Parameters Selected for Effluent Limitations

Pollutant parameters selected for limitation for this subcategory are those selected and discussed in Section IX, except that the conventional pollutants would be considered under BCT.

Effluent Limitations

Effluent concentrations from Table VII-21 for L&S technology are multiplied by the normalized process element flows shown in Table X-22 to determine the pollutant mass discharge limitations shown in Tables X-25 to X-27 (pages 876-877). These tables are presented as guidance for state or local pollution control agencies because effluent limitations for the discharges from this subcategory are not established for national regulation at BAT. The heat paper manufacturing process element is not shown in the tables because the limitations would be at no discharge of process wastewater pollutants. The air scrubber process elements are not shown in the tables because no toxic pollutants would need to be limited. The discharge limitation for any battery manufacturing plant may be determined by summing the mass discharge allowances for all of the applicable manufacturing process elements.

MAGNESIUM SUBCATEGORY

As discussed in Section IX for the magnesium subcategory, there is no BAT regulation at this time. However, technology options were analyzed for treating the raw waste streams in the subcategory and are discussed here for use in Section XI and XII. The magnesium subcategory generates three distinct wastewaters: wastewater Stream A is generated by heat paper production; wastewater Stream B is generated by the manufacture of silver chloride cathodes, cell testing, and floor and equipment wash; and wastewater Stream C is generated by air scrubbers on various plant operations. As discussed in Section IX, these wastewater streams are usually generated and treated separately.

Three alternative levels of treatment and control technology were considered beyond option 0 for this subcategory. Each of these options builds upon option 0 and, provides different treatment for one or more of the wastewater streams generated in this subcategory. All three options incorporate improvements in end-of-pipe treatment or recycle of treated wastewater. Except for one process element, in-process controls providing substantial reductions in process wastewater volumes or pollutant loads have not been identified.

Technology Options Summary

Because there are three distinct wastewater streams the technology options will be outlined for each wastewater stream. Options for waste Stream A are identical to heat paper production options in the calcium subcategory.

Option 0 for this subcategory (Figure IX-5, page 814) consists of the following technology.

A. Wastewater Stream A
   a) In-process technology:
      - None identified
   b) End-of-pipe treatment:
      - Settling
      - Chromium reduction
      - Chemical precipitation
      - Sedimentation
      - Sludge dewatering

B. Wastewater Stream B
   a) In-process technology:
      - Rinse water flow control
   b) End-of-pipe treatment:
      - Chemical precipitation
      - Sedimentation
      - Sludge dewatering

C. Wastewater Stream C
   a) In-process technology:
      - None identified
   b) End-of-pipe treatment:
      - Chemical precipitation
      - Sedimentation

Option 1 (Figure X-10, page 917) for this subcategory builds upon option 0.

A. Wastewater Stream A
   a) In-process technology:
      - None identified
   b) End-of-pipe treatment:

        - All option 0 end-of-pipe treatment
        - Polishing filtration (mixed media)

B. Wastewater Stream B
    a) In-process technology:
        - Countercurrent cascade rinse
    b) End-of-pipe treatment is identical to option 0

C. Wastewater Stream C treatment is identical to option 0

Option 2 (Figure X-11, page 918)

A. Wastewater Stream A
    a) In-process technology:
        - None identified
    b) End-of-pipe treatment:
        - Settling
        - Holding tank
        - Recycle to process

B. Wastewater Stream B
    a) In-process technology is unchanged from option 1.
    b) End-of-pipe treatment:
        - All option 0 end-of-pipe treatment
        - Polishing filtration (mixedmedia)

C. Wastewater Stream C treatment is unchanged from option 0.

Option 3 (Figure X-12, page 919).

A. Wastewater Stream A treatment is unchanged from option 2.

B. Wastewater Stream B treatment is upgraded by adding carbon adsorption to remove organics.

C. Wastewater Stream C
    a) In-process technology:
        - None identified
    b) End-of-pipe treatment:
        - All option 0 end-of-pipe treatment
        - Polishing filtration (mixed media)

Option 1

The option 1 treatment system for the magnesium subcategory, shown in Figure X-10, consists of three distinct treatment systems, each of which is directly associated with one of three major wastewater streams generated by this subcategory. These wastewater streams result from: A) heat paper production; B) silver chloride cathode manufacture, cell testing, and floor and equipment cleaning; and C) air scrubbers.

Wastewater Stream A, from heat paper production, is passed through a clarifier or settling tank where the suspended material is allowed to settle. The settled sludge is removed periodically for disposal as solid waste. The effluent from the initial settling is treated by chemical reduction to reduce hexavalent chromium to the trivalent state. The wastewater is then treated to remove dissolved metals using chemical precipitation (with lime) followed by settling in a clarifier. The settled solids are removed from the clarifier and dewatered in a vacuum filtration unit. The sludge filter cake is disposed of on a contract haul basis. The liquid filtrate from the vacuum filter is sent back to the treatment system to undergo further treatment.

In order to provide improved removal of metals and suspended solids, the clarified wastewater stream is passed through a mixed media filter prior to discharge. This filter is intended to act as a polishing unit on the treated wastewater stream. Periodic backwashes from the filter are sent back to the treatment system.

Wastewater stream B, from silver chloride cathode production, cell testing and floor and equipment wash, is reduced in volume by using three-stage countercurrent cascade rinsing of chemically reduced silver cathodes. Because the cathode material is smooth surfaced a high efficiency will be achieved and a rinse reduction factor of 30 is reasonable for this material. End-of-pipe treatment is the same as BPT.

Option 2 treatment for the heat paper wastewater stream, consists of settling after which the clarified effluent is discharged to a holding tank. From the tank all of the wastewater is recycled, with makeup water added to the system as required. This is discussed in detail in the calcium subcategory. Because of the recycle of the treated heat paper wastewater back to the process operation, the option 2 treatment equipment will not be required to remove hexavalent chromium from solution.

The option 2 treatment for silver chloride cathode production, cell testing, and floor and equipment wash wastewaters is the same as option 1 with the addition of a mixed media polishing filter to further reduce pollutant discharge.

The option 2 treatment system for Stream C is similar to the system described in option 1 with the addition of a mixed media polishing filter to remove additional amounts of solids.

The option 3 treatment system is very similar to the system previously described for option 2 treatment. It differs only in that carbon adsorption is included for the silver chloride cathode wastewater to further reduce organic pollutant (COD) discharges.

Option Selection

These three treatment and control options were studied carefully and the technical merits and disadvantages of each were compared. In the selection of a technology option from among these alternatives, the Agency considered pollutant reduction benefits, costs, and the status of demonstration of each technical alternative. Tables X-29 and X-30 (pages 879 and 880) provide a quantitative comparison of pollutant reduction benefits of the different technology options. The corresponding compliance costs are displayed in Table X-56. These tables present the pollutant removal which would occur if all of the existing plants in the magnesium subcategory used a particular treatment system, and shows the combined costs to all existing plants of using that treatment.

Because there are three distinct wastewater streams in this subcategory, it is necessary to consider and evaluate each of them separately in determining the most appropriate technology option for treatment and control of pollutants. The wastewater generated by heat paper production is identical to the heat paper production operation discussed in detail in the calcium subcategory. It is appropriate, employing the same logic as detailed in the calcium subcategory, to arrive at the same conclusion about treatment options for this operation. The technically preferred option for this segment of the subcategory is option 2. This option results in the maximum reduction in the discharge of pollutants at the least cost of any option considered for this wastewater stream.

The three options displayed for the treatment of silver chloride cathode, cell testing, and floor and equipment wash wastewaters are not practiced at any manufacturing plant in this subcategory. Since only minimal treatment is now provided to these wastewaters, it is necessary to transfer any technology for use in this segment. The first option employs water flow reduction, transferring countercurrent cascade rinsing from other subcategories. The basis for the use of countercurrent cascade rinsing is set forth in substantial detail in Section VII. A high level of rinsing efficiency is projected because of the compact, smooth nature of the surface being rinsed. This results in a thirtyfold reduction in wastewater discharge from the chemically reduced cathode production and a proportionate reduction in pollutant discharge.

The second option adds polishing filtration to the lime and settle end-of-pipe treatment employed at BPT to remove additional pollutants. This technology is widely used and is described in detail in Section VII.

The third option requires the use of carbon adsorption to remove COD. COD is known to contain phenol-like compounds which are not detected by the analytical procedures used. The applicability of the carbon adsorption technology is not well demonstrated on this particular wastewater, and therefore this option is not selected. The technically preferred option is option 2 based on the removal of pollutants and the proven effectiveness of the technology employed.

Wastewater Stream C, from air scrubbers, is not known to be treated effectively in any of the plants in this subcategory. No in-process technology is known which can be employed to substantially reduce the wastewater flow and the quantity of pollutants carried by that wastewater. The only technology applied above option 0 is the addition of a polishing filter. This occurs at option 3, however, since no toxics are removed by this option, option 0 is selected as the technically preferred option.

Pollutant Parameters Selected for Effluent Limitations

Pollutant parameters selected for limitation for this subcategory are those selected and discussed for BPT in Section IX, except that the conventional pollutants would be considered under BCT.

Effluent Limitations

The effluent concentrations attainable through the application of the recommended technology are displayed in Table VII-21. The mass discharge limitation for each process element can be calculated by multiplying these concentrations by the applicable BAT flow listed in Table X-28 (page 878). These limitations are expressed in terms of mg of pollutant per kg of production normalizing parameter and are displayed in Tables X-31 to X-34 (pages 882-883). These tables are presented as guidance for state or local pollution control agencies because effluent limitations for the discharges from this subcategory are not established for national regulation at BAT. By multiplying these limitation numbers by the actual production in a process element (kg of production normalizing parameter), the allowable mass discharge for that process element can be calculated in mg. The allowable masses for the different process elements can be summed to determine the total allowable mass discharge for a plant.

Of the eight plants which are reported active in the magnesium subcategory, five reported no wastewater discharge from the magnesium subcategory, thereby meeting all levels of discharge limitation. None of the three plants which reported wastewater discharge had the complete treatment technology system, although one plant had some components of the BAT system.

ZINC SUBCATEGORY

Four technology options are presented to display the most appropriate technology options. All four options build upon BPT (option 0) and provide reduced pollutant discharge by reducing wastewater volumes through the application of in-process control techniques. In addition, three of the options provide augmented end-of-pipe treatment.

BAT Options Summary

Option 0 for this subcategory (Figure IX-6, page 815) consists of the following:

a) In-process technology
  - Reuse of process solutions
  - Elimination of the use of chromates in cell washing
  - Segregation of noncontact cooling water
  - Segregation of organic bearing cell cleaning wastewater
  - Control electrolyte drips and spills
  - Control flow of rinse waters

b) End-of-pipe treatment
  - Oil skimming
  - Lime or acid precipitation
  - Sedimentation
  - Sludge dewatering

BAT Option 1 (Figure X-13, page 920) builds on option 0 by adding the following:

a) In-process technology
  - Countercurrent rinse amalgamated zinc powder
  - Recirculate amalgamation area floor wash water
  - Countercurrent rinse of formed zinc electrodes
  - Countercurrent rinse of electrodeposited silver powder
  - Countercurrent rinse of formed silver oxide electrodes
  - Reduce flow and countercurrent rinse silver peroxide
  - Flow controls and countercurrent rinse for impregnated nickel cathodes
  - Countercurrent rinse or rinse recycle for cell washing
  - Countercurrent rinse after etching silver grids
  - Dry cleanup or wash water reuse for floor and equipment

b) End-of-pipe treatment is unchanged from BPT.

BAT Option 2 (Figure X-14, page 921) builds on BAT Option 1.

a) In-process technology is unchanged from BAT Option 1.

b) End-of-pipe treatment continues BAT Option 1 and adds:
  - Polishing filtration (mixed media)

BAT Option 3 (Figure X-15, page 922) follows BAT Option 2.

a) In-process technology
  - All in-process technology employed at Option 2
  - Eliminate wastewater from gelled amalgam

b) End-of-pipe treatment
  - Oil skimming
  - Sulfide precipitation
  - Sedimentation
  - Filtration (membrane)
  - Sludge dewatering

BAT Option 4 (Figure X-16, page 923) provides reduced flow, improved end-of-pipe treatment, and recycle.

a) In-process technology

  - All in-process technology used in Option 3
  - Eliminate amalgamation wastewater

b) End-of-pipe treatment
  - Oil skimming
  - Lime or acid precipitation
  - Filtration
  - Reverse osmosis with recycle of permeate
  - Sulfide precipitation of brine
  - Sedimentation of precipated brine
  - Filtration (membrane)
  - Sludge dewatering

Option 1

Option 1 adds in-process control technology to the end-of-pipe treatment provided at BPT. This in-process technology substantially reduces the quantity of wastewater which must be treated before release. Normalized flows for the several elements of this subcategory are listed in Table X-35, (page 884). Specific flow reductions for each of the manufacturing process elements are discussed in detail.

Wet Amalgamated Zinc Powder Anode. Water is discharged as a result of rinsing the amalgamated zinc powder and of area floor washing. Area floor washing contributes 0.25 l/kg of the 3.8 l/kg BPT flow for this process element. Floor area wash water may be eliminated by reusing treated amalgam rinse water or by treatment and reuse of the floor wash water. By replacing the typical zinc powder series rinsing systems with countercurrent rinsing, the 3.55 l/kg can be reduced by a factor of 6.6 to 0.55

l/kg. The effluent flow of 0.55 l/kg is used for setting BAT effluent limitations for this process element.

Gelled Amalgam Zinc Powder Anode. Water discharged is a result of equipment and process area floor washing. Water used in washing amalgamation area floors becomes contaminated with mercury as well as suspended solids. Recycle of this water for continued use in floor washing is possible if the mercury and other contaminants are removed by treatment prior to removal of suspended solids. In order to control the dissolved solids content in the recirculation water, a small bleedoff or blowdown of wastewater may be necessary. This blowdown is established at a nominal level of 10 percent of the BPT flow for this element.

Zinc Oxide Formed Anode. Wastewater is generated in the post-formation rinse operation. The implementation of countercurrent rinsing for this operation will reduce the amount of wastewater discharged. Since existing practice does not provide examples of this flow reduction technique, attainable flow reductions for this process element are based upon the calculated flow rate requirement for the three-stage countercurrent rinse presented in Section VII. Applying a conservative rinse reduction ratio of 6.6 to the BPT flow of 143 l/kg, the BAT flow for this element becomes 21.67 l/kg.

Electrodeposited Zinc Anode. Wastewater results from post-electrodeposition and post-amalgamation rinsing operations. The application of countercurrent rinses will reduce the flow of wastewater from these rinsing operations after electrodeposition in a similar fashion to the flow reduction for the zinc oxide formed anode process element. Post-amalgamation rinsing is eliminated by proper control of amalgamation solution concentration. Hence, the BPT flow of 3,190 l/kg is halved by eliminating one rinsing step and further reduced by a factor of 6.6 by using three-stage countercurrent rinsing. The BAT flow for this process element is 241.7 l/kg.

Silver Powder Formed Cathode. This process element is similar to the two previously described process elements in that wastewater is generated as a result of rinsing operations. The flow reduction attained through the application of countercurrent rinses is also similar. Since this process element has only one rinsing operation (post-formation) the BAT flow is the BPT flow (196 l/kg) reduced by a factor of 6.6, or 29.70 l/kg.

Silver Oxide Powder Formed Cathodes. The water produced by this process element also results from rinsing operations. The attainable effluent flow reduction through the application of countercurrent rinses is the same as the three previously described process elements. The BAT flow is the BPT flow (131 l/kg) reduced by a factor of 6.6, or 19.85 l/kg.

Silver Peroxide Powder Cathode. The production of silver peroxide powder cathodes generates wastewater through spent bath dumps and rinses. The BAT is determined by applying countercurrent rinsing to the BPT flow of 31.4 l/kg to reduce the water use by a factor of 6.6 to 4.76 l/kg.

Nickel Impregnated Cathode. The production of nickel impregnated cathodes and the flow reductions possible through the application of BAT technology were previously described under the cadmium subcategory. The BAT flow allowed for this process element is 200 l/kg as developed and discussed under the cadmium subcategory.

Cell Wash. Reduced wastewater discharge from cell washing can be achieved through recycling of cell rinse water or by countercurrent cell rinsing. The BAT flow for the cell wash process element is determined by applying countercurrent rinsing to the BPT flow of 1.13 l/kg to reduce the water use by a factor of 6.6, to 0.17 l/kg.

Electrolyte Preparation. Wastewater is generated from spills occurring while preparing electrolyte solutions and filling cells. The BAT flow is determined to be the median or zero l/kg because it is already achieved by half of the existing plants by proper design and operation of filling equipment and reuse of drips and spills.

Silver Etch. Wastewater results from rinsing etched silver foil. The countercurrent rinse flow rate calculations presented in Section VII were used as the basis for determining attainable discharge flow rates from rinsing after silver foil etching operations. A rinsing efficiency factor of 6.6 is estimated and flow is reduced from 49.1 l/kg at BPT. The result of these calculations is a BAT flow basis of 7.44 l/kg for the silver etch process element.

Floor and Equipment Wash. Wastewater is generated from washing floors and production equipment. The wastewater discharge from floor wash (0.13 l/kg) remains unchanged from BPT. The BPT flow from equipment wash, 7.1 l/kg can be reduced by treatment and reuse with a blowdown at a nominal level of 10 percent of the BPT flow. With these in-process controls the BAT flow for floor and equipment wash is 0.84 l/kg.

Silver Peroxide Production. The production of silver peroxide is similar to silver powder production in that water is generated by rinsing operations and the rinse flows can be reduced by the implementation of countercurrent rinsing. The attainable flow reductions for this process element are calculated in the same manner as silver powder production, using a conservative rinse flow reduction factor of 6.6. The BPT flow of 52.2 l/kg is reduced to a BAT flow of 7.91 l/kg.

Silver Powder Production. Silver powder production generates wastewater as a result of rinses relating to this operation. The application of countercurrent rinsing in this operation will reduce the present rinse water flow of 21.2 l/kg. Since no examples of countercurrent rinsing on this operation exist, estimates of flow reductions are made based upon the calculated flow rate requirement for a three-stage countercurrent rinse presented in Section VII. When loose powders are rinsed, good rinse water contact and mixing can be achieved. Consequently, a lower factor for rinsing efficiency could be considered; however, the conservative 6.6 factor is used to establish a BAT flow of 3.21 l/kg.

Option 2

BAT option 2 builds on option 1 by including all of the in-process technology used to reduce wastewater flow and improves end-of-pipe treatment by adding a polishing filter.

Option 3

BAT option 3 provides some reduction in wastewater flow by eliminating wastewater from gelled amalgam production. End-of-pipe treatment is improved by using sulfide as the precipitation agent before settling and filtering the wastewater. The reduced solubility of the sulfide precipitate provides a basis of improved performance.

Option 4

BAT option 4 substantially revises the end-of-pipe treatment to allow reuse of the wastewater. This is accomplished by adding reverse osmosis after filtration and recycling the permeate. Brine from reverse osmosis is treated using sulfide to remove metal pollutants before discharge.

BAT Option Selection

Three technology options were originally developed and presented in the draft development document for consideration as BAT for the zinc subcategory. These options have been restructured into four options to better display the application of a full range of technologies to this subcategory. These options are somewhat modified from options outlined in the draft development document.

Most of the wastewater generation control has been concentrated in the first option while the second option adds filtration to improve effectiveness. The third and fourth options continue to depend on sulfide precipitation for pollutant removal.

The Agency developed quantitative estimates of the total cost and pollutant removal benefits of each BAT option. These estimates are based on all available data for each plant in the subcategory. As a first step, an estimate of total raw wastewater pollutant loads and wastewater flows from each manufacturing process element was developed from data presented in Section V. This forms the basis for estimating the mean raw waste used to calculate the pollutant reduction benefits and is shown in Table X-36, (page 885). All plants and process elements in the subcategory are taken into account in this calculation.

Total kg/yr for each pollutant within each process element were summed and divided by the total subcategory flow to obtain a total subcategory mean raw waste concentration. Table X-37 (page 888) displays the pollutant concentrations - both mg/l and mg/kg of the total subcategory anode weight for raw waste and after applying each treatment option. Effluent flow after application of each treatment option was estimated based on wastewater reduction achieved by the option. The mass of pollutant discharged after each treatment option was calculated by using the appropriate mean effluent concentrations shown in Table VII-21 and multiplying them by the treatment option annualized flow. The mass of pollutants discharged after application of treatment was subtracted from the total subcategory raw waste to determine the mass of pollutants removed by each level of control and treatment. The results of these calculations for the total subcategory are shown in Table X-38 (page 889) to display the pollutant reduction of each technology option. Results for direct dischargers only, based on reported flow and production data are shown in Table X-39 (page 890).

An estimate of total annual compliance costs of BPT and of each BAT option for the zinc subcategory was also prepared and is displayed in Table X-56 (page 907). These estimates were developed by estimating costs for each existing direct discharge plant in the subcategory based on reported production and wastewater flows, and summing individual plant costs for each level of treatment and control. The costs for technology options 2 and 3 are listed as being equal. The costs of the two options are estimated to be very close (within 10%) with option 2 slightly less expensive because of lower filter costs. An economic impact analysis based on estimated costs for each treatment and control option at each plant in the subcategory indicates that there are no potential plant closures projected for any options for direct dischargers.

Option 1 is the selected BAT option because limitations are achievable using technologies and practices that are currently in use at plants in the subcategory. Also, the result of implementing this technology is a significant reduction of toxic pollutant discharges. For this option flow is reduced to 8.11 million l/yr for the subcategory and to 1.87 million l/yr for direct dischargers. The annual toxic pollutant removal is 5701 kg/yr for the subcategory and 1311 kg/yr for direct dischargers. For plants to comply directly with this option, the estimated compliance capital cost is $437,000 for the subcategory ($90,000 for direct dischargers), and annual cost is $123,000 for the subcategory ($24,000 for direct dischargers).

Options 2, 3 and 4 were rejected because the technology yields small incremental pollutant removals when compared with option 1. The BAT limitations will remove approximately 99.81 percent of current toxic pollutant discharges. Given the results achieved by the technologies used as a basis for the promulgated limitations, further treatment would result only in de minimis, insignificant reductions in annual national discharges. Accordingly, EPA has determined that the total amount of each pollutant in the remaining discharges after compliance with BAT does not justify establishing a national requirement based on additional end-of-pipe technology.

Pollutant Parameters for Regulation

In selecting pollutant parameters for BAT regulation for the zinc subcategory, all pollutants considered for regulation in Section VI for the subcategory (Table VI-1, page 488) were evaluated. The choice of pollutants for regulation was dependent upon the toxicity of the pollutants, their use within the subcategory, and their presence in the raw waste streams at treatable concentrations. The pollutants do not have to appear in every process element or necessarily at high concentrations in the total raw waste streams of the plants which were sampled. Since plants in the zinc subcategory have a variety of different combinations of process elements, the appearance of a particular pollutant at significant concentrations in a single process element is sufficient reason for selection.

Pollutant parameters regulated at BAT for this subcategory are chromium, cyanide, mercury, nickel, silver, zinc and manganese. As discussed in Section IX, nickel is regulated for the nickel impregnated cathode and cell wash elements only, and cyanide is regulated for the cell wash element only. Other pollutants 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.

BAT 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 for the different process elements are calculated by multiplying these concentrations by the applicable BAT-1 flow listed in Table X-35. These BAT limitations (shown in Tables X-40 to 55, pages 891 to 906) are expressed in terms of mg of pollutant per kg of production normalizing parameter. To alleviate some of the monitoring burden, several process elements which occur at most plants and have the same pnp are combined in one regulatory table. Table X-53 (page 904) is the combined table for Tables X-48, 50, 51, and 52. By multiplying these limitation numbers by the production per unit time (e.g. kg/day) within a process element, the allowable mass discharge for that process element can be calculated in mg per unit of time. The allowable masses for the different process elements can be summed to determine the total allowable mass discharge for the plant.

No plant in this subcategory presently employs the selected technology in its entirety, although most plants employ some of the identified in-process and end-of-pipe technologies. Performance at these facilities may be compared to that attainable at BAT both in terms of the volume of wastewater produced and the concentrations of pollutants present in the treated effluent, as well as the mass of pollutants discharged.

The volumes of wastewater presently discharged from each plant in the zinc subcategory have been compared to the flows attainable by implementation of the selected BAT technology option. The present discharge flows are derived from the best available data including dcp, on-site measurements and data collection, and supplementary contacts. The attainable flows were calculated from individual plant production information and the individual process operation flows shown in Table X-35. Three of the 17 plants in the subcategory for which data are available achieve no discharge of process wastewater pollutants. Two additional plants have indicated substantial discharge flow reductions and plans for achieving zero discharge operation. Five plants in the data base have effluent flows only slightly above (about twice or less) the BAT technology option flow. Since 10 plants of 17 now meet or are close to the BAT flow it may be concluded that this part of the basis for BAT effluent limitations is reasonable and attainable.

As previously discussed in Section IX, present treatment practice in the subcategory was found to be uniformly ineffective, both as a result of the treatment technologies employed and of the manner in which the existing systems were operated. While one plant employs end-of-pipe treatment nominally equivalent to BAT, the system is not operated to provide effective removal of process wastewater pollutants. However, based on the information presented in Section VII and on careful examination of the processes and wastewaters in this subcategory, the BAT limitations are attainable by application of the selected technology.

TABLE X-1

PROCESS ELEMENT FLOW SUMMARY
CADMIUM SUBCATEGORY
Flow (l/kg)

Process Elements	Median	Mean	BPT (PSES 0)	BAT 1 (PSES 1)	BAT 2 (PSES 2)	BAT 3 (PSES 3)	BAT 4 (PSES 4)
Anodes							
Pasted & Pressed Powder	1.0	2.7	2.7	0.0	0.0	0.0	0.0
Electrodeposited	697.	697.	697.	35.15	35.15	5.27	0.0
Impregnated	998.	998.	998.	200.0	200.0	30.0	0.0
Cathodes							
Nickel Electrodeposited	569.	569.	569.	33.0	33.0	4.95	0.0
Nickel Impregnated	1720.	1640.	1640.	200.0	200.0	30.0	0.0
Ancillary Operations							
Cell Wash	3.33	4.93	4.93	0.75	0.75	0.112	0.0
Electrolyte Preparation	0.08	0.08	0.08	0.08	0.08	0.012	0.0
Floor and Equipment Wash	2.4	12.0	12.0	0.0	0.0	0.0	0.0
Employee Wash	1.5	1.5	1.5	1.5	1.5	0.225	0.0
Cadmium Powder Production	65.7	65.7	65.7	6.57	6.57	0.493	0.0
Silver Powder Production	21.2	21.2	21.2	3.21	3.21	0.482	0.0
Cadmium Hydroxide Production	0.9	0.9	0.9	0.14	0.14	0.021	0.0
Nickel Hydroxide Production	110.0	110.0	110.0	16.5	16.5	2.47	0.0

TABLE X-2

PROCESS ELEMENT WASTEWATER SUMMARY
CADMIUM SUBCATEGORY

	ANODES						CATHODES				ANCILLARY OPERATIONS			
	Pasted & Pressed Powder		Electrodeposited		Impregnated		Nickel Electrodeposited		Nickel Impregnated		Cell Wash		Electrolyte Preparation	
	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l*	kg/yr	mg/l*	kg/yr
Flow l/yr (10^6)		0.948		80.9		179.623		0.680		274.2		4.71		0.0371
Pollutants														
118 Cadmium	267.0	253.1	94.6	7653.0	31.7	5693.0	0.050	0.034	12.98	3559.0	37.2	175.2	37.2	1.376
119 Chromium	0.004	0.004	0.0	0.0	0.14	25.14	0.002	0.001	0.061	16.73	0.073	0.344	0.073	0.003
121 Cyanide	3.184	3.018	0.022	1.780	0.04	7.18	0.031	0.021	0.054	14.81	0.045	0.212	0.045	0.002
122 Lead	0.023	0.022	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.823	0.006	0.028	0.006	0.000
123 Mercury	0.0	0.0	0.001	0.081	0.02	3.59	0.016	0.011	0.004	1.097	0.006	0.028	0.006	0.000
124 Nickel	18.930	17.95	0.071	5.74	2.25	404.1	3.18	1.262	117.3	32164.0	56.4	256.6	56.4	2.087
126 Silver	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.024	0.113	0.024	0.001
128 Zinc	0.41	0.389	0.006	0.485	0.04	7.18	0.0	0.0	0.198	54.3	211.0	994.0	211.0	7.81
Cobalt	0.0	0.0	0.0	0.0	0.08	14.37	0.101	0.069	0.663	181.8	0.410	1.931	0.410	0.015
Oil & Grease	822.0	779.0	5.23	423.0	2.5	449.0	1.667	1.134	6.80	1865.0	6.42	30.24	6.42	0.238
TSS	1038.0	984.0	126.7	10250.0	204.0	36647.0	1.667	1.134	539.0	147794.0	330.0	1554.0	330.0	12.21

NA - Not analyzed (treated as zero in calculations).

* Based on flow weighted mean concentrations from sampled process elements.

TABLE X-2

PROCESS ELEMENT WASTEWATER SUMMARY
CADMIUM SUBCATEGORY

ANCILLARY OPERATIONS

	Floor and Equipment Wash		Employee Wash		Cadmium Powder Production		Silver Powder Production		Cadmium Hydroxide Production		Nickel Hydroxide Production		TOTAL SUBCATEGORY RAW WASTE	
	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l**	kg/yr	mg/l***	kg/yr	mg/l	kg/yr
Flow l/yr (10^6)		7.781		0.068		27.00		0.80		1.6		170.0		748.35
Pollutants														
118 Cadmium	29.2	227.2	0.069	0.005	177.3	4787.0	0.002	0.002	63.3	101.3	12.98	2207.0	32.96	24665.62
119 Chromium	0.081	0.630	0.0	0.0	0.004	0.108	0.933	0.746	0.19	0.304	0.061	10.37	0.073	54.63
121 Cyanide	NA	NA	0.022	0.001	0.026	0.702	NA	NA	0.06	0.096	0.054	9.18	0.049	36.67
122 Lead	0.0	0.0	0.0	0.0	0.0	0.0	0.147	0.118	0.0	0.0	0.003	0.510	0.002	1.50
123 Mercury	0.0	0.0	0.0	0.0	0.008	0.216	0.003	0.002	0.001	0.002	0.004	0.680	0.008	5.99
124 Nickel	9.08	70.6	0.130	0.009	0.062	1.674	0.877	0.702	3.300	5.28	117.3	19941.0	70.7	52908.35
126 Silver	NA	NA	NA	NA	NA	NA	16.67	13.34	NA	NA	NA	NA	0.018	13.47
128 Zinc	12.9	100.4	0.160	0.011	4272	115314	0.333	0.266	0.060	0.096	0.198	33.66	155.8	116592.93
Cobalt	5.04	39.21	0.0	0.0	0.0	0.0	0.900	0.720	0.110	0.176	0.663	112.7	0.469	350.98
Oil & Grease	NA	NA	167.0	11.36	4.37	117.9	NA	NA	2.700	4.320	6.80	1156.0	6.47	4841.82
TSS	NA	NA	197.3	13.42	17.47	471.7	21.0	16.8	354.1	567.0	539.0	91630.0	387.7	290135.30

NA - Not analyzed (treated as zero in calculations).

* - Based on flow weighted mean concentrations from sampled process elements.

** - Based on mean raw waste concentrations from Impregnated Anode Manufacture.

***- Based on mean raw waste concentrations from Nickel Impregnated Cathode Manufacture.

TABLE X-3
SUMMARY OF TREATMENT EFFECTIVENESS
CADMIUM 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)*	1303.740		1303.740		178.220		178.220		26.410		0.000	
118 CADMIUM	32.960	42971.270	0.079	102.995	0.079	14.079	0.049	8.733	0.049	1.294	0.000	0.000
119 CHROMIUM	0.073	95.173	0.073	95.173	0.080	14.258	0.070	12.475	0.070	1.849	0.000	0.000
121 CYANIDE	0.049	63.883	0.049	63.883	0.070	12.475	0.047	8.376	0.047	1.241	0.000	0.000
122 LEAD	0.002	2.607	0.002	2.607	0.015	2.607	0.015	2.607	0.080	2.113	0.000	0.000
123 MERCURY	0.008	10.430	0.008	10.430	0.059	10.430	0.036	6.416	0.036	0.951	0.000	0.000
124 NICKEL	70.700	92174.418	0.570	743.132	0.570	101.585	0.220	39.208	0.220	5.810	0.000	0.000
126 SILVER	0.018	23.467	0.018	23.467	0.100	17.822	0.070	12.475	0.070	1.849	0.000	0.000
128 ZINC	155.800	203122.692	0.300	391.122	0.300	53.466	0.230	40.991	0.230	6.074	0.000	0.000
COBALT	0.469	611.454	0.070	91.262	0.070	12.475	0.050	8.911	0.050	1.321	0.000	0.000
OIL & GREASE	6.470	8435.198	6.470	8435.198	10.000	1782.200	10.000	1782.200	10.000	264.100	0.000	0.000
TSS	387.700	505459.998	12.000	15644.880	12.000	2138.640	2.600	463.372	2.600	68.666	0.000	0.000

* Normalized flow based on total subcategory cadmium anode weight.

TABLE X-4
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
CADMIUM SUBCATEGORY - TOTAL

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 1/yr (10^6)	748.35		748.35		102.30		102.30		15.16		0.00
118 CADMIUM	24665.62	24606.50	59.12	24657.54	8.08	24660.61	5.01	24664.88	0.74	24665.62	0.00
119 CHROMIUM	54.63	0.00	54.63	46.45	8.18	47.47	7.16	53.57	1.06	54.63	0.00
121 CYANIDE	36.67	0.00	36.67	29.51	7.16	31.86	4.81	35.96	0.71	36.67	0.00
122 LEAD	1.50	0.00	1.50	0.00	1.50	0.00	1.50	0.29	1.21	1.50	0.00
123 MERCURY	5.99	0.00	5.99	0.00	5.99	2.31	3.68	5.44	0.55	5.99	0.00
124 NICKEL	52908.35	52481.79	426.56	52850.04	58.31	52885.84	22.51	52905.01	3.34	52908.35	0.00
126 SILVER	13.47	0.00	13.47	3.24	10.23	6.31	7.16	12.41	1.06	13.47	0.00
128 ZINC	116592.93	116368.42	224.51	116562.24	30.69	116569.40	23.53	116589.44	3.49	116592.93	0.00
COBALT	350.98	298.60	52.38	343.82	7.16	345.86	5.12	350.22	0.76	350.98	0.00
OIL & GREASE	4841.82	0.00	4841.82	3818.82	1023.00	3818.82	1023.00	4690.22	151.60	4841.82	0.00
TSS	290135.29	281155.09	8980.20	288907.69	1227.60	289869.31	265.98	290095.87	39.42	290135.29	0.00
TOXIC METALS	194242.49	193456.71	785.78	194119.51	122.98	194171.94	70.55	194231.04	11.45	194242.49	0.00
CONVENTIONALS	294977.11	281155.09	13822.02	292726.51	2250.60	293688.13	1288.98	294786.09	191.02	294977.11	0.00
TOTAL POLLU.	489607.25	474910.40	14696.85	487219.35	2387.90	488237.79	1369.46	489403.31	203.94	489607.25	0.00
SLUDGE GEN		4470633.08		4546037.03		4552391.04		4559114.87		4560299.05	

TABLE X-5
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
CADMIUM 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 1/yr (10^6)	538.45		538.45		73.61		73.61		10.91		0.00
118 CADMIUM	17747.32	17704.78	42.54	17741.51	5.81	17743.72	3.60	17746.79	0.53	17747.32	0.00
119 CHROMIUM	39.31	0.00	39.31	33.43	5.88	34.16	5.15	38.55	0.76	39.31	0.00
121 CYANIDE	26.38	0.00	26.38	21.23	5.15	22.92	3.46	25.87	0.51	26.38	0.00
122 LEAD	1.08	0.00	1.08	0.00	1.08	0.00	1.08	0.21	0.87	1.08	0.00
123 MERCURY	4.31	0.00	4.31	0.00	4.31	1.66	2.65	3.91	0.40	4.31	0.00
124 NICKEL	38068.42	37761.50	306.92	38026.46	41.96	38052.22	16.20	38066.02	2.40	38068.42	0.00
126 SILVER	9.69	0.00	9.69	2.33	7.36	4.54	5.15	8.93	0.76	9.69	0.00
128 ZINC	83890.51	83728.97	161.54	83868.43	22.08	83873.58	16.93	83888.00	2.51	83890.51	0.00
COBALT	252.54	214.85	37.69	247.39	5.15	248.85	3.69	251.99	0.55	252.54	0.00
OIL & GREASE	3483.77	0.00	3483.77	2747.67	736.10	2747.67	736.10	3374.67	109.10	3483.77	0.00
TSS	208757.06	202295.66	6461.40	207873.74	883.32	208565.67	191.39	208728.69	28.37	208757.06	0.00
TOXIC METALS	139760.64	139195.25	565.39	139672.16	88.48	139709.88	50.76	139752.41	8.23	139760.64	0.00
CONVENTIONALS	212240.83	202295.66	9945.17	210621.41	1619.42	211313.34	927.49	212103.36	137.47	212240.83	0.00
TOTAL POLLU.	352280.39	341705.76	10574.63	350562.19	1718.20	351294.99	985.40	352133.63	146.76	352280.39	0.00
SLUDGE GEN		3216693.20		3270947.21		3275519.04		3280357.34		3281209.35	

TABLE X-6

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	11.95	5.27
Chromium	15.47	6.33
Cyanide	10.19	4.22
Lead	14.76	7.03
Mercury	8.79	3.52
*Nickel	67.49	44.64
Silver	14.41	5.98
*Zinc	51.32	21.44
*Cobalt	7.38	3.16

*Regulated Pollutant

TABLE X-7

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Impregnated Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	68.0	30.0
Chromium	88.0	36.0
Cyanide	58.0	24.0
Lead	84.0	40.0
Mercury	50.0	20.0
*Nickel	384.0	254.0
Silver	82.0	34.0
*Zinc	292.0	122.0
*Cobalt	42.0	18.0

*Regulated Pollutant

TABLE X-8

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Nickel Electrodeposited Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	11.22	4.95
Chromium	14.52	5.94
Cyanide	9.57	3.96
Lead	13.86	6.60
Mercury	8.25	3.30
*Nickel	63.36	41.91
Silver	13.53	5.61
*Zinc	48.18	20.13
*Cobalt	6.93	2.97

*Regulated Pollutant

TABLE X-9

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Nickel Impregnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	68.0	30.0
Chromium	88.0	36.0
Cyanide	58.0	24.0
Lead	84.0	40.0
Mercury	50.0	20.0
*Nickel	384.0	254.0
Silver	82.0	34.0
*Zinc	292.0	122.0
*Cobalt	42.0	18.0

*Regulated Pollutant

TABLE X-10

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.26	0.11
Chromium	0.33	0.14
Cyanide	0.22	0.090
Lead	0.32	0.15
Mercury	0.19	0.075
*Nickel	1.44	0.95
Silver	0.31	0.13
*Zinc	1.10	0.46
*Cobalt	0.16	0.067

*Regulated Pollutant

TABLE X-11

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Electrolyte Preparation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.027	0.012
Chromium	0.035	0.014
Cyanide	0.023	0.009
Lead	0.033	0.016
Mercury	0.020	0.008
*Nickel	0.153	0.101
Silver	0.032	0.013
*Zinc	0.116	0.048
*Cobalt	0.016	0.007

*Regulated Pollutant

TABLE X-12

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.51	0.23
Chromium	0.66	0.27
Cyanide	0.44	0.18
Lead	0.63	0.30
Mercury	0.38	0.15
*Nickel	2.88	1.91
Silver	0.62	0.26
*Zinc	2.19	0.92
*Cobalt	0.32	0.14

*Regulated Pollutant

TABLE X-13

CADMIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.79	0.35
Chromium	1.03	0.42
Cyanide	0.68	0.28
Lead	0.98	0.47
Mercury	0.58	0.23
*Nickel	4.47	2.96
Silver	0.96	0.40
*Zinc	3.40	1.42
*Cobalt	0.49	0.21

*Regulated Pollutant

TABLE X-14

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Cadmium Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
*Cadmium	2.23	0.99
Chromium	2.89	1.18
Cyanide	1.91	0.79
Lead	2.76	1.31
Mercury	1.64	0.66
*Nickel	12.61	8.34
Silver	2.69	1.12
*Zinc	9.59	4.01
*Cobalt	1.38	0.59

*Regulated Pollutant

TABLE X-15

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
*Cadmium	1.09	0.48
Chromium	1.41	0.58
Cyanide	0.93	0.39
Lead	1.35	0.64
Mercury	0.80	0.32
*Nickel	6.16	4.08
*Silver	1.32	0.55
*Zinc	4.69	1.96
*Cobalt	0.67	0.29

*Regulated Pollutant

TABLE X-16

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Cadmium Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
*Cadmium	0.05	0.02
Chromium	0.061	0.025
Cyanide	0.040	0.016
Lead	0.058	0.028
Mercury	0.035	0.014
*Nickel	0.27	0.18
Silver	0.057	0.023
*Zinc	0.20	0.09
*Cobalt	0.03	0.01

*Regulated Pollutant

TABLE X-17

CADMIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Nickel Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used English Units - lb/1,000,000 lb of nickel used		
*Cadmium	5.61	2.48
Chromium	7.26	2.97
Cyanide	4.79	1.98
Lead	6.93	3.30
Mercury	4.13	1.65
*Nickel	31.68	20.96
Silver	6.77	2.81
*Zinc	24.09	10.07
*Cobalt	3.47	1.49

*Regulated Pollutant

TABLE X-18
SUMMARY OF TREATMENT EFFECTIVENESS
CALCIUM SUBCATEGORY

PARAMETER	RAW WASTE		BPT (PSES 0)		BAT 1 (PSES 1)		BAT 2 (PSES 2)	
	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
FLOW (l/kg)*	24.110		24.110		24.110		0.000	
116 ASBESTOS1/	315.000	7594.650	10.352	249.587	2.243	54.079	0.000	0.000
119 CHROMIUM	61.000	1470.710	0.080	1.929	0.070	1.688	0.000	0.000
TSS	368.000	8872.480	12.000	289.320	2.600	62.686	0.000	0.000

* Normalized flow based on total weight of reactants for heat paper production.

1/ Asbestos is in millions of fibers per liter and millions of fibers per kg.

TABLE X-19
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
CALCIUM SUBCATEGORY - TOTAL

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2	
	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)*	0.13		0.13		0.13		0.00
116 ASBESTOS1/	40.95	39.60	1.35	40.66	0.29	40.95	0.00
119 CHROMIUM	7.93	7.92	0.01	7.92	0.01	7.93	0.00
TSS	47.84	46.28	1.56	47.50	0.34	47.84	0.00
TOXIC METALS	7.93	7.92	0.01	7.92	0.01	7.93	0.00
CONVENTIONALS	47.84	46.28	1.56	47.50	0.34	47.84	0.00
TOTAL POLLU.	55.77	54.20	1.57	55.42	0.35	55.77	0.00
SLUDGE GEN		317.73		323.83		325.64	

* 100% of the total flow is for indirect dischargers.

1/ Asbestos is in trillions of fibers per year; not included in total.

TABLE X-20

POLLUTANT REDUCTION BENEFITS OF CONTROL OPTIONS
LECLANCHE SUBCATEGORY

	RAW WASTE			BPT & BAT (PSES)	
Flow l/yr (10^6)			16.71		0.200
l/kg*		0.758			0.009
POLLUTANTS	mg/l	mg/kg	kg/yr	Removed kg/yr	Discharged kg/yr
115 Arsenic	0.090	0.068	1.503	1.435	0.068
118 Cadmium	0.053	0.040	0.881	0.871	0.010
119 Chromium	0.409	0.310	6.84	6.826	0.014
120 Copper	0.466	0.353	7.78	7.702	0.078
122 Lead	0.101	0.076	1.684	1.668	0.016
123 Mercury	13.40	10.16	223.9	223.893	0.007
124 Nickel	1.212	0.919	20.25	20.206	0.044
125 Selenium	0.086	0.065	1.435	1.395	0.040
128 Zinc	317.5	240.7	5,305.4	5,305.35	0.046
Manganese	69.3	52.5	1,158.0	1,157.97	0.028
Oil and Grease	115.0	87.2	1,921.7	1,919.70	2.00
TSS	2,536	1,922	42,376.5	42,375.98	0.520
Toxic Metals			5,569.7	5,569.35	0.323
Conventionals			44,298.2	44,295.7	2.52
All Pollutants			51,025.9	51,023.0	2.87
Sludge Generated				288,555.0	

*Normalized flow based on total subcategory zinc anode weight.

TABLE X-21

LECLANCHE SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Foliar Battery Miscellaneous Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.092	0.038
Cadmium	0.013	0.005
Chromium	0.024	0.010
Copper	0.084	0.040
Lead	0.018	0.009
Mercury	0.010	0.004
Nickel	0.036	0.024
Selenium	0.054	0.024
Zinc	0.067	0.030
Manganese	0.019	0.015
Oil and Grease	0.66	0.66
TSS	0.99	0.79
pH	Within the range of 7.5 - 10.0 at all times	

TABLE X-22

PROCESS ELEMENT FLOW SUMMARY
LITHIUM SUBCATEGORY

Process Element	Flow (l/kg)			
	Median	Mean	BPT (PSES)	BAT (PSES)
Cathodes				
Lead Iodide	63.08	63.08	63.08	63.08
Iron Disulfide	7.54	7.54	7.54	7.54
Ancillary Operations				
Heat Paper Production	24.1	115.4	24.1	0.0
Lithium Scrap Disposal	nil.	nil.	--	--
Cell Testing	0.014	0.014	0.014	0.014
Cell Wash	0.929	0.929	0.0	0.0
Air Scrubbers	10.59	10.59	10.59	10.59
Floor & Equipment Wash	0.094	0.094	0.094	0.094

TABLE X-23
SUMMARY OF TREATMENT EFFECTIVENESS
LITHIUM SUBCATEGORY

PARAMETER	RAW WASTE		BPT (PSES 0)		BAT 1 (PSES 1)		BAT 2 (PSES 2)		BAT 3 (PSES 3)	
	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
HEAT PAPER PRODUCTION										
FLOW (l/kg)*	24.110		24.110		24.110		0.000		0.000	
116 ASBESTOS1/	315.000	7594.650	10.352	249.587	2.243	54.079	0.000	0.000	0.000	0.000
119 CHROMIUM	61.000	1470.710	0.080	1.929	0.070	1.688	0.000	0.000	0.000	0.000
122 LEAD			0.120	2.893	0.080	1.929				
128 ZINC			0.300	7.233	0.230	5.545				
COLBALT			0.070	1.688	0.050	1.206				
IRON			0.410	9.885	0.280	6.751				
TSS	368.000	8872.480	12.000	289.320	2.600	62.686	0.000	0.000	0.000	0.000
CATHODE AND ANCILLARY OPERATIONS										
FLOW (l/kg)**	0.575		0.575		0.575		0.575		0.575	
116 ASBESTOS1/	6.440	3.703	6.440	3.703	2.24	1.290	2.243	1.290	2.243	1.290
119 CHROMIUM	0.781	0.449	0.080	0.046	0.070	0.040	0.070	0.040	0.070	0.040
122 LEAD	4.880	2.806	0.120	0.069	0.080	0.046	0.080	0.046	0.080	0.046
128 ZINC	0.464	0.267	0.300	0.173	0.230	0.132	0.230	0.132	0.230	0.132
COBALT	0.175	0.101	0.070	0.040	0.050	0.029	0.050	0.029	0.050	0.029
IRON	54.153	31.138	0.410	0.236	0.280	0.161	0.280	0.161	0.280	0.161
COD	1424.242	818.939	10.000	5.750	10.000	5.750	10.000	5.750	10.000	5.750
TSS	43.279	24.885	12.000	6.900	2.600	1.495	2.600	1.495	2.600	1.495
AIR SCRUBBER WASTEWATERS										
FLOW (l/kg)**	10.590		10.590		10.590		10.590		10.590	
TSS	1208.750	12800.663	12.000	127.080	12.000	127.080	12.000	127.080	2.600	27.534

* Normalized flow based on total weight of reactants.

1/ Asbestos is millions of fibers per liter and millions of fibers per kilogram.

** Normalized flow based on process element(s) battery weight.

TABLE X-24
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LITHIUM SUBCATEGORY

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3	
	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
HEAT PAPER PRODUCTION									
FLOW l/yr (10^6)	0.04		0.04		0.04		0.00		0.00
116 ASBESTOS1/	12.60	12.19	0.41	12.51	0.09	12.60	0.00	12.60	0.00
119 CHROMIUM	2.44	2.44	0.00	2.44	0.00	2.44	0.00	2.44	0.00
122 LEAD		(-0.005)	0.005	(-0.003)	0.003				
128 ZINC		(-0.010)	0.010	(-0.008)	0.008				
COBALT		(-0.002)	0.002	(-0.002)	0.002				
IRON		(-0.014)	0.014	(-0.010)	0.010				
TSS	14.72	14.24	0.48	14.62	0.10	14.72	0.00	14.72	0.00
CATHODE AND ANCILLARY OPERATIONS									
FLOW l/yr (10^6)	0.21		0.21		0.21		0.21		0.21
116 ASBESTOS1/	1.35	0.00	1.35	0.88	0.47	0.88	0.47	0.88	0.47
119 CHROMIUM	0.16	0.14	0.02	0.15	0.01	0.15	0.01	0.15	0.01
122 LEAD	1.02	0.995	0.025	1.003	0.017	1.00	0.02	1.00	0.02
128 ZINC	0.10	0.050	0.050	0.058	0.042	0.05	0.05	0.05	0.05
COBALT	0.04	0.032	0.008	0.032	0.008	0.03	0.01	0.03	0.01
IRON	11.37	11.294	0.076	11.320	0.050	11.31	0.06	11.31	0.06
COD	299.09	296.99	2.10	296.99	2.10	296.99	2.10	296.99	2.10
TSS	9.09	6.57	2.52	8.54	0.55	8.54	0.55	8.54	0.55
AIR SCRUBBER WASTEWATERS									
FLOW l/yr (10^6)	0.11		0.11		0.11		0.11		0.11
TSS	132.96	131.64	1.32	131.64	1.32	131.64	1.32	132.67	0.29

1/ Asbestos is trillions of fibers per year; not included in totals.

TABLE X-24
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LITHIUM SUBCATEGORY

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3	
	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
LITHIUM SUBCATEGORY SUMMARY 2/									
FLOW l/yr (10^6)	0.36		0.36		0.36		0.32		0.32
116 ASBESTOS 1/	13.95	12.19	1.76	13.39	0.56	13.48	0.47	13.48	0.47
119 CHROMIUM	2.60	2.58	0.02	2.59	0.01	2.59	0.01	2.59	0.01
122 LEAD	1.02	0.99	0.03	1.00	0.02	1.00	0.02	1.00	0.02
128 ZINC	0.10	0.04	0.06	0.05	0.05	0.05	0.05	0.05	0.05
COBALT	0.04	0.03	0.01	0.03	0.01	0.03	0.01	0.03	0.01
IRON	11.37	11.28	0.09	11.31	0.06	11.31	0.06	11.31	0.06
COD	299.09	296.99	2.10	296.99	2.10	296.99	2.10	296.99	2.10
TSS	156.77	152.45	4.32	154.80	1.97	154.90	1.87	155.93	0.84
TOXIC METALS	3.72	3.61	0.11	3.64	0.08	3.64	0.08	3.64	0.08
CONVENTIONALS	156.77	152.45	4.32	154.80	1.97	154.90	1.87	155.93	0.84
TOTAL POLLU.	470.99	464.36	6.63	466.77	4.22	466.87	4.12	467.90	3.09
SLUDGE GEN		922.02		934.41		934.91		940.06	

1/ Asbestos is trillions of fibers per year; not included in totals.
2/ For direct dischargers only multiply totals by 0.01.
For indirect dischargers only multiply totals by 0.99.

TABLE X-25

LITHIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Lead Iodide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead English Units - lb/1,000,000 lb of lead		
Chromium	27.8	11.4
Lead	26.5	12.6
Zinc	92.1	38.5
Cobalt	13.3	5.68
Iron	75.7	38.5

TABLE X-26

LITHIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Iron Disulfide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of iron disulfide English Units - lb/1,000,000 lb of iron disulfide		
Chromium	3.32	1.36
Lead	3.17	1.51
Zinc	11.0	4.60
Cobalt	1.58	0.68
Iron	9.05	4.60

TABLE X-27

LITHIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.047	0.019
Lead	0.045	0.021
Zinc	0.157	0.065
Cobalt	0.022	0.009
Iron	0.129	0.065

TABLE X-28

PROCESS ELEMENT FLOW SUMMARY
MAGNESIUM SUBCATEGORY

	Flow (1/kg)			
Process Element	Median	Mean	BPT (PSES)	BAT (PSES)
Cathodes				
Silver Chloride (Chemically Reduced)	4915.	4915.	2458.	81.9
Silver Chloride (Electrolytic)	145.	145.	145.	145.
Ancillary Operations				
Heat Paper Production	24.1	115.4	24.1	0.0
Cell Testing	52.6	52.6	52.6	52.6
Floor & Equipment Wash	0.094	0.094	0.094	0.094
Air Scrubbers	206.5	206.5	206.5	206.5

TABLE X-29
SUMMARY OF TREATMENT EFFECTIVENESS
MAGNESIUM SUBCATEGORY

PARAMETER	RAW WASTE		BPT (PSES 0)		BAT 1 (PSES 1)		BAT 2 (PSES 2)		BAT 3 (PSES 3)	
	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
HEAT PAPER PRODUCTION										
FLOW (l/kg)*	24.110		24.110		24.110		0.000		0.000	
116 ASBESTOS 1/	315.000	7594.650	10.352	249.587	2.243	54.079	0.000	0.000	0.000	0.000
119 CHROMIUM	61.000	1470.710	0.080	1.929	0.070	1.688	0.000	0.000	0.000	0.000
TSS	368.000	8872.480	12.000	289.320	2.600	62.686	0.000	0.000	0.000	0.000
CELL TESTING AND FLOOR AND EQUIPMENT WASH										
FLOW (l/kg)*	52.700		52.700		52.700		52.700		52.700	
122 LEAD	1.220	64.294	0.120	6.324	0.120	6.324	0.080	4.216	0.080	4.216
124 NICKEL	0.110	5.797	0.110	5.797	0.110	5.797	0.110	5.797	0.110	5.797
126 SILVER	14.600	769.420	0.100	5.270	0.100	5.270	0.070	3.689	0.070	3.689
IRON	1.947	102.607	0.410	21.607	0.410	21.607	0.280	14.756	0.280	14.756
TSS	828.000	43635.600	12.000	632.400	12.000	632.400	2.600	137.020	2.600	137.020
SILVER CHLORIDE CATHODE PRODUCTION										
FLOW (l/kg)*	844.000		483.900		135.800		135.800		135.800	
122 LEAD	0.051	43.044	0.089	43.044	0.120	16.296	0.080	10.864	0.080	10.864
124 NICKEL	0.051	43.044	0.089	43.044	0.317	43.044	0.220	29.876	0.220	29.876
126 SILVER	0.248	209.312	0.100	48.390	0.100	13.580	0.070	9.506	0.070	9.506
IRON	0.560	472.640	0.410	198.399	0.410	55.678	0.280	38.024	0.280	38.024
COD	140.000	118160.000	10.000	4839.000	10.000	1358.000	10.000	1358.000	10.000	1358.000
TSS	0.705	595.020	1.230	595.020	4.382	595.020	2.600	353.080	2.600	353.080
AIR SCRUBBERS										
FLOW (l/kg)*	206.500		206.500		206.500		206.500		206.500	
TSS	1208.750	249606.875	12.000	2478.000	12.000	2478.000	12.000	2478.000	2.600	536.900

* Normalized flow based on weight of process element(s) production normalizing parameters.

1/ Asbestos is millions of fibers per liter and millions of fibers per kilogram.

TABLE X-30
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
MAGNESIUM SUBCATEGORY

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3	
	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
HEAT PAPER PRODUCTION									
FLOW 1/yr (10^6)	2.60		2.60		2.60		0.00		0.00
116 ASBESTOS 1/	819.00	792.08	26.92	813.17	5.83	819.00	0.00	819.00	0.00
119 CHROMIUM	158.60	158.39	0.21	158.42	0.18	158.60	0.00	158.60	0.00
TSS	956.80	925.60	31.20	950.04	6.76	956.80	0.00	956.80	0.00
CELL TESTING AND FLOOR AND EQUIPMENT WASH									
FLOW 1/yr (10^6)	0.11		0.11		0.11		0.11		0.11
122 LEAD	0.13	0.12	0.01	0.12	0.01	0.12	0.01	0.12	0.01
124 NICKEL	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
126 SILVER	1.61	1.60	0.01	1.60	0.01	1.60	0.01	1.60	0.01
IRON	0.21	0.16	0.05	0.16	0.05	0.18	0.03	0.18	0.03
TSS	91.08	89.76	1.32	89.76	1.32	90.79	0.29	90.79	0.29
SILVER CHLORIDE CATHODE PRODUCTION									
FLOW 1/yr (10^6)	0.75		0.43		0.12		0.12		0.12
122 LEAD	0.04	0.00	0.04	0.03	0.01	0.03	0.01	0.03	0.01
124 NICKEL	0.04	0.00	0.04	0.00	0.04	0.01	0.03	0.01	0.03
126 SILVER	0.19	0.15	0.04	0.18	0.01	0.18	0.01	0.18	0.01
IRON	0.42	0.24	0.18	0.37	0.05	0.39	0.03	0.39	0.03
COD	105.00	100.70	4.30	103.80	1.20	103.80	1.20	103.80	1.20
TSS	0.53	0.00	0.53	0.00	0.53	0.22	0.31	0.22	0.31
AIR SCRUBBERS									
FLOW 1/yr (10^6)	0.45		0.45		0.45		0.45		0.45
TSS	543.94	538.54	5.40	538.54	5.40	538.54	5.40	542.77	1.17

1/ Asbestos is trillions of fibers per year; not included in totals.

TABLE X-30
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
MAGNESIUM SUBCATEGORY

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3	
	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
MAGNESIUM SUBCATEGORY SUMMARY 2/									
FLOW 1/yr (10^6)	3.91		3.59		3.28		0.68		0.68
116 ASBESTOS 1/	819.00	792.08	26.92	813.17	5.83	819.00	0.00	819.00	0.68
119 CHROMIUM	158.60	158.39	0.21	158.42	0.18	158.60	0.00	158.60	0.00
122 LEAD	0.17	0.12	0.05	0.15	0.02	0.15	0.02	0.15	0.02
124 NICKEL	0.05	0.00	0.05	0.00	0.05	0.01	0.04	0.01	0.04
126 SILVER	1.80	1.75	0.05	1.78	0.02	1.78	0.02	1.78	0.02
IRON	0.63	0.40	0.23	0.53	0.10	0.57	0.06	0.57	0.06
COD	105.00	100.70	4.30	103.80	1.20	103.80	1.20	103.80	1.20
TSS	1592.35	1553.90	38.45	1578.34	14.01	1586.35	6.00	1590.58	1.77
TOXIC METALS	160.62	160.26	0.36	160.35	0.27	160.54	0.08	160.54	0.08
CONVENTIONALS	1592.35	1553.90	38.45	1578.34	14.01	1586.35	6.00	1590.58	1.77
TOTAL POLLU.	1858.60	1815.26	43.34	1843.02	15.58	1851.26	7.34	2674.49	3.11
SLUDGE GEN		9514.35		9638.83		9681.63		13797.78	

1/ Asbestos is trillions of fibers per year; not included in totals.

2/ For direct dischargers only multiply totals by 0.05.
For indirect dischargers only multiply totals by 0.95.

TABLE X-31

MAGNESIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Chloride Cathodes - Chemically Reduced

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	36.04	14.74
Lead	34.40	16.38
Nickel	157.3	104.0
Silver	33.58	13.92
Iron	98.28	49.96
COD	122900.0	59975.0

TABLE X-32

MAGNESIUM SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Chloride Cathodes - Electrolytic

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	63.8	26.1
Lead	60.9	29.0
Nickel	278.4	184.2
Silver	59.5	24.7
Iron	174.0	88.5
COD	7250.0	3538.0

TABLE X-33

MAGNESIUM SUBCATEGORY BAT EFFLUENT LIMITATIONS

Cell Testing

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	23.2	9.47
Lead	22.1	10.5
Nickel	101.0	66.8
Silver	21.6	8.94
Iron	63.1	32.1

TABLE X-34

MAGNESIUM SUBCATEGORY BAT EFFLUENT LIMITATIONS

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.041	0.016
Lead	0.039	0.018
Nickel	0.180	0.119
Silver	0.038	0.015
Iron	0.112	0.057

TABLE X-35

PROCESS ELEMENT FLOW SUMMARY
ZINC SUBCATEGORY

Flow (1/kg)

Process Element	Median	Mean	BPT	BAT 1&2 (PSES1&2)	BAT 3 (PSES 3)	BAT 4 (PSES 4)
Anodes						
Zinc Powder-Wet Amalgated	2.2	3.8	3.8	0.55	0.55	0.0
Zinc Powder-Gelled Amalgam	0.68	0.68	0.68	0.068	0.0	0.0
Zinc Oxide Powder-Pasted or Pressed, Reduced	117.	143.	143.	21.67	21.67	3.251
Zinc Electrodeposited	3190.	3190.	3190.	241.7	241.7	36.26
Cathodes						
Silver Powder Pressed and Electrolytically Oxidized	196.	196.	196.	29.70	29.70	4.45
Silver Oxide Powder - Thermally Reduced or Sintered, Electrolytically Formed	131.	131.	131.	19.85	19.85	2.978
Silver Peroxide Powder	12.8	31.4	31.4	4.76	4.76	0.714
Nickel Impregnated	1720.	1640.	1640.	200.0	200.0	30.0
Ancillary Operations						
Cell Wash	0.34	1.13	1.13	0.17	0.17	0.026
Electrolyte Preparation	0.0	0.12	0.12	0.0	0.0	0.0
Silver Etch	49.1	49.1	49.1	7.44	7.44	1.116
Mandatory Employee Wash	0.27	0.27	0.27	0.27	0.27	0.041
Reject Cell Handing	0.002	0.01	0.01	0.01	0.01	0.002
Floor & Equipment Wash	7.23	7.23	7.23	0.84	0.84	0.126
Silver Peroxide Production	52.2	52.2	52.2	7.91	7.91	1.187
Silver Powder Production	21.2	21.2	21.2	3.21	3.21	0.482

TABLE X-36
MANUFACTURING ELEMENT WASTEWATER SUMMARY
ZINC SUBCATEGORY

	ANODES								CATHODES			
	Zinc Powder Wet Amalgamated		Zinc Powder Gelled Amalgamated		Zinc Oxide Powder Pressed & Reduced		Zinc Electrodeposited		Silver Powder Electro. Oxidized		Silver Oxide Powder Electro. Formed	
	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr
Flow l/yr (10^6)		5.60		0.475		4.86		15.60		7.90		0.066
Pollutants												
115 Arsenic	0.050	0.280	0.512	0.243	0.047	0.228	0.0	0.0	0.022	0.174	0.0	0.0
118 Cadmium	0.001	0.006	0.058	0.028	0.044	0.214	0.0	0.0	0.043	0.340	0.0	0.0
119 Chromium	0.068	0.381	0.025	0.012	0.021	0.102	0.012	0.187	2.323	18.35	0.009	0.001
120 Copper	0.014	0.078	0.344	0.163	0.303	1.473	0.013	0.203	2.010	15.88	0.001	0.000
121 Cyanide	0.005	0.028	0.002	0.001	NA	NA	0.007	0.109	NA	NA	0.003	0.000
122 Lead	0.0	0.0	0.017	0.008	0.073	0.355	0.015	0.234	0.342	2.702	0.0	0.0
123 Mercury	0.453	2.537	0.595	0.283	0.069	0.335	14.71	229.5	0.034	0.269	0.017	0.001
124 Nickel	0.0	0.0	0.006	0.003	0.018	0.087	0.003	0.047	0.188	1.485	0.0	0.0
125 Selenium	0.0	0.0	0.063	0.030	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
126 Silver	0.009	0.050	0.004	0.002	0.098	0.476	0.175	2.730	1.904	15.04	8.50	0.561
128 Zinc	301.8	1690.	488.1	231.8	46.3	225.0	12.26	191.3	64.7	511.	0.014	0.001
Aluminum	0.0	0.0	3.13	1.487	0.160	0.778	0.0	0.0	0.888	7.02	0.175	0.012
Iron	NA	NA	0.522	0.248	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	0.043	0.241	1.774	0.843	0.004	0.019	0.0	0.0	0.016	0.126	0.0	0.0
Oil & Grease	9.2	51.5	14.60	6.94	NA	NA	4.233	66.0	NA	NA	10.65	0.703
TSS	12.00	67.2	282.6	134.2	57.0	277.0	7.83	122.1	143.8	1136.	3.55	0.234

TABLE X-36
MANUFACTURING ELEMENT WASTEWATER SUMMARY
ZINC SUBCATEGORY

	CATHODES				ANCILLARY OPERATIONS							
	Silver Peroxide Powder		Impregnated Nickel		Cell Wash		Electrolyte Preparation		Silver Etch		Reject Cell Handling	
	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr
Flow l/yr (10^6)		0.230		*		19.11		1.26		0.003		0.022
Pollutants												
115 Arsenic	0.0	0.0	NA	—	0.007	0.134	i	i	0.0	0.0	0.147	0.003
118 Cadmium	2.905	0.668	12.98	—	0.047	0.898	0.0	0.0	0.040	0.000	0.006	0.000
119 Chromium	0.119	0.027	0.061	—	77.1	1473.	0.0	0.0	0.009	0.000	0.030	0.001
120 Copper	0.003	0.001	NA	—	0.254	4.854	0.0	0.0	0.088	0.000	1.539	0.034
121 Cyanide	0.007	0.002	0.054	—	2.208	42.19	NA	NA	0.010	0.000	0.055	0.001
122 Lead	0.0	0.0	0.003	—	0.015	0.287	0.0	0.0	0.047	0.000	0.100	0.002
123 Mercury	0.007	0.002	0.004	—	1.019	19.47	0.040	0.050	0.009	0.000	4.710	0.104
124 Nickel	0.002	0.001	117.3	—	4.967	94.9	0.220	0.277	0.0	0.0	0.207	0.005
125 Selenium	0.0	0.0	NA	—	0.015	0.287	i	i	0.0	0.0	NA	NA
126 Silver	43.40	9.98	NA	—	0.203	3.879	0.790	0.995	36.30	0.109	0.898	0.020
128 Zinc	0.136	0.031	0.198	—	9.99	190.9	19.20	24.19	1.060	0.003	396.8	8.73
Aluminum	0.890	0.205	NA	—	0.028	0.535	0.0	0.0	0.65	0.002	106.0	2.332
Iron	NA	NA	NA	—	NA	NA	NA	NA	NA	NA	0.565	0.012
Manganese	0.0	0.0	NA	—	15.89	303.6	0.0	0.0	0.013	0.000	0.159	0.003
Oil & Grease	16.0	3.680	6.80	—	72.2	1380	NA	NA	0.0	0.0	12.76	0.281
TSS	459.5	105.7	539.0	—	40.3	770	70.0	88.2	7.0	0.021	857	18.85

* Negligable Flow.

i Invalid Analysis.

TABLE X-36
MANUFACTURING ELEMENT WASTEWATER SUMMARY
ZINC SUBCATEGORY

ANCILLARY OPERATIONS

	Equipment Wash		Floor Wash		Employee Wash		Silver Powder Production		Silver Peroxide Powder		TOTAL SUBCATEGORY RAW WASTE	
	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr	mg/l	kg/yr
Flow l/yr (10^6)		1.180		0.240		2.610		0.800		0.365		60.31
Pollutants												
115 Arsenic	0.049	0.058	0.0	0.0	0.0	0.0	0.0	0.0	5.91	2.157	0.054	3.26
118 Cadmium	0.062	0.073	0.040	0.010	0.0	0.0	0.002	0.002	0.0	0.0	0.037	2.23
119 Chromium	0.006	0.007	0.350	0.084	0.0	0.0	0.933	0.746	0.09	0.033	24.76	1493.28
120 Copper	0.024	0.028	0.230	0.055	0.022	0.057	6.41	5.13	0.0	0.0	0.464	27.98
121 Cyanide	NA	NA	NA	NA	0.0	0.0	NA	NA	NA	NA	0.702	42.34
122 Lead	0.002	0.002	4.130	0.991	0.0	0.0	0.147	0.118	0.0	0.0	0.078	4.70
123 Mercury 1/	0.194	0.229	I	I	0.0	0.0	0.003	0.002	0.037	0.014	12.71	766.54
124 Nickel	0.072	0.085	0.380	0.091	0.0	0.0	0.877	0.702	0.0	0.0	1.620	97.70
125 Selenium	0.030	0.035	0.0	0.0	NA	NA	0.0	0.0	4.800	1.752	0.035	2.11
126 Silver	0.336	0.396	49.50	11.88	0.0	0.0	16.67	13.34	0.770	0.281	0.991	59.77
128 Zinc	2.971	3.506	600	144.0	0.113	0.347	0.333	0.266	0.075	0.027	53.4	3220.55
Aluminum	0.041	0.048	5.83	1.399	NA	NA	5.29	4.232	0.0	0.0	0.299	18.03
Iron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.004	0.24
Manganese	0.028	0.033	0.340	0.082	0.228	0.595	0.096	0.077	0.0	0.0	5.07	305.77
Oil & Grease	NA	NA	NA	NA	17.43	45.49	NA	NA	NA	NA	25.78	1554.79
TSS	82.4	97.2	2800	672	90.8	237.0	21.00	16.80	31.0	11.32	62.26	3754.90

I Analytical Interference.

1/ See discussion of Analytical Interference in Section IX.

TABLE X-37
SUMMARY OF TREATMENT EFFECTIVENESS
ZINC 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)*	16.550		16.550		2.226		2.226		2.097		0.283	
115 ARSENIC	0.054	0.894	0.054	0.894	0.401	0.893	0.340	0.757	0.340	0.713	0.340	0.096
118 CADMIUM	0.037	0.612	0.037	0.612	0.079	0.176	0.049	0.109	0.010	0.021	0.010	0.003
119 CHROMIUM	24.760	409.778	0.080	1.324	0.080	0.178	0.070	0.156	0.050	0.105	0.050	0.014
120 COPPER	0.464	7.679	0.464	7.679	0.580	1.291	0.390	0.868	0.050	0.105	0.050	0.014
121 CYANIDE	0.702	11.618	0.070	1.159	0.070	0.156	0.047	0.105	0.047	0.099	0.047	0.013
122 LEAD	0.078	1.291	0.078	1.291	0.120	0.267	0.080	0.178	0.010	0.021	0.010	0.003
123 MERCURY	12.710	210.351	0.060	0.993	0.060	0.134	0.036	0.080	0.034	0.071	0.034	0.010
124 NICKEL	1.620	26.811	0.570	9.434	0.570	1.269	0.220	0.490	0.050	0.105	0.050	0.014
125 SELENIUM	0.035	0.579	0.010	0.166	0.010	0.022	0.007	0.016	0.007	0.015	0.007	0.002
126 SILVER	0.991	16.401	0.100	1.655	0.100	0.223	0.070	0.156	0.050	0.105	0.050	0.014
128 ZINC	53.400	883.770	0.300	4.965	0.300	0.668	0.230	0.512	0.010	0.021	0.010	0.003
ALUMINUM	0.299	4.948	0.299	4.948	1.110	2.471	0.740	1.647	0.740	1.552	0.740	0.209
IRON	0.004	0.066	0.004	0.066	0.030	0.066	0.030	0.066	0.031	0.066	0.233	0.066
MANGANESE	5.070	83.909	0.210	3.476	0.210	0.467	0.140	0.312	0.140	0.294	0.140	0.040
OIL & GREASE	25.780	426.659	10.000	165.500	10.000	22.260	10.000	22.260	10.000	20.970	10.000	2.830
TSS	62.260	1030.403	12.000	198.600	12.000	26.712	2.600	5.788	2.600	5.452	2.600	0.736

* Normalized flow based on total subcategory zinc anode weight.

TABLE X-38
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
ZINC SUBCATEGORY - TOTAL

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 1/yr (10^6)	60.31		60.31		8.11		8.11		7.64		1.03
115 ARSENIC	3.26	0.00	3.26	0.00	3.26	0.50	2.76	0.66	2.60	2.91	0.35
118 CADMIUM	2.23	0.00	2.23	1.59	0.64	1.83	0.40	2.15	0.08	2.22	0.01
119 CHROMIUM	1493.28	1488.46	4.82	1492.63	0.65	1492.71	0.57	1492.90	0.38	1493.23	0.05
120 COPPER	27.98	0.00	27.98	23.28	4.70	24.82	3.16	27.60	0.38	27.93	0.05
121 CYANIDE	42.34	38.12	4.22	41.77	0.57	41.96	0.38	41.98	0.36	42.29	0.05
122 LEAD	4.70	0.00	4.70	3.73	0.97	4.05	0.65	4.62	0.08	4.69	0.01
123 MERCURY	766.54	762.92	3.62	766.05	0.49	766.25	0.29	766.28	0.26	766.50	0.04
124 NICKEL	97.70	63.32	34.38	93.08	4.62	95.92	1.78	97.32	0.38	97.65	0.05
125 SELENIUM	2.11	1.51	0.60	2.03	0.08	2.05	0.06	2.06	0.05	2.10	0.01
126 SILVER	59.77	53.74	6.03	58.96	0.81	59.20	0.57	59.39	0.38	59.72	0.05
128 ZINC	3220.55	3202.46	18.09	3218.12	2.43	3218.68	1.87	3220.47	0.08	3220.54	0.01
ALUMINUM	18.03	0.00	18.03	9.03	9.00	12.03	6.00	12.38	5.65	17.27	0.76
IRON	0.24	0.00	0.24	0.00	0.24	0.00	0.24	0.00	0.24	0.00	0.24
MANGANESE	305.77	293.10	12.67	304.07	1.70	304.63	1.14	304.70	1.07	305.63	0.14
OIL & GREASE	1554.79	951.69	603.10	1473.69	81.10	1473.69	81.10	1478.39	76.40	1544.49	10.30
TSS	3754.90	3031.18	723.72	3657.58	97.32	3733.81	21.09	3735.04	19.86	3752.22	2.68
TOXIC METALS	5678.12	5572.41	105.71	5659.47	18.65	5666.01	12.11	5673.45	4.67	5677.49	0.63
CONVENTIONALS	5309.69	3982.87	1326.82	5131.27	178.42	5207.50	102.19	5213.43	96.26	5296.71	12.98
TOTAL POLLU.	11354.19	9886.50	1467.69	11145.61	208.58	11232.13	122.06	11245.94	108.25	11339.39	14.80
SLUDGE GEN		77122.08		85026.60		85644.34		85789.68		86415.27	

TABLE X-39
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
ZINC 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 1/yr (10^6)	13.87		13.87		1.87		1.87		1.76		0.24
115 ARSENIC	0.75	0.00	0.75	0.00	0.75	0.11	0.64	0.15	0.60	0.67	0.08
118 CADMIUM	0.51	0.00	0.51	0.36	0.15	0.42	0.09	0.49	0.02	0.51	0.00
119 CHROMIUM	343.42	342.31	1.11	343.27	0.15	343.29	0.13	343.33	0.09	343.41	0.01
120 COPPER	6.44	0.00	6.44	5.36	1.08	5.71	0.73	6.35	0.09	6.43	0.01
121 CYANIDE	9.74	8.77	0.97	9.61	0.13	9.65	0.09	9.66	0.08	9.73	0.01
122 LEAD	1.08	0.00	1.08	0.86	0.22	0.93	0.15	1.06	0.02	1.08	0.00
123 MERCURY	176.29	175.46	0.83	176.18	0.11	176.22	0.07	176.23	0.06	176.28	0.01
124 NICKEL	22.47	14.56	7.91	21.40	1.07	22.06	0.41	22.38	0.09	22.46	0.01
125 SELENIUM	0.49	0.35	0.14	0.47	0.02	0.48	0.01	0.48	0.01	0.49	0.00
126 SILVER	13.75	12.36	1.39	13.56	0.19	13.62	0.13	13.66	0.09	13.74	0.01
128 ZINC	740.66	736.50	4.16	740.10	0.56	740.23	0.43	740.64	0.02	740.66	0.00
ALUMINUM	4.15	0.00	4.15	2.07	2.08	2.77	1.38	2.85	1.30	3.97	0.18
IRON	0.06	0.00	0.06	0.00	0.06	0.00	0.06	0.00	0.06	0.00	0.06
MANGANESE	70.32	67.41	2.91	69.93	0.39	70.06	0.26	70.07	0.25	70.29	0.03
OIL & GREASE	357.57	218.87	138.70	338.87	18.70	338.87	18.70	339.97	17.60	355.17	2.40
TSS	863.55	697.11	166.44	841.11	22.44	858.69	4.86	858.97	4.58	862.93	0.62
TOXIC METALS	1305.86	1281.54	24.32	1301.56	4.30	1303.07	2.79	1304.77	1.09	1305.73	0.13
CONVENTIONALS	1221.12	915.98	305.14	1179.98	41.14	1197.56	23.56	1198.94	22.18	1218.10	3.02
TOTAL POLLU.	2611.25	2273.70	337.55	2563.15	48.10	2583.11	28.14	2586.29	24.96	2607.82	3.43
SLUDGE GEN		17736.59		19553.59		19696.31		19729.74		19873.97	

TABLE X-40

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Wet Amalgamated Powder Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	1.58	0.71
Cadmium	0.19	0.082
*Chromium	0.24	0.099
Copper	1.05	0.55
Lead	0.23	0.11
*Mercury	0.14	0.055
Nickel	1.06	0.70
Selenium	0.68	0.30
*Silver	0.23	0.093
*Zinc	0.80	0.34
Aluminum	3.54	1.76
Iron	0.66	0.34
*Manganese	0.37	0.16

*Regulated Pollutant

TABLE X-41

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Gelled Amalgam Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	0.20	0.087
Cadmium	0.023	0.010
*Chromium	0.030	0.012
Copper	0.13	0.068
Lead	0.028	0.013
*Mercury	0.017	0.007
Nickel	0.13	0.086
Selenium	0.083	0.037
*Silver	0.028	0.012
*Zinc	0.099	0.042
Aluminum	0.44	0.22
Iron	0.081	0.041
*Manganese	0.046	0.020

*Regulated Pollutant

TABLE X-42

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Zinc Oxide Anodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	62.19	27.74
Cadmium	7.37	3.25
*Chromium	9.53	3.90
Copper	41.17	21.67
Lead	9.10	4.34
*Mercury	5.42	2.17
Nickel	41.61	27.52
Selenium	26.66	11.92
*Silver	8.89	3.68
*Zinc	31.64	13.22
Aluminum	139.3	69.35
Iron	26.00	13.22
*Manganese	14.74	6.28

*Regulated Pollutant

TABLE X-43

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Arsenic	616.19	274.82
Cadmium	73.00	32.21
*Chromium	94.47	38.65
Copper	407.93	214.70
Lead	90.18	42.94
*Mercury	53.68	21.47
Nickel	412.23	272.67
Selenium	264.08	118.09
*Silver	88.03	36.50
*Zinc	313.46	130.97
Aluminum	1380.52	687.04
Iron	257.64	130.97
*Manganese	146.00	62.26

*Regulated Pollutant

TABLE X-44

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	85.24	38.02
Cadmium	10.10	4.46
*Chromium	13.07	5.35
Copper	56.43	29.70
Lead	12.48	5.94
*Mercury	7.43	2.97
Nickel	57.03	37.72
Selenium	36.53	16.34
*Silver	12.18	5.05
*Zinc	43.36	18.12
Aluminum	190.97	95.04
Iron	35.64	18.12
*Manganese	20.20	8.61

*Regulated Pollutant

TABLE X-45

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Oxide Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	56.97	25.41
Cadmium	6.75	2.98
*Chromium	8.73	3.57
Copper	37.72	19.85
Lead	8.34	3.97
*Mercury	4.96	1.99
Nickel	38.11	25.21
Selenium	24.42	10.92
*Silver	8.14	3.37
*Zinc	28.98	12.11
Aluminum	127.64	63.52
Iron	23.82	12.11
*Manganese	13.50	5.76

*Regulated Pollutant

TABLE X-46

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Peroxide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	13.66	6.09
Cadmium	1.62	0.72
*Chromium	2.09	0.87
Copper	9.05	4.76
Lead	2.00	0.95
*Mercury	1.19	0.48
Nickel	9.14	6.05
Selenium	5.86	2.62
*Silver	1.95	0.81
*Zinc	6.95	2.90
Aluminum	30.61	15.23
Iron	5.71	2.90
*Manganese	3.24	1.38

*Regulated Pollutant

TABLE X-47

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Nickel Impregnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Arsenic	574.0	256.0
Cadmium	68.0	30.0
*Chromium	88.0	36.0
Copper	380.0	200.0
Lead	84.0	40.0
*Mercury	50.0	20.0
*Nickel	384.0	254.0
Selenium	246.0	110.0
*Silver	82.0	34.0
*Zinc	292.0	122.0
Aluminum	1286.0	640.0
Iron	240.0	122.0
*Manganese	136.0	58.0

*Regulated Pollutant

TABLE X-48

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.49	0.22
Cadmium	0.057	0.025
*Chromium	0.074	0.030
Copper	0.32	0.17
*Cyanide	0.049	0.021
Lead	0.071	0.034
*Mercury	0.042	0.017
*Nickel	0.33	0.22
Selenium	0.21	0.093
*Silver	0.069	0.028
*Zinc	0.25	0.10
Aluminum	1.09	0.55
Iron	0.21	0.11
*Manganese	0.12	0.049

*Regulated Pollutant

TABLE X-49

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Etch

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Arsenic	21.35	9.52
Cadmium	2.53	1.12
*Chromium	3.27	1.34
Copper	14.14	7.44
Lead	3.13	1.49
*Mercury	1.86	0.74
Nickel	14.29	9.45
Selenium	9.15	4.09
*Silver	3.05	1.26
*Zinc	10.86	4.54
Aluminum	47.84	23.81
Iron	8.93	4.54
*Manganese	5.06	2.16

*Regulated Pollutant

TABLE X-50

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.78	0.35
Cadmium	0.091	0.040
*Chromium	0.12	0.048
Copper	0.51	0.27
*Cyanide	0.078	0.033
Lead	0.11	0.054
*Mercury	0.067	0.027
*Nickel	0.52	0.34
Selenium	0.33	0.15
*Silver	0.11	0.045
*Zinc	0.40	0.17
Aluminum	1.74	0.87
Iron	0.33	0.17
*Manganese	0.18	0.078

*Regulated Pollutant

TABLE X-51

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Reject Cell Handling

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.028	0.012
Cadmium	0.003	0.001
*Chromium	0.004	0.001
Copper	0.019	0.010
*Cyanide	0.003	0.001
Lead	0.004	0.002
*Mercury	0.002	0.001
*Nickel	0.019	0.012
Selenium	0.012	0.005
*Silver	0.004	0.001
*Zinc	0.014	0.006
Aluminum	0.064	0.032
Iron	0.012	0.006
*Manganese	0.006	0.002

*Regulated Pollutant

TABLE X-52

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	2.41	1.08
Cadmium	0.29	0.13
*Chromium	0.37	0.15
Copper	1.60	0.84
*Cyanide	0.24	0.10
Lead	0.35	0.17
*Mercury	0.21	0.084
*Nickel	1.61	1.07
Selenium	1.03	0.46
*Silver	0.35	0.14
*Zinc	1.23	0.51
Aluminum	5.40	2.69
Iron	1.01	0.51
*Manganese	0.57	0.24

*Regulated Pollutant

TABLE X-53

ZINC 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 cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	3.70	1.65
Cadmium	0.44	0.19
*Chromium	0.57	0.23
Copper	2.45	1.29
*Cyanide	0.38	0.16
Lead	0.54	0.26
*Mercury	0.32	0.13
*Nickel	2.48	1.64
Selenium	1.59	0.71
*Silver	0.53	0.22
*Zinc	1.88	0.79
Aluminum	8.30	4.13
Iron	1.55	0.79
*Manganese	0.88	0.37

*Regulated Pollutant

TABLE X-54

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Peroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Arsenic	22.70	10.13
Cadmium	2.69	1.19
*Chromium	3.48	1.42
Copper	15.03	7.91
Lead	3.32	1.58
*Mercury	1.98	0.79
Nickel	15.19	10.05
Selenium	9.73	4.35
*Silver	3.24	1.34
*Zinc	11.55	4.83
Aluminum	50.86	25.31
Iron	9.49	4.83
*Manganese	5.38	2.29

*Regulated Pollutant

TABLE X-55

ZINC SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Arsenic	9.21	4.11
Cadmium	1.09	0.48
*Chromium	1.41	0.58
Copper	6.10	3.21
Lead	1.35	0.64
*Mercury	0.80	0.32
Nickel	6.16	4.08
Selenium	3.95	1.77
*Silver	1.32	0.55
*Zinc	4.69	1.96
Aluminum	20.64	10.27
Iron	3.85	1.96
*Manganese	2.18	0.93

*Regulated Pollutant

TABLE X-56
BATTERY CATEGORY COSTS [1]

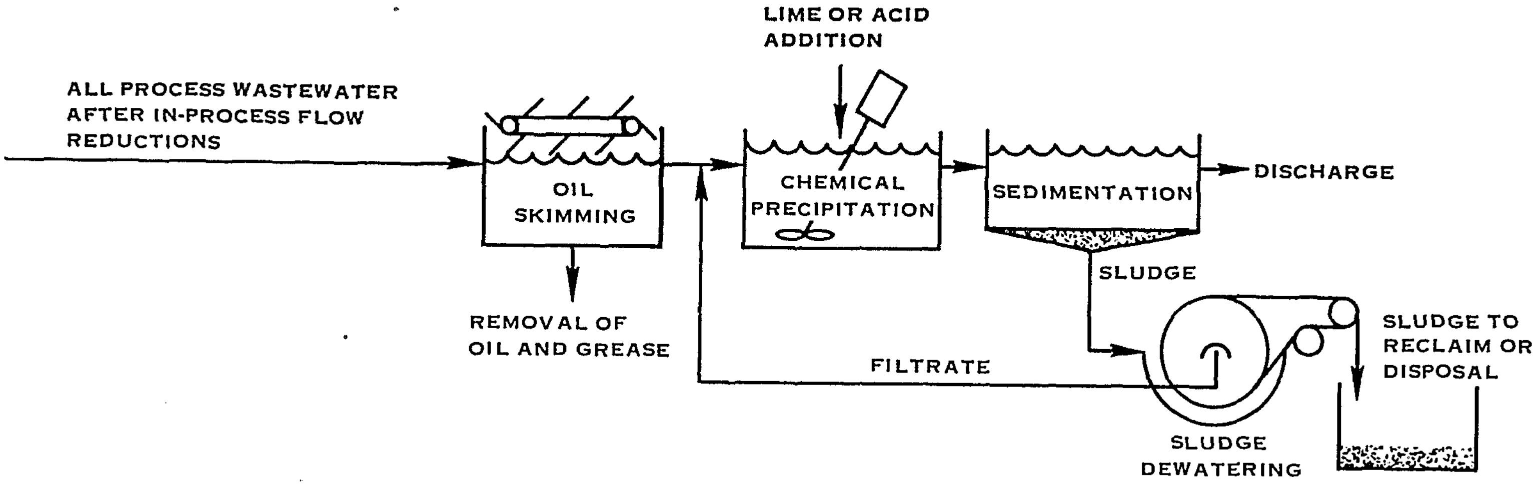
Subcategory	BPT (PSES 0) Capital Cost $	BPT (PSES 0) Annual Cost $	BAT 1 (PSES 1) Capital Cost $	BAT 1 (PSES 1) Annual Cost $	BAT 2 (PSES 2) Capital Cost $	BAT 2 (PSES 2) Annual Cost $	BAT 3 (PSES 3) Capital Cost $	BAT 3 (PSES 3) Annual Cost $	BAT 4 (PSES 4) Capital Cost $	BAT 4 (PSES 4) Annual Cost $
Cadmium										
Direct Dischargers	60472.	23065.	122762.	37576.	146732.	48575.	181070.	65933.	624290.	133643.
Indirect Dischargers	330090.	75625.	318290.	109185.	416245.	140330.	622480.	183368.	1501581.	490754.
Subcategory Total	390562.	98690.	441052.	146761.	562977.	188905.	803550.	249301.	2125871.	624397.
Calcium										
Direct Dischargers	---	---	---	---	---					
Indirect Dischargers	23434.	7338.	0.	9554.	4412.	3322.				
Subcategory Total[2]	23434.	7338.	0.	9554.	4412.	3322.				
Leclanche										
Direct Dischargers	---	---								
Indirect Dischargers	42845.	21603.								
Subcategory Total[3]	42845.	21603.								
Lithium										
Direct Dischargers	0.	494.	0.	494.	0.	494.	0.	494.		
Indirect Dischargers	0.	6080.	0.	6080.	0.	6080.	0.	6080.		
Subcategory Total[2]	0.	6574.	0.	6574.	0.	6574.	0.	6574.		
Magnesium										
Direct Dischargers	20908.	8134.	0.	14230.	0.	14230.	0.	14230.		
Indirect Dischargers	28272.	14571.	37371.	22407.	37371.	20236.	73784.	27846.		
Subcategory Total[3]	49180.	22705.	37371.	36637.	37371.	34466.	73784.	42076.		
Zinc										
Direct Dischargers	50294.	18219.	90013.	23918.	102156.	38187.	102156.	38187.	109028.	55191.
Indirect Dischargers[4]	258474.	88243.	346662.	100197.	405624.	159308.	405624.	159308.	547387.	252265.
Subcategory Total	308768.	102462.	436675.	123415.	507780.	197495.	507780.	197495.	656415.	307456.

[1] Reflect contract hauling costs when less than treatment costs. Costs are in 1978 dollars.

[2] Regulation proposed for new sources only.

[3] Regulation proposed for existing pretreatment and new sources only.

[4] Compliance cost for the selected PSES technology are $28,000 capitol and $12,000 annual.



ADDITIONAL RECOMMENDED IN-PROCESS TECHNOLOGY:

- RECYCLE OR REUSE FOR PASTED AND PRESSED POWDER ANODE WASTEWATER
- USE DRY METHODS TO CLEAN FLOORS AND EQUIPMENT
- CONTROL RINSE FLOW RATES
- RECIRCULATE WASTEWATER FROM AIR SCRUBBER
- DRY CLEAN IMPREGNATED ELECTRODES
- REDUCE CELL WASH WATER USE
- COUNTERCURRENT RINSE SILVER AND CADMIUM POWDER
- COUNTERCURRENT RINSE FOR SINTERED AND ELECTRODEPOSITED ANODES AND CATHODES

FIGURE X-1. CADMIUM SUBCATEGORY BAT OPTION 1 TREATMENT

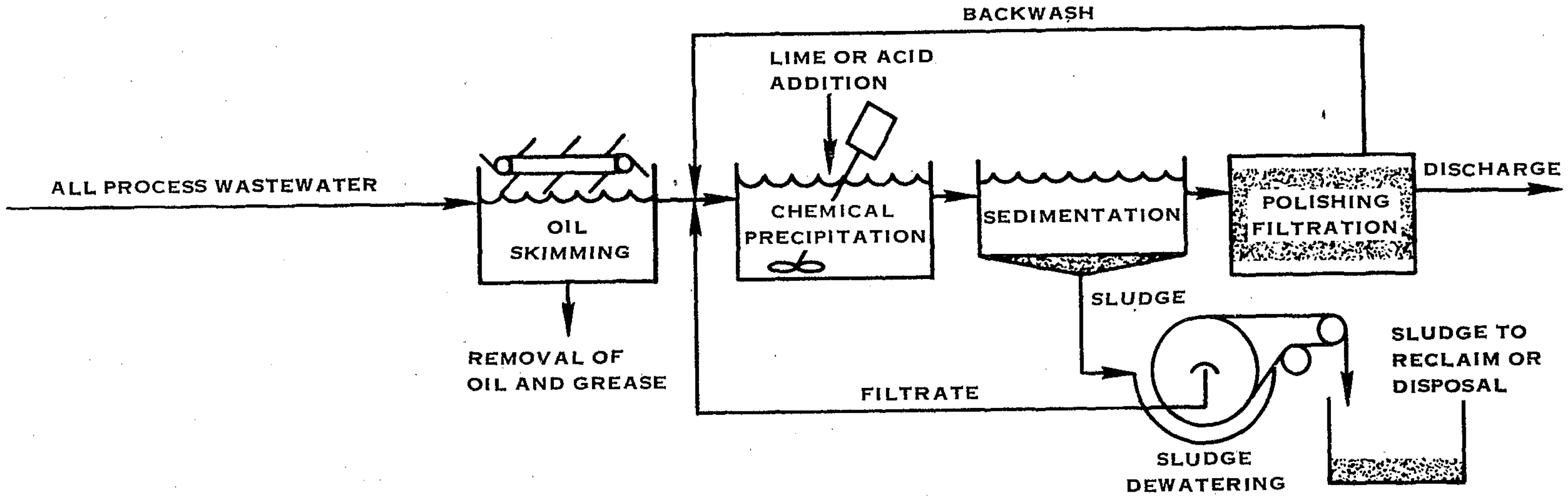
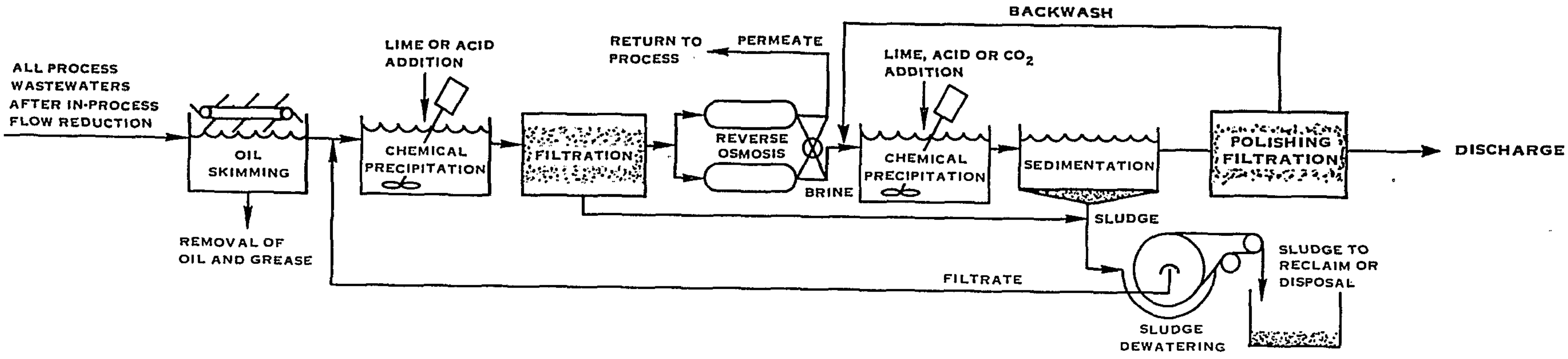
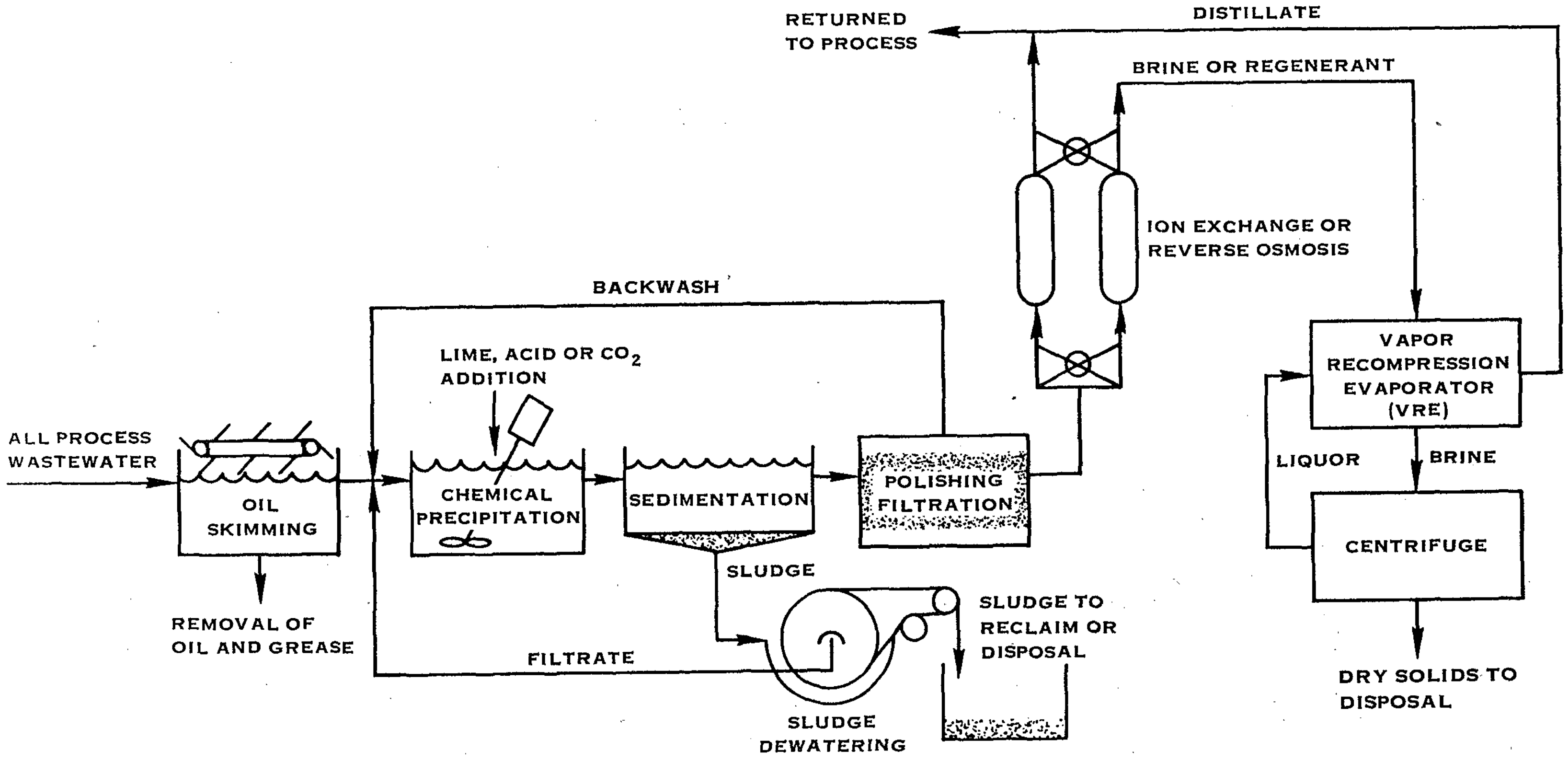


FIGURE X-2. CADMIUM SUBCATEGORY BAT OPTION 2 TREATMENT



ADDITIONAL RECOMMENDED IN-PROCESS TECHNOLOGY: REDUCE CADMIUM POWDER REWORK

FIGURE X-3. CADMIUM SUBCATEGORY BAT OPTION 3 TREATMENT



ADDITIONAL RECOMMENDED IN-PROCESS CONTROL TECHNOLOGY: ELIMINATION OF IMPREGNATION RINSE DISCHARGE

FIGURE X-4. CADMIUM SUBCATEGORY BAT OPTION 4 TREATMENT

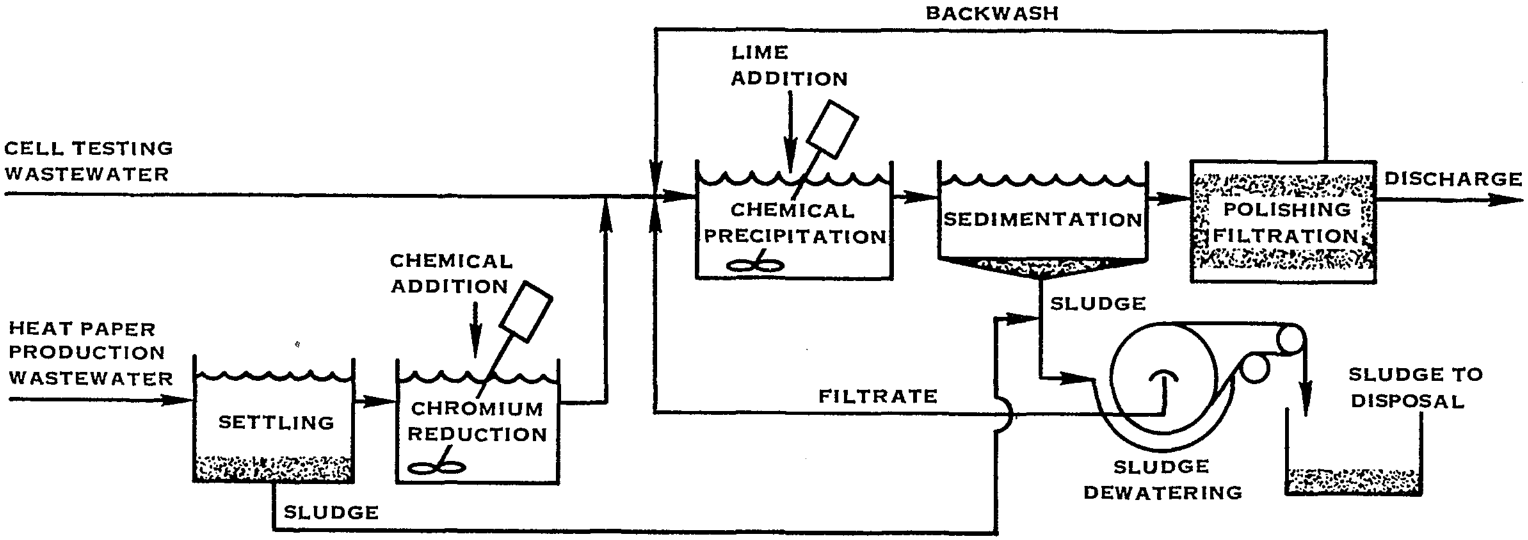


FIGURE X-5. CALCIUM SUBCATEGORY BAT OPTION 1 TREATMENT

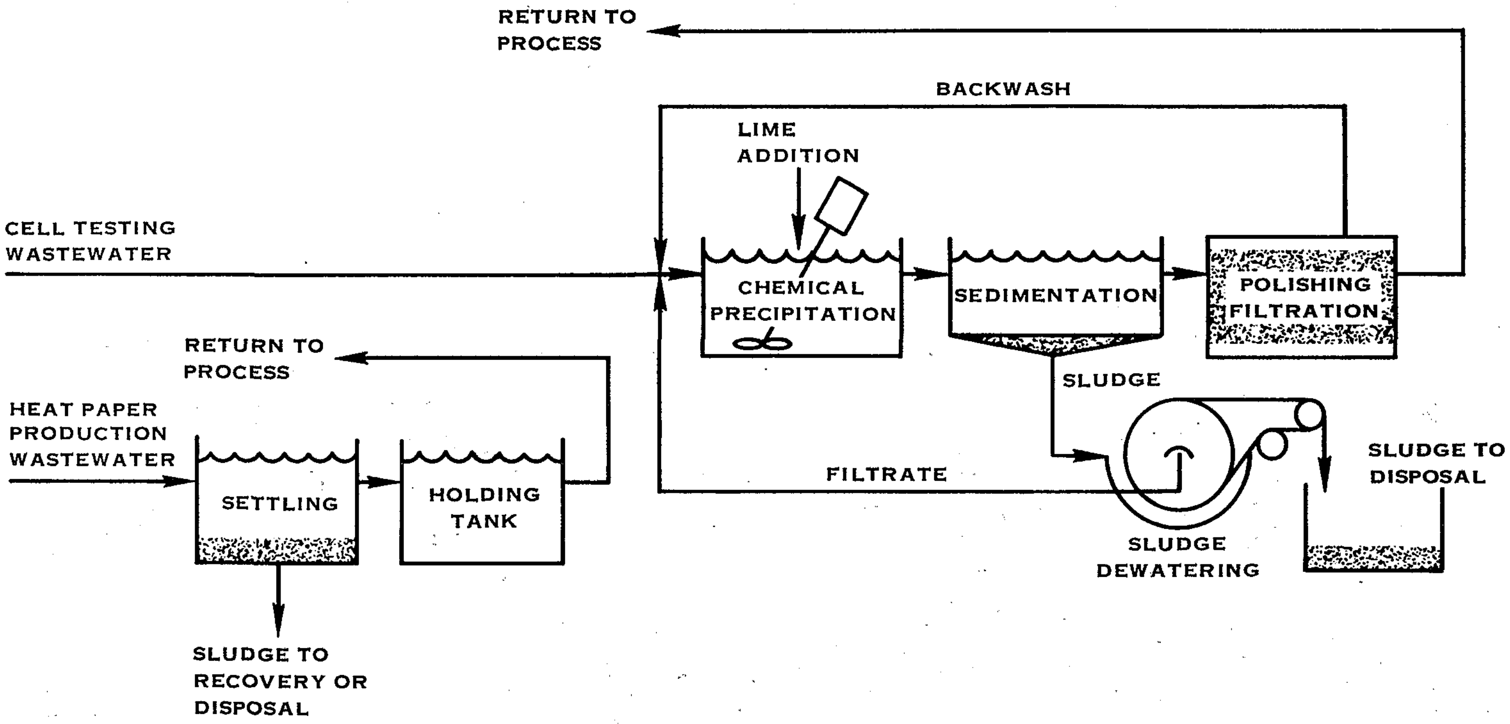


FIGURE X-6. CALCIUM SUBCATEGORY BAT OPTION 2 TREATMENT

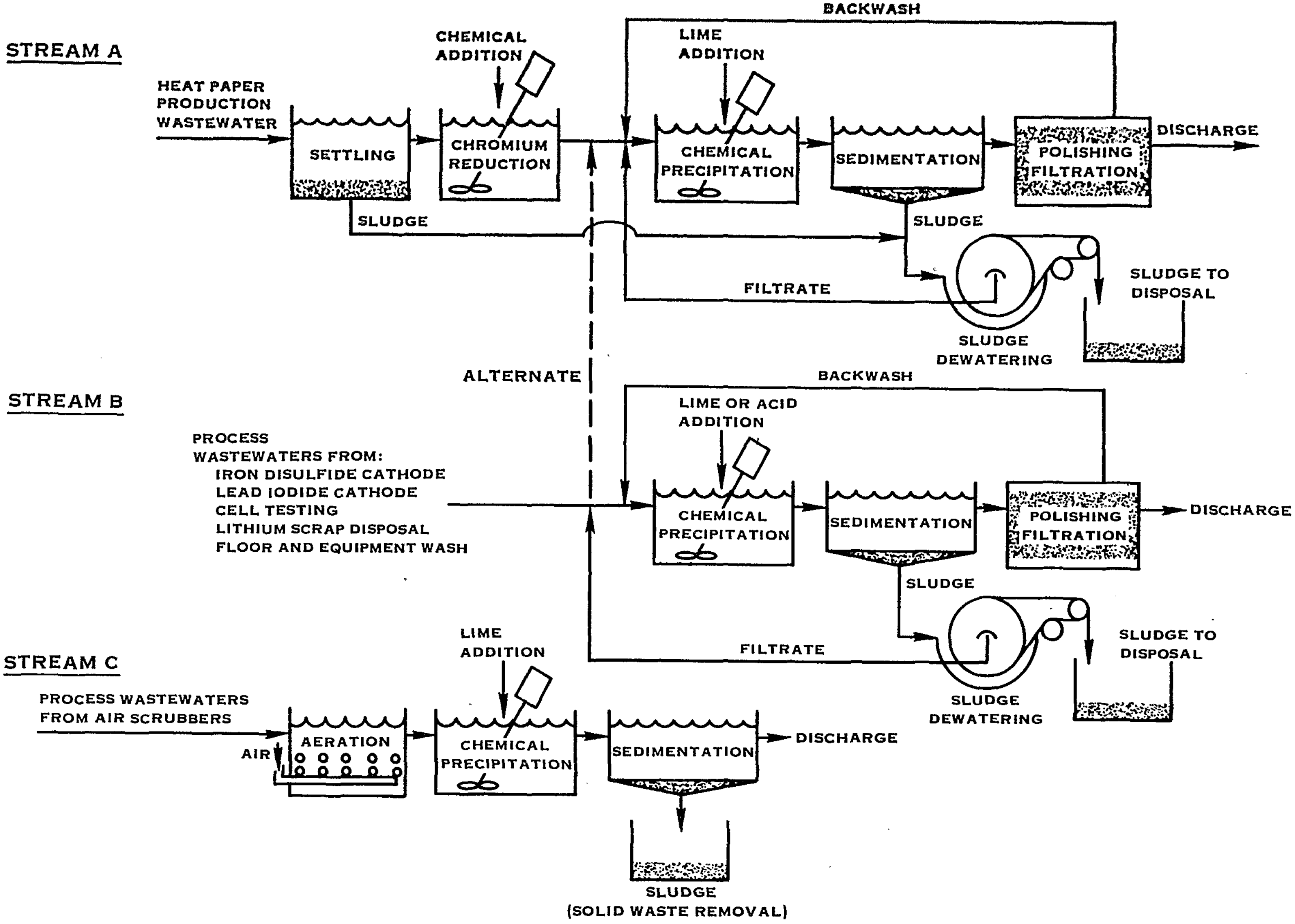


FIGURE X-7. LITHIUM SUBCATEGORY BAT OPTION 1 TREATMENT

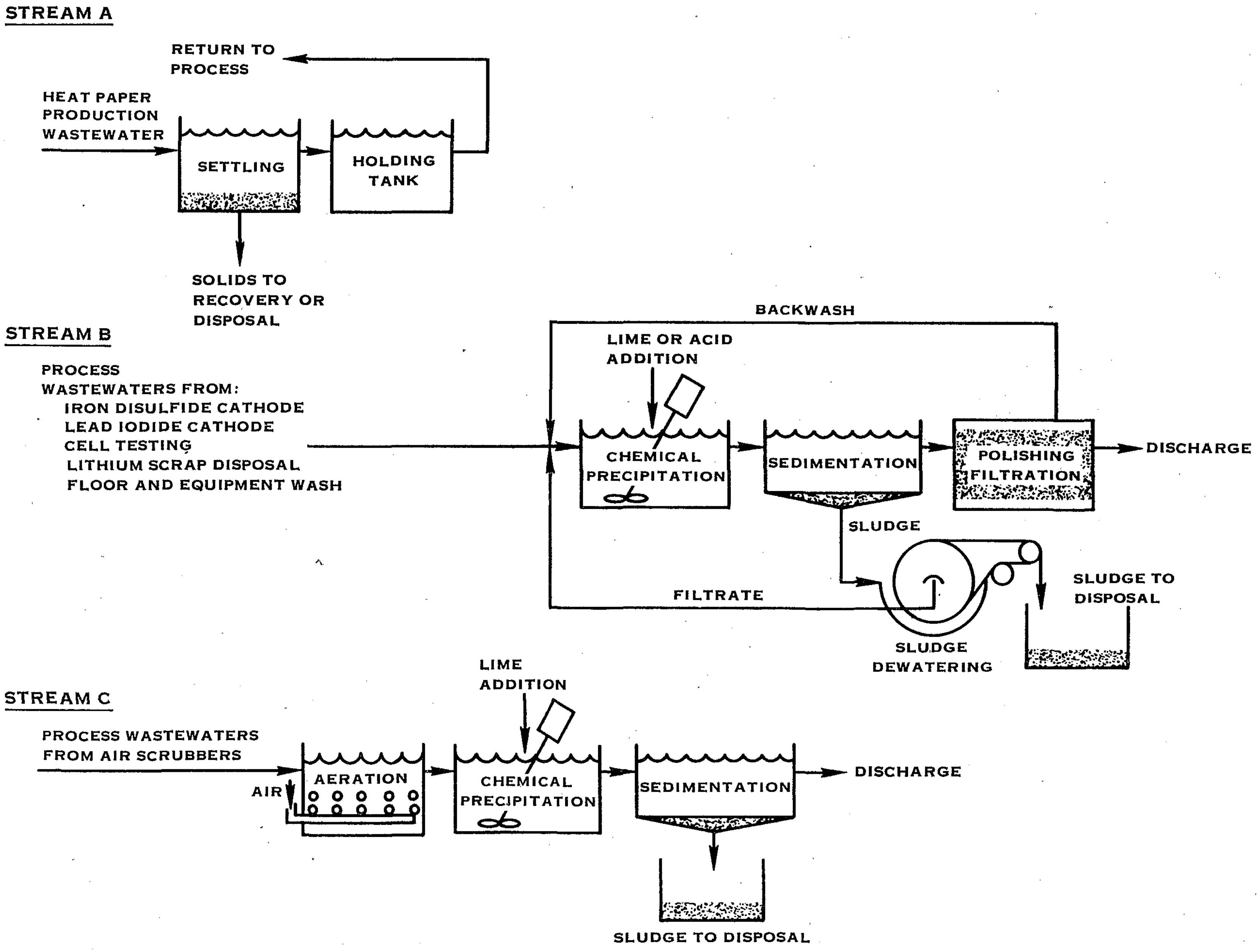


FIGURE X-8. LITHIUM SUBCATEGORY BAT OPTION 2 TREATMENT

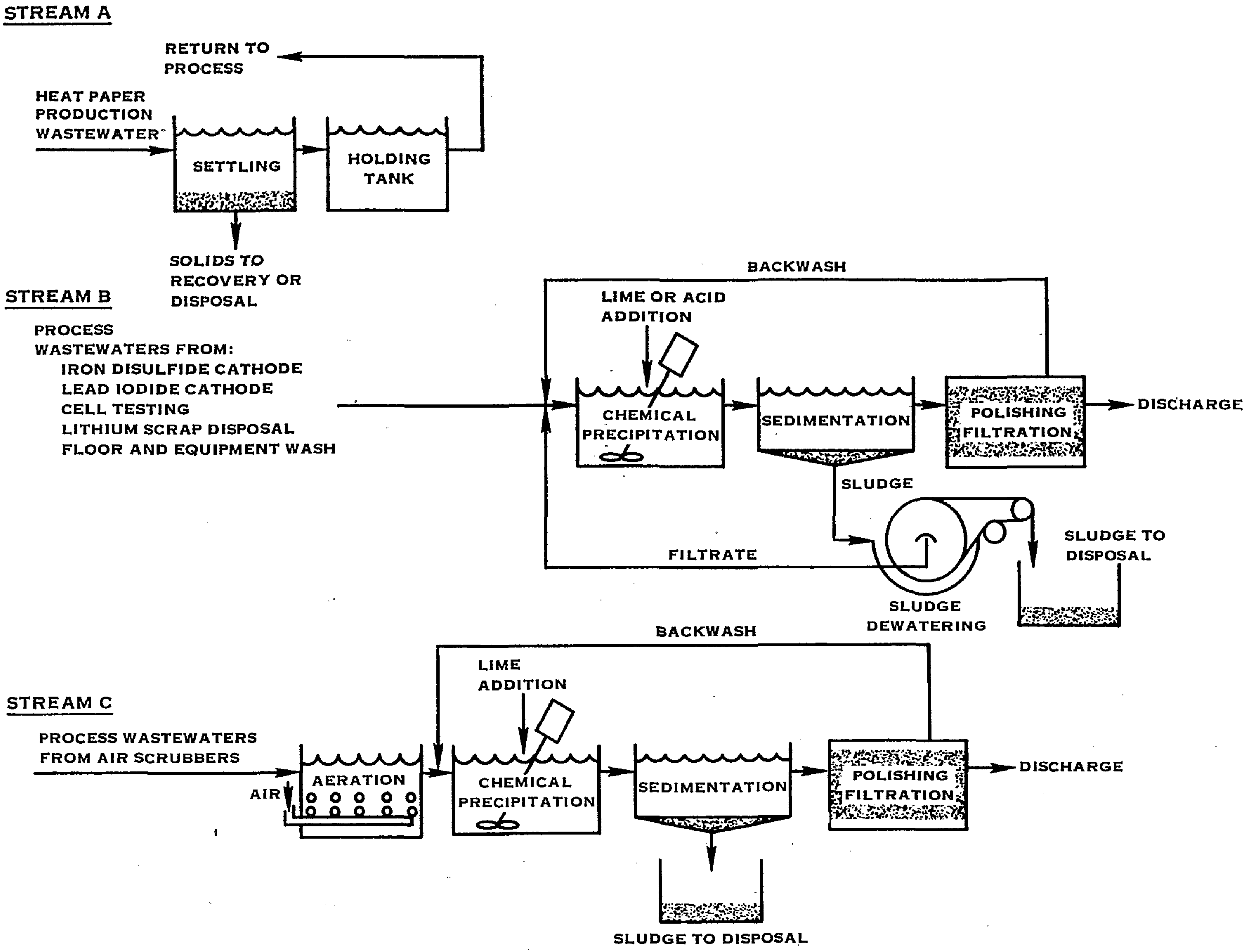


FIGURE X-9. LITHIUM SUBCATEGORY BAT OPTION 3 TREATMENT

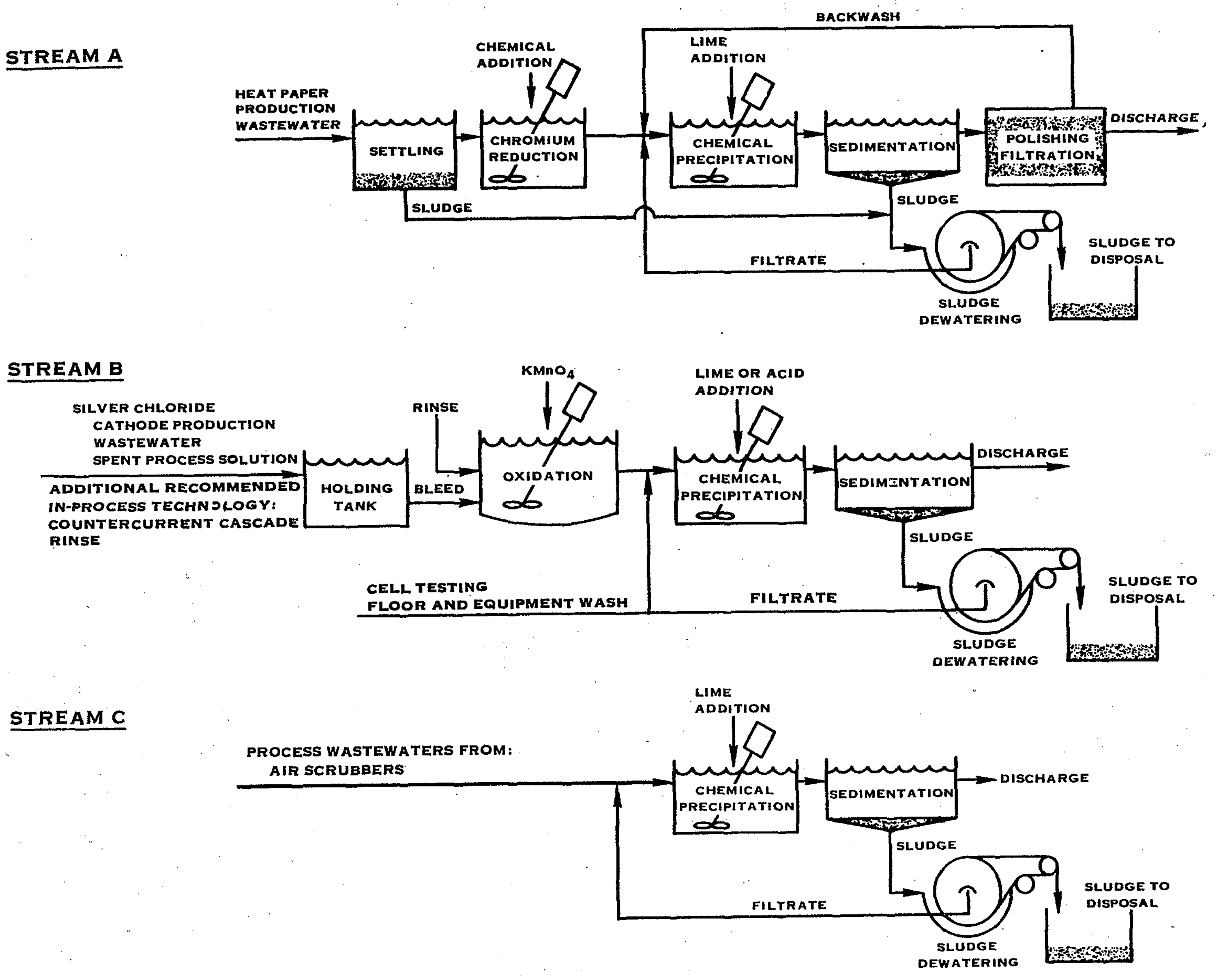


FIGURE X-10. MAGNESIUM SUBCATEGORY BAT OPTION 1 TREATMENT

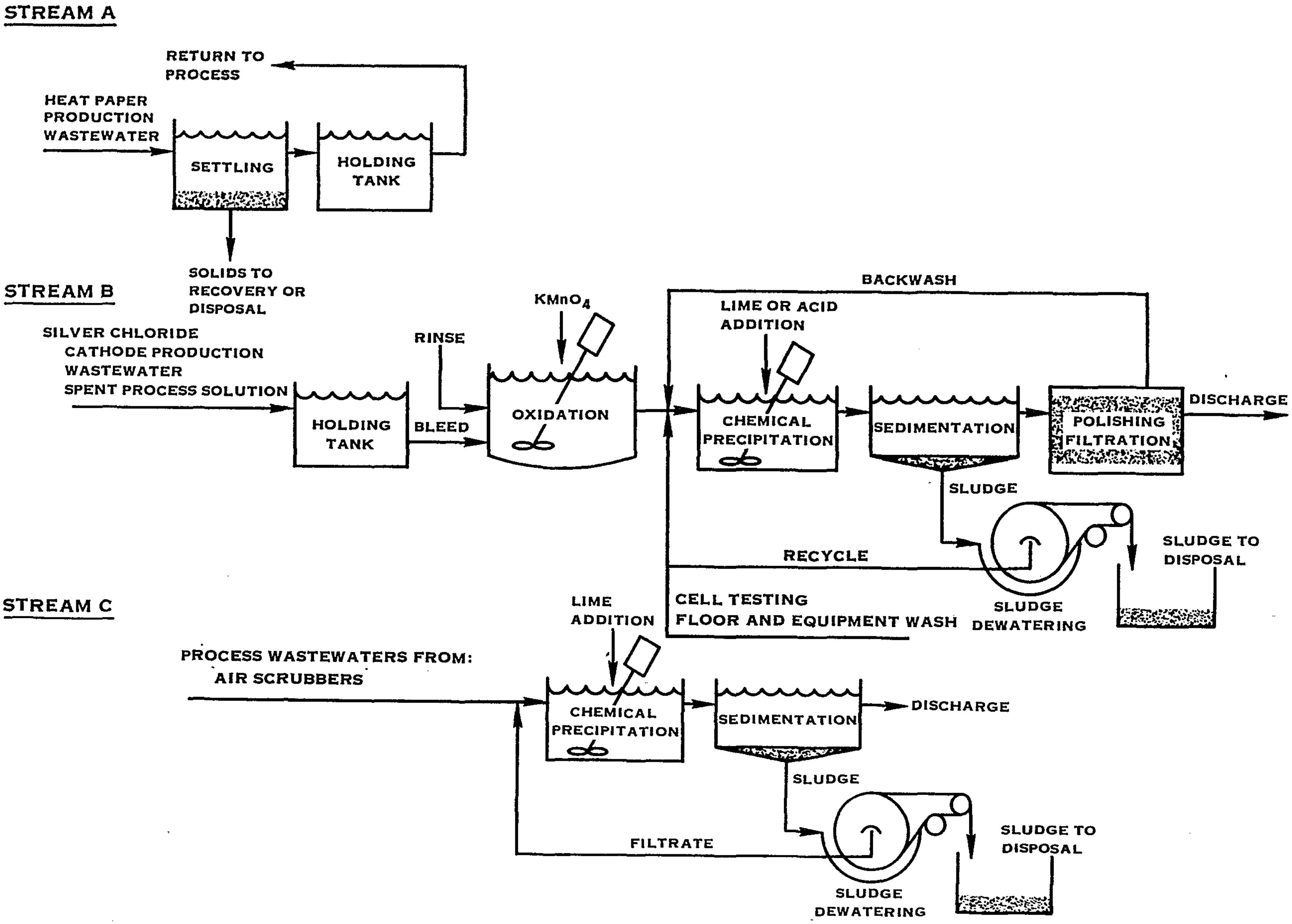


FIGURE X-11. MAGNESIUM SUBCATEGORY BAT OPTION 2 TREATMENT

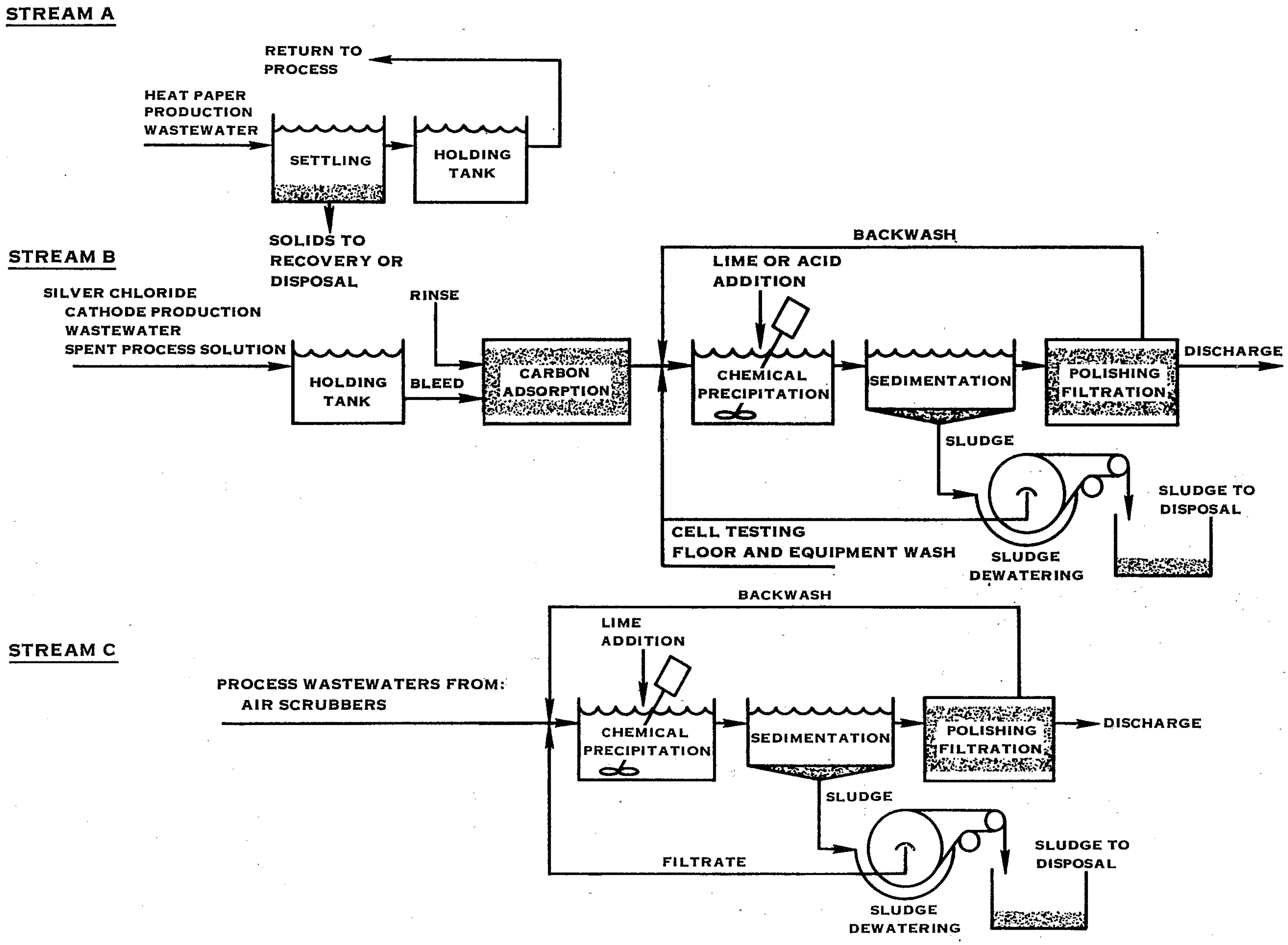
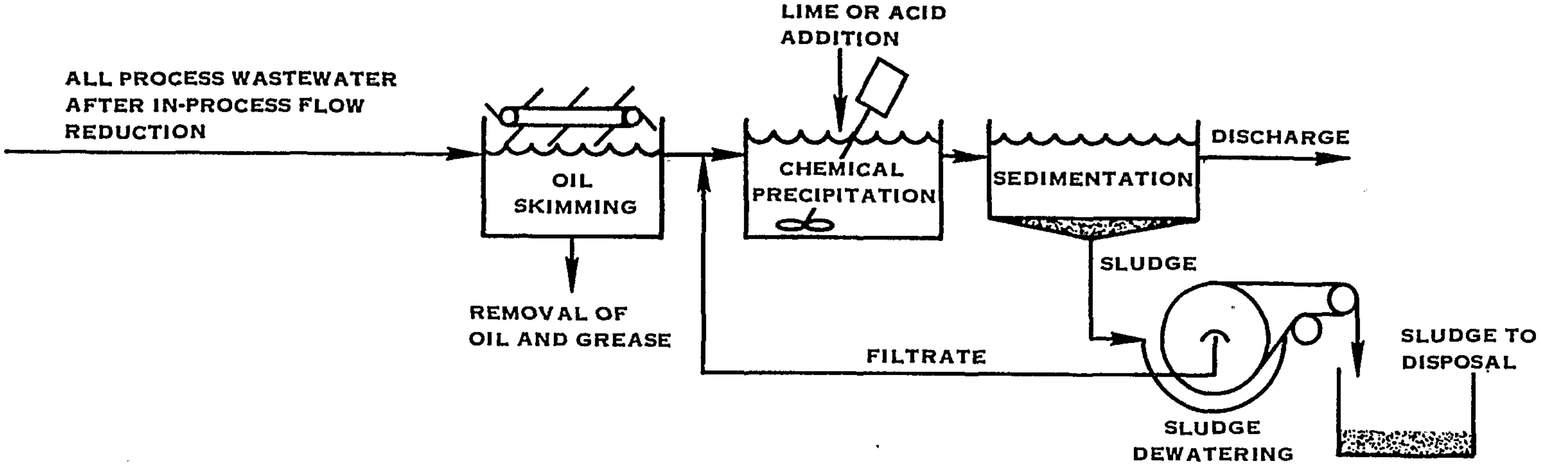


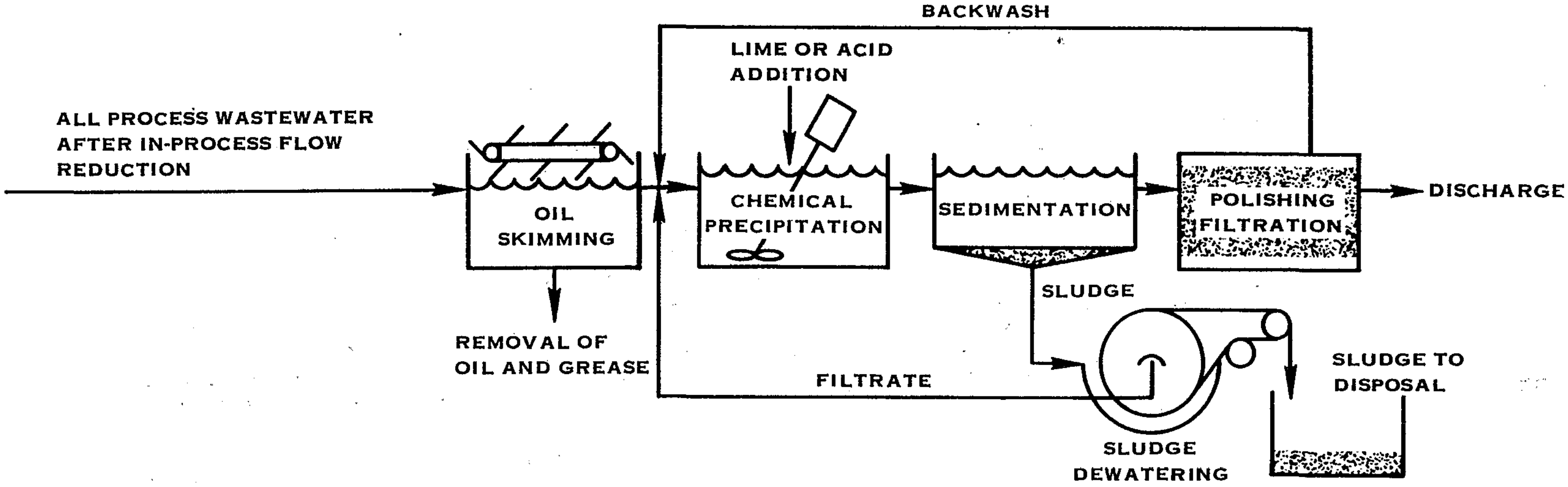
FIGURE X-12. MAGNESIUM SUBCATEGORY BAT OPTION 3 TREATMENT



ADDITIONAL RECOMMENDED IN-PROCESS TECHNOLOGY:

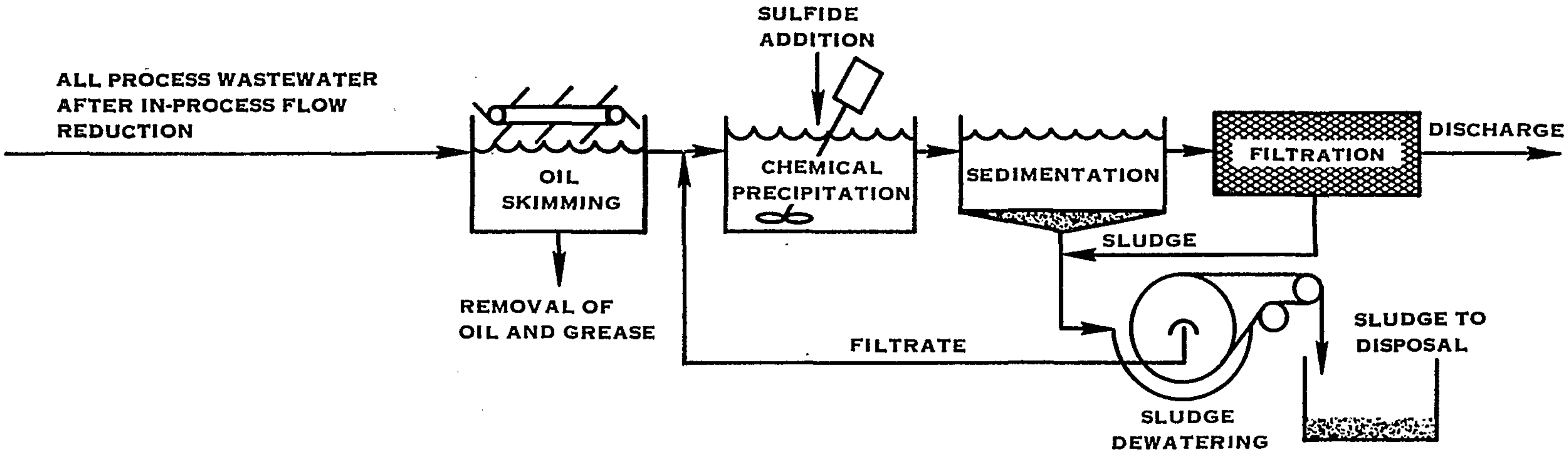
COUNTERCURRENT RINSE AMALGAMATED ZINC POWDER
RECIRCULATE AMALGAMATION AREA FLOOR WASH WATER
COUNTERCURRENT RINSE OF FORMED ZINC ELECTRODES
COUNTERCURRENT RINSE OF ELECTRODEPOSITED SILVER-POWDER
COUNTERCURRENT RINSE OF FORMED SILVER OXIDE ELECTRODES
REDUCE FLOW AND COUNTERCURRENT RINSE SILVER PEROXIDE
FLOW CONTROLS AND COUNTERCURRENT RINSE FOR IMPREGNATED NICKEL CATHODES
COUNTERCURRENT RINSE OR RINSE RECYCLE FOR CELL WASHING
ELIMINATE ELECTROLYTE PREPARATION SPILLS
COUNTERCURRENT RINSE AFTER ETCHING SILVER GRIDS
DRY CLEANUP OR WASH WATER REUSE FOR FLOOR AND EQUIPMENT

FIGURE X-13. ZINC SUBCATEGORY BAT OPTION 1 TREATMENT



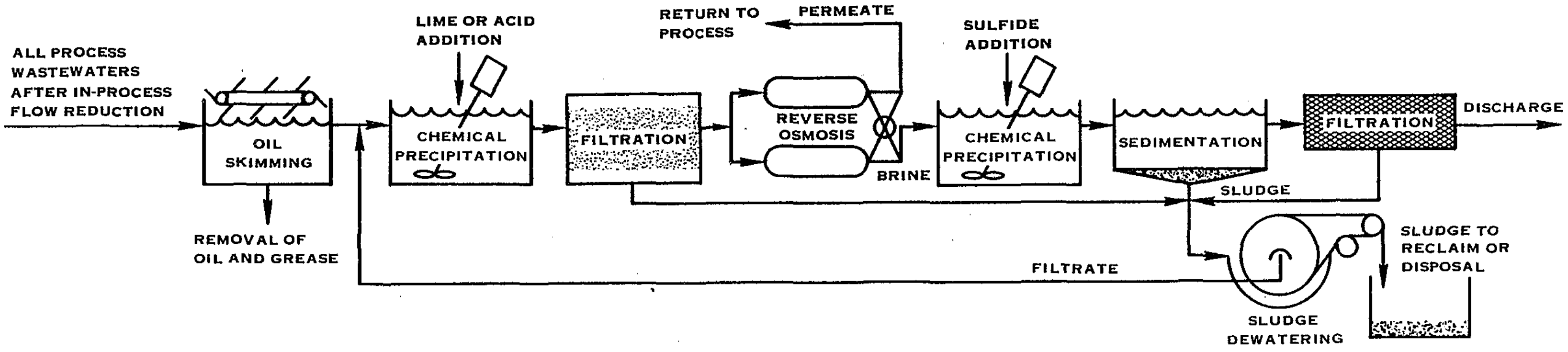
ADDITIONAL IN-PROCESS TECHNOLOGY: NONE

FIGURE X-14. ZINC SUBCATEGORY BAT OPTION 2 TREATMENT



ADDITIONAL IN-PROCESS TECHNOLOGY: ELIMINATE WASTEWATER FROM GELLED AMALGAM

FIGURE X-15. ZINC SUBCATEGORY BAT OPTION 3 TREATMENT



ADDITIONAL RECOMMENDED IN-PROCESS TECHNOLOGY: AMALGAMATION BY DRY PROCESSES

FIGURE X-16. ZINC 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 applcation of the best available demonstrated control technology (BDT), processes, operating methods, or other alternatives including, where practicable, a standard permitting no discharge of pollutants. Three levels of technology are discussed; cost, performance and environmental benefits are presented; and the rationale for selecting one of the levels is outlined. The selection of pollutant parameters for specific regulations is discussed and discharge limitations for the regulated pollutants are presented for each subcategory.

TECHNICAL APPROACH TO NSPS

As a general approach for the category, three or four levels of BDT technology options were evaluated for each subcategory. The levels evaluated are generally identical to the BAT technology options. These options and the detailed discussion and evaluation carried out in conjuntion with Section X will be incorporated here by specific reference rather than duplicate previous explanation and discussion.

CADMIUM SUBCATEGORY

The four options considered for BDT in the cadmium subcategory are identical with the four options considered at BAT. These options are described in summary form and in detail on pages 819-824. Schematics of the treatment systems are displayed on pages 908-911.

As discussed in the BAT options selection discussions on pages 824-826, the second treatment option includes process flow control followed by lime, settle and filter end-of-pipe treatment. This option was selected for NSPS because it provides additional removal of toxic pollutants but will not pose a barrier to entry into the subcategory for new plants. The NSPS limitations will remove approximately 99.96 percent of toxic pollutants from the raw waste generated by a new plant. Given the results achieved by the technologies used as a basis for the promulgated limitations, further treatment would result only in deminimis, insignificant reductions in annual national discharges. Accordingly, EPA has determined that the total amount of each pollutant in the remaining discharges after compliance with NSPS does not justify establishing a national requirement based on additional end-of-pipe technology.

Although EPA is not basing the final regulations directly on the additional technologies provided in options 3 and 4, their availability, effectiveness and affordability provides significant support for EPA's conclusion that the promulgated effluent limitations are both technologically and economically achievable.

New Source Performance Standards

The new source performance standards for the cadmium subcategory are set forth in Tables XI-1 to XI-12 (pages 931-942). Table XI-8 (page 938) is the combined table for Tables XI-5 to XI-7 (pages 935-937). These tables list standards for all the pollutants considered for regulation and all pollutants regulated are *'d.

CALCIUM SUBCATEGORY

The options considered as BDT for the calcium subcategory are identical with the two options considered in Section X. These options are described in summary form and detail on pages 827-829 and schematics of the processes are displayed on pages 912-913.

As discussed in substantial detail in the options selection discussions on pages 829 to 830, the second option, which includes process flow control, settling and complete recycle of process water results in no discharge of pollutants. This option was selected as the preferred technology option because the treatment costs associated with the removal of hexavalent chromium are eliminated by the implementation of recycle and reuse. One plant already achieves no discharge of wastewater pollutants. Therefore, this option is selected as the technology option basic to the new source performance standards for this subcategory. As discussed in the EIA, no entry impacts are projected with the selection of this option.

New Source Performance Standards

The new source performance standard for the calcium subcategory is no discharge of process wastewater pollutants.

LECLANCHE SUBCATEGORY

The technology selected for existing plants in this subcategory (except foliar batteries) is no discharge of process wastewater pollutants. Twelve existing plants already achieve no discharge of pollutants. This level of performance is continued for new sources and the new source standard for the Leclanche subcategory is no discharge of process wastewater pollutants. The discharge allowance for foliar batteries is the same as discussed under BPT page 742. No additional technology is identified to further reduce water use and LS&F end-of-pipe treatment is required.

New Source Performance Standards

The new source performance standards for the foliar battery miscellaneous wash element of the Leclanche subcategory are set forth in Table XI-13 (page 943). This table lists standards for all the pollutants considered for regulation and those pollutants regulated are *'d.

LITHIUM SUBCATEGORY

The options considered for BDT in the lithium subcategory are identical with the three options considered in Section X. These options are described in summary form and detail on pages 831-834 and schematics of the processes are displayed on pages 914-916.

As discussed in the technology options selection discussions (pages 834-835), the second option, provides the greatest level of toxic pollutant removal and is therefore selected as the basis for new source performance standards for the lithium subcategory. Two existing plants in the subcategory achieve no discharge of pollutants by choice of manufacturing processes. Many alternatives can be considered when constructing new plants. As discussed in the EIA, no entry impacts are projected with the selection of this option.

New Source Performance Standards

New source performance standards for the lithium subcategory are based on recycle and reuse technology for heat paper production, LS&F technology for the cathode process elements, and L&S technology for the air scrubber element. These standards are set forth in Tables XI-14 to XI-17 (pages 944 to 947). These tables list standards for all the pollutants considered for regulation and those pollutants regulated are *'d. Flows used as the basis for new source standards are displayed under BAT (PSES) in Table X-22 (page 872). Effluent concentrations achievable by the applications of the new source technology are displayed in Table VII-21. Pollutants regulated by the new source standards are: chromium, lead, iron, TSS, and pH for the cathode process elements, and the combined stream which includes floor and equipment wash, cell testing and lithium scrap disposal wastewater, TSS and pH were regulated for the air scrubber process element. The effluent standard for the heat paper element and cell wash element is no discharge of process wastewater pollutants.

MAGNESIUM SUBCATEGORY

The options considered for BDT in the magnesium subcategory are identical with the three options considered in Section X. These options are described in summary form and in detail on pages 836-838 and schematics of processes are displayed on pages 917-919.

As discussed in the technology options selection discussion section (pages 839-840) the second option, provides the greatest levels of toxic pollutant removal, and is therefore selected as the basis for new source performance standards for the magnesium subcategory. Four of the eight existing plants in the subcategory achieve no discharge by choice of manufacturing processes. Many alternatives can be considered when constructing a new plant. As discussed in the EIA, no entry impacts are projected with the selection of this option.

New Source Performance Standards

New source performance standards for the magnesium subcategory are based on recycle and reuse technology for heat paper production, L&S technology for the air scrubber process elements, and LS&F technology for all other waste streams. These standards are set forth in Tables XI-18 to XI-22 (pages 948-952). These tables list standards for all the pollutants considered for regulation and those pollutants regulated are *'d. Flows used as the basis for new source standards are displayed under BAT (PSES) in Table X-28 (page 878). Effluent concentrations achievable by the application of the new source technology are displayed in Table VII-21. Pollutants regulated by the new source standards are: lead, silver, iron, COD, TSS, and pH. The effluent standard for the heat paper production element is no discharge of process wastewater pollutants.

ZINC SUBCATEGORY

The technology options considered as possible BDT for the zinc subcategory are similar to the options considered at BAT. These options are discussed in outline form and in detail on pages 841-845 and are depicted schematically on pages 920-923. These options were evaluated for their applicability, cost, and pollution reduction benefits. Option 1 was selected as the preferred technology option for BAT. In making a selection of BAT, it was pointed out in the discussion that operational and applicability problems with sulfide as a precipitant and retrofitting costs at existing plants were taken into account and heavily weighted in the decision to not select a sulfide based treatment option. Additionally, the high cost of disposing of a toxic reactive sludge was weighed in the decision. The considerations, which were basic to the BAT selection, do not apply in a new plant. The handling, application and control of the use of sulfide precipitation, as well as adequate ventilation and other necessary precautions, can be readily and inexpensively built into a new plant. Also, retrofitting costs do not apply to new plants. Similarly, the point of siting for a new plant can be adjusted over a wide geographic area to provide an opportunity for convenient and inexpensive disposal of toxic sludges. Hence, the major technology objections to options 3 and 4 are overcome by the inherrent advantages of a new plant.

The promulgated NSPS is based on the sulfide, settle, and filter end-of-pipe treatment of option 3, plus additional in-process technology (shown in Figure X-16, page 923) which is to eliminate wastewater from gelled amalgam and wet amalgamated anode production. Option 3 is selected as the preferred technology option because it improves pollutant removal above option 1 (BAT) and option 2, and the technology is demonstrated. Also, as discussed in the EIA no entry impacts are projected with the selection of this option.

As shown in Table X-38, option 3 removes about 75 percent of the toxic pollutants remaining after the application of option 1 treatment, and 61 percent of the toxic pollutants remaining after option 2 making option 3 the more desirable option from the standpoint of pollutant reduction benefits. Sulfide precipitation is applied in some segments of battery manufacturing and other industrial segments such as nonferrous metals refining. Compliance costs associated with this option at existing plants are shown in Table X-56 (page 907). These costs overstate what would actually be incurred at a new plant because some retrofitting costs are included. To reduce compliance costs, new plants can also decide on whether to use processes which do not generate wastewater or implement end-of-pipe treatment to comply with the standards.

New Source Performance Standards

New source performance standards for this subcategory are based on the wastewater flow reductions achieved by improved control and recycle, and the pollutant concentrations achievable by sulfide precipitation, settle and filter end-of-pipe treatment. Some (13) process element streams are treated at new sources. Flows used as the basis for new source standards are displayed under BAT-1 and 2 (PSES-1 and 2) in Table X-35 (page 884), for all elements except zinc powder-wet amalgamated and zinc powder-gelled amalgam. No discharge allowance is provided for these elements under NSPS. Effluent concentrations achievable by the application of new source technology are displayed in Table VII-21.

The pollutants to be regulated are chromium, mercury, silver, zinc, manganese, oil and grease, TSS, and pH. Nickel is to be regulated for the nickel impregnated cathode and cell wash elements only. Cyanide is to be regulated for cell wash only. These are the same pollutants regulated at BAT with the addition of oil and grease, TSS, and pH.

Tables XI-23 to XI-36 (pages 953-966) display the new source performance standards for each element in the zinc subcategory. To alleviate some of the monitoring burden, several process elements which occur at most plants and have the same pnp are combined in one regulatory table. Table XI-34 (page 964) is the combined table for Tables XI-29, 31, 32 and 33. These tables list standards for all pollutants considered for regulation and those pollutants regulated are *'d.

TABLE XI-1

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	7.03	2.81
Chromium	13.01	5.27
Cyanide	7.03	2.81
Lead	9.84	4.57
Mercury	5.27	2.11
*Nickel	19.33	13.01
Silver	10.19	4.22
*Zinc	35.85	14.76
*Cobalt	4.92	2.46
*Oil and Grease	351.5	351.5
*TSS	527.3	421.8
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-2

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Impregnated Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	40.0	16.0
Chromium	74.0	30.0
Cyanide	40.0	16.0
Lead	56.0	26.0
Mercury	30.0	12.0
*Nickel	110.0	74.0
Silver	58.0	24.0
*Zinc	204.0	84.0
*Cobalt	28.0	14.0
*Oil and Grease	2000.0	2000.0
*TSS	3000.0	2400.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-3

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Nickel Electrodeposited Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied		
English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	6.60	2.64
Chromium	12.21	4.95
Cyanide	6.60	2.64
Lead	9.24	4.29
Mercury	4.95	1.98
*Nickel	18.15	12.21
Silver	9.57	3.96
*Zinc	33.66	13.86
*Cobalt	4.62	2.31
*Oil and Grease	330.0	330.0
*TSS	495.0	396.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-4

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Nickel Impegnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied		
English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	40.0	16.0
Chromium	74.0	30.0
Cyanide	40.0	16.0
Lead	56.0	26.0
Mercury	30.0	12.0
*Nickel	110.0	74.0
Silver	58.0	24.0
*Zinc	204.0	84.0
*Cobalt	28.0	14.0
*Oil and Grease	2000.0	2000.0
*TSS	3000.0	2400.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-5

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced		
English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.15	0.06
Chromium	0.28	0.11
Cyanide	0.15	0.06
Lead	0.21	0.097
Mercury	0.11	0.045
*Nickel	0.41	0.28
Silver	0.22	0.09
*Zinc	0.77	0.32
*Cobalt	0.11	0.052
*Oil and Grease	7.50	7.50
*TSS	11.3	9.00
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-6

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Electrolyte Preparation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.016	0.006
Chromium	0.029	0.012
Cyanide	0.016	0.006
Lead	0.022	0.010
Mercury	0.012	0.004
*Nickel	0.044	0.029
Silver	0.023	0.009
*Zinc	0.081	0.033
*Cobalt	0.011	0.005
*Oil and Grease	0.80	0.80
*TSS	1.20	0.96
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-7

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.30	0.12
Chromium	0.56	0.23
Cyanide	0.30	0.12
Lead	0.42	0.20
Mercury	0.23	0.090
*Nickel	0.83	0.56
Silver	0.44	0.18
*Zinc	1.53	0.63
*Cobalt	0.21	0.11
*Oil and Grease	15.0	15.0
*TSS	22.5	18.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-8

CADMIUM 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 cells produced		
English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.47	0.19
Chromium	0.86	0.35
Cyanide	0.47	0.19
Lead	0.65	0.30
Mercury	0.35	0.14
*Nickel	1.28	0.86
Silver	0.68	0.28
*Zinc	2.38	0.98
*Cobalt	0.33	0.16
*Oil and Grease	23.3	23.3
*TSS	35.0	28.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-9

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Cadmium Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
*Cadmium	1.31	0.53
Chromium	2.43	0.99
Cyanide	1.32	0.53
Lead	1.84	0.86
Mercury	0.99	0.40
*Nickel	3.61	2.43
Silver	1.91	0.79
*Zinc	6.70	2.76
*Cobalt	0.92	0.46
*Oil and Grease	65.70	65.70
*TSS	98.55	78.84
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-10

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
*Cadmium	0.64	0.26
Chromium	1.19	0.48
Cyanide	0.64	0.26
Lead	0.90	0.42
Mercury	0.48	0.19
*Nickel	1.77	1.19
*Silver	0.93	0.39
*Zinc	3.27	1.35
*Cobalt	0.45	0.22
*Oil and Grease	32.10	32.10
*TSS	48.15	38.52
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-11

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Cadmium Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
*Cadmium	0.028	0.011
Chromium	0.051	0.021
Cyanide	0.028	0.011
Lead	0.039	0.018
Mercury	0.021	0.008
*Nickel	0.077	0.051
Silver	0.040	0.016
*Zinc	0.142	0.058
*Cobalt	0.019	0.009
*Oil and Grease	1.40	1.40
*TSS	2.10	1.68
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-12

CADMIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Nickel Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used		
English Units - lb/1,000,000 lb of nickel used		
*Cadmium	3.30	1.32
Chromium	6.11	2.48
Cyanide	3.30	1.32
Lead	4.62	2.15
Mercury	2.48	0.99
*Nickel	9.08	6.11
Silver	4.79	1.98
*Zinc	16.83	6.93
*Cobalt	2.31	1.16
*Oil and Grease	165.0	165.0
*TSS	247.5	198.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-13

LECLANCHE SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Foliar Battery Miscellaneous Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.092	0.038
Cadmium	0.013	0.005
Chromium	0.024	0.010
Copper	0.084	0.040
Lead	0.018	0.009
*Mercury	0.010	0.004
Nickel	0.036	0.024
Selenium	0.054	0.024
*Zinc	0.067	0.030
*Manganese	0.019	0.015
*Oil and Grease	0.66	0.66
*TSS	0.99	0.79
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-14

LITHIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Lead Iodide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead English Units - lb/1,000,000 lb of lead		
*Chromium	23.34	9.46
*Lead	17.66	8.20
Zinc	64.34	26.49
Cobalt	75.70	38.48
*Iron	75.70	38.48
*TSS	946.2	756.96
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-15

LITHIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Iron Disulfide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of iron disulfide English Units - lb/1,000,000 lb of iron disulfide		
*Chromium	2.79	1.13
*Lead	2.11	0.98
Zinc	7.69	3.17
Cobalt	1.06	0.53
*Iron	9.05	4.60
*TSS	113.1	90.5
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-16

LITHIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
*Chromium	0.039	0.016
*Lead	0.030	0.014
Zinc	0.110	0.045
Cobalt	0.015	0.007
*Iron	0.129	0.066
*TSS	1.62	1.30
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-17

LITHIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Air Scrubbers

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	4.66	1.91
Lead	4.45	2.12
Zinc	15.46	6.46
Cobalt	2.22	0.95
Iron	12.71	6.46
*TSS	434.0	207.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-18

MAGNESIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Chloride Cathodes - Chemically Reduced

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	30.30	12.29
*Lead	22.93	10.65
Nickel	45.05	30.30
*Silver	23.75	9.83
*Iron	98.28	49.96
*TSS	1228.5	982.8
*COD	4095.0	1999.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-19

MAGNESIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Chloride Cathodes - Electrolytic

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	53.7	21.8
*Lead	40.6	18.9
Nickel	79.8	53.7
*Silver	42.1	17.4
*Iron	174.0	88.5
*TSS	2175.0	1740.0
*COD	7250.0	3540.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-20

MAGNESIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Cell Testing

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	19.5	7.89
*Lead	14.7	6.84
Nickel	28.9	19.5
*Silver	15.3	6.31
*Iron	63.1	32.1
*TSS	789.0	631.2
*COD	2630.0	1290.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-21

MAGNESIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.034	0.014
*Lead	0.026	0.012
Nickel	0.051	0.034
*Silver	0.027	0.011
*Iron	0.112	0.057
*TSS	1.41	1.13
*COD	4.70	2.30
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-22

MAGNESIUM SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Air Scrubbers

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	90.9	37.2
Lead	86.7	41.3
Nickel	396.5	262.3
Silver	84.7	35.1
Iron	247.8	126.0
*TSS	8467.0	4030.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-23

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Zinc Oxide Anodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	41.82	18.64
Cadmium	0.87	0.39
*Chromium	4.55	1.97
Copper	4.55	1.97
Lead	0.87	0.39
*Mercury	2.82	1.19
Nickel	4.55	1.97
Selenium	17.77	8.02
*Silver	4.55	1.97
*Zinc	0.87	0.39
Aluminum	132.4	58.73
Iron	26.01	13.22
*Manganese	6.50	4.98
*Oil and Grease	216.7	216.7
*TSS	325.0	260.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-24

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Arsenic	414.37	184.64
Cadmium	8.59	3.87
*Chromium	45.09	19.54
Copper	45.09	19.54
Lead	8.59	3.87
*Mercury	27.91	11.81
Nickel	45.09	19.54
Selenium	8.59	3.87
*Silver	45.09	19.54
*Zinc	8.59	3.86
Aluminum	1311.82	581.84
Iron	257.64	130.97
*Manganese	64.41	49.38
*Oil and Grease	2147.00	2147.00
*TSS	3220.50	2576.40
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-25

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied		
English Units - lb/1,000,000 lb of silver applied		
Arsenic	57.32	25.54
Cadmium	1.19	0.54
*Chromium	6.24	2.70
Copper	6.24	2.70
Lead	1.19	0.54
*Mercury	3.86	1.63
Nickel	6.24	2.70
Selenium	24.35	10.99
*Silver	6.24	2.70
*Zinc	1.19	0.53
Aluminum	181.47	80.49
Iron	35.64	18.12
*Manganese	8.91	6.83
*Oil and Grease	297.00	297.00
*TSS	445.5	356.40
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-26

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Oxide Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	38.3	17.1
Cadmium	0.79	0.36
*Chromium	4.17	1.81
Copper	4.17	1.81
Lead	0.79	0.36
*Mercury	2.58	1.09
Nickel	4.17	1.81
Selenium	16.3	7.35
*Silver	4.17	1.81
*Zinc	0.79	0.36
Aluminum	121.3	53.8
Iron	23.8	12.1
*Manganese	5.96	4.57
*Oil and Grease	198.5	198.5
*TSS	297.8	238.2
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-27

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Peroxide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	9.19	4.09
Cadmium	0.19	0.09
*Chromium	1.00	0.43
Copper	1.00	0.43
Lead	0.19	0.09
*Mercury	0.62	0.26
Nickel	1.00	0.43
Selenium	3.90	1.76
*Silver	1.00	0.43
*Zinc	0.19	0.09
Aluminum	29.1	12.9
Iron	5.71	2.90
*Manganese	1.43	1.09
*Oil and Grease	47.6	47.6
*TSS	71.4	57.1
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-28

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Nickel Impregnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied		
English Units - lb/1,000,000 lb of nickel applied		
Arsenic	386.0	172.0
Cadmium	8.0	3.6
*Chromium	42.0	18.2
Copper	42.0	18.2
Lead	8.0	3.6
*Mercury	26.0	11.0
*Nickel	42.0	18.2
Selenium	164.0	74.0
*Silver	42.0	18.2
*Zinc	8.0	3.6
Aluminum	1222.0	542.0
Iron	240.0	122.0
*Manganese	60.0	46.0
*Oil and Grease	2000.0	2000.0
*TSS	3000.0	2400.0
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-29

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced		
English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.33	0.15
Cadmium	0.006	0.003
*Chromium	0.035	0.015
Copper	0.035	0.015
*Cyanide	0.025	0.010
Lead	0.006	0.003
*Mercury	0.022	0.009
*Nickel	0.035	0.015
Selenium	0.14	0.062
*Silver	0.035	0.015
*Zinc	0.006	0.003
Aluminum	1.04	0.46
Iron	0.21	0.10
*Manganese	0.051	0.039
*Oil and Grease	1.70	1.70
*TSS	2.55	2.04
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-30

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Etch

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed		
English Units - lb/1,000,000 lb of silver processed		
Arsenic	14.36	6.40
Cadmium	0.30	0.13
*Chromium	1.56	0.68
Copper	1.56	0.68
Lead	0.30	0.13
*Mercury	0.97	0.41
Nickel	1.56	0.68
Selenium	6.10	2.75
*Silver	1.56	0.68
*Zinc	0.30	0.13
Aluminum	45.46	20.16
Iron	8.93	4.54
*Manganese	2.23	1.71
*Oil and Grease	74.40	74.40
*TSS	111.60	89.28
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-31

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.52	0.23
Cadmium	0.010	0.004
*Chromium	0.056	0.024
Copper	0.056	0.024
*Cyanide	0.039	0.016
Lead	0.010	0.004
*Mercury	0.035	0.014
*Nickel	0.056	0.024
Selenium	0.22	0.099
*Silver	0.056	0.024
*Zinc	0.010	0.004
Aluminum	1.65	0.73
Iron	0.33	0.16
*Manganese	0.081	0.062
*Oil and Grease	2.70	2.70
*TSS	4.05	3.21
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-32

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Reject Cell Handling

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.019	0.008
Cadmium	0.0004	0.00018
*Chromium	0.002	0.00091
Copper	0.002	0.00091
*Cyanide	0.0015	0.0006
Lead	0.0004	0.00018
*Mercury	0.001	0.00055
*Nickel	0.002	0.00091
Selenium	0.008	0.003
*Silver	0.002	0.00091
*Zinc	0.0004	0.00018
Aluminum	0.061	0.027
Iron	0.012	0.006
*Manganese	0.003	0.002
*Oil and Grease	0.10	0.10
*TSS	0.15	0.12
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-33

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	1.62	0.72
Cadmium	0.033	0.015
*Chromium	0.18	0.076
Copper	0.18	0.076
*Cyanide	0.12	0.051
Lead	0.033	0.015
*Mercury	0.11	0.046
Nickel	0.18	0.076
Selenium	0.69	0.31
*Silver	0.18	0.076
*Zinc	0.033	0.015
Aluminum	5.13	2.28
Iron	1.01	0.51
*Manganese	0.25	0.19
*Oil and Grease	8.40	8.40
*TSS	12.6	10.1
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-34

ZINC 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 cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	2.49	1.11
Cadmium	0.051	0.023
*Chromium	0.27	0.12
Copper	0.27	0.12
*Cyanide	0.039	0.016
Lead	0.051	0.023
*Mercury	0.17	0.07
*Nickel	0.27	0.12
Selenium	1.06	0.48
*Silver	0.27	0.12
*Zinc	0.05	0.02
Alumium	7.88	3.50
Iron	1.55	0.79
*Manganese	0.39	0.30
*Oil and Grease	12.90	12.90
*TSS	19.35	15.48
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-35

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Peroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produce English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Arsenic	15.27	6.80
Cadmium	0.32	0.14
*Chromium	1.66	0.72
Copper	1.66	0.72
Lead	0.32	0.14
*Mercury	1.03	0.44
Nickel	1.66	0.72
Selenium	6.49	2.93
*Silver	1.66	0.72
*Zinc	0.32	0.14
Aluminum	48.33	21.44
Iron	9.49	4.83
*Manganese	2.37	1.82
*Oil and Grease	79.10	79.10
*TSS	118.65	94.92
*pH	Within the range of 7.5 - 10.0 at all times	

*Regulated Pollutant

TABLE XI-36

ZINC SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Arsenic	6.20	2.76
Cadmium	0.13	0.057
*Chromium	0.67	0.29
Copper	0.67	0.29
Lead	0.13	0.057
*Mercury	0.42	0.18
Nickel	0.67	0.29
Selenium	2.63	1.19
*Silver	0.67	0.29
*Zinc	0.13	0.06
Aluminum	19.61	8.70
Iron	3.85	1.96
*Manganese	0.96	0.74
*Oil and Grease	32.10	32.10
*TSS	48.15	38.52
*pH	Within the range of 7.5 - 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 responsibilities and deadlines applicable to each part of 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 indicated by the data presented in Sections V and VII.

DISCHARGE OF WASTEWATERS TO A POTW

Most plants in the battery manufacturing category 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 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 on the minimization of pass through of toxic pollutants at POTW. For each subcategory, 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 rate were determined through a study conducted by the Agency at over 40 POTW and a statistical analysis of the data. (See Fate of Priority Pollutants In Publicly Owned Treatment Works, EPA 440/1-80-301, October, 1980; and Determining National Removal Credits for Selected Pollutants for Publicly Owned Treatment Works, 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 from 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 subcategory tables in this section.

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

As a general approach for the category, three or four options were developed for consideration as the basis for PSES and three or four for PSNS. These options generally provide for the removal of metals by chemical precipitation and removal of suspended solids by sedimentation or filtration. In addition, they generally provide for the reduction or control of wastewater discharge volume through the application of water use controls and a variety of in-process control techniques. The goal of pretreatment is to control pollutants which will pass through a POTW, interfere with its operation, or interfere with the use or disposal of POTW sludge. Because battery manufacturing wastewater streams characteristically contain toxic 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 generally combine both in-plant technology and wastewater treatment to reduce the mass of pollutants (especially 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. A major factor in all of the technology options considered is reduced pollutant discharge achieved through wastewater flow reductions. Mass based (rather than concentration based) limitations and standards are necessary to ensure the pollutant removals required by this regulation.

IDENTIFICATION OF PRETREATMENT OPTIONS

Option 0 for pretreatment standards for existing sources (PSES) and pretreatment standards for new sources (PSNS) are identical to BPT (option 0) for all subcategories as described in Section IX. PSES and PSNS options 1-4 for each subcategory 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. Selected pretreatment options for new sources are identical to BDT options for each subcategory as described in Section XI.

Effluent performance achieved by these pretreatment options will be the same as that provided by the respective BPT, BAT and BDT options and is indicated by the flow rate information provided in Section V and the technology performance data shown in Section VII. Compliance cost data for all options is displayed in Table X-56 (page 907).

CADMIUM SUBCATEGORY

PSES options 0-4 are identical to BPT and BAT options 1-4 as discussed on page 730 to 732 for BPT and pages 819 to 824 for BAT. Pollutant removals and cost discussions in this section are stated for existing indirect discharges only. Pollutant removals for this subcategory are displayed in Table XII-1 (page 978).

Pretreatment Option Selection

Option 1 is the selected PSES option because standards are achievable using technologies and practices that are currently in use at plants in the subcategory. Also the result of implementing this technology is a significant reduction of toxic pollutant discharges to POTW which would otherwise pass through. For this option flow is reduced to 28.7 million l/yr. The annual toxic pollutant removal is 54,456 kg/yr. For plants to comply directly with this option, the estimated compliance capital cost is $318,000 and annual cost is $109,000.

Option 0 is rejected because significant amounts of cadmium, nickel and zinc would pass through POTW and not be controlled. Also, the use of cadmium usually prevents POTW from using their sludges for land application. For this option flow is 210 million l/yr and annual toxic pollutant removal is 54,261 kg/yr. For plants to comply directly with this option, the estimated compliance capital cost is $330,000 and annual cost is $76,000.

Options 2, 3, and 4 are rejected because, as discussed in Section X the technology yields small incremental removals when compared with option 1. The PSES will remove approximately 99.93 percent of the estimated raw waste generation for toxic pollutants. Given the results achieved by the technologies used as a basis for the promulgated limitations, further treatment would result only in deminimis, insignificant reductions in annual national discharges. Accordingly, EPA has determined that the total amount of each pollutant in the remaining discharges after compliance with PSES does not justify establishing a national requirement based on additional end-of-pipe technology.

Although EPA is not basing the final regulations directly on these additional technologies, their availability, effectiveness and affordability provides significant support for EPA's conclusion that the promulgated pretreatment standards are both technologically and economically achievable.

Pollutant Parameters for Regulation

Pollutant parameters selected for pretreatment regulation in this subcategory are cadmium, nickel, silver, zinc and cobalt. As discussed in Section X, these pollutants were selected for their toxicity, use within the subcategory and treatability. For the pretreatment standards, POTW treatment and pass through (for cadmium, nickel, silver, and zinc) was also considered. Conventional pollutants are not specifically regulated because POTW are specifically designed to treat the conventional pollutants.

Pretreatment Effluent Standards

Effluent standards for existing pretreatment sources are identical to the BAT limitations as 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 presented in Tables XII-2 to XII-13 (pages 979-990). To alleviate some of the monitoring burden, several process elements which occur at most plants and have the same pnp are combined in one regulatory table. Table XII-9 is the combined table for Tables XII-6 to XII-8. These standard tables list all the pollutants which were considered for regulation, and those regulated are *'d.

PSNS are identical to NSPS discussed in Section XI, and are displayed in Tables XII-14 to XII-25 (pages 991-1002).

CALCIUM SUBCATEGORY

The options considered for pretreatment are identical to option 0 discussed in Section IX (pages 735-737) and the two options discussed in Section X (pages 827-829).

Pretreatment Selection

Currently, the discharge by indirect dischargers of process wastewater from this subcategory is small (less than 4,000,000 l/yr) and the quantity of toxic pollutants is also small (less than 50 kg/yr). Because of the small quantities, the Agency has elected not to establish national PSES for this subcategory. Applicable technologies, and potential standards (in this case no discharge) are set forth as guidance should a state or local pollution control agency desire to establish such standards.

Pollutant removals for each option are shown in Table XII-26 (page 1003). The option promulgated for new sources is equivalent to the one selected for NSPS, as discussed on page 926. This option results in no discharge of pollutants. As discussed in the EIA, no entry impacts are projected with the selection of this option, and as discussed in Section XI one existing plant already achieves no discharge.

Pretreatment Effluent Standards

PSNS for the calcium subcategory is no discharge of process wastewater pollutants.

LECLANCHE SUBCATEGORY

The option considered for pretreatment is identical to option 0 discussed in Section IX (pages 738-742). Pollutant removals for this subcategory are displayed in Table XII-27 (page 1004).

Pretreatment Option Selection

Option 0 is the selected PSES option because standards are achievable using technologies and practices that are currently in use at plants in the subcategory. Also the result of implementing this technology is a significant reduction of pollutant discharges (particularly mercury) which would otherwise pass through. For this option flow is reduced to 0.2 million l/yr. The annual toxic pollutant removal is 5569 kg/yr. For plants to comply with this option, the estimated compliance capital cost is $43,000 and annual cost is $22,000.

Pollutant Parameters for Regulation

Pollutant parameters selected for pretreatment regulation in this subcategory are mercury, zinc, and manganese. As discussed in Section IX, these pollutants were selected for their toxicity, use within the subcategory and treatability. For the pretreatment standards, POTW treatment and pass through (for mercury and zinc) was also considered. Conventional pollutants are not specifically regulated because POTW are specifically designed to treat the conventional pollutants.

Pretreatment Effluent Standards

The effluent standards for existing pretreatment sources involved in foliar battery production are identical to the BPT limitations discussed in Section IX. These standards are expressed in terms of mg of pollutant per kg of cell produced. PSES are presented in Table XII-28 (page 1005). This table lists all the pollutants which were considered for regulation, and those regulated are *'d.

PSNS are identical to PSES and are displayed in Table XII-29 (page 1006).

LITHIUM SUBCATEGORY

The options considered for pretreatment are identical to option 0 discussed in Section IX (pages 743-747) and the three options discussed in Section X (pages 831-834).

Pretreatment Selection

Currently, the discharge by indirect dischargers of process wastewater from this subcategory is small (less than 4,000,000 l/yr) and the quantity of toxic pollutants is also small (less than 50 kg/yr). Because of the small quantities, the Agency has elected not to establish national PSES standards for this subcategory. Applicable technologies, and potential standards are set forth as guidance should a state or local polution control agency desire to establish such standards.

Pollutant reduction benefits for the technology options are shown in Table XII-30 (page 1007). The option promulgated for new sources option 2, is equivalent to the one selected for NSPS, as discussed on page 927. This option allows no discharge from heat paper production and allows treated wastewater discharge from other subcategory processes which provides the greatest level of toxic pollutant removal. As discussed in the EIA, no entry impacts are projected with the selection of this option. Also, two existing plants in the subcategory achieve no discharge of pollutants by choice of manufacturing processes. Many alternatives can be considered when constructing a new plant.

Pollutant Parameters for Regulation

For pretreatment, chromium and lead are selected for regulation in this subcategory. 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 chromium and lead were also considered. In this subcategory asbestos is used as a raw material and would be controlled by regulating TSS. Because POTW are designed for treatment of conventional pollutants and adequately control TSS and thus asbestos, a specific standard for TSS is not promulgated. Also, POTW may use iron as a coagulant in the treatment process and iron is not promulgated for regulation.

Pretreatment Effluent Standards

Effluent standards for existing pretreatment sources are identical to the limitations presented in Section X. These standards are expressed in terms of mg of pollutant per kg of production normalizing parameter for each process element. Recommended standards for existing sources are displayed in Tables XII-31 to XII-33 (pages 1009-1011). These standard tables are presented as guidance should a state or local pollution control agency desire to establish such standards.

PSNS are identical to NSPS presented in Section XI with one exception; air scrubbers are used as a basis for regulation at NSPS and not PSNS to control TSS and thus, asbestos. Standards are displayed in Tables XII-34 to XII-36 (pages 1012-1014). These standard tables list all the pollutants which were considered for regulation, and regulated pollutants are *'d.

MAGNESIUM SUBCATEGORY

The options considered for pretreatment are identical to option 0 discussed in Section IX (pages 747-750) and the three options discussed in Section X (pages 835-838). Pollutant removals for this subcategory are displayed in Table XII-37 (page 1015). Compliance costs for existing plants are displayed in Table X-56 for each technology option.

Pretreatment Selection

Option 0 is the selected PSES option for all process wastewater streams except heat paper production, and option 2 is promulgated as the selected option for heat paper production because the standards are achievable at existing plants and the result of implementing the promulgated PSES is a significant reduction in the toxic pollutant discharges which would otherwise pass through POTW. For the final PSES, discharge flow is reduced to 1 million l/yr and the annual toxic pollutant removal is 160 kg/yr. For plants to comply directly with this option, the estimated compliance capital cost is $28,000 and the annual cost is $15,000 for existing plants, which is the least costly alternative for indirect dischargers in this subcategory.

All other options were rejected for existing sources because the toxic pollutant removals are about equal and the compliance costs for the options are higher than for the selected PSES. For option 0, estimated compliance capital costs are $28,000 and annual costs are $15,000.

For option 1 estimated compliance capital cost is $37,000 and annual cost is $22,000. For option 2 estimated compliance capital cost is $37,000 and annual cost is $20,000. For option 3 estimated compliance capital cost is $74,000 and annual cost is $28,000.

For new sources as discussed in Section XI, option 2 is selected because it provides for the greatest level of toxic pollutant removal. As discussed in the EIA, no entry impacts are projected with the selection of this option. Also, four existing plants in the subcategory achieve no discharge by choice of manufacturing processes. Many alternatives can be considered when constructing a new plant.

Pollutant Parameters for Regulation

For pretreatment lead and silver are selected for regulation in this subcategory. 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 these pollutants were also considered. In this subcategory asbestos is used as a raw material and would be controlled by regulating TSS. Because POTW are designed for treatment of conventional pollutants and adequately control TSS, and thus asbestos, a specific standard for TSS is not promulgated. Also, iron and COD are not regulated because POTW may use iron as a coagulant in the treatment process and POTW are designed to treat oxygen demand.

Pretreatment Effluent Standards

PSES are identical to the limitations presented in Section X. These standards are expressed in terms of mg of pollutant per kg of production normalizing parameter for each process element. Standards for existing sources are presented in Tables XII-38 to XII-41 (pages 1017-1020). These standard tables list all the pollutants which were considered for regulation, and those regulated are indicated by "*".

PSNS are identical to NSPS presented in Section XI with one exception; air scrubbers are promulgated for regulation at NSPS and not PSNS to control TSS and thus asbestos. Standards are displayed in Tables XII-42 to XII-45 (pages 1021-1024).

ZINC SUBCATEGORY

PSES options 0-4 are identical to BPT and BAT options 1-4 as discussed on pages 751 to 753 for BPT and pages 841 to 845 for BAT. Pollutant removals and cost discussions are stated for existing indirect discharges only. Pollutant removals for this subcategory are displayed in Table XII-46 (page 1025).

Pretreatment Option Selection

Option 1 is promulgated as the selected PSES option because standards are achievable using technologies and practices that are currently in use at plants in the subcategory. Also, the result of implementing this technology is a signficant reduction of toxic pollutants to POTW which would otherwise pass through. For this option flow is reduced to 6.25 million l/yr. The annual toxic pollutant removal is 4,390 kg/yr. For plants to directly comply with this option the estimated compliance capital cost is $347,000 and annual cost is $100,000.

Option 0 is rejected because significant amounts of toxic metals would pass through POTW and not be controlled. Also, the use of mercury in this subcategory usually prevents the POTW from using their sludges for land use purposes. For this option flow is 46 million l/yr and annual toxic pollutant removal is 4,320 kg/yr. For plants to comply directly with this option, the estimated compliance capital cost is $258,000 and annual cost is $88,000.

Options 2, 3, and 4 are rejected because, as discussed in Section X the technologies yield small incremental removals when compared to option 1. The PSES will remove approximately 99.81 percent of current toxic pollutant discharges. Given the results achieved by the technologies used as a basis for the promulgated limitations, further treatment would result only in de minimis, insignificant reductions in annual national discharges. Accordingly, EPA has determined that the total amount of each pollutant in the remaining discharges after compliance with PSES does not justify establishing a national requirement based on additional end-of-pipe technology.

Although EPA is not basing the final regulations directly on these additional technologies, their availability, effectiveness and affordability provides significant support for EPA's conclusion that the promulgated pretreatment standards are both technologically and economically achievable.

Pollutant Parameters for Regulation

Pollutant parameters selected for pretreatment regulation in this subcategory are chromium, mercury, silver, zinc and manganese. 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 (for chromium, mercury, silver and zinc) were also considered. Conventional pollutants are not specifically regulated because POTW are specifically designed to treat conventional pollutants.

Effluent 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-47 to XII-62 (pages 1026-1041). To alleviate some of the monitoring burden, several process elements which occur at most plants and have the same pnp are combined in one regulatory table. Table XII-60 is the combined table for tables XII-55, 57, 58, and 59. These standard tables list all the pollutants which were considered for regulation, and those regulated are *'d.

PSNS are identical to NSPS discussed in Section XI. Standards are displayed in Tables XII-63 to XII-76 (pages 1042-1055). Table XII-74 is the combined table for tables XII-69, 71, 72, and 73.

TABLE XII-1
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
CADMIUM 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)	209.90		209.90		28.69		28.69		4.25		0.00
118 CADMIUM	6918.30	6901.72	16.58	6916.03	2.27	6916.89	1.41	6918.09	0.21	6918.30	0.00
119 CHROMIUM	15.32	0.00	15.32	13.02	2.30	13.31	2.01	15.02	0.30	15.32	0.00
121 CYANIDE	10.29	0.00	10.29	8.28	2.01	8.94	1.35	10.09	0.20	10.29	0.00
122 LEAD	0.42	0.00	0.42	0.00	0.42	0.00	0.42	0.08	0.34	0.42	0.00
123 MERCURY	1.68	0.00	1.68	0.00	1.68	0.65	1.03	1.53	0.15	1.68	0.00
124 NICKEL	14839.93	14720.29	119.64	14823.58	16.35	14833.62	6.31	14838.99	0.94	14839.93	0.00
126 SILVER	3.78	0.00	3.78	0.91	2.87	1.77	2.01	3.48	0.30	3.78	0.00
128 ZINC	32702.42	32639.45	62.97	32693.81	8.61	32695.82	6.60	32701.44	0.98	32702.42	0.00
COBALT	98.44	83.75	14.69	96.43	2.01	97.01	1.43	98.23	0.21	98.44	0.00
OIL & GREASE	1358.05	0.00	1358.05	1071.15	286.90	1071.15	286.90	1315.55	42.50	1358.05	0.00
TSS	81378.23	78859.43	2518.80	81033.95	344.28	81303.64	74.59	81367.18	11.05	81378.23	0.00
TOXIC METALS	54481.85	54261.46	220.39	54447.35	34.50	54462.06	19.79	54478.63	3.22	54481.85	0.00
CONVENTIONALS	82736.28	78859.43	3876.85	82105.10	631.18	82374.79	361.49	82682.73	53.55	82736.28	0.00
TOTAL POLLU.	137326.86	133204.64	4122.22	136657.16	669.70	136942.80	384.06	137269.68	57.18	137326.86	0.00
SLUDGE GEN		1253939.88		1275089.82		1276872.00		1278757.53		1279089.70	

TABLE XII-2

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium		
English Units - lb/1,000,000 lb of cadmium		
*Cadmium	11.95	5.27
Chromium	15.47	6.33
Cyanide	10.19	4.22
Lead	14.76	7.03
Mercury	8.79	3.52
*Nickel	67.49	44.64
Silver	14.41	5.98
*Zinc	51.32	21.44
*Cobalt	7.38	3.16

*Regulated Pollutant

TABLE XII-3

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Impregnated Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	68.0	30.0
Chromium	88.0	36.0
Cyanide	58.0	24.0
Lead	84.0	40.0
Mercury	50.0	20.0
*Nickel	384.0	254.0
Silver	82.0	34.0
*Zinc	292.0	122.0
*Cobalt	42.0	18.0

*Regulated Pollutant

TABLE XII-4

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Nickel Electrodeposited Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	11.22	4.95
Chromium	14.52	5.94
Cyanide	9.57	3.96
Lead	13.86	6.60
Mercury	8.25	3.30
*Nickel	63.36	41.91
Silver	13.53	5.61
*Zinc	48.18	20.13
*Cobalt	6.93	2.97

*Regulated Pollutant

TABLE XII-5

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Nickel Impregnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	68.0	30.0
Chromium	88.0	36.0
Cyanide	58.0	24.0
Lead	84.0	40.0
Mercury	50.0	20.0
*Nickel	384.0	254.0
Silver	82.0	34.0
*Zinc	292.0	122.0
*Cobalt	42.0	18.0

*Regulated Pollutant

TABLE XII-6

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.26	0.11
Chromium	0.33	0.14
Cyanide	0.22	0.090
Lead	0.32	0.15
Mercury	0.19	0.075
*Nickel	1.44	0.95
Silver	0.31	0.13
*Zinc	1.10	0.46
*Cobalt	0.16	0.067

*Regulated Pollutant

TABLE XII-7

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Electrolyte Preparation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.027	0.012
Chromium	0.035	0.014
Cyanide	0.023	0.009
Lead	0.033	0.016
Mercury	0.020	0.008
*Nickel	0.153	0.101
Silver	0.032	0.013
*Zinc	0.116	0.048
*Cobalt	0.016	0.007

*Regulated Pollutant

TABLE XII-8

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.51	0.23
Chromium	0.66	0.27
Cyanide	0.44	0.18
Lead	0.63	0.30
Mercury	0.38	0.15
*Nickel	2.88	1.91
Silver	0.62	0.26
*Zinc	2.19	0.92
*Cobalt	0.32	0.14

*Regulated Pollutant

TABLE XII-9

CADMIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.79	0.35
Chromium	1.03	0.42
Cyanide	0.68	0.28
Lead	0.98	0.47
Mercury	0.58	0.23
*Nickel	4.47	2.96
Silver	0.96	0.40
*Zinc	3.40	1.42
*Cobalt	0.49	0.21

*Regulated Pollutant

TABLE XII-10

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Cadmium Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
*Cadmium	2.23	0.99
Chromium	2.89	1.18
Cyanide	1.91	0.79
Lead	2.76	1.31
Mercury	1.64	0.66
*Nickel	12.61	8.34
Silver	2.69	1.12
*Zinc	9.59	4.01
*Cobalt	1.38	0.59

*Regulated Pollutant

TABLE XII-11

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
*Cadmium	1.09	0.48
Chromium	1.41	0.58
Cyanide	0.93	0.39
Lead	1.35	0.64
Mercury	0.80	0.32
*Nickel	6.16	4.08
*Silver	1.32	0.55
*Zinc	4.69	1.96
*Cobalt	0.67	0.29

*Regulated Pollutant

TABLE XII-12

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Cadmium Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
*Cadmium	0.05	0.02
Chromium	0.061	0.025
Cyanide	0.040	0.016
Lead	0.058	0.028
Mercury	0.035	0.014
*Nickel	0.27	0.18
Silver	0.057	0.023
*Zinc	0.20	0.09
*Cobalt	0.03	0.01

*Regulated Pollutant

TABLE XII-13

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Nickel Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used English Units - lb/1,000,000 lb of nickel used		
*Cadmium	5.61	2.48
Chromium	7.26	2.97
Cyanide	4.79	1.98
Lead	6.93	3.30
Mercury	4.13	1.65
*Nickel	31.68	20.96
Silver	6.77	2.81
*Zinc	24.09	10.07
*Cobalt	3.47	1.49

*Regulated Pollutant

TABLE XII-14

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	7.03	2.81
Chromium	13.01	5.27
Cyanide	7.03	2.81
Lead	9.84	4.57
Mercury	5.27	2.11
*Nickel	19.33	13.01
Silver	10.19	4.22
*Zinc	35.85	14.76
*Cobalt	4.92	2.46

*Regulated Pollutant

TABLE XII-15

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Impregnated Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium English Units - lb/1,000,000 lb of cadmium		
*Cadmium	40.0	16.0
Chromium	74.0	30.0
Cyanide	40.0	16.0
Lead	56.0	26.0
Mercury	30.0	12.0
*Nickel	110.0	74.0
Silver	58.0	24.0
*Zinc	204.0	84.0
*Cobalt	28.0	14.0

*Regulated Pollutant

TABLE XII-16

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Nickel Electrodeposited Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	6.60	2.64
Chromium	12.21	4.95
Cyanide	6.60	2.64
Lead	9.24	4.29
Mercury	4.95	1.98
*Nickel	18.15	12.21
Silver	9.57	3.96
*Zinc	33.66	13.86
*Cobalt	4.62	2.31

*Regulated Pollutant

TABLE XII-17

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Nickel Impegnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied		
English Units - lb/1,000,000 lb of nickel applied		
*Cadmium	40.0	16.0
Chromium	74.0	30.0
Cyanide	40.0	16.0
Lead	56.0	26.0
Mercury	30.0	12.0
*Nickel	110.0	74.0
Silver	58.0	24.0
*Zinc	204.0	84.0
*Cobalt	28.0	14.0

*Regulated Pollutant

TABLE XII-18

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.15	0.06
Chromium	0.28	0.11
Cyanide	0.15	0.06
Lead	0.21	0.097
Mercury	0.11	0.045
*Nickel	0.41	0.28
Silver	0.22	0.09
*Zinc	0.77	0.32
*Cobalt	0.11	0.052

*Regulated Pollutant

TABLE XII-19

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Electrolyte Preparation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.016	0.006
Chromium	0.029	0.012
Cyanide	0.016	0.006
Lead	0.022	0.010
Mercury	0.012	0.004
*Nickel	0.044	0.029
Silver	0.023	0.009
*Zinc	0.081	0.033
*Cobalt	0.011	0.005

*Regulated Pollutant

TABLE XII-20

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.30	0.12
Chromium	0.56	0.23
Cyanide	0.30	0.12
Lead	0.42	0.20
Mercury	0.23	0.090
*Nickel	0.83	0.56
Silver	0.44	0.18
*Zinc	1.53	0.63
*Cobalt	0.21	0.11

*Regulated Pollutant

TABLE XII-21

CADMIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
*Cadmium	0.47	0.19
Chromium	0.86	0.35
Cyanide	0.47	0.19
Lead	0.65	0.30
Mercury	0.35	0.14
*Nickel	1.28	0.86
Silver	0.68	0.28
*Zinc	2.38	0.98
*Cobalt	0.33	0.16

*Regulated Pollutant

TABLE XII-22

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Cadmium Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium powder produced English Units - lb/1,000,000 lb of cadmium powder produced		
*Cadmium	1.31	0.53
Chromium	2.43	0.99
Cyanide	1.32	0.53
Lead	1.84	0.86
Mercury	0.99	0.40
*Nickel	3.61	2.43
Silver	1.91	0.79
*Zinc	6.70	2.76
*Cobalt	0.92	0.46

*Regulated Pollutant

TABLE XII-23

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
*Cadmium	0.64	0.26
Chromium	1.19	0.48
Cyanide	0.64	0.26
Lead	0.90	0.42
Mercury	0.48	0.19
*Nickel	1.77	1.19
*Silver	0.93	0.39
*Zinc	3.27	1.35
*Cobalt	0.45	0.22

*Regulated Pollutant

TABLE XII-24

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Cadmium Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cadmium used English Units - lb/1,000,000 lb of cadmium used		
*Cadmium	0.028	0.011
Chromium	0.051	0.021
Cyanide	0.028	0.011
Lead	0.039	0.018
Mercury	0.021	0.008
*Nickel	0.077	0.051
Silver	0.040	0.016
*Zinc	0.142	0.058
*Cobalt	0.019	0.009

*Regulated Pollutant

TABLE XII-25

CADMIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Nickel Hydroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel used		
English Units - lb/1,000,000 lb of nickel used		
*Cadmium	3.30	1.32
Chromium	6.11	2.48
Cyanide	3.30	1.32
Lead	4.62	2.15
Mercury	2.48	0.99
*Nickel	9.08	6.11
Silver	4.79	1.98
*Zinc	16.83	6.93
*Cobalt	2.31	1.16

*Regulated Pollutant

TABLE XII-26
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
CALCIUM SUBCATEGORY - TOTAL

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2	
	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)*	0.13		0.13		0.13		0.00
116 ASBESTOS 1/	40.95	39.60	1.35	40.66	0.29	40.95	0.00
119 CHROMIUM	7.93	7.92	0.01	7.92	0.01	7.93	0.00
TSS	47.84	46.28	1.56	47.50	0.34	47.84	0.00
TOXIC METALS	7.93	7.92	0.01	7.92	0.01	7.93	0.00
CONVENTIONALS	47.84	46.28	1.56	47.50	0.34	47.84	0.00
TOTAL POLLU.	55.77	54.20	1.57	55.42	0.35	55.77	0.00
SLUDGE GEN		317.73		323.83		325.64	

* 100% of the total flow is for indirect dischargers.

1/ Asbestos is in trillions of fibers per year; not included in total.

TABLE XII-27

POLLUTANT REDUCTION BENEFITS OF CONTROL OPTIONS
LECLANCHE SUBCATEGORY

	RAW WASTE			BPT & BAT (PSES)	
Flow l/yr (10^6)			16.71		0.200
l/kg*		0.758			0.009
POLLUTANTS	mg/l	mg/kg	kg/yr	Removed kg/yr	Discharged kg/yr
115 Arsenic	0.090	0.068	1.503	1.435	0.068
118 Cadmium	0.053	0.040	0.881	0.871	0.010
119 Chromium	0.409	0.310	6.84	6.826	0.014
120 Copper	0.466	0.353	7.78	7.702	0.078
122 Lead	0.101	0.076	1.684	1.668	0.016
123 Mercury	13.40	10.16	223.9	223.893	0.007
124 Nickel	1.212	0.919	20.25	20.206	0.044
125 Selenium	0.086	0.065	1.435	1.395	0.040
128 Zinc	317.5	240.7	5,305.4	5,305.35	0.046
Manganese	69.3	52.5	1,158.0	1,157.97	0.028
Oil and Grease	115.0	87.2	1,921.7	1,919.70	2.00
TSS	2,536	1,922	42,376.5	42,375.98	0.520
Toxic Metals			5,569.7	5,569.35	0.323
Conventionals			44,298.2	44,295.7	2.52
All Pollutants			51,025.9	51,023.0	2.87
Sludge Generated				288,555.0	

*Normalized flow based on total subcategory zinc anode weight.

TABLE XII-28

LECLANCHE SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Foliar Battery Miscellaneous Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.092	0.038
Cadmium	0.013	0.005
Chromium	0.024	0.010
Copper	0.084	0.040
Lead	0.018	0.009
*Mercury	0.010	0.004
Nickel	0.036	0.024
Selenium	0.054	0.024
*Zinc	0.067	0.030
*Manganese	0.019	0.015

*Regulated Pollutant

TABLE XII-29

LECLANCHE SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Foliar Battery Miscellaneous Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.092	0.038
Cadmium	0.013	0.005
Chromium	0.024	0.010
Copper	0.084	0.040
Lead	0.018	0.009
*Mercury	0.010	0.004
Nickel	0.036	0.024
Selenium	0.054	0.024
*Zinc	0.067	0.030
*Manganese	0.019	0.015

*Regulated Pollutant

TABLE XII-30
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LITHIUM SUBCATEGORY

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3	
	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
HEAT PAPER PRODUCTION									
FLOW 1/yr (10^6)	0.04		0.04		0.04		0.00		0.00
116 ASBESTOS1/	12.60	12.19	0.41	12.51	0.09	12.60	0.00	12.60	0.00
119 CHROMIUM	2.44	2.44	0.00	2.44	0.00	2.44	0.00	2.44	0.00
122 LEAD		(-0.005)	0.005	(-0.003)	0.003				
128 ZINC		(-0.010)	0.010	(-0.008)	0.008				
COBALT		(-0.002)	0.002	(-0.002)	0.002				
IRON		(-0.014)	0.014	(-0.010)	0.010				
TSS	14.72	14.24	0.48	14.62	0.10	14.72	0.00	14.72	0.00
CATHODE AND ANCILLARY OPERATIONS									
FLOW 1/yr (10^6)	0.21		0.21		0.21		0.21		0.21
116 ASBESTOS1/	1.35	0.00	1.35	0.88	0.47	0.88	0.47	0.88	0.47
119 CHROMIUM	0.16	0.14	0.02	0.15	0.01	0.15	0.01	0.15	0.01
122 LEAD	1.02	0.995	0.025	1.003	0.017	1.00	0.02	1.00	0.02
128 ZINC	0.10	0.050	0.050	0.058	0.042	0.05	0.05	0.05	0.05
COBALT	0.04	0.032	0.008	0.032	0.008	0.03	0.01	0.03	0.01
IRON	11.37	11.294	0.076	11.320	0.050	11.31	0.06	11.31	0.06
COD	299.09	296.99	2.10	296.99	2.10	296.99	2.10	296.99	2.10
TSS	9.09	6.57	2.52	8.54	0.55	8.54	0.55	8.54	0.55
AIR SCRUBBER WASTEWATERS									
FLOW 1/yr (10^6)	0.11		0.11		0.11		0.11		0.11
TSS	132.96	131.64	1.32	131.64	1.32	131.64	1.32	132.67	0.29

1/ Asbestos is trillions of fibers per year; not included in totals.

TABLE XII-30
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LITHIUM SUBCATEGORY

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3	
	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
LITHIUM SUBCATEGORY SUMMARY 2/									
FLOW 1/yr (10^6)	0.36		0.36		0.36		0.32		0.32
116 ASBESTOS 1/	13.95	12.19	1.76	13.39	0.56	13.48	0.47	13.48	0.47
119 CHROMIUM	2.60	2.58	0.02	2.59	0.01	2.59	0.01	2.59	0.01
122 LEAD	1.02	0.99	0.03	1.00	0.02	1.00	0.02	1.00	0.02
128 ZINC	0.10	0.04	0.06	0.05	0.05	0.05	0.05	0.05	0.05
COBALT	0.04	0.03	0.01	0.03	0.01	0.03	0.01	0.03	0.01
IRON	11.37	11.28	0.09	11.31	0.06	11.31	0.06	11.31	0.06
COD	299.09	296.99	2.10	296.99	2.10	296.99	2.10	296.99	2.10
TSS	156.77	152.45	4.32	154.80	1.97	154.90	1.87	155.93	0.84
TOXIC METALS	3.72	3.61	0.11	3.64	0.08	3.64	0.08	3.64	0.08
CONVENTIONALS	156.77	152.45	4.32	154.80	1.97	154.90	1.87	155.93	0.84
TOTAL POLLU.	470.99	464.36	6.63	466.77	4.22	466.87	4.12	467.90	3.09
SLUDGE GEN		922.02		934.41		934.91		940.06	

1/ Asbestos is trillions of fibers per year; not included in totals.
2/ For direct dischargers only multiply totals by 0.01.
For indirect dischargers only multiply totals by 0.99.

TABLE XII-31

LITHIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Lead Iodide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead English Units - lb/1,000,000 lb of lead		
Chromium	27.8	11.4
Lead	26.5	12.6
Zinc	92.1	38.5
Cobalt	13.3	5.68
Iron	75.7	38.5

TABLE XII-32

LITHIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Iron Disulfide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of iron disulfide English Units - lb/1,000,000 lb of iron disulfide		
Chromium	3.32	1.36
Lead	3.17	1.51
Zinc	11.0	4.60
Cobalt	1.58	0.68
Iron	9.05	4.60

TABLE XII-33

LITHIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.047	0.019
Lead	0.045	0.021
Zinc	0.157	0.065
Cobalt	0.022	0.009
Iron	0.129	0.065

TABLE XII-34

LITHIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Lead Iodide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead English Units - lb/1,000,000 lb of lead		
*Chromium	23.34	9.46
*Lead	17.66	8.20
Zinc	64.34	26.49
Cobalt	75.70	38.48
Iron	75.70	38.48

*Regulated Pollutant

TABLE XII-35

LITHIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Iron Disulfide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of iron disulfide English Units - lb/1,000,000 lb of iron disulfide		
*Chromium	2.79	1.13
*Lead	2.11	0.98
Zinc	7.69	3.17
Cobalt	1.06	0.53
Iron	9.05	4.60

*Regulated Pollutant

TABLE XII-36

LITHIUM 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 cells produced English Units - lb/1,000,000 lb of cells produced		
*Chromium	0.039	0.016
*Lead	0.030	0.014
Zinc	0.110	0.045
Cobalt	0.015	0.007
Iron	0.129	0.066

*Regulated Pollutant

TABLE XII-37
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
MAGNESIUM SUBCATEGORY

PARAMETER	RAW WASTE kg/yr	BPT & PSES 0 Removed kg/yr	BPT & PSES 0 Discharged kg/yr	BAT 1 & PSES 1 Removed kg/yr	BAT 1 & PSES 1 Discharged kg/yr	BAT 2 & PSES 2 Removed kg/yr	BAT 2 & PSES 2 Discharged kg/yr	BAT 3 & PSES 3 Removed kg/yr	BAT 3 & PSES 3 Discharged kg/yr
HEAT PAPER PRODUCTION									
FLOW l/yr (10^6)	2.60		2.60		2.60		0.00		0.00
116 ASBESTOS 1/	819.00	792.08	26.92	813.17	5.83	819.00	0.00	819.00	0.00
119 CHROMIUM	158.60	158.39	0.21	158.42	0.18	158.60	0.00	158.60	0.00
TSS	956.80	925.60	31.20	950.04	6.76	956.80	0.00	956.80	0.00
CELL TESTING AND FLOOR AND EQUIPMENT WASH									
FLOW l/yr (10^6)	0.11		0.11		0.11		0.11		0.11
122 LEAD	0.13	0.12	0.01	0.12	0.01	0.12	0.01	0.12	0.01
124 NICKEL	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
126 SILVER	1.61	1.60	0.01	1.60	0.01	1.60	0.01	1.60	0.01
IRON	0.21	0.16	0.05	0.16	0.05	0.18	0.03	0.18	0.03
TSS	91.08	89.76	1.32	89.76	1.32	90.79	0.29	90.79	0.29
SILVER CHLORIDE CATHODE PRODUCTION									
FLOW l/yr (10^6)	0.75		0.43		0.12		0.12		0.12
122 LEAD	0.04	0.00	0.04	0.03	0.01	0.03	0.01	0.03	0.01
124 NICKEL	0.04	0.00	0.04	0.00	0.04	0.01	0.03	0.01	0.03
126 SILVER	0.19	0.15	0.04	0.18	0.01	0.18	0.01	0.18	0.01
IRON	0.42	0.24	0.18	0.37	0.05	0.39	0.03	0.39	0.03
COD	105.00	100.70	4.30	103.80	1.20	103.80	1.20	103.80	1.20
TSS	0.53	0.00	0.53	0.00	0.53	0.22	0.31	0.22	0.31
AIR SCRUBBERS									
FLOW l/yr (10^6)	0.45		0.45		0.45		0.45		0.45
TSS	543.94	538.54	5.40	538.54	5.40	538.54	5.40	542.77	1.17

1/ Asbestos is trillions of fibers per year; not included in totals.

TABLE XII-37
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
MAGNESIUM SUBCATEGORY

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3	
	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
MAGNESIUM SUBCATEGORY SUMMARY 2/									
FLOW 1/yr (10^6)	3.91		3.59		3.28		0.68		0.68
116 ASBESTOS 1/	819.00	792.08	26.92	813.17	5.83	819.00	0.00	819.00	0.68
119 CHROMIUM	158.60	158.39	0.21	158.42	0.18	158.60	0.00	158.60	0.00
122 LEAD	0.17	0.12	0.05	0.15	0.02	0.15	0.02	0.15	0.02
124 NICKEL	0.05	0.00	0.05	0.00	0.05	0.01	0.04	0.01	0.04
126 SILVER	1.80	1.75	0.05	1.78	0.02	1.78	0.02	1.78	0.02
IRON	0.63	0.40	0.23	0.53	0.10	0.57	0.06	0.57	0.06
COD	105.00	100.70	4.30	103.80	1.20	103.80	1.20	103.80	1.20
TSS	1592.35	1553.90	38.45	1578.34	14.01	1586.35	6.00	1590.58	1.77
TOXIC METALS	160.62	160.26	0.36	160.35	0.27	160.54	0.08	160.54	0.08
CONVENTIONALS	1592.35	1553.90	38.45	1578.34	14.01	1586.35	6.00	1590.58	1.77
TOTAL POLLU.	1858.60	1815.26	43.34	1843.02	15.58	1851.26	7.34	2674.49	3.11
SLUDGE GEN		9514.35		9638.83		9681.63		13797.78	

1/ Asbestos is trillions of fibers per year; not included in totals.

2/ For direct dischargers only multiply totals by 0.05.
For indirect dischargers only multiply totals by 0.95.

TABLE XII-38

MAGNESIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Chloride Cathodes - Chemically Reduced

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	36.04	14.74
*Lead	34.40	16.38
Nickel	157.3	104.0
*Silver	33.58	13.92
Iron	98.28	49.96
COD	122900.0	59975.0

*Regulated Pollutant

TABLE XII-39

MAGNESIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Chloride Cathodes - Electrolytic

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	63.8	26.1
*Lead	60.9	29.0
Nickel	278.4	184.2
*Silver	59.5	24.7
Iron	174.0	88.5
COD	7250.0	3538.0

*Regulated Pollutant

TABLE XII-40

MAGNESIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Cell Testing

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	23.2	9.47
*Lead	22.1	10.5
Nickel	101.0	66.8
*Silver	21.6	8.94
Iron	63.1	32.1

*Regulated Pollutant

TABLE XII-41

MAGNESIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.041	0.016
*Lead	0.039	0.018
Nickel	0.180	0.119
*Silver	0.038	0.015
Iron	0.112	0.057

*Regulated Pollutant

TABLE XII-42

MAGNESIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Chloride Cathodes - Chemically Reduced

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	30.30	12.29
*Lead	22.93	10.65
Nickel	45.05	30.30
*Silver	23.75	9.83
Iron	98.28	49.96
COD	4095.0	1999.0

*Regulated Pollutant

TABLE XII-43

MAGNESIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Chloride Cathodes - Electrolytic

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Chromium	53.7	21.8
*Lead	40.6	18.9
Nickel	79.8	53.7
*Silver	42.1	17.4
Iron	174.0	88.5
COD	7250.0	3540.0

*Regulated Pollutant

TABLE XII-44

MAGNESIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Cell Testing

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	19.5	7.89
*Lead	14.7	6.84
Nickel	28.9	19.5
*Silver	15.3	6.31
Iron	63.1	32.1
COD	2630.0	1290.0

*Regulated Pollutant

TABLE XII-45

MAGNESIUM SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Chromium	0.034	0.014
*Lead	0.026	0.012
Nickel	0.051	0.034
*Silver	0.027	0.011
Iron	0.112	0.057
COD	4.70	2.30

*Regulated Pollutant

TABLE XII-46
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
ZINC 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 l/yr (10^6)	46.44		46.44		6.24		6.24		5.88		0.79
115 ARSENIC	2.51	0.00	2.51	0.00	2.51	0.39	2.12	0.51	2.00	2.24	0.27
118 CADMIUM	1.72	0.00	1.72	1.23	0.49	1.41	0.31	1.66	0.06	1.71	0.01
119 CHROMIUM	1149.86	1146.15	3.71	1149.36	0.50	1149.42	0.44	1149.57	0.29	1149.82	0.04
120 COPPER	21.54	0.00	21.54	17.92	3.62	19.11	2.43	21.25	0.29	21.50	0.04
121 CYANIDE	32.60	29.35	3.25	32.16	0.44	32.31	0.29	32.32	0.28	32.56	0.04
122 LEAD	3.62	0.00	3.62	2.87	0.75	3.12	0.50	3.56	0.06	3.61	0.01
123 MERCURY	590.25	587.46	2.79	589.87	0.38	590.03	0.22	590.05	0.20	590.22	0.03
124 NICKEL	75.23	48.76	26.47	71.68	3.55	73.86	1.37	74.94	0.29	75.19	0.04
125 SELENIUM	1.62	1.16	0.46	1.56	0.06	1.57	0.05	1.58	0.04	1.61	0.01
126 SILVER	46.02	41.38	4.64	45.40	0.62	45.58	0.44	45.73	0.29	45.98	0.04
128 ZINC	2479.89	2465.96	13.93	2478.02	1.87	2478.45	1.44	2479.83	0.06	2479.88	0.01
ALUMINUM	13.88	0.00	13.88	6.96	6.92	9.26	4.62	9.53	4.35	13.30	0.58
IRON	0.18	0.00	0.18	0.00	0.18	0.00	0.18	0.00	0.18	0.00	0.19
MANGANESE	235.45	225.69	9.76	234.14	1.31	234.57	0.88	234.63	0.82	235.34	0.11
OIL & GREASE	1197.22	732.82	464.40	1134.82	62.40	1134.82	62.40	1138.42	58.80	1189.32	7.90
TSS	2891.35	2334.07	557.28	2816.47	74.88	2875.12	16.23	2876.06	15.28	2889.29	2.06
TOXIC METALS	4372.26	4290.87	81.39	4357.91	14.35	4362.94	9.32	4368.68	3.58	4371.76	0.50
CONVENTIONALS	4088.57	3066.89	1021.68	3951.29	137.28	4009.94	78.63	4014.49	74.08	4078.61	9.96
TOTAL POLLU.	8742.94	7612.80	1130.14	8582.46	160.48	8649.02	99.92	8659.65	83.29	8731.57	11.37
SLUDGE GEN		59385.49		65473.01		65948.03		66059.94		66541.30	

TABLE XII-47

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Wet Amalgamated Powder Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	1.58	0.71
Cadmium	0.19	0.082
*Chromium	0.24	0.099
Copper	1.05	0.55
Lead	0.23	0.11
*Mercury	0.14	0.055
Nickel	1.06	0.70
Selenium	0.68	0.30
*Silver	0.23	0.093
*Zinc	0.80	0.34
Aluminum	3.54	1.76
Iron	0.66	0.34
*Manganese	0.37	0.16

*Regulated Pollutant

TABLE XII-48

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Gelled Amalgam Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	0.20	0.087
Cadmium	0.023	0.010
*Chromium	0.030	0.012
Copper	0.13	0.068
Lead	0.028	0.013
*Mercury	0.017	0.007
Nickel	0.13	0.086
Selenium	0.083	0.037
*Silver	0.028	0.012
*Zinc	0.099	0.042
Aluminum	0.44	0.22
Iron	0.081	0.041
*Manganese	0.046	0.020

*Regulated Pollutant

TABLE XII-49

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Zinc Oxide Anodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	62.19	27.74
Cadmium	7.37	3.25
*Chromium	9.53	3.90
Copper	41.17	21.67
Lead	9.10	4.34
*Mercury	5.42	2.17
Nickel	41.61	27.52
Selenium	26.66	11.92
*Silver	8.89	3.68
*Zinc	31.64	13.22
Aluminum	139.3	69.35
Iron	26.00	13.22
*Manganese	14.74	6.28

*Regulated Pollutant

TABLE XII-50

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Arsenic	616.19	274.82
Cadmium	73.00	32.21
*Chromium	94.47	38.65
Copper	407.93	214.70
Lead	90.18	42.94
*Mercury	53.68	21.47
Nickel	412.23	272.67
Selenium	264.08	118.09
*Silver	88.03	36.50
*Zinc	313.46	130.97
Aluminum	1380.52	687.04
Iron	257.64	130.97
*Manganese	146.00	62.26

*Regulated Pollutant

TABLE XII-51

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	85.24	38.02
Cadmium	10.10	4.46
*Chromium	13.07	5.35
Copper	56.43	29.70
Lead	12.48	5.94
*Mercury	7.43	2.97
Nickel	57.03	37.72
Selenium	36.53	16.34
*Silver	12.18	5.05
*Zinc	43.36	18.12
Aluminum	190.97	95.04
Iron	35.64	18.12
*Manganese	20.20	8.61

*Regulated Pollutant

TABLE XII-52

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Oxide Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	56.97	25.41
Cadmium	6.75	2.98
*Chromium	8.73	3.57
Copper	37.72	19.85
Lead	8.34	3.97
*Mercury	4.96	1.99
Nickel	38.11	25.21
Selenium	24.42	10.92
*Silver	8.14	3.37
*Zinc	28.98	12.11
Aluminum	127.64	63.52
Iron	23.82	12.11
*Manganese	13.50	5.76

*Regulated Pollutant

TABLE XII-53

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Peroxide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	13.66	6.09
Cadmium	1.62	0.72
*Chromium	2.09	0.87
Copper	9.05	4.76
Lead	2.00	0.95
*Mercury	1.19	0.48
Nickel	9.14	6.05
Selenium	5.86	2.62
*Silver	1.95	0.81
*Zinc	6.95	2.90
Aluminum	30.61	15.23
Iron	5.71	2.90
*Manganese	3.24	1.38

*Regulated Pollutant

TABLE XII-54

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Nickel Impregnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Arsenic	574.0	256.0
Cadmium	68.0	30.0
*Chromium	88.0	36.0
Copper	380.0	200.0
Lead	84.0	40.0
*Mercury	50.0	20.0
*Nickel	384.0	254.0
Selenium	246.0	110.0
*Silver	82.0	34.0
*Zinc	292.0	122.0
Aluminum	1286.0	640.0
Iron	240.0	122.0
*Manganese	136.0	58.0

*Regulated Pollutant

TABLE XII-55

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.49	0.22
Cadmium	0.057	0.025
*Chromium	0.074	0.030
Copper	0.32	0.17
*Cyanide	0.049	0.021
Lead	0.071	0.034
*Mercury	0.042	0.017
*Nickel	0.33	0.22
Selenium	0.21	0.093
*Silver	0.069	0.028
*Zinc	0.25	0.10
Aluminum	1.09	0.55
Iron	0.21	0.11
*Manganese	0.12	0.049

*Regulated Pollutant

TABLE XII-56

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Etch

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Arsenic	21.35	9.52
Cadmium	2.53	1.12
*Chromium	3.27	1.34
Copper	14.14	7.44
Lead	3.13	1.49
*Mercury	1.86	0.74
Nickel	14.29	9.45
Selenium	9.15	4.09
*Silver	3.05	1.26
*Zinc	10.86	4.54
Aluminum	47.84	23.81
Iron	8.93	4.54
*Manganese	5.06	2.16

*Regulated Pollutant

TABLE XII-57

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.78	0.35
Cadmium	0.091	0.040
*Chromium	0.12	0.048
Copper	0.51	0.27
*Cyanide	0.078	0.033
Lead	0.11	0.054
*Mercury	0.067	0.027
*Nickel	0.52	0.34
Selenium	0.33	0.15
*Silver	0.11	0.045
*Zinc	0.40	0.17
Aluminum	1.74	0.87
Iron	0.33	0.17
*Manganese	0.18	0.078

*Regulated Pollutant

TABLE XII-58

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Reject Cell Handling

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.028	0.012
Cadmium	0.003	0.001
*Chromium	0.004	0.001
Copper	0.019	0.010
*Cyanide	0.003	0.001
Lead	0.004	0.002
*Mercury	0.002	0.001
*Nickel	0.019	0.012
Selenium	0.012	0.005
*Silver	0.004	0.001
*Zinc	0.014	0.006
Aluminum	0.064	0.032
Iron	0.012	0.006
*Manganese	0.006	0.002

*Regulated Pollutant

TABLE XII-59

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced		
English Units - lb/1,000,000 lb of cells produced		
Arsenic	2.41	1.08
Cadmium	0.29	0.13
*Chromium	0.37	0.15
Copper	1.60	0.84
*Cyanide	0.24	0.10
Lead	0.35	0.17
*Mercury	0.21	0.084
*Nickel	1.61	1.07
Selenium	1.03	0.46
*Silver	0.35	0.14
*Zinc	1.23	0.51
Aluminum	5.40	2.69
Iron	1.01	0.51
*Manganese	0.57	0.24

*Regulated Pollutant

TABLE XII-60

ZINC 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 cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	3.70	1.65
Cadmium	0.44	0.19
*Chromium	0.57	0.23
Copper	2.45	1.29
*Cyanide	0.38	0.16
Lead	0.54	0.26
*Mercury	0.32	0.13
*Nickel	2.48	1.64
Selenium	1.59	0.71
*Silver	0.53	0.22
*Zinc	1.88	0.79
Aluminum	8.30	4.13
Iron	1.55	0.79
*Manganese	0.88	0.37

*Regulated Pollutant

TABLE XII-61

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Peroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Arsenic	22.70	10.13
Cadmium	2.69	1.19
*Chromium	3.48	1.42
Copper	15.03	7.91
Lead	3.32	1.58
*Mercury	1.98	0.79
Nickel	15.19	10.05
Selenium	9.73	4.35
*Silver	3.24	1.34
*Zinc	11.55	4.83
Aluminum	50.86	25.31
Iron	9.49	4.83
*Manganese	5.38	2.29

*Regulated Pollutant

TABLE XII-62

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Arsenic	9.21	4.11
Cadmium	1.09	0.48
*Chromium	1.41	0.58
Copper	6.10	3.21
Lead	1.35	0.64
*Mercury	0.80	0.32
Nickel	6.16	4.08
Selenium	3.95	1.77
*Silver	1.32	0.55
*Zinc	4.69	1.96
Aluminum	20.64	10.27
Iron	3.85	1.96
*Manganese	2.18	0.93

*Regulated Pollutant

TABLE XII-63

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Zinc Oxide Anodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc English Units - lb/1,000,000 lb of zinc		
Arsenic	41.82	18.64
Cadmium	0.87	0.39
*Chromium	4.55	1.97
Copper	4.55	1.97
Lead	0.87	0.39
*Mercury	2.82	1.19
Nickel	4.55	1.97
Selenium	17.77	8.02
*Silver	4.55	1.97
*Zinc	0.87	0.39
Aluminum	132.4	58.73
Iron	26.01	13.22
*Manganese	6.50	4.98

*Regulated Pollutant

TABLE XII-64

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Electrodeposited Anodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of zinc deposited English Units - lb/1,000,000 lb of zinc deposited		
Arsenic	414.37	184.64
Cadmium	8.59	3.87
*Chromium	45.09	19.54
Copper	45.09	19.54
Lead	8.59	3.87
*Mercury	27.91	11.81
Nickel	45.09	19.54
Selenium	8.59	3.87
*Silver	45.09	19.54
*Zinc	8.59	3.86
Aluminum	1311.82	581.84
Iron	257.64	130.97
*Manganese	64.41	49.38

*Regulated Pollutant

TABLE XII-65

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	57.32	25.54
Cadmium	1.19	0.54
*Chromium	6.24	2.70
Copper	6.24	2.70
Lead	1.19	0.54
*Mercury	3.86	1.63
Nickel	6.24	2.70
Selenium	24.35	10.99
*Silver	6.24	2.70
*Zinc	1.19	0.53
Aluminum	181.47	80.49
Iron	35.64	18.12
*Manganese	8.91	6.83

*Regulated Pollutant

TABLE XII-66

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Oxide Powder Cathodes, Formed

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	38.3	17.1
Cadmium	0.79	0.36
*Chromium	4.17	1.81
Copper	4.17	1.81
Lead	0.79	0.36
*Mercury	2.58	1.09
Nickel	4.17	1.81
Selenium	16.3	7.35
*Silver	4.17	1.81
*Zinc	0.79	0.36
Aluminum	121.3	53.8
Iron	23.8	12.1
*Manganese	5.96	4.57

*Regulated Pollutant

TABLE XII-67

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Peroxide Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver applied English Units - lb/1,000,000 lb of silver applied		
Arsenic	9.19	4.09
Cadmium	0.19	0.09
*Chromium	1.00	0.43
Copper	1.00	0.43
Lead	0.19	0.09
*Mercury	0.62	0.26
Nickel	1.00	0.43
Selenium	3.90	1.76
*Silver	1.00	0.43
*Zinc	0.19	0.09
Aluminum	29.1	12.9
Iron	5.71	2.90
*Manganese	1.43	1.09

*Regulated Pollutant

TABLE XII-68

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Nickel Impregnated Cathodes

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of nickel applied English Units - lb/1,000,000 lb of nickel applied		
Arsenic	386.0	172.0
Cadmium	8.0	3.6
*Chromium	42.0	18.2
Copper	42.0	18.2
Lead	8.0	3.6
*Mercury	26.0	11.0
*Nickel	42.0	18.2
Selenium	164.0	74.0
*Silver	42.0	18.2
*Zinc	8.0	3.6
Aluminum	1222.0	542.0
Iron	240.0	122.0
*Manganese	60.0	46.0

*Regulated Pollutant

TABLE XII-69

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Cell Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.33	0.15
Cadmium	0.006	0.003
*Chromium	0.035	0.015
Copper	0.035	0.015
*Cyanide	0.025	0.010
Lead	0.006	0.003
*Mercury	0.022	0.009
*Nickel	0.035	0.015
Selenium	0.14	0.062
*Silver	0.035	0.015
*Zinc	0.006	0.003
Aluminum	1.04	0.46
Iron	0.21	0.10
*Manganese	0.051	0.039

*Regulated Pollutant

TABLE XII-70

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Etch

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver processed English Units - lb/1,000,000 lb of silver processed		
Arsenic	14.36	6.40
Cadmium	0.30	0.13
*Chromium	1.56	0.68
Copper	1.56	0.68
Lead	0.30	0.13
*Mercury	0.97	0.41
Nickel	1.56	0.68
Selenium	6.10	2.75
*Silver	1.56	0.68
*Zinc	0.30	0.13
Aluminum	45.46	20.16
Iron	8.93	4.54
*Manganese	2.23	1.71

*Regulated Pollutant

TABLE XII-71

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Employee Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.52	0.23
Cadmium	0.010	0.004
*Chromium	0.056	0.024
Copper	0.056	0.024
*Cyanide	0.039	0.016
Lead	0.010	0.004
*Mercury	0.035	0.014
*Nickel	0.056	0.024
Selenium	0.22	0.099
*Silver	0.056	0.024
*Zinc	0.010	0.004
Aluminum	1.65	0.73
Iron	0.33	0.16
*Manganese	0.081	0.062

*Regulated Pollutant

TABLE XII-72

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Reject Cell Handling

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	0.019	0.008
Cadmium	0.0004	0.00018
*Chromium	0.002	0.00091
Copper	0.002	0.00091
*Cyanide	0.0015	0.0006
Lead	0.0004	0.00018
*Mercury	0.001	0.00055
*Nickel	0.002	0.00091
Selenium	0.008	0.003
*Silver	0.002	0.00091
*Zinc	0.0004	0.00018
Aluminum	0.061	0.027
Iron	0.012	0.006
*Manganese	0.003	0.002

*Regulated Pollutant

TABLE XII-73

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Floor and Equipment Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	1.62	0.72
Cadmium	0.033	0.015
*Chromium	0.18	0.076
Copper	0.18	0.076
*Cyanide	0.12	0.051
Lead	0.033	0.015
*Mercury	0.11	0.046
*Nickel	0.18	0.076
Selenium	0.69	0.31
*Silver	0.18	0.076
*Zinc	0.033	0.015
Aluminum	5.13	2.28
Iron	1.01	0.51
*Manganese	0.25	0.19

*Regulated Pollutant

TABLE XII-74

ZINC 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 cells produced English Units - lb/1,000,000 lb of cells produced		
Arsenic	2.49	1.11
Cadmium	0.051	0.023
*Chromium	0.27	0.12
Copper	0.27	0.12
*Cyanide	0.039	0.016
Lead	0.051	0.023
*Mercury	0.17	0.07
*Nickel	0.27	0.12
Selenium	1.06	0.48
*Silver	0.27	0.12
*Zinc	0.05	0.02
Alumium	7.88	3.50
Iron	1.55	0.79
*Manganese	0.39	0.30

*Regulated Pollutant

TABLE XII-75

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Peroxide Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver in silver peroxide produced English Units - lb/1,000,000 lb of silver in silver peroxide produced		
Arsenic	15.27	6.80
Cadmium	0.32	0.14
*Chromium	1.66	0.72
Copper	1.66	0.72
Lead	0.32	0.14
*Mercury	1.03	0.44
Nickel	1.66	0.72
Selenium	6.49	2.93
*Silver	1.66	0.72
*Zinc	0.32	0.14
Aluminum	48.33	21.44
Iron	9.49	4.83
*Manganese	2.37	1.82

*Regulated Pollutant

TABLE XII-76

ZINC SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Silver Powder Production

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of silver powder produced English Units - lb/1,000,000 lb of silver powder produced		
Arsenic	6.20	2.76
Cadmium	0.13	0.057
*Chromium	0.67	0.29
Copper	0.67	0.29
Lead	0.13	0.057
*Mercury	0.42	0.18
Nickel	0.67	0.29
Selenium	2.63	1.19
*Silver	0.67	0.29
*Zinc	0.13	0.06
Aluminum	19.61	8.70
Iron	3.85	1.96
*Manganese	0.96	0.74

*Regulated Pollutant

SECTION XIII

BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

The 1977 amendments added section 301(b)(2)(E) to the Act, establishing "best conventional pollutant control technology" (BCT) for discharges of conventional pollutants from existing industrial point sources. Conventional pollutants are those defined in section 304(a)(4) [biological oxygen-demanding pollutants (BOD_5), (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 heavy metals from wastewater.

Chemical Treatment - Treating contaminated water by chemical means.

Clarifier - A unit which provides settling and removal of solids from wastewater.

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 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.

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.

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 closest 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 flotation and mechanical separation of the phases.

Total Cyanide - The total content of cyanide including simple and/or complex ions. In analytical terminology, total cyanide is the sum of cyanide amenable to chlorination and that which is not 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.

Wet Charge Process - 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.

Wet Shelf Life - The period of time that a secondary battery can stand in the charged condition before total degradation.

Wet Scrubber - A unit in which dust and fumes are removed from an air or gas stream to a liquid. Gas-liquid contact is promoted by jets, sprays, bubble chambers, etc.

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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.