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GALVANIC SLUDGE RECYCLING PILOT PLANT
SI/HUN/94/801

UNIDO CONTRACT No. 95/101/ML

FINAL REPORT

TO

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

by

ADVANCED WASTE MANAGEMENT SYSTEMS, INC.

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U.S.A.

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1.0 Executive Summary

The following draft final report includes the work presented in the interim report along with the engineering and test program design of a galvanic sludge recycling pilot plant.

The text, tables, and drawings included in this report will provide the bases for construction of the pilot plant.

The report includes the design basis; process system definition; process description; and test program plan. Tables include materials balances; equipment guidelines; and general process drawings. Appendices include design packages.

The project team has been very encouraged by the tasks completed thus far in that it has been possible to maintain an objective of simplicity which should enhance durability. Also, this allows for design from readily available components and thus greatly enhances the plant's serviceability.

Given the assumptions and limitations drawn from the full scale plant design, and the objective of dual use for the facility (i.e. pilot operations for process refinement and later use as a transportable commercially operable satellite plant) the project team has not encountered any insurmountable obstacles.

2.0 Process Design

2.1 Design Basis

Table 2-1 summarizes the Design Basis for the Galvanic Sludge Recovery Pilot Plant. This Design Basis consists of five parts: Capacity; Siting Requirements; Sludge Composition Limitations; Equipment Inclusion/Configuration; and Operating Assumptions. Together, these determine equipment requirements in terms of scope (items or units included), sizing and specific features/attributes.

Five aspects of the Design Basis constitute the primary factors in defining the equipment requirements:

- **Capacity** - It is desired to have a pilot plant capacity of roughly 500 tons of sludge (as received) per year. This is intended to allow the pilot plant to be used to "campaign" certain sludges during the more mature periods of the test program and/or after the test program has been completed. It is assumed that this capacity would be achieved through seven day per week, 24 hour per day operation. This would then translate to a daily capacity of about 1.5 tons. Recognizing that the pilot plant would typically be operated during many test periods at about 60-75% capacity and only five days per week, the actual throughput during testing would probably be less than half the design capacity.

- **Transportability** - It is desired to have the pilot plant be transportable (not necessarily mobile). In light of the capacity constraints noted above, a truly mobile pilot plant would not be feasible. Transportability dictates constraints in terms of number, dimensions and loads for equipment skids to allow over-the-road haulage.

- **Utilities Availability** - It has been assumed that the pilot plant would be located at facilities where basic utilities would be available, principally potable water, power and compressed air. Thus, generators, compressors and water treatment equipment are not included in the design.

- **Sludge Limitations** - Restrictions have been placed on the compositions of sludges to be treated in the pilot plant, at least for the first phases of testing. These restrictions derive from limitations identified during the process development work and conditions that will minimize the complexity of the system for initial operations. As experience is gained with equipment operation and performance, the pilot plant can be expanded, if needed, with additional equipment as defined during initial testing to handle more types of sludges and/or improve overall performance.

- **Flexibility/Simplicity** - The overriding philosophy in the pilot plant design is to keep it as simple and as flexible as possible. In addition to the aspects of sludge limitations and utilities as noted above, this includes the following considerations:

  - minimal use of automatic controls;
  - decoupling of sequential batch operations to the greatest extent possible;
  - maximum use of hoses for interconnecting skids and to a lesser extent equipment within skids;
  - commonality in the selection and design of tanks, pumps, agitators and other process equipment; and,

- sizing of support systems wherever possible to allow only one shift operation.

2.2 Process System Definition

2.2.1 Process System Scope

A complete Galvanic Sludge Recovery plant based upon the preliminary design developed as a part of the Phase II effort encompasses seven process areas. For various reasons discussed previously and noted in Table 2-1, not all process areas are considered either necessary or desirable for the pilot plant, at least for the initial design and operation. The seven process areas are listed below; **those included in the pilot plant design are shown in bold.**

(1) Sludge receiving and storage - Sludge storage and receiving is assumed to be provided by the facility at which the pilot plant is installed.

(2) **Sludge/solids preparation** - Sludge is mixed with (hot) water and milled to a prescribed particle size distribution.

(3) **Sulfuric acid extraction** - The milled slurry is extracted in two or three stages with sulfuric acid. The extract is sent to Metals Recovery and the residue is filtered and washed for disposal.

(4) **Metals recovery** - Metal values are precipitated from the extract by treatment in a succession of steps with limestone and sodium carbonate. The metals are precipitated as hydoxy, oxide carbonates. Some calcium will also be precipitated as phosphates and sulfates.

(5) Residue treatment - The residue from sulfuric acid extraction is further treated with hydrochloric acid and other additives to remove the last traces of metals, especially lead and, perhaps, small amounts of cadmium among other difficult to extract metals. This system is not considered essential for the initial pilot plant operation given the limitations on sludge composition, so equipment requirements are provided only as an option. Laboratory scale testing of residue treatment should be conducted in parallel with the pilot plant operation, as required, to confirm residue treatment equipment requirements.

(6) Sodium sulfate crystallization - Sodium sulfate is recovered from the liquor by crystallization with recovered water recycled for reuse. A crystallization system to recover sodium sulfate has not been included. Not only would the cost be quite high, but more importantly, the design parameters are not yet well-defined. Solutions generated during initial test periods after pilot plant shakedown will need to be sent to crystallization system suppliers for evaluation and subsequent design specification

(7) Auxiliary support systems - Auxiliary systems include bulk chemical storage and feed systems, scrubber systems, and utilities. The pilot plant design is predicated on provisions for storage of bulk chemicals and effluent liquors in either existing onsite tankage or transportable tankage. Utilities are assumed to be available. Scrubber systems are provided only for control of potentially significant emissions from the acid extraction area.

2.2.2 Process Flow and Control Diagrams

A combined Process Flow Diagram (PFD) and Piping and Instrumentation Diagram (P&ID) has been prepared entitled a Process Flow and Control Diagram (PFCD). This type of diagram is used for process systems where there are a limited number of unit operations and control concepts are relatively uncomplicated. The PFCDs are provided in Drawing Numbers 95-547-110 and -111.

These PFCDs define the basic system configuration and delineate the major process system equipment requirements.

2.2.3 Process Material Balances

Four complete Material Balances have been prepared in support of the Pilot Plant design effort. The assumptions and conditions prescribed for these Material Balances are provided in Table 2-2. The four Material Balances accompany the PFCD and are labeled Drawing Numbers 95-547-100 A, B, C and D.

2.2.4 Process Equipment Lists

A Process Equipment List is provided in Table 2-3. This listing denotes all the principal process equipment and identifies equipment type, nominal operating conditions, minimum materials of construction and special features, where pertinent and the extent that they can be defined in the development of the process design package. The list covers all process areas required for the initial Pilot Plant system. It also includes several options that may be desirable based upon results of initial tests as well as a preliminary list for the Residue Treatment area which is not expected to be required.

2.2.5 Process Instrumentation Lists

Two Process Instrument Lists are provided. One for In-Line Instrumentation given in Table 2-4A; and, one for Off-Line Instrumentation given in Table 2-4B. The latter includes only that instrumentation required in the Pilot Plant itself to monitor and control operations. It does not include analytical instrumentation required to perform chemical analyses.

2.3 Design Considerations

2.3.1 Equipment Specifications

Considerations in equipment selection are provided in Table 2-5. These are not requirements, rather suggestions and factors to be taken into account in preparing the detailed design and cost estimates.

2.3.2 Equipment Layouts

While equipment layouts are the prerogative of the detailed design function, preliminary layout concepts have been developed as a starting point for the detailed design. These preliminary concepts derive from an initial assessment of logical skid configurations based upon considerations of equipment functionality and overall equipment transportability. Table 2-6 shows an example of a skid schedule; and, Drawing Number 95-547-115 shows preliminary general arrangements (layouts and section views) for several representative skids. It must be reiterated that these should be considered preliminary and exemplary in nature.

SECTION 2: PROCESS DESIGN TABLES AND DRAWINGS

Table 2-1. **Pilot Plant Design Basis**

Capacity

- 500 metric tons per year of sludge (as received)

Siting Requirements

- Equipment is to be transportable, preferably skid mounted (not necessarily mobile)
- An existing building/enclosure is available for equipment installation with:
  - adequate heating and ventilation
  - fire protection as required
  - safety showers and eye washes
  - area containment for spills and leaks
- Adjacent, contained and covered storage is available for sludges and residues
- Battery Limits utilities and services are available, as follows:
  - power
  - compressed air
  - makeup water
  - hot water (optional)
- Onsite bulk storage for chemicals is available as follows:
  - concentrated sulfuric acid (93-98%) - tanker trucks can be used
  - concentrated sodium hydroxide (50%) - tanker trucks can be used
  - waste sodium sulfate liquor (8-20%) - tanker trucks can be used
  - sodium carbonate (powder or in ~15% solution)
  - limestone (powder)
- Onsite or offsite disposition of the treated liquor effluent is available

Sludge Composition Limitations

- Basic sludge types - The system is not designed to accommodate the following:
  - chloride sludges such as those obtained from HCl pickling operations
  - liquids or sludges containing free-draining liquids
  - oily sludges
- Sludge compositions - The following limits apply to the sludges treated:
  - Low chloride content - this limitation relates to the constraints on disposition of the treated effluent liquor
  - No cyanide - provisions have not been included to destroy cyanides
  - No mercury - the system is not designed to handle mercury in any form
  - Arsenic < 0.05 wt% - the system is not designed to handle arsenic
  - Low lead content (< 0.1 wt%)
  - Fe(II)/Fe(III) ratio < 0.1 - the system does not have provisions to oxidize Fe(II) to Fe(III). This was studied during bench scale testing and was not adequately resolved. Further study/analysis is required

Table 2-1. Pilot Plant Design Basis (Continued)

Equipment Inclusion/Configuration

System configuration will essentially be a mini-version of the preliminary full scale design entailing a series of batch operations. The following subsystems/equipment, though, are either not included or modified in the pilot plant design.

- Sodium Sulfate Crystallization - A crystallization system to recover sodium sulfate from the effluent liquor has not been included because the cost would be quite high and the design parameters are not yet well-defined. Solutions generated during initial test periods after pilot plant shakedown will need to be sent to crystallization system suppliers for evaluation and subsequent design specification. A preliminary specification for the liquor composition has been provided as a part of this package. It is assumed that the liquor can be transported to a pulp and paper mill for disposition.

- Residue treatment system - This system is not considered essential for the initial pilot plant operation, so equipment requirements are provided only as an option. Initial operation needs to focus on solids preparation, sulfuric acid extraction and byproduct recovery. Thus, low lead content sludges should be tested first. Once the operational requirements and performance aspects of these areas have been determined, then consideration can be given to the need for and requirements of a residue treatment system. Laboratory scale testing of residue treatment should be conducted in parallel with the pilot plant operation, as required, to confirm residue treatment equipment requirements.

- Vent gas scrubbing systems - A full scale facility would be expected to have a number of vent gas scrubbing systems. These will be limited in the pilot design.

  (1) Control of sulfuric acid mist from the acid extraction area tanks - All the tanks in the sulfuric acid extraction area have the potential for sulfuric acid emissions, especially the acid mix/feed tank, the hot/warm acid extraction tanks, and the first stage dilute acid dissolution tank during initial solids/slurry feed when CO_2 offgassing can carry entrained acid. The amount of emissions will depend upon the design of these tanks and the operating procedures. A sodium hydroxide scrubber unit is provided to capture acid mist emissions from these tanks.

  (2) Control of hydrochloric acid mist from the residue treatment area - The acid mix/feed tank, the residue extraction tank, and the extraction liquor hold tank have potential for HCl emissions; however, this system is not being installed initially.

  (3) Recovery of CO_2 offgas from the first stage acid extraction tank and the byproduct precipitation reactors - This is primarily for economic considerations and to minimize any greenhouse gas emissions. This is not considered necessary or desirable for the pilot plant given the greater degree of complexity involved in trying to capture and recover the small amounts of CO_2 emitted in this scale of operation.

Table 2-1. **Pilot Plant Design Basis (Continued)**

Operating Assumptions

- Overall - Normal operation is assumed to be five days per week, three shifts per day. To achieve design capacity with most sludges it may be necessary to operate seven days per week. This will be dependent upon the number of stages of acid extraction required and the cycle times (see below).

- Solids Preparation Area - Solids/slurry milling is assumed to have the capacity to operate one shift per day.

- Acid Makeup - The sulfuric acid makeup subsystem in the Acid Extraction Area is assumed to be operated one shift per day.

- Acid Extraction Area Stages - Three stages of acid extraction have been provided in the design; however, bench-scale testing has indicated that it may be possible to complete acid extraction in two stages for many sludges.

- Acid Extraction Area Cycle Times - A six-hour cycle time has been assumed in the equipment sizing. This is consistent with the most conservative results from bench-scale testing. Four-hour cycle times may be achievable.

Table 2-2. Pilot Plant Material Balances

Four complete material balances have been prepared for the expressed purpose of developing equipment specifications and determining operating requirements. A number of simplifying assumptions, therefore, have been made in the material balance calculations rather than speculating on the details of the chemistry that need to be verified by the pilot plant operations.

- All filter cakes are assumed to be 50% solids.
- Three displacement washes are indicated for filtered sludge residue and two for filtered precipitates. These are assumed to remove all dissolved solids.
- Partitioning/precipitation of metals as a function of pH are rough estimates.
- Calcium phosphates are assumed to precipitate as $Ca_3(PO_4)_2$ at pH levels of 6 and above. (Actually, at pH levels of 5 to 7.5, calcium phosphate may precipitate preferentially as Ca_2HPO_4.)
- Sodium carbonate can be fed either as a solution or a slurry. The solution is 15% solids; the slurry is 40% total solids (15% solution + 25% suspended solids).
- The vent scrubber is not explicitly shown in balances because of the uncertainty in the tank designs; however, it is implicitly included, since it is an internal loop. All sulfuric acid mist is assumed to be captured in the scrubber and all Na_2SO_4 formed in the scrubber is returned to the Metals Recovery Area.

Material Balances Cases

Assumptions/ Conditions	Base Case	Optimal Operation	Typical Campaign	Typical Campaign
Sludge				
Type	Composite	Composite	ELZETT	BHG
Solids Content	30%	35%	40%	50%
Differentiating Characteristics	• Low Solids • Mod Alkalinity • Mod Insolubles	• Avg Solids • Mod Alkalinity • Mod Insolubles	• High Solids • Low Alkalinity • Low Insolubles • High Cr,P	• High Solids • High Alkalinity • Low
Acid Extraction				
Acid Stoichiometry	130%	110%	120%	120%
Acid Concentration	20%	25%	20%	20%
Number of Stages	3	2	3	3
Cycle Time (H)	6	4	6	6
Metals Recovery				
Limestone Feed	40% Slurry	40% Slurry	40% Slurry	None
Na_2CO_3 Feed	15% Solution	15% Solution	15% Solution	40% Slurry

Table 2-3. Pilot Plant Process Equipment List

Process Area	Tag Number	Number		Capacity	Type/Description	Nominal Conditions			Materials	Special Requirements
		On-line	Shelf			T (C)	pH	TSS (%)	(Minimum)	
Solids Preparation	**(Area 100)**									
Vessels										
Milled Solids Slurry	V101 & V102	2	-	~2.5 c.m. working vol	~1.5m D x 2.0m H, Baffled, Covered	20 - 40	5 - 9	25	FRP	
Mills										
Feed Solids Ball Mill	B121	1	-	~2500 kg/shift		25 - 40	5 - 9	25	CS	95%-325 mesh Capability
Solids Feeders										
Mill Feed Conveyor	C122	1	-	To match Ball Mill		25 - 30	5 - 9	30 - 50		
Pumps										
Slurry Transfer	P101 & P102	2	1	1.0 l/s (max)	Diaphragm	25 - 40	5 - 9	25	316 SS	
Agitators										
Milled Solids Slurry	A101 & A102	2	0	-----	Pitched Blade Turbine Variable Speed	25 - 40	5 - 9	25	CSRL	Uniform solids suspension
Other - Optional (Not on PFCD)										
Feed Solids Screens/Grizzlies	TBD	(2)	0	TBD	TBD					
Acid Extraction	**(Area 200)**									
Vessels										
1st Stage Extraction	V201	1		~1.5 c.m. working vol	~1.2m D x 1.8m H, Baffled, Closed Top	40	~1	10	FRP	
1st Stage Feed Liquor	V202	1	-	~1.5 c.m. working vol	~1.2m D x 1.8m H, Baffled, Closed Top	50	<<1	Nil	FRP	Hot water heating coil
2nd Stage Extraction	V203	1	-	~1.5 c.m. working vol	~1.2m D x 1.8m H, Baffled, Closed Top	50	<<1	5	FRP	and/or
2nd Stage Feed Liquor	V204	1		~1.5 c.m. working vol	~1.2m D x 1.8m H, Baffled, Closed Top	60	<<1	Nil	FRP	Electrical heating element
3rd Stage Extraction	V205	1	-	~1.5 c.m. working vol	~1.2m D x 1.8m H, Baffled, Closed Top	60	<<1	5	FRP	
Acid Mix/Feed	V206	1		~2.0 c.m. working vol	~1.2m D x 2.2m H, Baffled, Closed Top	65	<<1	Nil	FRP	
Vent Gas Scrubber	V207	1	-	~1500 c.m. gas/h	~0.5m D, Internal Recirc. Reservoir	25	10 - 14	Nil	FRP	
Solids Separation										
Solids Filter Traps	S202 & S204	2	1	N/S	Sock/Tube Type	40 - 50	<<1	<1	PP/LS	
Residue Filters	S221 & S222	2	1	~200 kg(dry)/h (max)	Plate & Frame (Gasketed)	60	<<1 2	5 - 10	PP/LS	Wash capability
Hydroclones	S223 & S224	2	1	~200 kg(dry)/h (max)		40 - 50	<<1	5 - 10	FRP/PVC	
Residue Filter Hoppers	H221 & H222	2	0	~250 kg	Wheeled Carts	30	~2	50	FRP	
Pumps										
Extraction Tanks	P201 & P203	2	2	1.0 l/s (max)	Centrifugal	40 - 50	<<1	5 - 10	CSRL	
Extraction & Hold Tanks	P202 P204 P205	3	3	1.0 l/s (max)	Diaphragm	40 - 65	<<1	5 - 10	Butyl	
Acid Feed	P206A & 206B	2	0	0.5 l/s (max)	Centrifugal	65	<<1	Nil	CSRL	
Scrubber Recirculation	P207A & 207B	2	0	0.25 l/s (max)	Centrifugal	30	8 - 13	Nil	FRP	
Fans										
Vent Gas Scrubber	F207	1	0	~1500 c.m. gas/h	Centrifugal	30	3 - 13	---	FRP	
Agitators										
Extraction & Hold Tanks	A201-A205	5	0	-----	Pitched Blade Turbine Variable Speed	40 - 65	<<1	5 - 10	CSRL	Uniform solids suspension
Acid Feed/Mix Tank	A206	1	0	-----	Pitched Blade Turbine Variable Speed	65	<<1	Nil	CSRL	Liquid blending

Table 2-3. Pilot Plant Process Equipment List (Continued)

Process Area	Tag Number	Number		Capacity	Type/Description	Nominal Conditions			Materials	Special Requirements
		On-line	Shelf			T (C)	pH	TSS (%)	(Minimum)	
Metals Recovery	**(Area 300)**									
Vessels										
Feed/Neutralization	V301	1	-	~3.2 c.m. working vol	~1.5m D x 2.2m H Baffled, Covered	35	~1	<0.5	PE	Immersion pH probe
Interim Storage	V302 & V303	2	-	~1.5 c.m. working vol	~1.2m D x 1.8m H Baffled, Covered	25	3 - 8	1 - 3	PE	Immersion pH probe
1st Stage Precipitation	V304	1	-	~1.5 c.m. working vol	~1.2m D x 1.8m H Baffled, Covered	25	~3	1 - 3	PE	Immersion pH probe
2nd Stage Precipitation	V305	1	-	~1.5 c.m. working vol	~1.2m D x 1.8m H Baffled, Covered	25	~6	1 - 3	PE	Immersion pH probe
3rd Stage Precipitation	V306	1	-	~1.5 c.m. working vol	~1.2m D x 1.8m H Baffled, Covered	25	~9	1 - 3	PE	Immersion pH probe
Sodium Hydroxide Mix/Feed	V307	1	-	~1.5 c.m. working vol	~1.2m D x 1.8m H Baffled, Covered	25	14	Nil	PE	
Sodium Carbonate Mix/Feed	V308	1	-	~1.5 c.m. working vol	~1.2m D x 1.8m H Baffled, Covered	25	12	0 - 25	PE	
Limestone (Slurry) Mix/Feed	V309	1		~1.5 c.m. working vol	~1.2m D x 1.8m H Baffled, Covered	25	8	40	PE	
Polymer Mix/Feed Tanks	V310 & V311	2	-			25	-	~0.1		
Solids Separation										
Solids Filter Traps	S301-S306	6	1	N/S	Sock/Tube Type	25 - 40	1 - 7	<1	PP/LS	
Byproduct Filters	S321-S323	3	1	~200 kg dry/h (max)	Plate & Frame (Gasketed)	30	3 - 10	50	PP/LS	Wash capability
Byproduct Filter Hoppers	H321-H323	3	0	~250 kg	Wheeled Carts	25	6 - 9	50	FRP	
Pumps										
Neut., Precip. & Storage Tanks	P301-P306	6	2	1.0 l/s (max)	Diaphragm	25 - 40	1 - 10	<1 - ?	Butyl	
Sodium Hydroxide Feed	P307A & P307B	2	0	10 l/m (max)	Metering	25	14	Nil	PVC	
Sodium Carbonate Solution Feed	P308A & P308B	2	0	10 l/m (max)	Centrifugal	25	11	Nil	CSRL	
Limestone (Slurry) Feed	P309A & P309B	2	0	10 l/m (max)	Diaphragm	25	8 - 11	10 - 40	316 SS	
Polymer Feed Pumps	P310 & P311	2	2		Manufacturer's Std	25 - 40	7	~0.1	—	
Agitators										
Neut., Precip. & Storage Tanks	A301-A306	6	0	-----	Pitched Blade Turbine Variable Speed	25 - 40	1 - 10	<1 - 5	CSRL	Uniform solids suspension
Chemical Mix/Feed Tanks	A307-A309	3	0	-----	Pitched Blade Turbine Variable Speed	25	See Pumps		CSRL	Liquid blending
Polymer Feed Tanks	A310 & A311	2	0	-----	Manufacturer's Std	25 - 40	7	~0.1	304 SS	
Optional - Requirements to be determined during initial operations										
Vessels										
Sludge Conditioning Tanks-Opt	V312-V314	3	-			25 - 35	3 - 9	10 - 20	FRP	
Pumps										
Filter Feed Pumps-Opt	P312-P314	3	1		Diaphragm	25 - 35	3 - 9	10 - 20	Butyl	
Agitators										
Sludge Conditioning Tanks-Opt	A312-A314	3	0		Pitched Blade Turbine	25 - 35	3 - 9	10 - 20	CSRL	

Table 2-3. Pilot Plant Process Equipment List (Continued)

Process Area	Tag Number	Number		Capacity	Type/Description	Nominal Conditions			Materials	Special Requirements
		On-line	Shelf			T (C)	pH	TSS (%)	(Minimum)	
Residue Treatment	**(Area 400)**	**LATER**								
Vessels										
Feed/Storage	V401	1	-	~1 8 c m working vol	~1 2m D x 2 0m H Baffled Covered	25	3 - 6	20	FRP	
Acid Extraction	V402	1	-	~1 2 c m working vol	~1 0m D x 1 5m H Baffled Closed Top	40	<1	20	FRP	
Iron Removal	V403	1	-	~1 2 c m working vol	~1 0m D x 1 5m H Baffled Closed Top	35	<1	20	FRP	
Post-Neutralization	V404	1		~1 2 c m working vol	~1 0m D x 1 5m H Baffled Covered	30	8	20	FRP	
HCl Mix/Feed	V405	1	-	~1 5 c m working vol	~1 2m D x 1 8m H Baffled Closed Top	25 - 40	<<1	Nil	FRP	
Additive Slurry Mix/Feed	V406	1	-	~1 5 c m working vol	~1 2m D x 1 8m H Baffled Covered	25	8	20 - 40	FRP	
Solids Separation										
Residue Filter	S421	1		~400 kg(dry)/h (max)	Plate & Frame	25	8	20		Wash capability
Residue Hopper	H421	1	0	~250 kg	Wheeled Cart	25	8	50	FRP	
Pumps										
Residue Feed Transfer	P401	1	0	1 0 l/s (max)	Diaphragm	25	3 - 6	20		
Acid Extraction Transfer	P402	1	0	1 0 l/s (max)	Diaphragm	40	<1	20		
Iron Removal Transfer	P403	1	0	1 0 l/s (max)	Diaphragm	35	<1	20		
Post-Neutralization Transfer	P404	1	0	1 0 l/s (max)	Diaphragm	30	8	20		
Acid Feed	P405	2	0		Metering	25 - 40	<<1	Nil		
Additive Slurry Feed	P406	2	0		Metering	25	8	20 - 40		
Agitators										
Feed/Storage Tank	A401	1	0	-----	Pitched Blade Turbine Variable Speed	25	3 - 6	20		
Acid Extraction Tank	A402	1	0	-----	Pitched Blade Turbine,Variable Speed	40	<1	20		
Iron Removal Tank	A403	1	0	-----	Pitched Blade Turbine Variable Speed	35	<1	20		
Post-Neutralization Tank	A404	1	0	-----	Pitched Blade Turbine,Variable Speed	30	8	20		
HCl Mix/FeedTank	A405	1	0	-----	Pitched Blade Turbine Variable Speed	25 - 40	<<1	Nil		
Additive Mix/Feed Tank	A406	1	0	-----	Pitched Blade Turbine Variable Speed	25	8	20 - 40		
Sulfate Recovery	**(AREA 500)**	**LATER**								
Tank Storage	**(AREA 600)**	**LATER**								
Vessels										
Feed/Storage	V601 & V602	2	-	~1 8 c m working vol	~1 2m D x 2 0m H Baffled Covered	15 - 40	3 - 10	3 - 30	PE	
Solids Separation										
Solids Filter Traps	S621 & S62	2	-		Sock/Tube Type					
Pumps										
Slurry Transfer	P601 & P602	2	1	1 0 l/s (max)	Diaphragm				316 SS	
Agitators										
Mixed Solids Slurry	A601 & A602	2	0	-----	Pitched Blade Turbine,Variable Speed				CSRL	Uniform solids suspension

Materials Key

- Butyl — Butyl Rubber
- CSRL — Carbon Steel - Rubber Lined
- FRP — Fiberglass
- LS — Epoxy Coated Steel
- PE — Polyethylene
- PP — Polypropylene
- PVC — Polyvinyl Chloride
- 304 SS — Stainless Steel - Type 304
- 316 SS — Stainless Steel - Type 316

Table 2-4A. Pilot Plant Instrument List - On-line Instruments

Process Area	Equipment Tag Number	On-Line Measurements* Level	Temp.	Pressure Inlet	Pressure Outlet	pH	Flow	Other/Comments
Solids Preparation	**(Area 100)**							
<u>Vessels</u>								
Milled Solids Slurry	V101 & V102	A	I					
<u>Mills</u>								
Feed Solids Ball Mill	B121							Motor Amps
<u>Solids Feeders</u>								
Mill Feed Conveyor	C122							Belt Speed Indication Weight Indication and Totalizer
<u>Pumps</u>								
Slurry Transfer	P101 & P102							
<u>Lines</u>								
Water to Mill	---						I/Q	
Water to Slurry Tanks	---						I/Q	
Acid Extraction	**(Area 200)**							
<u>Vessels</u>								
1st Stage Extraction	V201	I/A	I					
1st Stage Feed Liquor	V202	I/A	I					
2nd Stage Extraction	V203	I/A	I					
2nd Stage Feed Liquor	V204	I/A	I					
3rd Stage Extraction	V205	I/A	I					
Acid Mix/Feed	V206	I/A	I					
Vent Gas Scrubber	V207	I/A	I			I		
<u>Solids Separation</u>								
Residue Filters	S221 & S222			I	I			
<u>Pumps</u>								
1st & 2nd Stage Extraction	P201 & P203				I			
Other Extraction Liquor	P202,P204 & P205							Air Feed Pressure Indication
Acid Feed	P206A & 206B				I			
Scrubber Recirculation	P207A & 207B				I			
<u>Lines</u>								
Water Flow to Acid Mix Tank	---						I/Q	
Acid Flow to Acid Mix Tank	---						I/Q	
Acid Flow to 1st Stage Extraction							I/Q	
Acid Flow to 2nd Stage Extraction							I/Q	
Acid Flow to 3rd Stage Extraction							I/Q	
Water Flow to 1st Stage Extraction							I/Q	
Water Flow to 2nd Stage Extraction							I/Q	
Water Flow to 3rd Stage Extraction							I/Q	
Wash Water Flow to Residue Filter	---						I/Q	
Seal Water to Pumps 201 & 203	---						I/Q	
Slurry Flow from V-201 to S-223							I	Flow indicators to be "strap-on" type
Slurry Flow from V-203 to S-224							I	(e.g., Doppler meters)
Scrubber Recirculation							I	

Table 2-4A. Pilot Plant Instrument List - On-line Instruments (Continued)

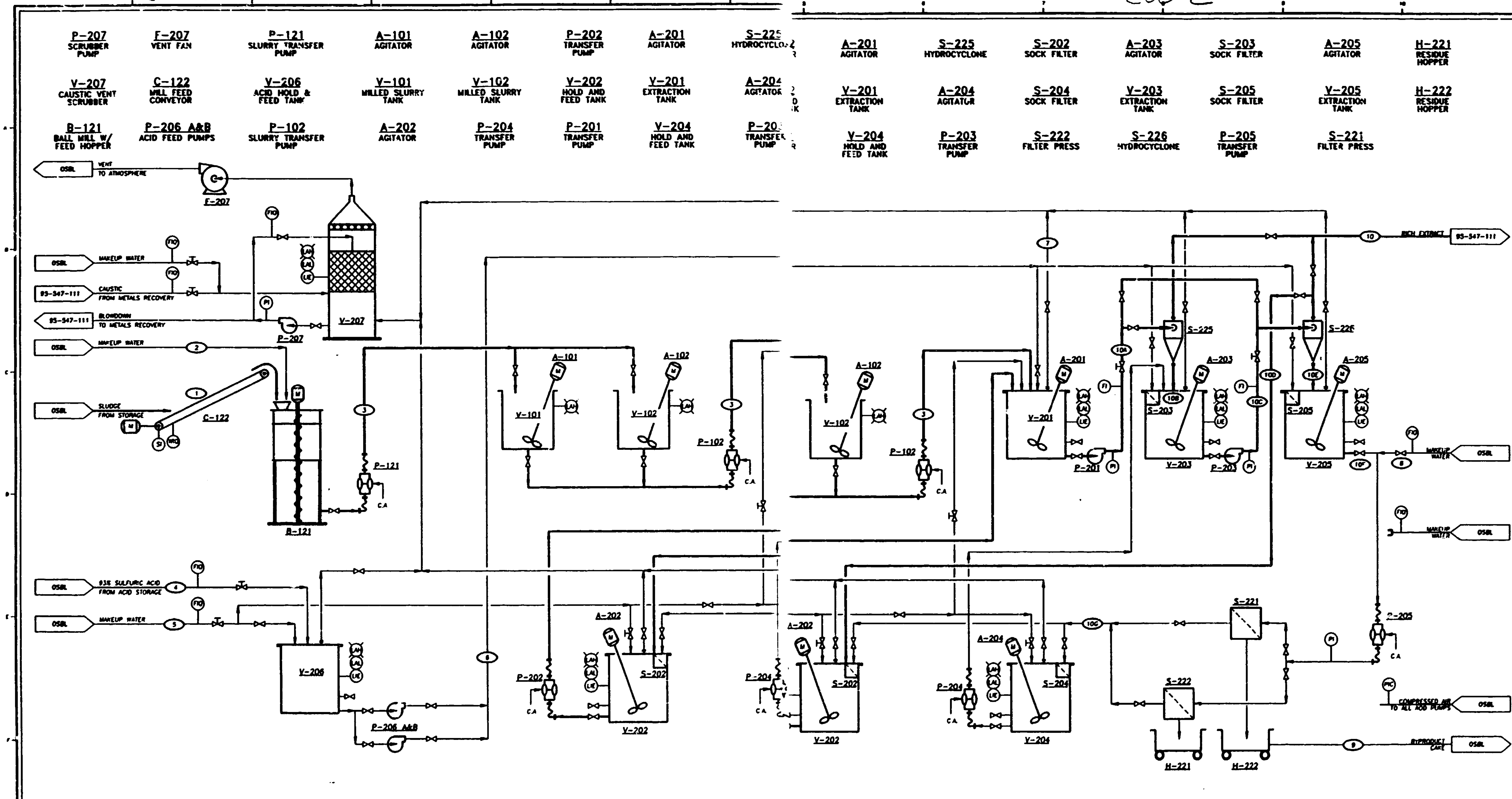
Process Area	Equipment Tag Number	On-Line Measurements*						
		Level	Temp.	Pressure Inlet	Pressure Outlet	pH	Flow	Other/Comments
Metals Recovery	**(Area 300)**							
Vessels								
Pre-Neutralization/Feed	V301	I/A	I			I		
Extra Tank - Interim Storage/Reaction	V302 & V303	I/A	I			I		
1st Stage Precipitation	V304	I/A	I			I		
2nd Stage Precipitation	V305	I/A	I			I		
3rd Stage Precipitation	V306	I/A	I			I		
Sodium Hydroxide Mix/Feed	V307	I/A	I					
Sodium Carbonate SolutionMix/ Feed	V308	I/A	I					
Limestone (Other) Slurry Mix/Feed	V309	I/A	I					
Solids Separation								
Byproduct Filters	S311-S313			I	I			
Pumps								
Neutralization, Precipitation & Storage Tanks	P301-P306							Air Feed Pressure Indication
Sodium Hydroxide Feed	P307							
Sodium Carbonate Solution Feed	P308				I			
Limestone(Other) Slurry Feed	P309							Air Feed Pressure Indication
Lines								
Sodium Hydroxide Feed to Vent Scrubber							I/Q	
Sodium Hydroxide to Pre-Neutralization							I/Q	
Water to Sodium Carbonate Solution Tank							T	
Water to Slurry (Limestone/Soda Ash) Tank							T	
Sodium Carbonate to Pre-Neutralization							I/Q	
Sodium Carbonate to 1st Stage Precipitation							I/Q	
Sodium Carbonate to 2nd Stage Precipitation							I/Q	
Sodium Carbonate to 3rd Stage Precipitation							I/Q	
Limestone (Other) to 1st Stage Precipitation							I/Q	
Limestone (Other) to 2nd Stage Precipitation							I/Q	
Limestone (Other) to 3rd Stage Precipitation							I/Q	
Wash Water to Byproduct Filters(3)							I/Q	
Overall System								
Lines								
Total Water							T	
Total Water to each Area							T	
Water on each Hose							I/Q	

Notations

A Local Alarm
I Local Indication
Q Local Totalizer

Table 2-4B. Pilot Plant Instrument List - Off-line Instruments

Instrument Description	Instrument Requirements/Comments
Solids Preparation	
• Roll-on weigh scale (1)	Cart weight plus one ton of solids
• Solids (Slurry) screening set-up (1)	To measure grinding performance of ball mill
Acid Extraction	
• Bench top pH meters (2)	High sodium electrodes
Metals Recovery	
• Roll-on weigh scales (2)	Cart weight plus one ton of solids
• Bench top pH meters (2)	High sodium electrodes
Overall System	
• Single pan analytical balances (2)	
• Microwave ovens (2)	
• Assorted labware for acid/base titrations	Complete set-up for acidity and alkalinity titrations
• Spring density meter	



DWG. NO.	REFERENCE DRAWINGS
95-547-111	PROCESS FLOW AND CONTROL DIAGRAM - METALS RECOVERY

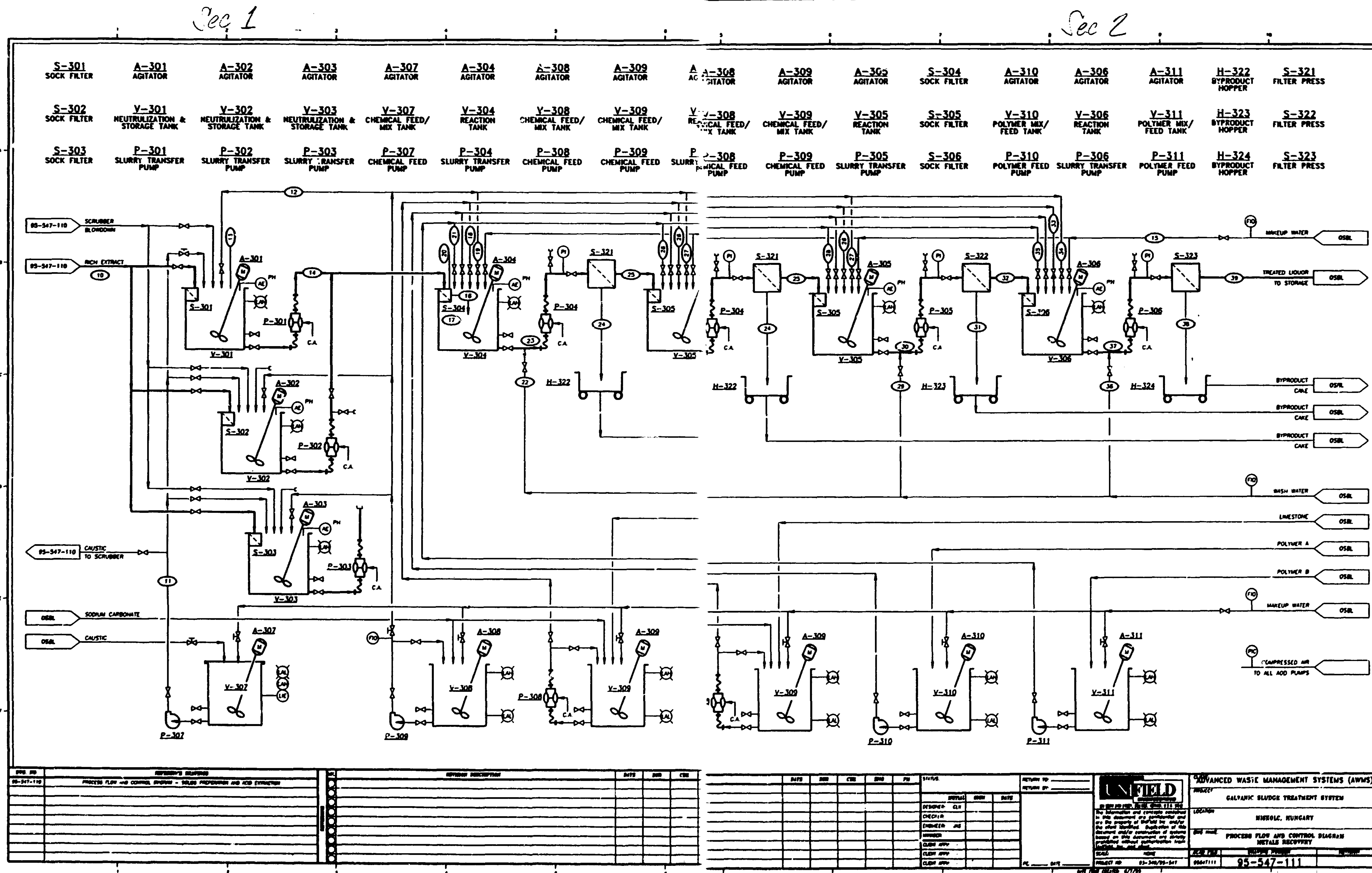
CLIENT: ADVANCED WASTE MANAGEMENT SYSTEMS (AWMS)

PROJECT: GALVANIC SLUDGE TREATMENT SYSTEM

LOCATION: MISKOLC, HUNGARY

DWG. NAME: PROCESS FLOW AND CONTROL DIAGRAM SOLIDS PREPARATION AND ACID EXTRACTION

DRAWING NUMBER: 95-547-110


Sec 1
Sec 2
S-301 SOCK FILTER
A-301 AGITATOR
A-302 AGITATOR
A-303 AGITATOR
A-307 AGITATOR
A-304 AGITATOR
A-308 AGITATOR
A-309 AGITATOR
A-305 AGITATOR
S-304 SOCK FILTER
A-310 AGITATOR
A-306 AGITATOR
A-311 AGITATOR
H-322 BYPRODUCT HOPPER
S-321 FILTER PRESS
S-302 SOCK FILTER
V-301 NEUTRALIZATION & STORAGE TANK
V-302 NEUTRALIZATION & STORAGE TANK
V-303 NEUTRALIZATION & STORAGE TANK
V-307 CHEMICAL FEED/ MIX TANK
V-304 REACTION TANK
V-308 CHEMICAL FEED/ MIX TANK
V-309 CHEMICAL FEED/ MIX TANK
V-305 REACTION TANK
S-305 SOCK FILTER
V-310 POLYMER MIX/ FEED TANK
V-306 REACTION TANK
V-311 POLYMER MIX/ FEED TANK
H-323 BYPRODUCT HOPPER
S-322 FILTER PRESS
S-303 SOCK FILTER
P-301 SLURRY TRANSFER PUMP
P-302 SLURRY TRANSFER PUMP
P-303 SLURRY TRANSFER PUMP
P-307 CHEMICAL FEED PUMP
P-304 SLURRY TRANSFER PUMP
P-308 CHEMICAL FEED PUMP
P-309 CHEMICAL FEED PUMP
P-305 SLURRY TRANSFER PUMP
S-306 SOCK FILTER
P-310 POLYMER FEED PUMP
P-306 SLURRY TRANSFER PUMP
P-311 POLYMER FEED PUMP
H-324 BYPRODUCT HOPPER
S-323 FILTER PRESS
95-547-110 SCRUBBER BLOWDOWN
95-547-110 RICH EXTRACT
95-547-110 CAUSTIC TO SCRUBBER
OSBL SODIUM CARBONATE
OSBL CAUSTIC
MAKEUP WATER OSBL
TREATED LIQUOR TO STORAGE OSBL
BYPRODUCT CAKE OSBL
BYPRODUCT CAKE OSBL
BYPRODUCT CAKE OSBL
WASH WATER OSBL
LIMESTONE OSBL
POLYMER A OSBL
POLYMER B OSBL
MAKEUP WATER OSBL
COMPRESSED AIR TO ALL AOD PUMPS
REFERENCE DRAWINGS
95-547-110 PROCESS FLOW AND CONTROL DIAGRAM - SOLIDS PREPARATION AND ACID EXTRACTION
REVISION DESCRIPTION
ADVANCED WASTE MANAGEMENT SYSTEMS (AWMS)
GALVANIC SLUDGE TREATMENT SYSTEM
MISKOLC, HUNGARY
PROCESS FLOW AND CONTROL DIAGRAM METALS RECOVERY
95-547-111

Drawing No. 95-547-100A

Sludge-Composite										
Cycle Times (h):										
Extraction	6									
Byproduct	6									
Acid Stoichiometry	1.3									
Capacity Factor	0.6									
Stream Number		25	26	27	28	29	30	31	32	33
Stream Description		Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)	Liquor Filtrate	Limestone Sodium Ca 40%
Compositions		kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations										
Ag		0.00				0.00		0.00	0.00	
Al		15.03				15.03		15.03	0.00	
As		0.00				0.00		0.00	0.00	
Ba		0.00				0.00		0.00	0.00	
Ca		4.06	41.41			45.47		41.92	3.55	0
Cd		1.74				1.74		0.00	1.74	
Co		0.06				0.06		0.00	0.06	
Cr		11.40				11.40		11.39	0.01	
Cu		19.80				19.80		16.25	3.55	
Fe(Total)		0.59				0.59		0.45	0.14	
K		0.60				0.60		0.00	0.60	
Mg		6.47				6.47		0.03	6.47	
Mn		0.47				0.47		0.47	0.00	
Mo		0.00				0.00		0.00	0.00	
Na		258.32		18.94		277.27		0.00	277.27	
Ni		16.20				16.20		0.00	16.20	
Pb		0.00				0.00		0.00	0.00	
Sb		0.00				0.00		0.00	0.00	
Sn		1.74				1.74		0.00	1.74	
Te		0.00				0.00		0.00	0.00	
Ti		0.00				0.00		0.00	0.00	
Tl		0.00				0.00		0.00	0.00	
Zn		42.60				42.60		0.00	42.60	
Subtotal Metal Cations		379.09	41.41	18.94		439.44		85.50	353.94	0.
H (Acidity as H+)		0.00				0.00		0.00	0.00	
Total Cations		379.09	41.41	18.94		439.44		85.50	353.94	0.
Anions										
OH		0.00				0.00		0.00	0.00	
CO3 (Total)		0.00	62.12	24.71		86.83		86.39	0.43	0.
Cl		0.60				0.60		0.00	0.60	
PO4 (Total)		72.00				72.00		66.37	5.63	
SO4 (Total)		701.27				701.27		0.00	701.27	
Total Anions		773.87	62.12	24.71		860.70		152.77	707.93	0.
Total Salts		1,152.97	103.53	43.65		1,300.14		238.27	1,061.87	0.
Inert		0.00	5.18		0.08	5.25		5.25	0.00	0.
Total Solids		1,152.97	108.70	43.65	0.08	1,305.39		243.52	1,061.87	0.
H2O		7,108.45	163.06	247.37	37.59	7,556.48	487.04	243.52	7,636.94	0.
CO2 Gas										
Total Stream		8,261.42	271.76	291.02	37.67	8,861.87	487.04	487.04	8,698.81	0.
Loading (kg/cycle)		2,065.36	67.94	72.76	9.42	2,215.47	121.76	121.76	2,174.70	0.
Maximum Flow (l/m)		59.24	1.36	2.06		62.97	4.05		63.64	0.
Maximum Temp (C)						30				
Wt% Total Solids		14.0	40.0	15.0	0.2	14.7	0.0	50.0	12.2	0.0
Wt% Insoluble Solids		0.0	40.0	0.0	0.2	2.7	0.0	50.0	3.0	0.0
pH						6.0±0.25				

Sec 2

30	31	32	33	34	35	36	37	38	39
Water	Filter Cake (Washed)	Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)	Liquor Filtrate
kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
	0.00	0.00				0.00		0.00	0.00
	15.03	0.00				0.00		0.00	0.00
	0.00	0.00				0.00		0.00	0.00
	0.00	0.00				0.00		0.00	0.00
	41.92	3.55	0.00			3.55		3.55	0.00
	0.00	1.74				1.74		1.74	0.00
	0.00	0.06				0.06		0.06	0.00
	11.39	0.01				0.01		0.01	0.00
	16.25	3.55				3.55		3.55	0.00
	0.45	0.14				0.14		0.14	0.00
	0.00	0.60				0.60		0.00	0.60
	0.00	6.47				6.47		4.56	1.91
	0.47	0.00				0.00		0.00	0.00
	0.00	0.00				0.00		0.00	0.00
	0.00	277.27		55.09		332.36		0.00	332.36
	0.00	16.20				16.20		16.20	0.00
	0.00	0.00				0.00		0.00	0.00
	0.00	0.00				0.00		0.00	0.00
	0.00	1.74				1.74		0.00	1.74
	0.00	0.00				0.00		0.00	0.00
	0.00	0.00				0.00		0.00	0.00
	0.00	0.00				0.00		0.00	0.00
	0.00	42.60				42.60		42.60	0.00
	85.50	353.94	0.00	55.09		409.03		72.42	336.61
	0.00	0.00				0.00		0.00	0.00
	85.50	353.94	0.00	55.09		409.03		72.42	336.61
	0.00	0.00				0.00		0.00	0.00
	86.39	0.43	0.00	71.86		72.29		71.50	0.79
	0.00	0.60				0.60		0.00	0.60
	66.37	5.63				5.63		5.63	0.00
	0.00	701.27				701.27		0.00	701.27
	152.77	707.93	0.00	71.86		779.79		77.13	702.66
	238.27	1,061.87	0.00	126.95		1,188.82		149.55	1,039.27
	5.25	0.00	0.00		0.08	0.08		0.08	0.00
	243.52	1,061.87	0.00	126.95	0.08	1,188.90		149.63	1,039.27
487.04	243.52	7,6[illegible]6.94	0.00	719.37	41.78	8,398.09	299.27	149.63	8,547.72
487.04	487.04	8,698.81	0.00	846.31	41.87	9,586.99	299.27	299.27	9,586.99
121.76	121.76	2,174.70	0.00	211.58	10.47	2,396.75	74.82	74.82	2,396.75
4.06		63.64	0.00	5.99		69.98	2.49		71.23
						30			
0.0	50.0	12.2	0.0	15.0	0.2	12.4	0.0	50.0	10.8
0.0	50.0	0.0	0.0	0.0	0.2	1.6	0.0	50.0	0.0
						9.0±0.5			9.0±0.5

Drawing No. 95-547-100A

Sludge-Composite																					
Cycle Times (h):																					
Extraction	6																				
Byproduct	6																				
Acid Stoichiometry	1.3																				
Capacity Factor	0.6																				
Stream Number		10	11	In Tank	12	13	14	15	16	17	14	15	16	17	18	19	20	21	22	23	24
Stream Description		Extraction Liquor	Sodium Hydroxide 50%	Intermediate PreNeutralized Liquor	Sodium Carbonate 15%	Carbon Dioxide Offgas	Precipitate Slurry	Wash Water	Filtered Solids (Washed)	Liquor Filtra	Precipitate Slurry	Wash Water	Filtered Solids (Washed)	Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Carbon Dioxide Offgas	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)
Compositions		kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/da	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations																					
Ag		0.03		0.03			0.03		0.03	0	0.03		0.03	0.00					0.00		0.00
Al		15.03		15.03			15.03		0.00	15	15.03		0.00	15.03					15.03		0.00
As		0.09		0.09			0.09		0.09	0	0.09		0.09	0.00					0.00		0.00
Ba		0.00		0.00			0.00		0.00	0	0.00		0.00	0.00					0.00		0.00
Ca		4.06		4.06			4.06		0.00	4	4.06		0.00	4.06					4.06		0.00
Cd		1.74		1.74			1.74		0.00	1	1.74		0.00	1.74					1.74		0.00
Co		0.06		0.06			0.06		0.00	0	0.06		0.00	0.06					0.06		0.00
Cr		11.40		11.40			11.40		0.00	11	11.40		0.00	11.40					11.40		0.00
Cu		19.80		19.80			19.80		0.00	19	19.80		0.00	19.80					19.80		0.00
Fe(Total)		62.03		62.03			62.03		0.62	6	62.03		0.62	61.41					61.41		60.82
K		0.60		0.60			0.60		0.00	0	0.60		0.00	0.60					0.60		0.00
Mg		6.47		6.47			6.47		0.00	6	6.47		0.00	6.47					6.47		0.00
Mn		1.62		1.62			1.62		0.00	[illegible]	1.62		0.00	1.62					1.62		1.15
Mo		0.00		0.00			0.00		0.00	0	0.00		0.00	0.00					0.00		0.00
Na		17.40	162.67	180.07	1.17		181.24		0.00	18	181.24		0.00	181.24		77.08			258.32		0.00
Ni		16.20		16.20			16.20		0.00	16	16.20		0.00	16.20					16.20		0.00
Pb		0.03		0.03			0.03		0.03	0	0.03		0.03	0.00					0.00		0.00
Sb		0.00		0.00			0.00		0.00	0	0.00		0.00	0.00					0.00		0.00
Sn		1.74		1.74			1.74		0.00	[illegible]	1.74		0.00	1.74					1.74		0.00
Te		0.30		0.30			0.30		0.30	0	0.30		0.30	0.00					0.00		0.00
Ti		0.06		0.06			0.06		0.00	0	0.06		0.00	0.06					0.06		0.06
Tl		0.06		0.06			0.06		0.06	0	0.06		0.06	0.00					0.00		0.00
Zn		42.60		42.60			42.60		0.00	4	42.60		0.00	42.60					42.60		0.00
Subtotal Metal Cations		201.32	162.67	363.99	1.17		365.16		1.13	36	365.16		1.13	364.04	0.00	77.08			441.12		62.04
H (Acidity as H+)		7.13		0.05			0.00		0.00	0	0.00		0.00	0.05					0.00		0.00
Total Cations		208.45	162.67	364.05	1.17		365.16		1.13	36	365.16		1.13	364.08	0.00	77.08			441.12		62.04
Anions																					
OH		0.00	120.23	0.00			0.00		0.00	0	0.00		0.00	0.00					0.00		0.00
CO3 (Total)		0.00		0.00	1.53		1.27		1.27	0	1.27		1.27	0.00		100.54			99.30		99.30
Cl		0.60		0.60			0.60		0.00	0	0.60		0.00	0.60					0.60		0.00
PO4 (Total)		72.00		72.00			72.00		0.00	7	72.00		0.00	72.00					72.00		0.00
SO4 (Total)		701.27		701.27			701.27		0.00	70	701.27		0.00	701.27					701.27		0.00
Total Anions		773.87	120.23	773.87	1.53		775.15		1.27	77	775.15		1.27	773.87	0.00	100.54			873.18		99.30
Total Salts		982.33	282.90	1,137.92	2.70		1,140.31		2.40	1,13	1,140.31		2.40	1,137.96	0.00	177.63			1,314.30		161.34
Inert		0.00		0.00			0.00		0.00	0	0.00		0.00	0.00				0.07	0.07		0.07
Total Solids		982.33	282.90	1,137.92	2.70		1,140.31		2.40	1,13	1,140.31		2.40	1,137.96	0.00	177.63		0.07	1,314.37		161.41
H2O		5,477.59	282.90	5,887.80	15.28		5,900.77	4.80	2.40	5,90	5,900.77	4.80	2.40	5,905.56	0.00	1,006.55		34.56	5,785.64	322.81	161.41
CO2 Gas						0.19											0.91				
Total Stream		6,459.92	565.81	7,025.73	17.98	0.19	7,041.08	4.80	4.80	7,04	7,041.08	4.80	4.80	7,043.52	0.00	1,184.18	0.91	34.63	8,100.01	322.81	322.81
Loading (kg/cycle)		1,614.98	141.45	1,756.43	4.50	0.05	1,760.27	1.20	1.20	1,76	1,760.27	1.20	1.20	1,760.88	0.00	296.04	0.23	8.66	2,025.00	80.70	80.70
Maximum Flow (l/m)		45.65	2.36	49.07	0.13		49.17	0.04		4	49.17	0.04		49.21	0.00	8.39			56.55	2.69	
Maximum Temp (C)		40		40			35				35								30		
Wt% Total Solids		15.2	50.0	16.2	15.0	0.0	16.2	0.0	50.0	16	16.2	0.0	50.0	16.2	0.0	15.0	0.0	0.2	16.2	0.0	50.0
Wt% Insoluble Solids		0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.	0.0	0.0		0.0	0.0	0.0	0.0	0.2	2.0	0.0	50.0
pH		-1		2.5±0.25			2.75±0.25				2.75±0.25								3.25±0.25		

Drawing No. 95-547-100A

Sludge-Composite										
Cycle Times (h):										
Extraction	6									
Byproduct	6									
Acid Stoichiometry	1.3									
Capacity Factor	0.6									
Stream Number			1	2	3	4	5	6	7	8
Stream Description		Basis Dry Solids	Feed Sludge 30%	Makeup Water	Milled Slurry 25%	Sulfuric Acid 93%	Makeup Water	Sulfuric Acid 20%	Carbon Dioxide Offgas	Wash W[illegible]
Compositions		gm/kg	kg/day			kg/day	kg/day	kg/day	kg/day	kg/d[illegible]
Cations										
Ag		0.05	0.03		0.03					
Al		30.00	18.00		18.00					
As		0.15	0.09		0.09					
Ba		0.50	0.30		0.30					
Ca		74.00	44.40		44.40					
Cd		2.90	1.74		1.74					
Co		0.10	0.06		0.06					
Cr		19.00	11.40		11.40					
Cu		33.00	19.80		19.80					
Fe(Total)		105.50	63.30		63.30					
K		1.00	0.60		0.60					
Mg		11.00	6.60		6.60					
Mn		2.70	1.62		1.62					
Mo		0.00	0.00		0.00					
Na		29.00	17.40		17.40					
Ni		27.00	16.20		16.20					
Pb		1.00	0.60		0.60					
Sb		0.00	0.00		0.00					
Sn		2.90	1.74		1.74					
Te		0.50	0.30		0.30					
Ti		3.60	2.16		2.16					
Tl		0.10	0.06		0.06					
Zn		71.00	42.60		42.60					
Subtotal Metal Cations		415.00	249.00		249.00	0.00	0.00	0.00		
H (Acidity as H+)		0.00	0.00		0.00	16.05		16.05		
Total Cations		415.00	249.00		249.00	16.05	0.00	16.05		
Anions										
OH		160.00	96.00		96.00					
CO3 (Total)		164.00	98.40		98.40					
Cl		1.00	0.60		0.60					
PO4 (Total)		120.00	72.00		72.00					
SO4 (Total)		90.00	54.00		54.00	770.61		770.61		
Total Anions		535.00	321.00		321.00	770.61	0.00	770.61	0.00	
Total Salts		950.00	570.00		570.00	786.67	0.00	786.67	0.00	
Inert		50.00	30.00		30.00	0.00		0.00		
Total Solids		1,000.00	600.00		600.00	786.67	0.00	786.67	0.00	
H2O			1,400.00	400.00	1,800.00	59.21	3,087.45	3,146.66	2.26	60[illegible]
CO2 Gas			0.00		0.00			0.00	72.16	
Total Stream			2,000.00	400.00	2,400.00	845.88	3,087.45	3,933.33	74.42	6[illegible]
Loading (kg/cycle)			500.00	100.00	600.00	211.47	771.86	983.33	18.60	1[illegible]
Maximum Flow (l/m)						3.92	25.73	26.22		
Maximum Temp (C)			30	85	40	30	25	65		
Wt% Total Solids			30.0		25.0	93.0	0.0	20.0	0.0	0
Wt% Insoluble Solids			30.0		25.0	0.0	0.0	0.0	0.0	0
pH										

Stream Number	6	7	8	9	10A	10B	10C	10D	10E	10F	10G
Stream Description	Sulfuric Acid 20%	Carbon Dioxide Offgas	Wash Water	Washed Residue	1st Stage Slurry	1st Stage Sludge	2nd Stage Slurry	2nd Stage Extract	2nd Stage Sludge	3rd Stage Slurry	3rd Stage Extract
Compositions	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations											
Ag				0.00							
Al				2.97							
As				0.00							
Ba				0.30							
Ca				40.34							
Cd				0.00							
Co				0.00							
Cr				0.00							
Cu				0.00							
Fe(Total)				1.27							
K				0.00							
Mg				0.13							
Mn				0.00							
Mo				0.00							
Na				0.00							
Ni				0.00							
Pb				0.57							
Sb				0.00							
Sn				0.00							
Te				0.00							
Ti				2.10							
Tl				0.00							
Zn				0.00							
Subtotal Metal Cations	0.00			47.68							
H (Acidity as H+)	16.05			0.00							
Total Cations	16.05			47.68							
Anions											
OH				0.00							
CO3 (Total)				0.00							
Cl				0.00							
PO4 (Total)				0.00							
SO4 (Total)	770.61			123.34							
Total Anions	770.61	0.00	0.00	123.34							
Total Salts	786.67	0.00	0.00	171.01							
Inert	0.00			30.00							
Total Solids	786.67	0.00	0.00	201.01							
H2O	3,146.66	2.26	603.04	201.01	6,072.65	595.08	4,580.92	4,143.74	437.18	3,583.84	3,985.86
CO2 Gas	0.00	72.16									
Total Stream	3,933.33	74.42	603.04	402.02	7,462.45	1,002.53	5,873.41	5,136.87	736.54	4,669.87	4,870.88
Loading (kg/cycle)	983.33	18.60	150.76	100.51	1,865.61	250.63	1,468.35	1,284.22	184.13	1,167.47	1,217.72
Maximum Flow (l/m)	26.22		5.03		50.61	4.96	38.17	34.53	3.64	29.87	33.22
Maximum Temp (C)	65				40		50			60	
Wt% Total Solids	20.0	0.0	0.0	50.0	18.6	40.6	22.0	19.3	40.6	23.3	18.2
Wt% Insoluble Solids	0.0	0.0	0.0	50.0	4.0	30.0	3.8	0.0	30.0	4.3	0.0
pH											

Drawing No. 95-547-100B

Sludge-Composite	
Cycle Times (h):	
Extraction	4
Byproduct	4
Acid Stoichiometry	1.1
Capacity Factor	0.6

Stream Number		1	2	3	4	5	6	7	8	9	10A	10B	10C	10D	10E	10F	10G
Stream Description	Basis	Feed Sludge	Makeup Water	Milled Slurry	Sulfuric Acid	Makeup Water	Sulfuric Acid	Carbon Dioxide	Wash Water	Washed	1st Stage	Not	Not	Not	1st Stage	3rd Stage	3rd Stage
	Dry Solids	35%		25%	93%		25%	Offgas		Residue	Slurry	Used	Used	Used	Sludge	Slurry	Extract
Compositions	gm/kg	kg/day			kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations																	
Ag	0.05	0.03		0.03						0.00							
Al	30.00	18.00		18.00						2.97							
As	0.15	0.09		0.09						0.00							
Ba	0.50	0.30		0.30						0.30							
Ca	74.00	44.40		44.40						41.26							
Cd	2.90	1.74		1.74						0.00							
Co	0.10	0.06		0.06						0.00							
Cr	19.00	11.40		11.40						0.00							
Cu	33.00	19.80		19.80						0.00							
Fe(Total)	105.50	63.30		63.30						1.27							
K	1.00	0.60		0.60						0.00							
Mg	11.00	6.60		6.60						0.13							
Mn	2.70	1.62		1.62						0.00							
Mo	0.00	0.00		0.00						0.00							
Na	28.00	17.40		17.40						0.00							
Ni	27.00	16.20		16.20						0.00							
Pb	1.00	0.60		0.60						0.58							
Sb	0.00	0.00		0.00						0.00							
Sn	2.90	1.74		1.74						0.00							
Te	0.50	0.30		0.30						0.00							
Ti	3.60	2.16		2.16						2.10							
Tl	0.10	0.06		0.06						0.00							
Zn	71.00	42.60		42.60						0.00							
Subtotal Metal Cations	415.00	249.00		249.00	0.00	0.00	0.00			48.60							
H (Acidity as H+)	0.00	0.00		0.00	13.58		13.58			0.00							
Total Cations	415.00	249.00		249.00	13.58	0.00	13.58			48.60							
Anions																	
OH	160.00	96.00		96.00						0.00							
CO3 (Total)	164.00	98.40		98.40						0.00							
Cl	1.00	0.60		0.60						0.00							
PO4 (Total)	120.00	72.00		72.00						0.00							
SO4 (Total)	90.00	54.00		54.00	652.06		652.06			125.55							
Total Anions	535.00	321.00		321.00	652.06	0.00	652.06	0.00	0.00	125.55							
Total Salts	950.00	570.00		570.00	665.64	0.00	665.64	0.00	0.00	174.15							
Insert	50.00	30.00		30.00	0.00		0.00			30.00							
Total Solids	1,000.00	600.00		600.00	665.64	0.00	665.64	0.00	0.00	204.15							
H2O		1,114.29	685.71	1,800.00	50.10	1,946.82	1,996.92	2.26	612.45	204.15	4,924.50				590.37	2,587.29	2,995.59
CO2 Gas		0.00		0.00			0.00	72.16									
Total Stream		1,714.29	685.71	2,400.00	715.74	1,946.82	2,662.56	74.42	612.45	408.30	6,202.67				1,010.37	3,672.93	3,877.06
Loading (kg/cycle)		285.71	114.29	400.00	119.29	324.47	443.76	12.40	102.07	68.05	1,033.78				168.40	612.16	646.18
Maximum Flow (l/m)					2.21	10.82	11.09		3.40		27.36				3.28	14.37	16.64
Maximum Temp (C)		30	85	40	30	25	65				40					60	
Wt% Total Solids		35.0		25.0	93.0	0.0	25.0	0.0	0.0	50.0	20.8				41.6	29.6	22.7
Wt% Insoluble Solids		35.0		25.0	0.0	0.0	0.0	0.0	0.0	50.0	4.9				30.0	5.6	0.0
pH																	

Sec 1

Sec 2

Drawing No. 95-547-100B

Sludge-Composite									
Cycle Times (h):									
Extraction	4								
Byproduct	4								
Acid Stoichiometry	1.1								
Capacity Factor	0.6								
Stream Number		10	11	In Tank	12	13	14	15	16
Stream Description		Extraction Liquor	Sodium Hydroxide 50%	Intermediate PreNeutralized Liquor	Sodium Carbonate 15%	Carbon Dioxide Offgas	Precipitate Slurry	Wash Water	Filtered Solids (Washed)
Compositions		kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations									
Ag		0.03		0.03			0.03		0.03
Al		15.03		15.03			15.03		0.00
As		0.09		0.09			0.09		0.09
Ba		0.00		0.00			0.00		0.00
Ca		3.14		3.14			3.14		0.00
Cd		1.74		1.74			1.74		0.00
Co		0.06		0.06			0.06		0.00
Cr		11.40		11.40			11.40		0.00
Cu		19.80		19.80			19.80		0.00
Fe(Total)		62.03		62.03			62.03		0.62
K		0.60		0.60			0.60		0.00
Mg		6.47		6.47			6.47		0.00
Mn		1.62		1.62			1.62		0.00
Mo		0.00		0.00			0.00		0.00
Na		17.40	106.12	123.52	1.17		124.69		0.00
Ni		16.20		16.20			16.20		0.00
Pb		0.02		0.02			0.02		0.02
Sb		0.00		0.00			0.00		0.00
Sn		1.74		1.74			1.74		0.00
Te		0.30		0.30			0.30		0.30
Ti		0.06		0.06			0.06		0.00
Tl		0.06		0.06			0.06		0.06
Zn		42.60		42.60			42.60		0.00
Subtotal Metal Cations		200.40	106.12	306.52	1.17		307.69		1.12
H (Acidity as H+)		4.66		0.04			0.00		0.00
Total Cations		205.06	106.12	306.57	1.17		307.69		1.12
Anions									
OH		0.00	78.44	0.00			0.00		0.00
CO3 (Total)		0.00		0.00	1.52		1.27		1.27
Cl		0.60		0.60			0.60		0.00
PO4 (Total)		72.00		72.00			72.00		0.00
SO4 (Total)		580.51		580.51			580.51		0.00
Total Anions		653.11	78.44	653.11	1.52		654.38		1.27
Total Salts		858.16	184.56	959.67	2.69		962.07		2.39
Inert		0.00		0.00			0.00		0.00
Total Solids		858.16	184.56	959.67	2.6[illegible]		962.07		2.39
H2O		4,334.13	184.56	4,601.75	15.26		4,614.70	4.78	2.39
CO2 Gas						0.19			
Total Stream		5,192.29	369.13	5,561.42	17.96	0.19	5,576.77	4.78	4.78
Loading (kg/cycle)		865.38	61.52	926.90	2.99	0.03	929.46	0.80	0.80
Maximum Flow (l/m)		24.08	1.03	25.57	0.08		25.64	0.03	
Maximum Temp (C)		40		40			35		
Wt% Total Solids		16.5	50.0	17.3	15.0	0.0	17.3	0.0	50.0
Wt% Insoluble Solids		0.0	0.0	0.0	0.0	0.0	0.0	0.0	
pH		-1		2.5±0.25			2.75±0.25		

Stream Number	15	16	17	18	19	20	21	22	23	24
Stream Description	Wash Water	Filtered Solids (Washed)	Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Carbon Dioxide Offgas	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)
Compositions	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Ag		0.03	0.00					0.00		0.00
Al		0.00	15.03					15.03		0.00
As		0.09	0.00					0.00		0.00
Ba		0.00	0.00					0.00		0.00
Ca		0.00	3.14					3.14		0.00
Cd		0.00	1.74					1.74		0.00
Co		0.00	0.06					0.06		0.00
Cr		0.00	11.40					11.40		0.00
Cu		0.00	19.80					19.80		0.00
Fe(Total)		0.62	61.41					61.41		60.95
K		0.00	0.60					0.60		0.00
Mg		0.00	6.47					6.47		0.00
Mn		0.00	1.62					1.62		1.25
Mo		0.00	0.00					0.00		0.00
Na		0.00	124.69		77.33			202.02		0.00
Ni		0.00	16.20					16.20		0.00
Pb		0.02	0.00					0.00		0.00
Sb		0.00	0.00					0.00		0.00
Sn		0.00	1.74					1.74		0.00
Te		0.30	0.00					0.00		0.00
Ti		0.00	0.06					0.06		0.06
Tl		0.06	0.00					0.00		0.00
Zn		0.00	42.60					42.60		0.00
Subtotal Metal Cations		1.12	306.57	0.00	77.33			383.90		62.27
H (Acidity as H+)		0.00	0.03					0.00		0.00
Total Cations		1.12	306.61	0.00	77.33			383.90		62.27
OH		0.00	0.00					0.00		0.00
CO3 (Total)		1.27	0.00		100.87			99.62		99.62
Cl		0.00	0.60					0.60		0.00
PO4 (Total)		0.00	72.00					72.00		0.00
SO4 (Total)		0.00	580.51					580.51		0.00
Total Anions		1.27	653.11	0.00	100.87			752.73		99.62
Total Salts		2.39	959.71	0.00	178.20			1,136.63		161.89
Inert		0.00	0.00				0.06	0.06		0.06
Total Solids		2.39	959.71	0.00	178.20		0.06	1,136.69		161.94
H2O	4.78	2.39	4,619.48	0.00	1,009.79		28.15	5,495.84	323.89	161.94
CO2 Gas						0.91				
Total Stream	4.78	4.78	5,579.19	0.00	1,187.99	0.91	28.20	6,632.53	323.89	323.89
Loading (kg/cycle)	0.80	0.80	929.87	0.00	198.00	0.15	4.70	1,105.42	53.98	53.98
Maximum Flow (l/m)	0.03		25.66	0.00	5.61			30.53	1.80	
Maximum Temp (C)								30		
Wt% Total Solids	0.0	50.0	17.2	0.0	15.0	0.0	0.2	17.1	0.0	50.0
Wt% Insoluble Solids	0.0		0.0	0.0	0.0	0.0	0.2	2.4	0.0	50.0
pH								3.25±0.25		

Drawing No. 95-547-100B

Sludge-Composite																			
Cycle Times (h):																			
Extraction	4																		
Byproduct	4																		
Acid Stoichiometry	1.1																		
Capacity Factor	0.6																		
Stream Number		25	26	27	28	29	30	31	32	30	31	32	33	34	35	36	37	38	39
Stream Description		Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)	Liquor Filtrate	Limesash Water Sodium	Filter Cake (Washed)	Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)	Liquor Filtrate
Compositions		kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations																			
Ag		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Al		15.03				15.03		15.03	0.00		15.03	0.00				0.00		0.00	0.00
As		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Ba		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Ca		3.14	42.33			45.47		42.56	2.91		42.56	2.91	0.00			2.91		2.91	0.00
Cd		1.74				1.74		0.00	1.74		0.00	1.74				1.74		1.74	0.00
Co		0.06				0.06		0.00	0.06		0.00	0.06				0.06		0.06	0.00
Cr		11.40				11.40		11.39	0.01		11.39	0.01				0.01		0.01	0.00
Cu		19.80				19.80		16.89	2.91		16.89	2.91				2.91		2.91	0.00
Fe(Total)		0.46				0.46		0.35	0.12		0.35	0.12				0.12		0.12	0.00
K		0.60				0.60		0.00	0.60		0.00	0.60				0.60		0.00	0.60
Mg		6.47				6.47		0.00	6.47		0.00	6.47				6.47		4.88	1.58
Mn		0.37				0.37		0.37	0.00		0.37	0.00				0.00		0.00	0.00
Mo		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Na		202.02		18.14		220.17		0.00	220.17		0.00	220.17		55.21		275.37		0.00	275.37
Ni		16.20				16.20		0.00	16.20		0.00	16.20				16.20		16.20	0.00
Pb		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Sb		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Sn		1.74				1.74		0.00	1.74		0.00	1.74				1.74		0.00	1.74
Te		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Ti		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Tl		0.00				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Zn		42.60				42.60		0.00	42.60		0.00	42.60				42.60		42.60	0.00
Subtotal Metal Cations		321.64	42.33	18.14		382.11		86.59	295.52		86.59	295.52	0.00	55.21		350.73		71.43	279.30
H (Acidity as H+)		(0.01				0.00		0.00	0.00		0.00	0.00				0.00		0.00	0.00
Total Cations		321.63	42.33	18.14		382.11		86.59	295.52		86.59	295.52	0.00	55.21		350.73		71.43	279.30
Anions																			
OH		0.00				0.00		0.00	0.00		0.00	0.00				[illegible]		0.00	0.00
CO3 (Total)		0.00	63.50	23.67		87.16		86.73	0.43		86.73	0.43	0.00	72.01		[illegible]		71.65	0.79
Cl		0.60				0.60		0.00	0.60		0.00	0.60				0.60		0.00	0.60
PO4 (Total)		72.00				72.00		67.39	4.61		67.39	4.61				4.61		4.61	0.00
SO4 (Total)		580.51				580.51		0.00	580.51		0.00	580.51				580.51		0.00	580.51
Total Anions		653.11	63.50	23.67		740.27		154.12	586.15		154.12	586.15	0.00	72.01		658.15		76.26	581.90
Total Salts		974.74	105.83	41.81		1,122.38		240.71	881.67		240.71	881.67	0.00	127.21		1,008.89		147.69	861.20
Inert		0.00	5.29		0.06	5.35		5.35	0.00		5.35	0.00	0.00		0.07	0.07		0.07	0.00
Total Solids		974.74	111.12	41.81	0.06	1,127.74		246.06	881.67		246.06	881.67	0.00	127.21	0.07	1,008.96		147.76	861.20
H2O		5,819.73	166.68	236.93	31.12	6,254.46	492.13	246.06	6,333.84	492.13	246.06	6,333.84	0.00	720.87	35.27	7,089.99	295.52	147.76	7,237.75
CO2 Gas																			
Total Stream		6,794.47	277.80	278.74	31.18	7,382.20	492.13	492.13	7,215.52	492.13	492.13	7,215.52	0.00	848.08	35.34	8,098.94	295.52	295.52	8,098.94
Loading (kg/cycle)		1,132.41	46.30	46.46	5.20	1,230.37	82.02	82.02	1,202.59	82.02	82.02	1,202.59	0.00	141.35	5.89	1,349.82	49.25	49.25	1,349.82
Maximum Flow (l/m)		32.33	0.93	1.32			2.73		35.19	2.73		35.19	0.00	4.00			1.64		40.21
Maximum Temp (C)						30										30			
Wt% Total Solids		14.3	40.0	15.0	0.2	15.3	0.0	50.0	12.2	0.0	50.0	12.2	0.0	15.0	0.2	12.5	0.0	50.0	10.6
Wt% Insoluble Solids		0.0	40.0	0.0	0.2	3.3	0.0	50.0	0.0	0.0	50.0	0.0	0.0	0.0	0.2	1.8	0.0	50.0	0.0
pH						6.0±0.25										9.0±0.5			9.0±0.5

Drawing No. 95-547-100C

Sludge-ELZETT																		
Cycle Times (h):																		
Extraction	6																	
Byproduct	6																	
Acid Stoichiometry	1.2																	
Capacity Factor	0.6																	
Stream Number			1	2	3	4	5	6	7	8	9	10A	10B	10C	10D	10E	10F	10G
Stream Description		Basis	Feed Sludge	Makeup Water	Milled Slurry	Sulfuric Acid	Makeup Water	Sulfuric Acid	Carbon Dioxide	Wash Water	Washed	1st Stage	1st Stage	2nd Stage	2nd Stage	2nd Stage	3rd Stage	3rd Stage
		Dry Solids	40%		25%	93%		20%	Offgas		Residue	Slurry	Sludge	Slurry	Extract	Sludge	Slurry	Extract
Compositions		gm/kg	kg/day			kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations																		
Ag		0.00	0.00		0.00						0.00							
Al		45.66	27.40		27.40						4.52							
As		0.39	0.23		0.23						0.00							
Ba		0.22	0.13		0.13						0.13							
Ca		120.62	72.37		72.37						68.26							
Cd		0.01	0.01		0.01						0.00							
Co		0.05	0.03		0.03						0.00							
Cr		86.16	51.69		51.69						0.00							
Cu		4.48	2.69		2.69						0.00							
Fe(Total)		20.68	12.41		12.41						0.25							
K		3.62	2.17		2.17						0.00							
Mg		14.65	8.79		8.79						0.18							
Mn		1.81	1.09		1.09						0.00							
Mo		0.00	0.00		0.00						0.00							
Na		28.43	17.06		17.06						0.00							
Ni		46.52	27.91		27.91						0.00							
Pb		0.39	0.23		0.23						0.21							
Sb		0.00	0.00		0.00						0.00							
Sn		0.86	0.52		0.52						0.00							
Te		0.39	0.23		0.23						0.00							
Ti		0.01	0.01		0.01						0.01							
Tl		0.00	0.00		0.00						0.00							
Zn		39.63	23.78		23.78						0.00							
Subtotal Metal Cations		414.56	248.74		248.74	0.00	0.00	0.00			73.55							
H (Acidity as H+)		0.00	0.00		0.00	16.39		16.39			0.00							
Total Cations		414.56	248.74		248.74	16.39	0.00	16.39			73.55							
Anions																		
OH		192.99	115.79		115.79						0.00							
CO3 (Total)		14.22	8.53		8.53						0.00							
Cl		9.48	5.69		5.69						0.00							
PO4 (Total)		318.78	191.27		191.27						0.00							
SO4 (Total)		28.43	17.06		17.06	786.80		786.80			189.67							
Total Anions		563.90	338.34		338.34	786.80	0.00	786.80	0.00	0.00	189.67							
Total Salts		978.46	587.08		587.08	803.19	0.00	803.19	0.00	0.00	263.22							
Inert		21.54	12.92		12.92	0.00		0.00			12.92							
Total Solids		1,000.00	600.00		600.00	803.19	0.00	803.19	0.00	0.00	276.14							
H2O			900.00	900.00	1,800.00	60.46	3,152.30	3,212.75	0.20	828.42	276.14	3,399.16	709.16	5,054.72	4,474.19	580.53	3,793.28	4,345.56
CO2 Gas			0.00		0.00			0.00	6.25									
Total Stream			1,500.00	900.00	2,400.00	863.64	3,152.30	4,015.94	6.45	828.42	552.28	7,875.98	1,190.35	6,456.87	5,482.43	974.44	4,990.38	5,266.52
Loading (kg/cycle)			375.00	225.00	600.00	215.91	788.07	1,003.99	1.61	207.11	138.07	1,968.99	297.59	1,614.22	1,370.61	243.61	1,247.60	1,316.63
Maximum Flow (l/m)						4.00	26.27	26.77		6.90		53.33	5.91	42.12	37.28	4.84	31.61	36.21
Maximum Temp (C)			30	85	40	30	25	65				40		50			60	
Wt% Total Solids			40.0		25.0	93.0	0.0	20.0	0.0	0.0	50.0	18.8	40.4	21.7	18.4	40.4	24.0	17.5
Wt% Insoluble Solids			40.0		25.0	0.0	0.0	0.0	0.0	0.0	50.0	4.5	30.0	4.5	0.0	30.0	5.5	0.0
pH																		

Drawing No. 95-547-100C

Sludge-ELZETT										
Cycle Times (h):										
Extraction	6									
Byproduct	6									
Acid Stoichiometry	1.2									
Capacity Factor	0.6									
Stream Number		10	11	In Tank	12	13	14	15	16	17
Stream Description		Extraction Liquor	Sodium Hydroxide 50%	Intermediate PreNeutralized Liquor	Sodium Carbonate 15%	Carbon Dioxide Offgas	Precipitate Slurry	Wash Water	Filtered Solids (Washed)	Liquo Filtrat
Compositions		kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/da
Cations										
Ag		0.00		0.00			0.00		0.00	0.
Al		22.88		22.88			22.88		0.00	22.
As		0.23		0.23			0.23		0.23	0.
Ba		0.00		0.00			0.00		0.00	0.
Ca		4.11		4.11			4.11		0.00	4.
Cd		0.01		0.01			0.01		0.00	0.
Co		0.03		0.03			0.03		0.00	0.
Cr		51.69		51.69			51.69		0.00	51.
Cu		2.69		2.69			2.69		0.00	2.
Fe(Total)		12.16		12.16			12.16		0.12	12
K		2.17		2.17			2.17		0.00	2
Mg		8.61		8.61			8.61		0.00	6.
Mn		1.09		1.09			1.09		0.00	1
Mo		0.00		0.00			0.00		0.00	0
Na		17.06	212.50	229.55	0.54		230.10		0.00	230
Ni		27.91		27.91			27.91		0.00	27
Pb		0.03		0.03			0.03		0.03	0
Sb		0.00		0.00			0.00		0.00	0
Sn		0.52		0.52			0.52		0.00	0
Te		0.23		0.23			0.23		0.23	0
Ti		0.00		0.00			0.00		0.00	0
Tl		0.00		0.00			0.00		0.00	0
Zn		23.78		23.78			23.78		0.00	23
Subtotal Metal Cations		175.19	212.50	387.69	0.54		388.23		0.61	387
H (Acidity as H+)		9.30		0.06			0.00		0.00	0
Total Cations		184.49	212.50	387.74	0.54		388.23		0.61	387
Anions										
OH		0.00	157.06	0.00			0.00		0.00	0
CO3 (Total)		0.00		0.00	0.71		0.59		0.59	0
Cl		5.69		5.69			5.69		0.00	5
PO4 (Total)		191.27		191.27			191.27		0.00	191
SO4 (Total)		614.19		614.19			614.19		0.00	614
Total Anions		811.14	157.06	811.14	0.71		811.73		0.59	811
Total Salts		995.63	369.56	1,198.88	1.25		1,199.96		1.20	1,19
Inert		0.00		0.00			0.00		0.00	0
Total Solids		995.63	369.56	1,198.88	1.25		1,199.06		1.20	1,19
H2O		5,690.00	369.56	6,225.86	7.11		6,231.80	2.41	1.20	6,234
CO2 Gas						0.09				
Total Stream		6,685.63	739.11	7,424.74	8.36	0.09	7,431.76	2.41	2.41	7,43
Loading (kg/cycle)		1,671.41	184.78	1,856.19	2.09	0.02	1,857.94	0.60	0.60	1,85
Maximum Flow (l/m)		47.42	3.08	51.88	0.06		51.93	0.02		51
Maximum Temp (C)		40		40			35			
Wt% Total Solids		14.9	50.0	16.1	15.0	0.0	16.1	0.0	50.0	16.
Wt% Insoluble Solids		0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
pH		~1		2.5±0.25			2.75±0.25			

Sec 2

15	16	17	18	19	20	21	22	23	24
Wash Water	Filtered Solids	Liquor	Limestone or	Sodium	Carbon Dioxide	Polymer	Precipitate	Wash Water	Filter Cake
	(Washed)	Filtrate	Sodium Carbonate	Carbonate	Offgas		Slurry		(Washed)
			40%	15%					
kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
	0.00	0.00					0.00		0.00
	0.00	22.88					22.88		0.00
	0.23	0.00					0.00		0.00
	0.00	0.00					0.00		0.00
	0.00	4.11					4.11		0.00
	0.00	0.01					0.01		0.00
	0.00	0.03					0.03		0.00
	0.00	51.69					51.69		0.00
	0.00	2.69					2.69		0.00
	0.12	12.04					12.04		11.41
	0.00	2.17					2.17		0.00
	0.00	8.61					8.61		0.00
	0.00	1.09					1.09		0.59
	0.00	0.00					0.00		0.00
	0.00	230.10		14.76			244.86		0.00
	0.00	27.91					27.91		0.00
	0.03	0.00					0.00		0.00
	0.00	0.00					0.00		0.00
	0.00	0.52					0.52		0.00
	0.23	0.00					0.00		0.00
	0.00	0.00					0.00		0.00
	0.00	0.00					0.00		0.00
	0.00	23.78					23.78		0.00
	0.61	387.62	0.00	14.76			402.38		12.00
	0.00	0.05					0.00		0.00
	0.61	387.67	0.00	14.76			402.38		12.00
	0.00	0.00					0.00		0.00
	0.59	0.00		19.26			19.02		19.02
	0.00	5.69					5.69		0.00
	0.00	191.27					191.27		0.00
	0.00	614.19					614.19		0.00
	0.59	811.14	0.00	19.26			830.16		19.02
	1.20	1,198.81	0.00	34.02			1,232.54		31.02
	0.00	0.00				0.06	0.06		0.06
	1.20	1,198.81	0.00	34.02		0.06	1,232.60		31.08
2.41	1.20	6,234.21	0.00	192.77		32.13	6,428.10	62.16	31.08
					0.17				
2.41	2.41	7,433.02	0.00	226.78	0.17	32.20	7,660.70	62.16	62.16
0.60	0.60	1,858.25	0.00	56.70	0.04	8.05	1,915.18	15.54	15.54
0.0[illegible]		51.95	0.00	1.61			53.57	0.52	
							30		
0.0	50.0	16.1	0.0	15.0	0.0	0.2	16.1	0.0	50.0
0.0		0.0	0.0	0.0	0.0	0.2	0.4	0.0	50.0
							3.25±0.25		

Sec 1

Sec 2

Drawing No. 95-547-100C

Sludge-ELZETT										
Cycle Times (h):										
Extraction	6									
Byproduct	6									
Acid Stoichiometry	1.2									
Capacity Factor	0.6									
Stream Number		25	26	27	28	29	30	31	32	3
Stream Description		Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)	Liquor Filtrate	Limes… Sodium… 4…
Compositions		kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg…
Cations										
Ag		0.00				0.00		0.00	0.00	
Al		22.88				22.88		22.88	0.00	
As		0.00				0.00		0.00	0.00	
Ba		0.00				0.00		0.00	0.00	
Ca		4.11	111.92			116.03		112.79	3.25	
Cd		0.01				0.01		0.00	0.01	
Co		0.03				0.03		0.00	0.03	
Cr		51.69				51.69		51.68	0.01	
Cu		2.69				2.69		0.00	2.69	
Fe(Total)		0.62				0.62		0.49	0.13	
K		2.17				2.17		0.00	2.17	
Mg		8.61				8.61		0.00	8.61	
Mn		0.50				0.50		0.50	0.00	
Mo		0.00				0.00		0.00	0.00	
Na		244.86		0.00		244.86		0.00	244.86	
Ni		27.91				27.91		0.00	27.91	
Pb		0.00				0.00		0.00	0.00	
Sb		0.00				0.00		0.00	0.00	
Sn		0.52				0.52		0.00	0.52	
Te		0.00				0.00		0.00	0.00	
Ti		0.00				0.00		0.00	0.00	
Tl		0.00				0.00		0.00	0.00	
Zn		23.78				23.78		0.00	23.78	
Subtotal Metal Cations		390.38	111.92	0.00		502.30		188.34	313.96	
H (Acidity as H+)		0.05				0.00		0.00	0.00	
Total Cations		390.43	111.92	0.00		502.30		188.34	313.96	
Anions										
OH		0.00				0.00		0.00	0.00	
CO3 (Total)		0.00	167.88	0.00		167.88		167.05	0.84	
Cl		5.69				5.69		0.00	5.69	
PO4 (Total)		191.27				191.27		178.58	12.69	
SO4 (Total)		614.19				614.19		0.00	614.19	
Total Anions		811.14	167.88	0.00		979.02		345.62	633.40	
Total Salts		1,201.57	279.80	0.00		1,481.32		533.96	947.36	
Inert		0.00	13.99		0.07	14.06		14.06	0.00	
Total Solids		1,201.57	293.79	0.00	0.07	1,495.38		548.02	947.36	
H2O		6,490.26	440.69	0.00	34.65	6,965.60	1,096.04	548.02	7,072.93	
CO2 Gas										
Total Stream		7,691.83	734.48	0.00	34.72	8,460.98	1,096.04	1,096.04	8,020.30	
Loading (kg/cycle)		1,922.96	183.62	0.00	8.68	2,115.25	274.01	274.01	2,005.07	
Maximum Flow (l/m)		54.09	3.67	0.00		58.05	9.13		58.94	
Maximum Temp (C)						30				
Wt% Total Solids		15.6	40.0	0.0	0.2	17.7	0.0	50.0	11.8	4…
Wt% Insoluble Solids		0.0	40.0	0.0	0.2	6.5	0.0	50.0	0.0	4…
pH						6.0±0.25				

Stream Number	31	32	33	34	35	36	37	38	39
Stream Description	Filter Cake (Washed)	Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)	Liquor Filtrate
Compositions	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Ag	0.00	0.00				0.00		0.00	0.00
Al	22.88	0.00				0.00		0.00	0.00
As	0.00	0.00				0.00		0.00	0.00
Ba	0.00	0.00				0.00		0.00	0.00
Ca	112.79	3.25	4.77			8.02		8.02	0.00
Cd	0.00	0.01				0.01		0.01	0.00
Co	0.00	0.03				0.03		0.03	0.00
Cr	51.68	0.01				0.01		0.01	0.00
Cu	0.00	2.69				2.69		2.69	0.00
Fe(Total)	0.49	0.13				0.13		0.13	0.00
K	0.00	2.17				2.17		0.00	2.17
Mg	0.00	8.61				8.61		6.84	1.77
Mn	0.50	0.00				0.00		0.00	0.00
Mo	0.00	0.00				0.00		0.00	0.00
Na	0.00	244.86		48.49		293.35		0.00	293.35
Ni	0.00	27.91				27.91		27.91	0.00
Pb	0.00	0.00				0.00		0.00	0.00
Sb	0.00	0.00				0.00		0.30	0.00
Sn	0.00	0.52				0.52		0.00	0.52
Te	0.00	0.00				0.00		0.00	0.00
Ti	0.00	0.00				0.00		0.00	0.00
Tl	0.00	0.00				0.00		0.00	0.00
Zn	0.00	23.78				23.78		23.78	0.00
Subtotal Metal Cations	188.34	313.96	4.77	48.49		367.22		69.42	297.81
H (Acidity as H+)	0.00	0.00				0.00		0.00	0.00
Total Cations	188.34	313.96	4.77	48.49		367.22		69.42	297.81
Anions									
OH	0.00	0.00				0.00		0.00	0.00
CO3 (Total)	167.05	0.84	7.16	63.25		71.24		70.05	1.19
Cl	0.00	5.69				5.69		0.00	5.69
PO4 (Total)	178.58	12.69				12.69		12.69	0.00
SO4 (Total)	0.00	614.19				614.19		0.00	614.19
Total Anions	345.62	633.40	7.16	63.25		703.80		82.74	621.06
Total Salts	533.96	947.36	11.93	111.73		1,071.02		152.16	918.86
Inert	14.06	0.00	0.60		0.08	0.67		0.67	0.00
Total Solids	548.02	947.36	12.52	111.73	0.08	1,071.70		152.83	918.86
H2O	548.02	7,072.93	18.78	633.16	38.62	7,763.50	305.67	152.83	7,897.55
CO2 Gas									
Total Stream	1,096.04	8,020.30	31.30	744.89	38.70	8,835.20	305.67	305.67	8,816.41
Loading (kg/cycle)	274.01	2,005.07	7.83	186.22	9.68	2,208.80	76.42	76.42	2,204.10
Maximum Flow (l/m)		58.94	0.16	5.28		64.70	2.55		65.81
Maximum Temp (C)						30			
Wt% Total Solids	50.0	11.8	40.0	15.0	0.2	12.1	0.0	50.0	10.4
Wt% Insoluble Solids	50.0	0.0	40.0	0.0	0.2	1.7	0.0	50.0	0.0
pH						9.0±0.5			9.0±0.5

Drawing No, 95-547-100D

Sludge-BHG										
Cycle Times (h):										
Extraction	6									
Byproduct	6									
Acid Stoichiometry	1.2									
Capacity Factor	0.6									
Stream Number			1	2	3	4	5	6	7	8
Stream Description		Basis	Feed Sludge	Makeup Water	Milled Slurry	Sulfuric Acid	Makeup Water	Sulfuric Acid	Carbon Dioxide	Wash W
		Dry Solids	50%		25%	93%		20%	Offgas	
Compositions		gm/kg	kg/day			kg/day	kg/day	kg/day	kg/day	kg/da
Cations										
Ag		0.00	0.00		0.00					
Al		1.70	1.02		1.02					
As		0.00	0.00		0.00					
Ba		0.31	0.19		0.19					
Ca		331.22	198.73		198.73					
Cd		0.01	0.01		0.01					
Co		0.00	0.00		0.00					
Cr		0.04	0.03		0.03					
Cu		20.59	12.35		12.35					
Fe(Total)		2.33	1.40		1.40					
K		0.07	0.04		0.04					
Mg		17.01	10.21		10.21					
Mn		0.09	0.05		0.05					
Mo		0.00	0.00		0.00					
Na		2.95	1.77		1.77					
Ni		0.00	0.00		0.00					
Pb		1.61	0.97		0.97					
Sb		0.00	0.00		0.00					
Sn		5.82	3.49		3.49					
Te		0.03	0.02		0.02					
Ti		0.04	0.03		0.03					
Tl		0.00	0.00		0.00					
Zn		1.16	0.70		0.70					
Subtotal Metal Cations		385.00	231.00		231.00	0.00	0.00	0.00		
H (Acidity as H+)		0.00	0.00		0.00	13.84		13.84		
Total Cations		385.00	231.00		231.00	13.84	0.00	13.84		
Anions										
OH		8.95	5.37		5.37					
CO3 (Total)		304.37	182.62		182.62					
Cl		0.90	0.54		0.54					
PO4 (Total)		246.18	147.71		147.71					
SO4 (Total)		35.81	21.48		21.48	664.55		664.55		
Total Anions		596.20	357.72		357.72	664.55	0.00	664.55	0.00	0
Total Salts		981.20	588.72		588.72	678.40	0.00	678.40	0.00	0
Inert		18.80	11.28		11.28	0.00		0.00		
Total Solids		1,000.00	600.00		600.00	678.40	0.00	678.40	0.00	0
H2O			600.00	1,200.00	1,800.00	51.06	2,662.53	2,713.59	4.19	907
CO2 Gas			0.00		0.00			0.00	133.92	
Total Stream			1,200.00	1,200.00	2,400.00	729.46	2,662.53	3,391.99	138.11	907
Loading (kg/cycle)			300.00	300.00	600.00	182.36	665.63	848.00	34.53	226
Maximum Flow (l/m)						3.38	22.19	22.61		
Maximum Temp (C)			30	85	40	30	25	65		
Wt% Total Solids			50.0		25.0	93.0	0.0	20.0	0.0	0.0
Wt% Insoluble Solids			50.0		25.0	0.0	0.0	0.0	0.0	0.0
pH										

Stream Number	6	7	8	9	10A	10B	10C	10D	10E	10F	10G
Stream Description	uric Acid	Carbon Dioxide	Wash Water	Washed	1st Stage	1st Stage	2nd Stage	2nd Stage	2nd Stage	3rd Stage	3rd Stage
	20%	Offgas		Residue	Slurry	Sludge	Slurry	Extract	Sludge	Slurry	Extract
Compositions	g/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Ag				0.00							
Al				0.17							
As				0.00							
Ba				0.19							
Ca				84.38							
Cd				0.00							
Co				0.00							
Cr				0.00							
Cu				0.00							
Fe(Total)				0.03							
K				0.00							
Mg				0.20							
Mn				0.00							
Mo				0.00							
Na				0.00							
Ni				0.00							
Pb				0.94							
Sb				0.00							
Sn				0.00							
Te				0.00							
Ti				0.03							
Tl				0.00							
Zn				0.00							
Subtotal Metal Cations	0.00			85.94							
H (Acidity as H+)	13.84			0.00							
Total Cations	13.84			85.94							
OH				0.00							
CO3 (Total)				0.00							
Cl				0.00							
PO4 (Total)				0.00							
SO4 (Total)	664.55			205.16							
Total Anions	664.55	0.00	0.00	205.16							
Total Salts	678.40	0.00	0.00	291.10							
Inert	0.00			11.28							
Total Solids	678.40	0.00	0.00	302.38							
H2O	2,713.59	4.19	907.13	302.38	5,938.41	763.79	4,725.25	4,082.13	643.12	3,356.71	3,961.46
CO2 Gas	0.00	133.92									
Total Stream	3,391.99	138.11	907.13	604.75	7,212.19	1,255.94	6,007.83	4,950.30	1,057.52	4,449.51	4,751.89
Loading (kg/cycle)	848.00	34.53	226.78	151.19	1,803.05	313.98	1,501.96	1,237.58	264.38	1,112.38	1,187.97
Maximum Flow (l/m)	22.61		7.56		49.49	6.36	39.38	34.02	5.36	27.97	33.01
Maximum Temp (C)	65				40		50			60	
Wt% Total Solids	20.0	0.0	0.0	50.0	17.7	39.2	21.3	17.5	39.2	24.6	16.6
Wt% Insoluble Solids	0.0	0.0	0.0	50.0	5.2	30.0	5.3	0.0	30.0	6.8	0.0
pH											

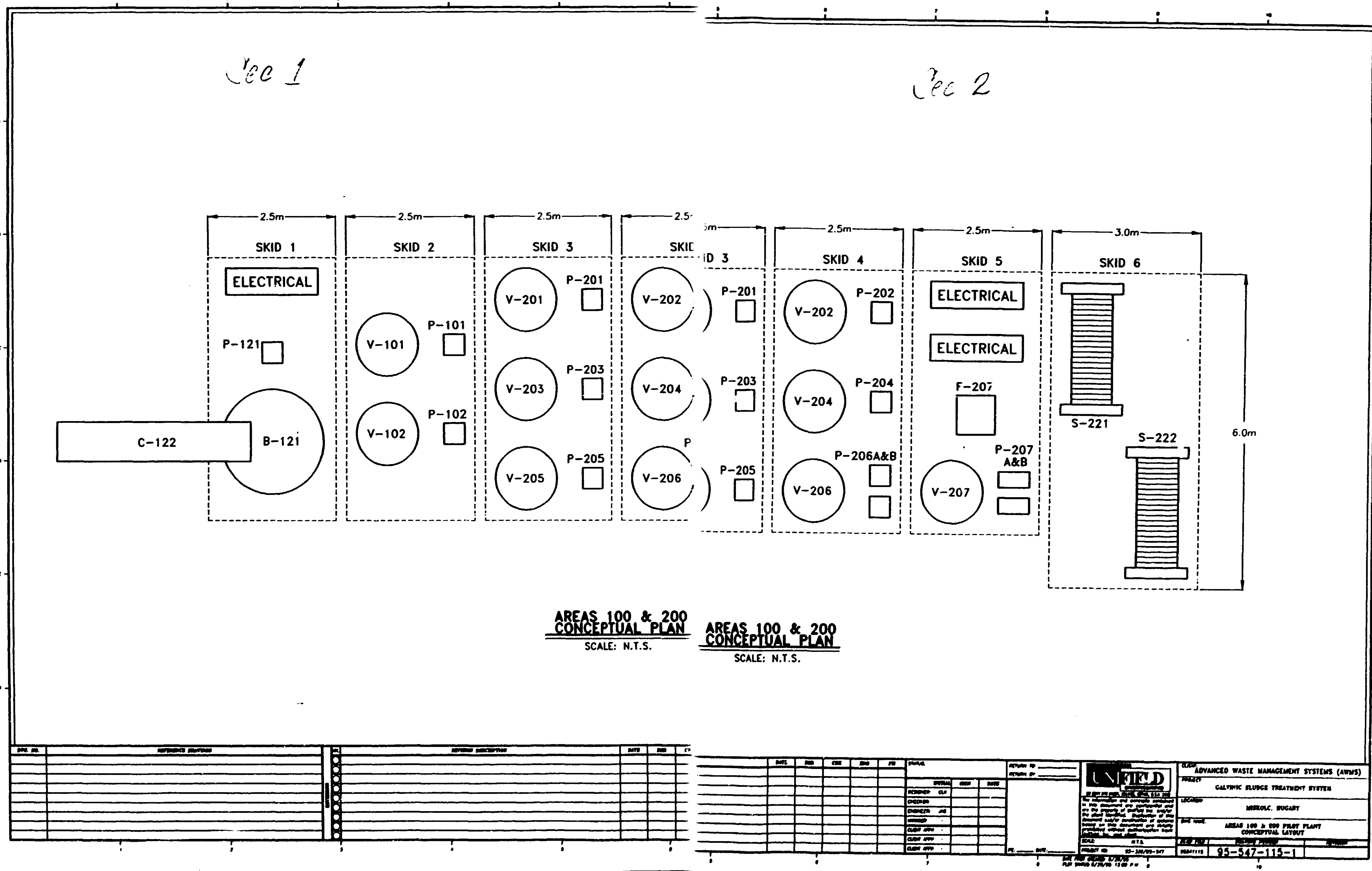
Drawing No, 95-547-100D

Sludge-BHG									
Cycle Times (h):									
Extraction	6								
Byproduct	6								
Acid Stoichiometry	1.2								
Capacity Factor	0.6								
Stream Number		10	11	In Tank	12	13	14	15	16
Stream Description		Extraction Liquor	Sodium Hydroxide 50%	Intermediate PreNeutralized Liquor	Sodium Carbonate 15%	Carbon Dioxide Offgas	Precipitate Slurry	Wash Water	Filtered Solids (Washed)
Compositions		kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations									
Ag		0.00		0.00			0.00		0.00
Al		0.85		0.85			0.85		0.00
As		0.00		0.00			0.00		0.00
Ba		0.00		0.00			0.00		0.00
Ca		114.35		114.35			114.35		0.00
Cd		0.01		0.01			0.01		0.00
Co		0.00		0.00			0.00		0.00
Cr		0.03		0.03			0.03		0.00
Cu		12.35		12.35			12.35		0.00
Fe(Total)		1.37		1.37			1.37		0.01
K		0.04		0.04			0.04		0.00
Mg		10.00		10.00			10.00		0.00
Mn		0.05		0.05			0.05		0.00
Mo		0.00		0.00			0.00		0.00
Na		1.77	169.97	171.74	0.03		171.77		0.00
Ni		0.00		0.00			0.00		0.00
Pb		0.02		0.02			0.02		0.02
Sb		0.00		0.00			0.00		0.00
Sn		3.49		3.49			3.49		0.00
Te		0.02		0.02			0.02		0.02
Tl		0.00		0.00			0.00		0.00
Tl		0.00		0.00			0.00		0.00
Zn		0.70		0.70			0.70		0.00
Subtotal Metal Cations		145.06	169.97	315.02	0.03		315.06		0.05
H (Acidity as H+)		7.44		0.05			0.00		0.00
Total Cations		152.50	169.97	315.08	0.03		315.06		0.05
Anions									
OH		0.00	125.63	0.00			0.00		0.00
CO3 (Total)		0.00		0.00	0.04		0.04		0.04
Cl		0.54		0.54			0.54		0.00
PO4 (Total)		147.71		147.71			147.71		0.00
SO4 (Total)		480.88		480.88			480.88		0.00
Total Anions		629.13	125.63	629.13	0.04		629.16		0.04
Total Salts		781.63	295.59	944.20	0.08		944.22		0.09
Inert		0.00		0.00			0.00		0.00
Total Solids		781.63	295.59	944.20	0.08		944.22		0.09
H2O		5,174.62	295.59	5,603.23	0.44		5,603.58	0.18	0.09
CO2 Gas						0.01			
Total Stream		5,956.25	591.18	6,547.43	0.51	0.01	6,547.80	0.18	0.18
Loading (kg/cycle)		1,489.06	147.80	1,636.86	0.13	0.00	1,636.95	0.04	0.04
Maximum Flow (l/m)		43.12	2.46	46.69	0.00		46.70	0.00	
Maximum Temp (C)		40		40			35		
Wt% Total Solids		13.1	50.0	14.4	15.0	0.0	14.4	0.0	50.0
Wt% Insoluble Solids		0.0	0.0	0.0	0 0	0.0	0.0	0.0	
pH		-1		2.5±0.25			2.75±0.25		

15	16	17	18	19	20	21	22	23	24
Wash Water	Filtered Solids (Washed)	Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Carbon Dioxide Offgas	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)
kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
	0.00	0.00					0.00		0.00
	0.00	0.85					0.85		0.00
	0.00	0.00					0.00		0.00
	0.00	0.00					0.00		0.00
	0.00	114.35					114.35		0.00
	0.00	0.01					0.01		0.00
	0.00	0.00					0.00		0.00
	0.00	0.03					0.03		0.00
	0.00	12.35					12.35		0.00
	0.01	1.35					1.35		0.79
	0.00	0.04					0.04		0.00
	0.00	10.00					10.00		0.00
	0.00	0.05					0.05		(0.39
	0.00	0.00					0.00		0.00
	0.00	171.77		0.66			172.43		0.00
	0.00	0.00					0.00		0.00
	0.02	0.00					0.00		0.00
	0.00	0.00					0.00		0.00
	0.00	3.49					3.49		0.00
	0.02	0.00					0.00		0.00
	0.00	0.00					0.00		0.00
	0.00	0.00					0.00		0.00
	0.00	0.70					0.70		0.00
	0.05	315.00	0.00	0.66			315.66		0.40
	0.00	0.05					0.00		0.00
	0.05	315.06	0.00	0.66			315.66		0.40
	0.00	0.00					0.00		0.00
	0.04	0.00		0.86			0.85		0.85
	0.00	0.54					0.54		0.00
	0.00	147.71					147.71		0.00
	0.00	480.88					480.88		0.00
	0.04	629.13	0.00	0.86			629.98		0.85
	0.09	944.18	0.00	1.52			945.64		1.25
	0.00	0.00				0.06	0.06		0.06
	0.09	944.18	0.00	1.52		0.06	945.70		1.31
0.18	0.09	5,603.76	0.00	8.61		28.06	5,639.13	2.61	1.31
					0.01				
0.18	0.18	6,547.94	0.00	10.13	0.01	28.12	6,584.82	2.61	2.61
0.04	0.04	1,636.99	0.00	2.53	0.00	7.03	1,646.21	0.65	0.65
0.00		46.70	0.00	0.07			46.99	0.02	
							30		
0.0	50.0	14.4	0.0	15.0	0.0	0.2	14.4	0.0	50.0
0.0		0.0	0.0	0.0	0.0	0.2	0.0	0.0	50.0
							3.25±0.25		

Drawing No, 95-547-100D

Sludge-BHG																
Cycle Times (h):																
Extraction	6															
Byproduct	6															
Acid Stoichiometry	1.2															
Capacity Factor	0.6															
Stream Number		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Stream Description		Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)	Liquor Filtrate	Limestone or Sodium Carbonate 40%	Sodium Carbonate 15%	Polymer	Precipitate Slurry	Wash Water	Filter Cake (Washed)	Liquor Filtrate
Compositions		kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
Cations																
Ag		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Al		0.85				0.85		0.85	0.00				0.00		0.00	0.00
As		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Ba		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Ca		114.35	0.00			114.35		89.73	24.63	0.00			24.63		24.63	0.00
Cd		0.01				0.01		0.00	0.01				0.01		0.01	0.00
Co		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Cr		0.03				0.03		0.02	0.01				0.01		0.01	0.00
Cu		12.35				12.35		9.53	2.82				2.82		2.82	0.00
Fe(Total)		0.56				0.56		0.45	0.11				0.11		0.11	0.00
K		0.04				0.04		0.00	0.04				0.04		0.00	0.04
Mg		10.00				10.00		0.00	10.00				10.00		8.52	1.48
Mn		0.45				0.45		0.45	0.00				0.00		0.00	0.00
Mo		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Na		172.43	10.08	0.00		182.51		0.00	182.51	43.26	0.00		225.77		0.00	225.77
Ni		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Pb		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Sb		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Sn		3.49				3.49		0.00	3.49				3.49		0.00	3.49
Te		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Ti		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Tl		0.00				0.00		0.00	0.00				0.00		0.00	0.00
Zn		0.70				0.70		0.00	0.70				0.70		0.70	0.00
Subtotal Metal Cations		315.26	10.08	0.00		325.34		101.02	224.32	43.26	0.00		267.58		36.79	230.78
H (Acidity as H+)		0.05				0.00		0.00	0.00				0.00		0.00	0.00
Total Cations		315.31	10.08	0.00		325.34		101.02	224.32	43.26	0.00		267.58		36.79	230.78
Anions																
OH		0.00				0.00		0.00	0.00				0.00		0.00	0.00
CO3 (Total)		0.00	13.15	0.00		13.15		13.09	0.07	56.42	0.00		56.49		56.14	0.35
Cl		0.54				0.54		0.00	0.54				0.54		0.00	0.54
PO4 (Total)		147.71				147.71		142.07	5.64				5.64		5.64	0.00
SO4 (Total)		480.88				480.88		0.00	480.88				480.88		0.00	480.88
Total Anions		629.13	13.15	0.00		642.28		155.15	487.13	56.42	0.00		543.55		61.78	481.77
Total Salts		944.44	23.23	0.00		967.62		256.17	711.45	99.67	0.00		811.12		98.57	712.55
Inert		0.00	1.16		0.06	1.22		1.22	0.00	4.98		0.06	5.04		5.04	0.00
Total Solids		944.44	24.39	0.00	0.06	968.84		257.39	711.45	104.66	0.00	0.06	816.17		103.62	712.55
H2O		5,641.74	36.59	0.00	28.39	5,706.72	514.78	257.39	5,927.52	156.99	0.00	30.42	6,114.93	207.24	103.62	6,061.56
CO2 Gas																
Total Stream		6,586.18	60.99	0.00	28.45	6,675.56	514.78	514.73	6,638.97	261.65	0.00	30.48	6,931.10	207.24	207.24	6,774.11
Loading (kg/cycle)		1,646.55	15.25	0.00	7.11	1,668.89	128.70	128.70	1,659.74	65.41	0.00	7.62	1,732.78	51.81	51.81	1,693.53
Maximum Flow (l/m)		47.01	0.30	0.00		47.56	4.29		49.40	1.31	0.00		50.96	1.73		50.51
Maximum Temp (C)						30							30			
Wt% Total Solids		14.3	40.0	0.0	0.2	14.5	0.0	50.0	10.7	40.0	0.0	0.2	11.8	0.0	50.0	10.5
Wt% Insoluble Solids		0.0	25.0	0.0	0.2	3.9	0.0	50.0	0.0	25.0	0.0	0.2	1.5	0.0	50.0	0.0
pH						6.0±0.25							9.0±0.5			9.0±0.5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SKID 4
SKID 5
SKID 6
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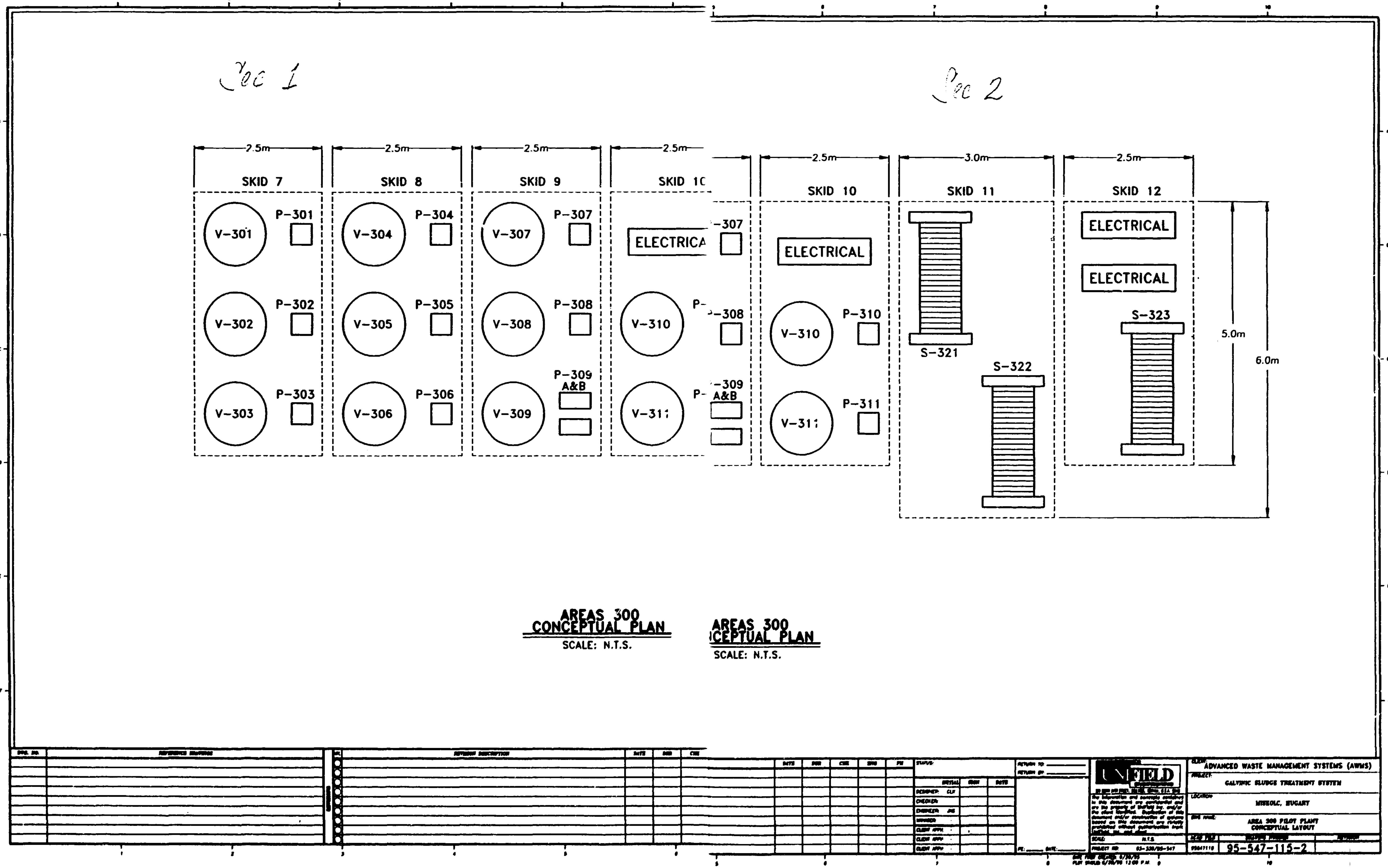
C-122
B-121
V-101
P-101
V-102
P-102
V-201
P-201
V-202
P-202
V-203
P-203
V-204
P-204
V-205
P-205
V-206
P-206A&B
ELECTRICAL
ELECTRICAL
F-207
V-207
P-207 A&B
S-221
S-222
AREAS 100 & 200 CONCEPTUAL PLAN
SCALE: N.T.S.
ADVANCED WASTE MANAGEMENT SYSTEMS (AWMS)
GALVINIC SLUDGE TREATMENT SYSTEM
MISKOLC, HUGARY
AREAS 100 & 200 PILOT PLANT CONCEPTUAL LAYOUT
N.T.S.
95-547-115-1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SKID 12
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V-303
P-301
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P-303
V-304
V-305
V-306
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P-306
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ELECTRICAL
V-310
V-311
P-310
P-311
S-321
S-322
S-323
5.0m
6.0m
AREAS 300 CONCEPTUAL PLAN
SCALE: N.T.S.
CLIENT: ADVANCED WASTE MANAGEMENT SYSTEMS (AWMS)
PROJECT: GALVANIC SLUDGE TREATMENT SYSTEM
LOCATION: MISKOLC, HUGARY
AREA 300 PILOT PLANT CONCEPTUAL LAYOUT
SCALE: N.T.S.
95-547-115-2

Table 2-5. Pilot Plant Design Considerations

General Equipment Selection and Layout

- Use of hoses for interconnection of equipment within skids and especially between skids particularly where liquors offer little safety concerns. This can add a great deal of flexibility and reduce costs, such as in the Metals Recovery area and solids preparation.

- Use of acid resistant hose for tank vent connections to the sodium hydroxide scrubber. These can be relatively easily removed and reconnected for transportability.

- The largest skid size is limited to the following inside dimensions: (to comply with Hungarian transportation regulations for truck trailer size)

  2.4 m width x 13.6 m length x 2.4 m height

  The actual skid sizes are given in the design drawings in appendix 4.

- There are several pieces of equipment in the process design designated as optional -- i.e. the sludge conditioning tanks and the liquor storage tanks. It is not believed that these are required at this point until experience has been gained in operation with different sludges and exact requirements can be established. Therefore, these have not been included in the PFCDs. There are other vessels that also may not be required depending upon the facilities available at the site location and/or the form and availability of makeup chemicals. These include:
  - Sulfuric Acid Mix/Feed Tank (V-206) - This tank is not absolutely necessary, especially if there exists a bulk acid storage tank from which acid can be fed directly to the third stage extraction tank (where it is mi[illegible]d with makeup water). It has been included because of the need for transportability.
  - Sodium Hydroxide Feed Tank (V-307) - This tank is also not absolutely necessary, especially if there exists a bulk sodium hydroxide storage tank from which sodium hydroxide can be fed directly to the Pre-neutralization Tank (V-301) or if sodium hydroxide can be delivered in "super tanks" from which it can be fed. It has been included because of the need for transportability.
  - Extra Metals Recovery Area Tanks (V-301 and V-302) - Neither of these tanks is a requirement. They have been included to enhance flexibility and support capacity requirements.

- Filter traps have been included in both the Acid Extraction area and the Metals Recovery area to capture carrythrough of solids from one stage of operation to the next. None of these are essential, but some are more important than others. Therefore, some of these could be eliminated or considered future design enhancements based upon needs established from operating experience. In any case they need to be accessible and removable.
  - Acid Extraction Area (S-202 and S-204) - These socks are on the liquor hold tanks for their respective acid extraction reactors. They simply prevent the build-up of fines in the extraction system and make analysis of extraction stage performance easier. The more important of the two is S-202 since it filters liquor discharged from the third stage hydroclone, which is likely to pass fines. S-204 filters the filtrate from the residue filters. It is mainly intended to capture fines that pass the filter during startup, when there has been little cake formed, or to capture solids during filter cloth tears.

Table 2-5. Pilot Plant Design Considerations (Continued)

- Metals Recovery Area (S-301 through S-304) - These are the most important filter traps in the Metals Recovery area. S-301 (and potentially S-302 and S-303) filters liquor discharged from the second stage hydroclone, which is likely to pass fines. S-304 filters solids formed in V-301 during pre -neutralization. While little to no solids should be formed during this step, it is probably desirable to have the capability to segregate any such solids from the precipitate formed in the first stage of precipitation, especially if thee is any arsenic present.

  - Metals Recovery Area (S-305 and S-306) - These are similar in function to S-204 in the Acid Extraction area, filtering filtrate from precipitate filters.

Specific Equipment Requirements

- Tank heaters (where indicated in the Equipment List) should be sized to provide a temperature increase of 30 C over about two hours. If possible, portable or removal heaters are desirable. Hot water immersion heating coils should also be specified in addition to electric heaters for use at Miskolc.

- In-tank immersion pH probes for the Metals Recovery area are recommended to be specified and installed as follows:
  - top entering mounting through downcomer pipes anchored to the tank wall;
  - pH elements should be mounted at a depth of about one-half to one-third from the tank bottom;
  - elements should protrude at least 100 mm from the end of the downcomer;
  - pH elements should be fitted with ultrasonic cleaners if glass electrodes are used;
  - pH elements should be specified for high sodium solution service; and,
  - consideration should be given to solid state FET probes.

- The recommendation for tank level indicators for all slurry containing tanks is a top entering, capacitance-type probe with local indication.

- Indications for minimum materials of construction are offered as a guideline. Final selection should depend upon availability and cost of equipment.

- It is intended that all the tanks be purchased as a standard design readily available from small tank suppliers. Therefore, tank dimensions should be considered approximate and **strict adherence to tank dimensions shown is not required.** What are most important are the approximate working volumes shown; a normal liquid level roughly equivalent to the tank diameter or slightly more; and, a freeboard allowance of about 500 mm or more.

Table 2-6. Pilot Plant Concept Layout - Example Skid Schedule

Processing Area	Skid	Equipment	Tag Numbers
Solids Preparation (Area 100)	Skid 1 (Solids Milling)	Ball Mill with Feed Hopper (1) Mill Feed Conveyor (1)	B121 C122
	Skid 2 (Slurry Storage)	Milled Slurry Tanks (2) Agitators(2) Slurry Transfer Pumps (2)	V101/102 A101/102 P101/102
Acid Extraction (Area 200)	Skid 3 (Acid Extraction)	Extraction Tanks (3) Agitators (3) Slurry Transfer Pumps (3)	V201/203/205 A201/203/205 P201/203/205
	Skid 4 (Extraction Support)	Hold & Feed Tanks (3) Agitators (3) Sock Filters (2) Hydroclones (2) Slurry Transfer Pumps (2) Acid Feed Pumps (2)	V202/204/206 A202/204/206 S202/204 S223/224 P202/204 P206A/B
	Skid 5 (Extraction Support)	Vent Scrubber (1) Vent Fan (1) Scrubber Recirc Pumps (2)	V207 F207 P207A/B
	Skid 6 (Residue Filtration)	Residue Filters (2) Residue Hoppers (2)	S221/222 H221/222
Metals Recovery (Area 300)	Skid 7 (Recovery Liquor)	Neut. & Storage Tanks (3) Agitators (3) Sock Filters (3) Slurry Transfer Pumps (3)	V301/302/303 A301/302/303 S301/302/303 P301/302/303
	Skid 8 (Metals Precipitation)	Reaction Tanks (3) Agitators (3) Sock Filters (3) Slurry Transfer Pumps (3)	V304/305/306 A304/305/306 S304/305/306 P304/305/306
	Skid 9 (Recovery Support)	Chemical Mix/Feed Tanks (3) Agitators (3) Chemical Feed Pumps (6)	V307/308/309 A307/308/309 P307/308/309-A&B
	Skid 10 (Recovery Support)	Polymer Mix/Feed Tanks (2) Agitators (2) Polymer Feed Pumps (2)	V310/311 A310/311 P310/311
	Skid 11 (Byproduct Filtration)	Byproduct Filters (3) Byproduct Hoppers (3)	S321/322/323 H321/322/323
	Skid 12-OPTIONAL (Sludge Conditioning)	Sludge Conditioning Tanks (3) Agitators (3) Filter Feed Pumps (3)	V312/313/314 A312/313/314 P312/313/314
Residue Treament (Area 400) LATER	Skid (Residue Extraction)	Reaction Tanks (3) Agitators (3) Slurry Transfer Pumps (3)	V402-404 A402-404 P302-304
	Skid (Extraction Support)	Feed & Mix Tanks (3) Agitators (3) Slurry Transfer Pump (1) Chemical Feed Pumps (4)	V401/405/406 A401/405/406 P301 P405/406-A&B
	Skid (Residue Filtration)	Residue Filter (1) Residue Hopper (1)	S411 H411
Sulfate Recovery (Area 500) LATER			
Tank Storage (Area 600) OPTIONAL/LATER	Skid (Storage Tanks)	Hold Tanks (2) Agitators (2) Sock Filters (2) Slurry Transfer Pumps (2)	V601/602 A601/602 S601/602 P601/602

3.0 Process Description

3.1 Area Operations

The Pilot Plant is broken down into three major process areas

1) Sludge Preparation (Area 100)
2) Sulfuric Acid Extraction (Area 200)
3) Metals Recovery (Areas 300)

An annotated tabulation of the batch operating cycles for the major process unit operations is provided in Table 3-1. Table 3-2 provides a cycle diagram summarizing the sequence of operations for a basic six hour cycle period for each area.

2.1.1 Sludge Preparation

General Design Approach

The first step involves milling the sludge to create a high surface area to expose the heavy metals to the extraction chemicals. This is accomplished in a ball-type mill, either a conventional ball mill or a tower mill. Either should provide adequate service, since the sizing criteria for the mill is for one shift of operation per day. This should give adequate down time for maintenance in a pilot plant service. In a full scale application, a tower mill is preferred for several reasons. First, it is particularly suited to this application in grinding materials of moderate to low grinding index with roughly two-thirds the energy of a conventional ball mill. Second, it's profile and footprint are easily accommodated within a plant configuration. Finally, it is slightly less expensive and should be easier to operate. Tower mills should require two to three days routine maintenance outages twice a year.

Equipment Description

The Solids Preparation area of the pilot plant consists of the ball mill, the ball mill feed conveyor and two milled slurry storage tanks. The ball mill and feed conveyor are to have a processing capacity of at least two metric tons of sludge per shift to allow one shift operation. Assuming batch operations and a two to three hour cycle time for filling, milling and discharging the mill, this equates to a feed conveyor capacity of roughly two metric tons per hour (one-half hour to fill the mill) and a mill capacity of about one metric ton per hour (one hour of milling time).

The feed conveyor has a weighing capability to allow accurate addition of sludge to the mill. Water is fed to the mill along with the sludge to attain a prescribed solids content in the range of 20% - 30% solids. Hot water may be desirable in winter months, although heating is provided for the Sulfuric Acid Extraction tanks to ensure proper extraction temperatures. The mill is specified for a capability of 95% through 325 mesh grind, but should be capable of achieving a range of solids attrition from 150 to 325 mesh.

Slurry from the mill is discharged to one of two Milled Slurry Storage Tanks (V-101 and V-102). These are agitated tanks constructed of abrasion resistant fiberglass fitted with anti-swirl baffles. Each has a working capacity of approximately 2.5 m^3. Thus, each has sufficient capacity to store one day's feed requirement of slurry for the plant. Air operated diaphragm pumps with stainless steel diaphragms are used for feed of slurry from the storage tanks to the Sulfuric Acid Extraction area.

It should be noted that because the pilot plant is to be transportable, no provisions are included in the design for the receipt, storage and handling of sludges prior to loading of the feed conveyor. Thus, containment areas and mobile equipment are not addressed

3.1.2 Sulfuric Acid Extraction

General Design Approach

Sulfuric Acid Extraction entails a three-stage, countercurrent operation (i.e., the strongest acid contacts residues that are almost depleted of the heavy metals while the fresh milled slurry is contacted with acid used in the strong acid steps). Such countercurrent extraction schemes are commonplace in hydrometallurgy processing. Each stage is a batch operation with a cycle time coordinated with the other reaction vessels.

After three stages of leaching, it is expected that all of the heavy metals except for lead will be extracted from the sludge. The treatment is focused upon dissolving the heavy metals while minimizing the dissolution of host material. Test work has indicated that between 20% and 35% of the initial sludge weight can remain in the solid phase. The amount of residue will depend primarily upon the soluble calcium content and the quantity of acid insoluble inerts ("refractory" materials). A significant amount of calcium that dissolves may re-precipitate as gypsum (calcium sulfate dihydrate) which can tend to increase slightly the residue quantity. If the remaining residue contains only small amount of lead, this residue is expected to be non-hazardous and can be disposed without further treatment.

There are four principal unit operations in the Sulfuric Acid Extraction area: first stage acid extraction; second stage acid extraction; third stage acid extraction; and, vent gas scrubbing. This discussion is predicated upon operation of all three stages assuming an overall cycle time for each stage of six hours. In this regard, it should be noted that test work has indicated that for many sludges it may be possible to accomplish the extraction process in only two stages and that it may be possible to reduce the cycle times to four hours. The limiting steps in these cycles may not be reaction time, rather the time it takes to fill and empty tanks, especially for solids separation.

All operations are performed through manual controls using local instrumentation and sampling and offline measurement of pH and/or acidity titrations when required. In-line and In-tank pH elements have proven highly unreliable in these types of operations due to the abrasive nature of the slurries and the high dissolved solids levels (which affect the accuracy and drift of the elements). Also, pH alone is not always a good measure of solution composition at such low pH levels, although it may be used as a good control indication once familiarity is gained for one type of sludge.

First Stage Extraction

The initial extraction is accomplished in the first reactor, contacting the freshly milled sludge slurry with acid that has been partially depleted from succeeding extraction steps. The sludge is expected to react significantly and rather quickly. All carbonates and bicarbonates and any hydroxides are expected to decompose. For many sludges, there will also be significant CO_2 evolution. The CO_2 along with any acid mist carryover is vented to a sodium hydroxide scrubber.

The first stage consists of two vessels -- a 2 m^3 agitated reactor (V-201) and a 2 m^3 hold tank (V-202). Both vessels are constructed of fiberglass and fitted with anti-swirl baffles. The working volume of each vessel is about 1.5 m^3. The additional volume provides free board to better accommodate offgassing of CO_2 during the initial reaction.

There are several options for operating the first stage of acid extraction because the reactions are expected to be rapid, most likely reaching completion in well under one hour. The following description conforms to the cycle diagram in Table 2-2. In this mode the first stage is run through two short, three-hour cycles for every six-hour cycle for each of the other stages. This allows the liquor from the second stage to be "cut" (diluted) and used in two steps.

At the start of the first three hour cycle, acid from the second stage leach, which is stored in the first stage liquor hold tank (V-202), is fed to the reactor vessel along with water at pre-set proportions to a pre-established level to attain about at 10% acid solution and 10% slurry once solids are added. Makeup acid from the sulfuric acid mix tank (V-206) is added as required. Milled slurry from one of the milled slurry hold tanks (V-101 or V-102) is then introduced. (Alternatively, the acid, water and slurry can be introduced together, especially if significant CO_2 evolution is expected.) After evolution of CO_2, additional acid may need to be added to adjust the pH to slightly below 1. The tank is agitated for one-half hour and the pH checked while the dissolution reactions proceed to ensure it is maintained below 1. The reaction temperature is expected to be 40 C ± 5 C based on the heat content of liquor from the second stage and use of hot water in the ball mill, if required. After one-half hour, the solids are separated. The solids are sent to the second stage reactor (V-203) and the liquor to the Pre-neutralization/Hold Tank in the Metals Recovery area (V-301). There are two principal options for solids separation:

(1) Directly pumping the entire slurry through the second stage hydroclone with the solids underflow from the hydroclone discharged directly to the second stage reaction vessel. This should take about one-half hour.

(2) Turning off the agitator and allowing the solids to settle after which the thickened solids are pumped to the second stage and the clarified liquor through the hydroclone to vessel V-301. This will probably take at least one hour.

It should be noted that in either case a filter trap is provided for the feed to vessel V-301 to capture any residue that may escape the hydroclone. This filter needs to be checked and emptied manually when it begins to fill or plug with solids. (Note - The filter should be washed with water prior to being emptied.)

A second three-hour cycle is then repeated using the remainder of the liquor from hold tank V-202 and fresh slurry. In neither the first or second cycle is it necessary to completely empty the first stage reactor vessel unless a changeover to a different sludge composition is anticipated.

Second Stage Extraction

The second acid leaching is expected to take five to six hours, matching the double cycle time of the first stage. It will be at a slightly elevated temperature of 50 C and a much higher acidity level, using liquor remaining from the third stage. Most of the heavy metals should dissolve in the acidity level of this stage. Again, the slurry concentration will be about ten percent or less. While CO_2 evolution should be negligible the tanks are vented to the scrubbing system due to the higher acid vapor pressure.

The second stage leach also consists of two vessels, both similar in design and construction to the first stage vessels. Sulfuric acid and residue wash water recovered from filtration of the residue discharged from the third stage is fed to the second stage hold tank (V-204) from which it is fed to the reactor vessel along with acid, if required. The liquor is fed to the second stage reactor prior to introduction of the first load of solids from the first stage. The acid, if needed, is added later. Extraction is then commenced with the first load of solids and continued for at least one hour beyond introduction of the second load of solids from the first stage. After completion of extraction, approximately four hours total, the contents of the reactor vessel is discharged. The solids are separated and fed to the third stage (V-205) and the liquor sent to the first stage hold tank (V-202). As in the case with the first stage extraction, there are two principal options for separating solids. The preferred route is direct discharge of the entire contents of the vessel through the third stage hydroclone since it should be faster.

Third Stage Extraction

In order to ensure that any residual heavy metals are dissolved, such as cadmium, copper and nickel, the third stage of acid extraction is provided which is another five to six hour cycle, but at 60 C.

The third stage also consists of two vessels as well as two filter presses. The reactor vessel (V-205) is sized identical to those of the first two stages for simplicity of design, although the required working volume of this reactor is considerably less, only about one-half of the others. The second vessel (V-206) is the Makeup Acid mix/feed tank in which 20-25% acid is prepared. This vessel has a working volume of about 2 m^3, sufficient to allow acid makeup for two charges of the third stage reactor.

In this third stage, acid from the Acid Makeup tank (V-206) is fed to the third stage reactor vessel just prior to introduction of solids from the second stage. Heat is provided primarily by the heat of dilution of mixing the concentrated H_2SO_4 and water. Some heat may be required for startup either through addition of hot water or use of power heaters.

When the cycle is finished, the entire contents of the reactor are filtered, with the filtrate fed to the second stage hold tank (V-204). After the slurry is filtered, the cake is washed with at least three displacement washes to remove residual acid from the cake. Wash water is also sent to the second stage hold tank. Two filter presses are provided in case one is shut down for maintenance and for additional flexibility as described below. The filter cake is disposed of as solid waste.

Vent Gas Scrubbing

All tanks and reactor vessels are vented to a sodium hydroxide scrubber. This packed bed tower captures acid mists that may carry over at the somewhat elevated acid concentrations and temperatures. Sodium hydroxide is fed as required from the sodium hydroxide feed tank in the Metals Recovery area along with makeup water to yield about an 8% sodium hydroxide solution. CO_2 carried over, primarily from the first stage will also be absorbed, although most of the resulting sodium carbonate will probably be converted to sodium sulfate. Spent liquor is sent to the pre-neutralization tank (V-301) in the Metals Recovery Area.

Provisions for Alternative Operations

The following provisions have been made in the design for added flexibility:

- Two-stage acid extraction - Provision is made to operate with only two stages by entirely bypassing the second stage should three stages not be required for a particular sludge. In this case slurry from the first stage would be fed directly to the third stage, and the filtrate from the filter presses would be returned to the first stage hold tank (V-202), rather than the second stage hold tank (V-204).

- Dual filtration - It is also possible to utilize one of the filters to dewater solids from the second stage as well as the third stage during normal cycling should the second stage solids setting be too slow to allow settling or the hydroclone prove ineffective in providing adequate solids separation.

- Vessels - Vessels heaters are provided primarily for startup under cold conditions. However, these can also be used to operate a pre-established temperatures should these prove more advantageous in accomplishing the extraction, especially with only two stages.

3.1.3 Metals Recovery

General Design Approach

The rich extraction liquor from the first stage of the Sulfuric Acid Extraction area is sent to the Pre-neutralization storage tank (V-301). This tank to provide a buffer between the extraction steps and metal recovery. Metal recovery is accomplished by raising the pH for selective precipitation of the metals in a sequence of steps as shown in Table 3-1

- The pH is first raised from approximately 0.5-1 to about 2.5. It is not expected that any salts will precipitate at this low pH nor is it intended to induce precipitation. The purpose is to smooth out pH variations from the extraction area to provide a fairly consistent feed for byproduct recovery. Sodium hydroxide, or a combination of sodium hydroxide followed by sodium carbonate, will be used to limit CO_2 evolution (and minimize acid gas carryover) as well as minimize localized precipitation phenomena.

- The pH is then raised 3.0 to 3.5 in the next step with additional sodium carbonate. Iron will come down as an oxide or oxy-hydroxide, in possibly the hematite (Fe_2O_3) form. Along with the iron may come down small amounts of copper and chromium but it appears that with proper pH control, this can be kept to a minimum. The pH limit will be a function of the copper concentration -- the higher the copper level, the lower the pH setpoint must be. A pH set point of 3.25 is anticipated. The limiting condition on pH is the amount of copper precipitate. This must be kept to a minimum (<0.1%) to assure that the iron precipitate is acceptable to a sintering operation.

- The next step of precipitation is at a pH of about 6, where the copper and chromium precipitate as basic carbonates contaminated with some Fe. Depending upon the calcium and phosphate levels in solution this can be accomplished with either sodium carbonate or limestone, or a combination. The use of limestone should enhance the precipitation of calcium phosphates, reducing both calcium and phosphate in the final liquor making it more acceptable for disposition.

- The final step is at a pH of about 9, which will precipitate the nickel and zinc and other remaining metals in solution. Depending upon calcium and phosphate levels in solution this can be accomplished with either sodium carbonate or limestone, or a combination. At a pH of 9, test work indicates that the predominant "contaminants" in this final byproduct will be calcium, cadmium, iron, magnesium and manganese.

- The resulting solution is sent to a storage tank for disposition.

It was found in the test work that a considerable amount of phosphates appear in the residue that enters the plant. The phosphates, if they are in the sludge, will to some extent dissolve in the initial sulfuric acid leach step (in the material balances it has been assumed that all of the phosphate would dissolve); but, as the pH is raised in the resulting recovery steps, it is anticipated that most of the phosphates will precipitate in the early precipitation steps so long as appropriate insoluble compounds such as calcium phosphate can be formed. It is an area that has to be further investigated.

Equipment Description

The Metals Recovery area consists of eleven vessels and three on-line filter presses.

- One designated Pre-neutralization/Storage Tank to collect and equalize rich extraction liquor from the Sulfuric Acid Extraction area. This is the largest vessel in the pilot plant having a working volume of roughly 3.2 m^3, sufficient to handle 12 hours of liquor at design conditions As discussed above it is used to partially neutralize the extraction liquor prior to targeted metals recovery.

- Three agitated reactors for metals precipitation. Each has a working volume of about 1.5 m^3. These reactors can be constructed of high density polyethylene or fiberglass.

- Two extra agitated tanks for use in accumulating extraction liquors, intermediate storage of offspec precipitation liquors, or even precipitation reactors. These have working volumes identical to the three precipitation reactors.

- Three chemical feed tanks -- one for sodium hydroxide, one for sodium carbonate solution and one for slurries of limestone, sodium carbonate or other additives.

- Two mix/feed tanks for feed of polymer to the precipitation reactor vessels. It is expected that each would contain a different polymer that would be effective in coagulation of suspended solids at different pHs or solids types.

- Three filter presses, one for each of the three principal precipitation reactors.

The Metals Recovery system operates in a sequential batch mode in a manner similar to the Sulfuric Acid Extraction system except that the reactors operate in series with clarified liquor fed forward along with any cake wash water (rather than countercurrent). The cycle times for all reactors are the same, about three hours each -- one hour fill, one hour retention, one hour empty.

Sodium hydroxide and sodium carbonate are first fed to the liquor in Hold Tank V-301 to neutralize the liquor raising the pH to about 2 - 2.5. Sodium hydroxide has been selected for this neutralization primarily to minimize CO_2 evolution. However, should economics and/or availability dictate, sodium carbonate could also be used especially in combination with sodium hydroxide. While it is not intended, some precipitation of salts may occur, such as some amounts of iron, thallium, lead, and tellurium. After neutralization, the liquor is fed to the first precipitation stage, V-304, where the liquor is fed through a filter trap to capture any precipitate formed during neutralization. These solids need to be occasionally washed and removed from the filter, which needs to be done manually.

In the first stage precipitation reactor, sodium carbonate solution or slurry is added to raise the pH to about 2.5. The resultant slurry is then filtered, the cake washed and the combined filtrate and wash water fed to the second stage precipitation reactor, V-305. The filter cake is primarily iron and manganese salts with considerably lesser amounts of other trace heavy metals dissolved from the sludge (e.g., silver and thallium).

This process of neutralization/precipitation continues through the third stage precipitation reactor where the mixed zinc and nickel basic carbonates are precipitated. Three chemicals -- sodium carbonate solution, sodium carbonate slurry, and/or limestone -- are expected to be used for these operations, depending upon the composition of the liquor (calcium and phosphate in particular, as discussed above). Filtrate discharged from the last byproduct filter is discharged to a storage tank outside the scope of this design.

Each filter is sized to process the content of one precipitation reactor in one hour. Because the slurries are relatively thin -- e.g., 1-3% solids -- the filters are generally sized based upon filtrate capacity constraints, rather than solids filtration alone. The byproduct filter cakes are discharged directly to wheeled carts for removal of the solids to interim storage areas outside the scope of this design.

3.2 Operating Requirements

Table 3-3 summarizes the range of operating requirements based upon estimates derived from the material balances performed.

SECTION 3: TABLES AND DRAWINGS

Table 3-1. Pilot Plant Unit Operations

Process Unit	Unit Number	Description	Objective	Processing Conditions	Total Cycle Time	Comments
Sludge Milling	B-121	Feed sludge is fed to the Ball Mill along with (hot) water for milling. Mill is intended to operate just one shift per day.	Prescribed PSD down to 95% < 325 mesh.	1 or 2 hour	2 - 3 hours	Hot water makeup is an option
Milled Slurry Storage/Feed	V-101/102	Milled slurry is stored for feed to V-201. It can also be "cut" with water if necessary to reduce solids content.	Daily storage of milled solids.			
1st Stage Extraction	V-201	Weak acid dissolution. After extraction, solids sent to 2nd Stage (V-203) and liquor to Metals Recovery (V-301). Can be run in one or two sequential batches. Slurry can be settled first or put directly through 2nd Stage hydroclone for separation.	Neutralize sludge alkalinity values (Hydroxide and carbonate/ bicarbonate).	1 or 2 hour extraction per batch 40 C (pH<1.0)	6 hours (2 x 3 hours or 1 x 6 hours)	Carbon dioxide offgas is vented to scrubber along with any acid mist
2nd Stage Extraction	V-203	Strong acid dissolution. After extraction, solids sent to 3rd Stage (V-205) and liquor to Hold Tank (V-202). Slurry can be settled first or put directly through 3rd Stage hydroclone for separation.	Remove residual heavy metals	1 hour extraction 50 C 20% acid	6 hours	If 3rd Stage is not req'd, 2nd Stage solids are filtered and washed and liquor sent to Hold Tank V-202.
3rd Stage Extraction	V-205	Final strong acid leach. Slurry is filtered and washed. Filter cake is discharged (or, later, sent to enhanced acid leach). Filtrate is sent to Hold Tank V-204.	Remove traces of heavy metals except lead	1 hour extraction 60 C 20% acid	6 hours	3rd Stage acid extraction may not be required, especially with low lead content sludges.
Residue Filter	S-221/222	Plate & frame filter presses (one operating/one standby).	Dewater and wash residue	1 hour 60/25 C	(Included in 205)	Minimize acid loss and render solids nonhazardous
Interim Hold Tanks	V-202/204	Receive/hold/return extraction liquors to accomodate cycles of extraction process	Provide interim storage of liquors	(Included above)	(Included above)	Vented to Scrubber
Acid Mix/Feed Tank	V-206	Mix, store and feed sulfuric acid at chosen concentrations.	Acid makeup	55 - 65 C	On demand	Vented to Scrubber
Vent Gas Scrubber	V-207	Vent gases from all Acid Extraction Area Tanks are vented to the Scrubber. Caustic makeup is from the Metals Recovery Area and Scrubber blowdown is sent to Tank V-301.	Control acid mist emissions	~30 C	Continuous	Makeup and blowdown are on a batch basis as dictated by pH

Table 3-2. Operating Cycle Diagram - Example for 6-Hour Overall Cycles

Activity	Hour of Operation											
	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Solids Preparation												
Milling												
Feed to Mill												
Milling												
Slurry to Storage Tanks												
Slurry Storage												
Tank Filling												
Feed to Extraction												
Acid Extraction												
Acid Makeup												
Acid & Water to MU Tank												
Acid to 3rd Stage												
1st Stage												
Liquor to Feed Tank												
Liquor to Reactor												
Slurry to Reactor												
Extraction												
Residue Separation												
2nd Stage												
Liquor to Feed Tank												
Liquor to Reactor												
Solids to Reactor												
Extraction												
Residue Separation												
3rd Stage												
Acid to Reactor												
Solids to Reactor												
Extraction												
Residue Separation												
Metals Recovery												
PreNeutralization												
Storage/Feed Tank Fill												
Chemical Feeds												
Discnarge to Stage 1												
1st Stage												
Tank Fill												
Chemical Feeds												
Precipitation												
Solids Separation												
2nd Stage												
Tank Fill												
Chemical Feeds												
Precipitation												
Solids Separation												
3rd Stage												
Tank Fill												
Chemical Feeds												
Precipitation												
Solids Separation												

Table 3-3. Pilot Plant Operating Requirements

The following estimates of operating requirements derive from the material balances calculated as previously described.

Commodity	Specifications	Units	Maximum Daily Rate	Typical Daily Rate
Chemicals				
Sulfuric Acid	93%	tons	1	0.75
Sodium Hydroxide	50%	tons	0.8	0.6
Soda Carbonate	Powder	tons	0.5	0.25
Limestone	95%<325 mesh	tons	0.4	0.15
Utilities				
Power (Process Only)	N/A	kwh	700	450
Compressed Air	TBD	scfm	TBD	TBD
Makeup Water	Potable	m^3	9	6
Hot Water (Optional)	85 C	m^3	(10)	-
Waste/Byproducts				
Waste Residue	50% Solids	tons	1.2	0.5
Treated Liquor	15±5% TDS	m^3	10	7
Metal Byproducts	50% Solids	tons	2	1

4.0 Test Program Plan

4.1 Introduction

4.1.1 Purpose and Objectives

The purpose of the pilot plant test program is to assess the overall technical and economic feasibility of this hydrometallurgical process for treatment of galvanic sludges. To this end, there are five specific objectives, which together set the tone for the test program plan:

1) determine the technical feasibility;

2) define the range of process applicability;

3) optimize the process design;

4) develop full-scale equipment design parameters; and,

5) establish the basis and technical data for assessment of full-scale economics.

4.1.2 Scope

The scope of the program is one year (nominal) of testing covering the range of galvanic sludges defined during the laboratory batch testing. This specifically excludes the following types of galvanic sludges:

- oily sludges;
- sludges containing arsenic;
- sludges containing cyanide;
- sludges containing mercury;
- sludges from HCL pickling and other high chloride content sludges; and,
- liquids.

4.1.3 Approach

The test program plan is structured in a progressive fashion comprised of a series of test periods, each building on the knowledge and experience obtained in prior tests. Each test period begins with reasonably conservative conditions (I.e., conditions which are expected to result in acceptable performance), then proceeds to studies of options to simplify operations and finally examines ways to optimize performance. This approach is reflected in the selection of sludges and the organization of the test periods.

4.2 Test Plan Overview

Table 4-1 provides a summary of the overall test program as defined by the succession of test periods. This program structure is intended to provide overall guidance for testing, rather than being completely prescriptive. It is expected that the program will evolve based upon the results of previous tests. Changes are not only anticipated, but encouraged. Changes, though, need to be founded on knowledgeable expectations of performance.

A total of at least seven test periods are envisioned. Six of these have been defined in this Test Program Plan. The seventh, or even eighth, test period (depending upon the amount of time available) should be defined based upon the results of the first six test periods. Most test periods involve what are termed "variational" tests. These are individual sludge "campaigns" which focus on evaluating each major process area in succession. Each ends with a short demonstration test at "optimal" conditions. One longer duration "demonstration" test is included for a sludge composite. Two demonstration conditions are planned to assist in optimizing overall performance.

The first test period is expected to be longer than later test periods. The first test period will involve additional activities associated with program startup, including:

- gaining familiarity with equipment and general plant operation;
- development and validation of analytical procedures;
- fine tuning data acquisition and record keeping;
- finalizing standard operating procedures/practices (SOPs);
- setting up laboratory testing equipment and developing associated protocols; and,
- making modifications to equipment and controls determined during initial operations.

It is anticipated that the first test period will also be extended relative to later test periods due to:

- inefficiencies in plant operation and conduct of testing;
- the need to rerun some early tests where results are questionable or incomplete; and,
- rerunning of tests to demonstrate reproducibility.

Table 4-2 gives the recommended set of characteristics for sludges referenced in Table 4-1. This set of sludge characteristics reflects an increasing level of complexity in system chemistry and/or an increasing degree of difficulty expected in sludge treatment. The sludges recommended for the first three test periods were selected to minimize the potential requirement for residue treatment. This potential increases with higher levels of lead and probably cadmium, and to a lesser extent, copper.

Table 4-3 summarizes the principal performance objectives and the primary and secondary control variables for each major process area. These derive principally from the results of laboratory batch testing, and serve as the basis for defining the testing parameters as well as the sequence of tests, as discussed later.

It is expected that laboratory, batch-type testing will be conducted in parallel with pilot plant testing, as needed. Such testing should serve two purposes. First, troubleshooting problems and assisting in setting direction for future test conditions. This is may be required in support of the Acid Extraction and Metals Recovery areas. Second, to perform Residue Treatment Area testing, which is expected to be needed for sludges containing high levels of lead and/or cadmium.

4.3 Variational Test Periods

Five of the test periods have been specified as variational testing with single sludges. Each is intended to begin at the front end of the process with sludge preparation and work through the process, sequentially focusing on successive process areas. The rationale is to systematically investigate and optimize each process step with increasingly more complex sludges. The last stage or segment of each variational test period is devoted to a short demonstration run at operating conditions established during the previous set of parametric tests.

Each variational test period is characterized by relatively intensive sampling and analysis. The recommended data requirements and sampling/analysis program are discussed in Sections 4.4 and 4.5.

4.3.1 Sludge Preparation

Grinding of sludges was not tested as a part of the laboratory program, so guidelines for initiating the test program derive from general considerations and experience in dealing with similar types of materials. To the extent available, these are summarized in Table 4-4.

The initial objective established for sludge milling is 90-95% through 200 mesh (equivalent to 75 micron). The operating parameters available to achieve this objective are first, and foremost, grinding time. Secondary parameters are mill rpm, ball charge and slurry concentration. Dilution of slurry concentration is the least desirable control variable adjustment to achieve the degree of milling desired. Usually, the lower the concentration, the greater the efficiency of sludge solids attrition. However, diluting the slurry has potentially undesirable consequences in terms of: the ability to control acid concentration and stoichiometry in the extraction stage; increased energy utilization in later salt byproduct recovery; and, potential for creating a wastewater stream.

If the degree of fineness required cannot be readily achieved, it may be necessary to conduct offsite testing through an equipment supplier to determine what equipment modifications are needed or possibly explore other types of advanced equipment such as vibrating mills. Vibrating mills are expected to be able to produce micron and submicron particle size distributions; although, such fineness is not expected to be required.

4.3.2 Acid Extraction

Table 4-5 summarizes the performance objectives and the "baseline conditions" for initiating testing of the Acid Extraction area. Table 4-6 sets forth the environmental performance criteria for achieving "nonhazardous" solids status referenced in Table 4-5.

Figure 4-1 provides a decision "logic" diagram relative to the conduct of testing. This diagram is intended to provide guidelines for adjustments to control variables in achieving performance objectives and optimizing system configuration and operation. ***These are only guidelines*** developed from the results of laboratory batch testing. They do, however, establish a framework that balances the relative importance of operating and design parameters that impact technical and economic feasibility with the attainment of process performance objectives.

In developing the course of pilot testing, the following are believed to represent realistic goals, at least for the simplest sludges.

Parameter	Initial Baseline	Goal
Number of Stages	3	2
Acid Stoichiometry	120%	<110%
Solids Grind	90-95%<200 mesh	90-95%<200 mesh
Stage Holdup Times-1st/2nd/3rd	½/2 hours	½/- hours
Stage Temperatures-1st/2nd/3rd	40/50/60 C	40/50/- C

At the end of each variational test period, Baseline Conditions should be re-evaluated and adjusted as warranted from the results of the tests.

4.3.3 Metals Recovery

Table 4-7 summarizes the performance objectives and the "baseline conditions" for initiating testing of the Metals Recovery area. Table 4-6 sets forth the environmental performance criteria for wastewater referenced in Table 4-7.

Figure 4-2 provides a decision "logic" diagram relative to the conduct of testing. This diagram is intended to provide guidelines for adjustments to control variables in achieving performance objectives and optimizing system configuration and operation. ***These are only guidelines*** developed from the results of laboratory batch testing. They do, however, establish a framework that balances the relative importance of operating and design parameters that impact technical and economic feasibility with the attainment of process performance objectives. In developing the course of pilot testing, the following are believed to represent realistic goals, at least for the simplest sludges.

Parameter	Initial Baseline	Goal
Number of Stages	4	4
Chemicals	NaOH (20-50%) Na_2CO_3 (15% solution)	NaOH (20-50%) $CaCO_3$ (>30% slurry) Na_2CO_3 (>30% slurry)
Holdup Times-Each Stage	1 hour	1-2 hours
Temperatures-Each Stage	Uncontrolled (20-35 C)	Uncontrolled (20-35 C)
Solids Seeding	None	To 5% (some Stages)

At the end of each variational test period, Baseline Conditions should be re-evaluated and adjusted as warranted from the results of the tests.

4.3.4 Residue Treatment

Table 4-8 summarizes the performance objectives and the "baseline conditions" for initiating testing for Residue Treatment. Table 4-6 sets forth the environmental performance criteria for achieving "nonhazardous" solids status referenced in Table 4-8.

Figure 4-3 illustrates the possible "process" treatment steps required to effect extraction of lead or other difficult to remove metals present in residues from Acid Extraction. This diagram indicates the types of equipment and testing procedures that may be needed.

Figure 4-4 provides a decision "logic" diagram relative to the conduct of testing. This diagram is intended to provide guidelines for adjustments to control variables in achieving performance objectives and optimizing system configuration and operation. ***These are only guidelines*** developed from the results of laboratory batch testing. They do, however, establish a framework that balances the relative importance of operating and design parameters that impact technical and economic feasibility with the attainment of process performance objectives. In developing the course of pilot testing, the following are believed to represent realistic goals, at least for the simplest sludges.

Parameter	Initial Baseline	Goal
Number of Stages	1	1
Chemicals	HCl $CaCO_3$	HCl $CaCO_3$
Holdup Time	4 hours	2 hours
Temperature	50 C	40 C
Residue Grinding	None	None

At the end of each variational test period, Baseline Conditions should be re-evaluated and adjusted as warranted from the results of the tests.

4.3.5 Byproduct (Na_2SO_4) Recovery

Table 4-9 summarizes the performance objectives and the "baseline conditions" for initiating testing of the Byproduct Recovery. Byproduct Recovery was not tested as a part of the laboratory program and equipment was not included in the original pilot plant design because of high costs and the lack of definitive design parameters. It is assumed that Byproduct Recovery testing would be carried out offsite through equipment suppliers.

4.4 Demonstration Testing

Two types of demonstration testing have been included in the test program plan. The first is as a last segment or run in each variational test period. These are intended to serve as a verification of overall system performance under "near optimal" conditions with a single sludge. As such, it should cover normal variations in sludge properties as well as the normal range of fluctuations in system controls and operational upsets. These runs are necessary to discount potential performance deficiencies or abnormalities under more complex conditions. They should also establish full scale design and operating parameters.

The second is a separate test period for demonstration testing reserved for a composite sludge representative of that which might be processed in a full scale system. Two separate demonstration runs are recommended at slightly different operating conditions -- first, at relatively conservative conditions at which performance objectives can be fairly confidently projected; and, second, at somewhat more aggressive conditions that challenge the system performance and offer the opportunity to reduce design constraints. The sludge composite envisioned for this demonstration test period is a combination of at least two, and no more than four, individual sludges with the following attributes:

- not expected to require residue treatment based upon results of variational testing (e.g., low in lead and cadmium);
- would not normally be segregated for separate campaigns (e.g., no "unique" sludges such as high molybdenum, high acidity or "complex" sludges from a chemistry standpoint); and,
- meet all other constraints on sludge constituents and forms as delineated in Table 4-2.

4.5 Data Requirements

Data requirements vary according to the type of testing and familiarity with test conditions. In general, data acquisition is expected to be most intensive and comprehensive during variational testing and, especially, at the initial stages of testing under new conditions or with new sludges. It is absolutely essential that a detailed set of protocols be established for each type of testing, subject to review and revision continuously throughout the course of the test program.

During variational testing, data acquisition and, in particular, sampling/analysis need to focus on performance of individual unit operations in order to develop an understanding of the process chemistry and equipment performance. As such, data requirements may be highly variable, and general requirements that are prescriptive in nature are not easily established.

Demonstration testing, on the other hand, needs to focus on overall performance and should emphasize closure of material balances and battery limits analyses. Table 4-10 provides a "first cut" summary of samples and analysis for routine pilot plant demonstration testing. These would be applicable to the short demonstration periods at the end of each variational test period as well as the longer demonstration test period.

4.6 Sampling and Analysis

4.6.1 Importance of Effective Sampling and Analysis

Metal-bearing sludges often exhibit substantial variation in composition among the samples both in the minor as well as major components. Because of this variability, developing a process to treat even individual sludges, much less mixed wastes, imposes an additional burden on sampling and analysis over that required for plants which run on relatively uniform feedstocks such as ores or industrial intermediates. This becomes particularly important in process development programs where a thorough understanding of the characteristics of sludges, intermediates, residues and associated solutions are key to defining test conditions and optimizing operations.

Optimizing a process to extract hazardous constituents and/or byproduct values (target components) while leaving the nonhazardous matrix, it is critical to understand the form and distribution of the constituents in order to ensure that the reaction conditions are appropriate to selectively removing them from the substrate matrix. If all constituents are uniformly distributed throughout the matrix as for example in a solid solution, then it may be necessary to dissolve and reform (e.g., reprecipitate) the entire matrix. On the other hand, if the target materials are present as discrete particles or are preferentially enriched in certain fractions of the matrix which are then physically distributed within the matrix, (either uniformly or in "pockets" of localized concentrations), then it may be possible to either remove target materials selectively by physical as well as chemical means, or to "target" chemical extraction based upon a detailed knowledge of the target constituent chemical nature. Thus, well-planned and well-executed sampling and analysis of solids (feeds, intermediates, and residues) are an essential first step in ensuring process optimization.

4 6 2 Sampling

Bulk Solids

Automatic sampling systems such composition samplers are not expected to be useful for this program. All sampling is anticipated to be conducted manually by trained technicians. Sampling should be accomplished by recognized techniques including the use of "thiefing" for highly nonhomogeneous materials. "Thiefing" involves taking selective portions of a particular material based upon the technician's observation of nonhomogeneities to "create" a representative sample. This is often much more desirable than random sampling or attempting to produce a homogeneous mass from which a sample is withdrawn. Producing a homogeneous mass often requires physical alteration which then affects not only the analysis of the distribution of constituents but also the process itself if homogenizing is done on a large scale.

Slurries

When it is important to obtain representative solids either for TSS or solids analyses, slurry samples should generally be withdrawn either directly from tanks or from lines discharging into tanks. In general, separation of solids from slurries should be done immediately, especially for reacting systems that are time sensitive where changes to solids or solution composition are probable. To accommodate these samples, there should be, as a minimum, an aspirator-assisted filtration apparatus in the pilot plant area. Preservation of solids samples usually also requires immediate washing with an appropriate liquor/solution to remove entrained mother liquor. This is most frequently accomplished with two to three displacement rinses with water.

4.6.3 Analyses

Solids Moisture Content

Accurate measurements of moisture content can be determined by drying solids at 105 C ± 5 C in a forced draft oven. Drying should be continued to constant sample weight (i.e., <0.1 % change in weight over a two hour period). Microwave ovens can also be used for approximate checks on moisture content; although the use of microwaves should be cross-checked against the results of convection ovens prior to reliance on results.

Preparation and Dissolution of Metals

Methods for sample preparation and measurement based upon procedures given in USEPA Report SW-846 for Analysis of Solid Wastes should prove useful. For metals analyses, samples can be solubilized by digestion in hot nitric acid (use of approximately 30% HNO_3 for initial digestion followed by incremental addition of hydrogen peroxide after one or two hours; insolubles are filtered off and the solution diluted prior to analysis). This will dissolve most, but not all metals. Lead is a notable exception. The acid insoluble fraction, therefore, needs to be further analyzed. This can be accomplished by fusing the nitric acid-insoluble residue with a sodium carbonate/sodium borate mixture. The fused residue is then leached with water to remove excess fluxing agent, and the solids dissolved in dilute hydrochloric acid for analysis. Careful measurements must be maintained on both fractions to ensure accurate recovery of all metals.

Analysis of Metals in Solution

It is assumed that the analysis of metals in solids and liquors will be accomplished by some form of atomic spectroscopy, which requires that the elements to be measured be dissolved in solution. The measurement techniques which might be used for general elements include induction-coupled plasma emission spectrometry (ICPES), flame atomic absorption spectrophotometry (FLAA) and graphite furnace atomic absorption spectrophotometry (GFAA). There are also specialized techniques appropriate for selected elements such as cold vapor AA for mercury, and hydride generation AA for elements that form volatile hydrides such as selenium and tellurium. The use of these techniques will vary with the circumstances of the operation and the nature of the sample, especially the compositional matrix. Some general comments about these techniques should provide some perspective on applicability and capability. Our preference is the use of IPCES, although some allowances must be made for alternative means for analyses of tin in the presence of high concentrations of iron if tin is an element of concern.

- ICPES involves the measurement of light emitted at characteristic wavelengths by analyte elements when they are passing through a high temperature plasma (argon) discharge. The spectra of most elements contain several lines of different sensitivities providing some opportunities to select wavelengths based upon expected intensity of emission (i.e., concentration range) and potential interferences from other elements expected in the samples. The large number of lines from all elements present as well as the plasma itself result in significant interelement interferences which requires careful selection and performance checking in order to ensure the instrument is delivering accurate results. A primary advantage of IPCES over AA techniques is that IPCES instruments are designed to afford simultaneous or rapid sequential measurement of a suite of elements.

  A typical ICPES instrument may incorporate several channels (up to 30 in some cases) which can be set up for measurement of many elements which might be found in various types of samples, together with interelement corrections in the data handling software. Thus, the simultaneous ICPES approach is often selected for metals measurements in preference to AA spectrophotometry because ICPES offers much faster analysis throughput and is more cost effective for multiple elements.

  Typical sensitivities at optimal analysis wavelengths for IPCES for various elements of interest are given in Table 4-11. These are spectral emission lines often used for wastewater applications and generally afford good sensitivity for this type of process. Interferences in trace element measurements from the presence of high concentrations of major matrix elements such as iron and calcium can be checked by analyzing high purity iron and calcium solutions which have been spiked with trace elements whose spectral lines might suffer interferences. There is, however, one significant interference in the IPCES lines noted -- that of iron on tin (@ 242.95 nanometers) where 20 mg/liter iron gives a response equivalent to 1 mg/liter tin. This proved to be problematic in laboratory analytical work.

- FLAA involves measurement of light absorbed at characteristic wavelengths by analyte elements as they are passing through a flame (generally acetylene with air or N_2O). AA measurements (flame or furnace) are generally carried out as single element measurements. FLAA measurements, which are made at specific element-unique wavelengths, are relatively free of interferences from other elements. Typical sensitivities at optimal analysis wavelengths for FLAA for various elements of interest are given in Table 4-11.

- Graphite furnace AA. in which an electrically heated graphite tube at very high temperatures is used in place of the flame. offers significantly increased sensitivity for many elements over that of FLAA: but, it is a much more complex technique involving transfer of microvolumes of sample into the tube and addition of various reagents to effect accurate analyses. While it is extremely sensitive, the technique has the potential for many interferences from various elements and compounds present in samples, and thus is of limited use in samples with a complex, varying composition.

- If X-ray fluorescence or other methods for direct analysis of solids (e.g., spark source emission or mass spectrometry) which do not require dissolution of the sample are employed, then sample preparation steps must be directed toward ensuring that the samples presented to the instrument are uniform and homogeneous in composition, including moisture content. Solid standards of known composition and uniformity must be used to calibrate the measurement instrument. It is particularly important to utilize a standard with a matrix similar to that of the samples to be measured.

<u>Matrix Substrate Anions and Cations</u>

Measurement of anions and specific cation species in the sludges and sludge residues can be carried out using standard wastewater and microchemical analytical methods shown in Table 4-12.

SECTION 4: TEST PROGRAM PLAN TABLES AND DRAWINGS

Table 4-1. Summary of Test Periods

Test Periods	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
Expected Duration	2 - 3 Months	1 - 2 Months	1 - 2 Months	1 Month	1 - 2 Months	1 - 2 Months	OPEN
Sludge	Sludge A	Sludge B	Sludge C	Composite	Sludge D	Sludge E	TBD
Sludge Type(s)	Simple	Simple	Simple	Simple	Complex	Complex	TBD
Testing Style	Variational	Variational	Variational	Demonstration	Variational	Variational	TBD
Focus of Segments							
Segment 1	Sludge Milling	Sludge Milling	Sludge Milling	Condition 1[2]	Sludge Milling	Sludge Milling	
Segment 2	Acid Extraction	Acid Extraction	Acid Extraction	Condition 2[2]	Acid Extraction	Acid Extraction	
Segment 3	Metals Recovery	Metals Recovery	Metals Recovery	---	Metals Recovery	Metals Recovery	
Segment 4	2 Week Demo	2 Week Demo	2 Week Demo	---	2 Week Demo	2 Week Demo	
Offline Testing[1]							
General	Lab Techniques	Lab Techniques	---	---	Lab Techniques	---	
Acid Extraction	Grind Temperature	Grind Temperature	Grind Temperature	---	Grind Temperature	Grind Temperature	
Metal Recovery	pH/Partitioning	pH/Partitioning	pH/Partitioning	---	pH/Partitioning	pH/Partitioning	
Residue Treating	Not Expected	Not Expected	Not Expected	---	Expected	Expected	
Offsite Testing	Sodium Sulfate Recovery (during Demo)	Sodium Sulfate Recovery (during Demo)	Sodium Sulfate Recovery (during Demo)	Sodium Sulfate Recovery (One Condition)	Sodium Sulfate Recovery (during Demo)	Sodium Sulfate Recovery (during Demo)	

[1]**Offline testing requirements will vary depending upon system performance**

[2]**See section 4.4**

Table 4-2. Example Matrix of Sludges

General Constraints:
No Arsenic (<0.05%)
No Cyanide
No Mercury
No Oily Sludges
No Chloride Sludges (e.g., HCl Pickling)

Characteristics	Sludge A	Sludge B	Sludge C	Sludge D	Sludge E
General					
Sludge Consistency	Dry	Dry/Moist	Dry/Moist	No Free Draining	No Free Draining
Source Consistency	High	High	High	Moderate	Moderate
Substrate					
Chloride	Low	Low	Low/Moderate	Low/Moderate	Low/Moderate
Alkalinity	Low	Low/Moderate	Low/Moderate	No Limit	No Limit
Phosphate/Sulfate Ratio	Low	No Limit	No Limit	No Limit	No Limit
Ammonia	Nil	Nil	Nil	Nil	Low
Metals					
Lead	<0.1%	<0.1%	<0.1%	Low/Moderate	Low/Moderate
Cadmium	<0.05%	<0.05%	<0.05%	Low/Moderate	Low/Moderate
Fe^{+2}/Fe^{+3} Ratio	<0.10	<0.10	<0.10	<0.10	Unspecified
Copper	Low	Low	High	Unspecified	Unspecified
Other	Low Molybdenum	Low Molybdenum	Low Molybdenum	Unspecified	Unspecified
Representative Sludges	**Rubikon**	**Elzett**	**BHG & Ganz**	**MOM**	---

Table 4-3. Summary of Performance Objectives and Control Variables

Process Area	Principal Performance Parameters	Control Variables		Other Significant Process Issues
		Principal	Secondary	
Sludge Preparation -Milling	• Sludge PSD	• Holdup Time • Slurry Concentration	• Ball Charge • Power Requirement	
Acid Extraction	• Metals Dissolution • Residue Properties - "Nonhazardous" - Dewaterability	• Acid Stoichiometry • No. of Stages • Holdup Time • Temperature	• Degree of Agitation • Acid Concentration	• Gas Evolution - Acid (SO_3,HCl) - Other(NH_3)?
Metals Recovery	• Metals Recovery • Metals Partitioning • Phosphate Removal	• pH • Use of Limestone • Holdup Time • Solids "Seeding"	• Degree of Agitation • Use of Soda Ash Slurry • Limestone Grind	• Disposition of Cl^- • Fe^{+2}/Fe^{+3} Ratio Impact
Residue Treatment (Offline Testing)	• Pb Removal • Cu & Cd Removal	• HCl Requirement • Temperature • Fe Cementation • Residue Grinding	• Degree of Agitation • Holdup Time	• Acid Gas Evolution • Fe^{+2}/Fe^{+3} Ratio Impact
Sodium Sulfate Crystallization (Offsite Testing)	• Salt Purity • Salt Recovery	• Wastewater Minimization • Number of Effects	• Energy Requirement	• Cl^- Impact • Phosphate Impact

Table 4-4. Sludge Preparation Area Testing (Solids Grinding)

Performance Objectives

Primary:	1)	Achieve specified solids particle size distribution (PSD), nominally set at 90-95% < 200 mesh (75 micron).
	2)	Achieve specified solids particle size distribution at slurry concentrations of 25 - 30 wt% insoluble solids or greater.
Secondary:	3)	Optimize net solids holdup time at minimum machine size.

Initial Baseline Conditions (Nominal)

Grinding of sludge solids was not tested as a part of the laboratory test program. Therefore, testing of the milling of sludges will need to rely on experiential information and empirical results. The following represent first approximations to conditions expected to achieve the desired performance objectives.

Number of Milling Stages:	1
Mill Holdup Time:	1 - 2 hours batch basis (solids throughput)
Slurry Concentration:	25 to 30% suspended solids

Variational Conditions (Potential)

There is no current basis for setting the ranges of operational parameters for variational testing. The following are based upon experience and are intended to serve as guidelines only.

Number of Milling Stages:	1
Mill Holdup Time:	1 - 6 hours batch basis (solids throughput)
Slurry Concentration:	20 to 40% suspended solids
Other:	Ball charge Machine RPM Slurry charge

Table 4-5. Acid Extraction Area Testing

Performance Objectives

Primary: 1) Dissolution/extraction of metals to achieve a "nonhazardous" residue in accordance with the criteria set forth in Table 4-6.

Secondary: 2) Produce a residue which is readily dewatered.
3) Optimize acid stoichiometry in concert with sludge milling requirements, number of extraction stages, operating temperature and holdup times.

Initial Baseline Conditions (Nominal)

The following "Baseline Conditions" derive from the results of laboratory batch testing and should be considered *initial* starting points for the overall test program. As experience is gained through actual pilot plant operations with different sludges, these conditions should be re-evaluated and new *standard* conditions established as warranted.

Number of Extraction Stages:	3
Milled Solids Particle Size:	90-95% < 200 mesh
Overall Acid Stoichiometry:	120%
Operating Temperatures:	3rd Stage - 60 C 2nd Stage - 50 C 1st Stage - 40 C
Extraction Holdup Times:	3rd Stage - 2 hours 2nd Stage - 2 hours 1st Stage - 1 hour

Variational Conditions (Potential)

The following range of conditions derive from the results of laboratory batch testing and should be considered *initial* starting points for the overall test program in setting conditions for parametric tests during different Test Periods. As experience is gained through actual pilot plant operations with different sludges, these conditions should be re-evaluated and new ranges established as warranted.

Number of Extraction Stages:	2 or 3
Milled Solids Particle Size:	90-95% < 325 mesh to 90-95% < 100 mesh
Overall Acid Stoichiometry:	105% to 140%
Operating Temperatures:	3rd Stage - 50 - 80 C 2nd Stage - 40 - 80 C 1st Stage - 30 - 40 C
Extraction Holdup Times:	3rd Stage - 1 to 4 hours 2nd Stage - 1 to 4 hours 1st Stage - 0.5 to 1 hour

Table 4-6. Environmental Performance Criteria

Hazardous Waste Standards - Metals in Soils & Solids

Element	Concentration	Element	Concentration
As	15	F	500
B	100	Hg	2
Be	10	Mo	10
Cd	5	Ni	100
Co	50	Pb	100
Cr	100	Se	10
Cu	100	Zn	300

Wastewater Discharge Standards (Penalty-Free)

Parameter	Concentration (mg/kg)	Parameter	Concentration (mg/kg)
COD	100	Phosphate (Total)	2
Oil & Grease	10	Cyanide (Free)	0.2
Organic Solvent	5	Cyanide (Total)	10
Detergent	0.05 (cc/l)	Toxicity (Dilution)	LC 50% Demand
pH	5-9 (pH units)	Ag (Total)	0.1
Total Salt (Natural)	2000	As (Total)	0.1
Total Salt (Technical)	2000	Cd (Total)	0.05
Sodium Equivalent	45	Cr (Total)	1
Phenol	3	Cr(VI)	0.5
Total Floating Mat'l	200	Cu (Total)	2
Bitumen	2	Fe (Total)	20
Ammonia (Total, N)	30	Hg (Total)	0.01
Sulfide	2	Mn (Total)	5
Chlorine (Active)	2	Ni (Total)	1
Fluoride	10	Pb (Total)	0.2
Nitrate	80	Zn (Total)	5

Table 4-7. Metals Recovery Area Testing

Performance Objectives

Primary:
1) Complete precipitation of metals to achieve metals concentrations in accordance with wastewater discharge standards set forth in Table 4-6.
2) Achieve partitioning of metal values into precipitates compatible with market acceptability.
3) Produce precipitates which are readily dewatered.

Secondary:
4) Selectively remove phosphate from solution.
5) Optimize use of caustic, soda ash and limestone.

Initial Baseline Conditions (Nominal)

The following "Baseline Conditions" derive from the results of laboratory batch testing and should be considered *initial* starting points for the overall test program. As experience is gained through actual pilot plant operations with different sludges, these conditions should be re-evaluated and new *standard* conditions established as warranted.

Number of Recovery Stages:	4 (Including Pre-Neutralization)
Chemical Additives:	Caustic Sodium Carbonate - as solution (~15%)
pH Target Levels:	Pre-Neutralization - ~2.8 1st Stage - ~3.3 2nd Stage - ~6 3rd Stage - ~9
Operating Temperatures:	20 - 35 C (Uncontrolled)
Extraction Holdup Times:	1 hour each Stage
Solids Recycle (Seeding):	None

Variational Conditions (Potential)

The following range of conditions derive from the results of laboratory batch testing. These should be considered *initial* starting points for the overall test program in setting conditions for parametric tests during different Test Periods. As experience is gained through actual pilot plant operations, these conditions should be re-evaluated and new ranges established as warranted.

Number of Recovery Stages:	3 to 5
Chemical Additives:	Caustic Sodium Carbonate - as solution (up to 20%) - as slurry (up to 50%) Limestone - as slurry (up to 40%) - PSD of 95% < 325 mesh to 95% < 200 mesh

Table 4-7. Metals Recovery Area Testing (CONT.)

pH Target Levels:	To be determined
Operating Temperatures	Controlled (Undefined/Variable)
Extraction Holdup Times:	0.5 to 1.5 hours each Stage
Solids Recycle (Seeding):	to 5%?

Table 4-8. Residue Treatment Area (Onsite Bench-Scale Testing)

Performance Objectives

Primary:
1) Complete dissolution/extraction of residual metal values (expected to be primarily Pb or, to a lesser extent, Cd or Cu) to achieve a "nonhazardous" residue in accordance with the criteria set forth in Table 4-6.
2) Selectively recover dissolved iron by cementation.
3) Produce residue which is readily dewatered.

Secondary:
4) Minimize dissolution of iron.
5) Single stage extraction at less than 60 C.

Initial Baseline Conditions (Nominal)

The following "Baseline Conditions" derive from the results of laboratory batch testing and should be considered *initial* starting points for the overall test program. As experience is gained through actual pilot plant operations with different sludges, these conditions should be re-evaluated and new *standard* conditions established as warranted.

Number of Extraction Stages:	1
Chemicals:	Hydrochloric Acid Limestone
Operating Temperature:	50 C
Extraction Holdup Time:	4 hours
Pre-Extraction Solids Grinding:	None

Variational Conditions (Potential)

The following range of conditions derive from the results of laboratory batch testing and should be considered *initial* starting points for the overall test program in setting conditions for parametric tests during different Test Periods. As experience is gained through actual pilot plant operations with different sludges, these conditions should be re-evaluated and new ranges established as warranted.

Number of Extraction Stages:	1 or 2
Chemicals:	Hydrochloric Acid Limestone Other Additives
Operating Temperatures:	40 - 60 C
Extraction Holdup Times:	2 to 6 hours
Pre-Extraction Solids Grinding:	To be determined

Table 4-9. Byproduct (Na_2SO_4) Recovery Area (Offline Testing)

Performance Objectives

Primary:
1) Attain 90+% recovery of Na_2SO_4 from residual solution.
2) Attain 98% Na_2SO_4 salt purity.

Secondary:
3) Minimize dissolution of iron.
4) Single stage extraction at less than 60 C.

Initial Baseline Conditions (Nominal)

Byproduct recovery (of Na_2SO_4) was not tested as a part of the laboratory test program. Testing will need to be conducted offline and rely on the expertise of crystallization/evaporation of equipment/systems suppliers.

Table 4-10. Summary of Data Recommendations

Table 4-10A. Sampling/Analysis Recommendations for Demonstration Testing (Part 1)

	General Plant						Sludge Preparation		
								Milled Slurry*	
	Makeup Water (Cold)	Makeup Water (Hot)	Sodium Hydroxide Supply	Sodium Carbonate Solids Supply	Limestone Solids Supply	Sulfuric Acid Supply	Sludge Feed	Solids Fraction	Solution Fraction
Sampling Frequency	W	W	L	L	L	L	B	B	B
Analysis Frequency	W	W	T	T	L	T	B	B	B
Analyses									
Substrate Cations									
Aluminum	W	W	---	T	T	T	B	B	T
Calcium	W	W	---	T	L	T	B	B	T
Iron (II)	W	W	---	T	T	T	B	B	T
Iron (Total)	W	W	---	T	T	T	B	B	T
Magnesium	W	W	---	T	T	T	B	B	T
Manganese	W	W	---	T	T	T	B	B	T
Potassium	W	W	---	T	T	T	B	B	T
Sodium	W	W	T	T	T	T	B	B	T
Tin	W	W	---	T	T	T	B	B	T
Titanium	W	W	---	T	T	T	B	B	T
Major Anions									
Carbonate	W	W	---	T	L	---	B	B	---
Chloride	W	W	---	T	T	T	B	B	T
Cyanide	W	W	---	T	T	---	B	B	---
Fluoride	W	W	---	T	T	T	B	B	T
Nitrate	W	W	---	T	T	T	B	B	T
Phosphate	W	W	---	T	T	T	B	B	T
Silica	W	W	---	T	T	T	B	B	T
Sulfate	W	W	---	T	T	T	B	B	T
Other Parameters									
TSS/% Solids*	W	W	---	---	B	B	B	B	---
Solids PSD	---	---	---	---	L	---	B	B	---
pH*	W	W	---	---	---	---	---	---	T
Acidity/Alkalinity	W	W	T	---	T	T	B	B	T
Total Carbon	W	W	---	T	T	T	B	B	T
Ammonia	W	W	---	---	T	---	B	B	---
Acid Insolubles	W	W	---	T	T	T	B	B	T
Full Metals Suite	N	N	T	T	T	T	B	N	T
Target Metals Suite	W	W	T	T	T	T	B	B	T

Codes:

- B Each "Batch"
- L Each delivery "Load"
- N As "Needed" based upon sludge composition
- W "Weekly"
- T "Troubleshooting" only
- * Analysis on slurry prior to splitting into fractions or solids prior to analytical washing

Table 4-10B. Sampling/Analysis Recommendations for Demonstration Testing (Part 2)

	Acid Extraction Area										
	1st Stage					Intermediate Stage (If Used)			Last Stage		
	Feed Slurry*		Filter Cake		Filtrate	Filter Cake		Filtrate	Filter Cake		Filtrate
	Solids Fraction	Solution Fraction	As Produced	Analytically Washed	Liquor	As Produced	Analytically Washed	Liquor	As Produced	Analytically Washed	Liquor
Sampling Frequency	B	B	B	B	B	B	B	B	B	B	B
Analysis Frequency	B	W	T	T	B	T	T	T	B	B	T
Analyses											
Substrate Cations						T	T	T	B	B	T
Aluminum	B	W	T	T	B	T	T	T	B	B	T
Calcium	B	W	T	T	B	T	T	T	B	B	T
Iron (II)	B	W	T	T	B	T	T	T	B	B	T
Iron (Total)	B	W	T	T	B	T	T	T	B	B	T
Magnesium	B	W	T	T	B	T	T	T	B	B	T
Manganese	B	W	T	T	B	T	T	T	B	B	T
Potassium	B	W	T	T	B	T	T	T	B	B	T
Sodium	B	W	T	T	B	T	T	T	B	B	T
Tin	B	W	T	T	B	T	T	T	B	B	T
Titanium	B	W	T	T	B	T	T	T	B	B	T
Major Anions											
Carbonate	B	W	T	T	B	T	T	T	B	B	T
Chloride	B	W	T	T	B	T	T	T	B	B	T
Cyanide	B	W	T	T	B	T	T	T	B	B	T
Fluoride	B	W	T	T	B	T	T	T	B	B	T
Nitrate	B	W	T	T	B	T	T	T	B	B	T
Phosphate	B	W	T	T	B	T	T	T	B	B	T
Silica	B	W	T	T	B	T	T	T	B	B	T
Sulfate	B	W	T	T	B	T	T	T	B	B	T
Other Parameters											
TSS/% Solids*	B	B	B	B	B	B	B	B	B	B	B
Solids PSD	B	—	—	—	—	—	—	—	—	—	—
pH*	—	B	—	—	B	—	—	B	—	—	B
Acidity/Alkalinity	B	B	T	T	B	T	T	T	B	B	T
Total Carbon	B	W	T	T	B	T	T	T	B	B	T
Ammonia	B	W	T	T	B	T	T	T	B	B	T
Acid Insolubles	B	W	T	T	B	T	T	T	B	B	T
Full Metals Suite	N	N	T	T	N	T	T	T	N	N	T
Target Metals Suite	B	W	T	T	B	T	T	T	B	B	T

Codes:

- **B** Each "Batch"
- **L** Each delivery "Load"
- **N** As "Needed" based upon sludge composition
- **W** "Weekly"
- **T** "Troubleshooting" only
- * Analysis on slurry prior to splitting into fractions or solids prior to analytical washing

Table 4-10C. Sampling/Analysis Recommendations for Demonstration Testing (Part 3)

	Metals Recovery Area						
				Each Precipitation Stage			
	Sodium Carbonate Solution	Sodium Carbonate Slurry	Limestone Slurry	Reacted Slurry	Filter Cake		Filtrate Liquor
					As Produced	Analytically Washed	
Sampling Frequency	B	B	B	B	B	B	B
Analysis Frequency	T	T	T	B	B	B	B
Analyses							
Substrate Cations							B
Aluminum	T	T	T	B	B	B	B
Calcium	T	T	T	B	B	B	B
Iron (II)	T	T	T	B	B	B	B
Iron (Total)	T	T	T	B	B	B	B
Magnesium	T	T	T	B	B	B	B
Manganese	T	T	T	B	B	B	B
Potassium	T	T	T	B	B	B	B
Sodium	T	T	T	B	B	B	B
Tin	T	T	T	B	B	B	B
Titanium	T	T	T	B	B	B	B
Major Anions							
Carbonate	T	T	T	B	B	B	B
Chloride	T	T	T	B	B	B	B
Cyanide	T	T	T	B	B	B	B
Fluoride	T	T	T	B	B	B	B
Nitrate	T	T	T	B	B	B	B
Phosphate	T	T	T	B	B	B	B
Silica	T	T	T	B	B	B	B
Sulfate	T	T	T	B	B	B	B
Other Parameters							
TSS/% Solids*	B	B	B	B	B	B	B
Solids PSD	—	W	W	—	—	—	—
pH*	—	—	—	B	—	—	B
Acidity/Alkalinity	T	T	T	B	B	B	B
Total Carbon	T	T	T	B	B	B	B
Ammonia	T	T	T	B	B	B	B
Acid Insolubles	T	T	T	B	B	B	B
Full Metals Suite	T	T	T	T	T	T	T
Target Metals Suite	T	T	T	B	B	B	B

Codes:

- **B** Each "Batch"
- **L** Each delivery "Load"
- **N** As "Needed" based upon sludge composition
- **W** "Weekly"
- **T** "Troubleshooting" only
- * Analysis on slurry prior to splitting into fractions or solids prior to analytical washing

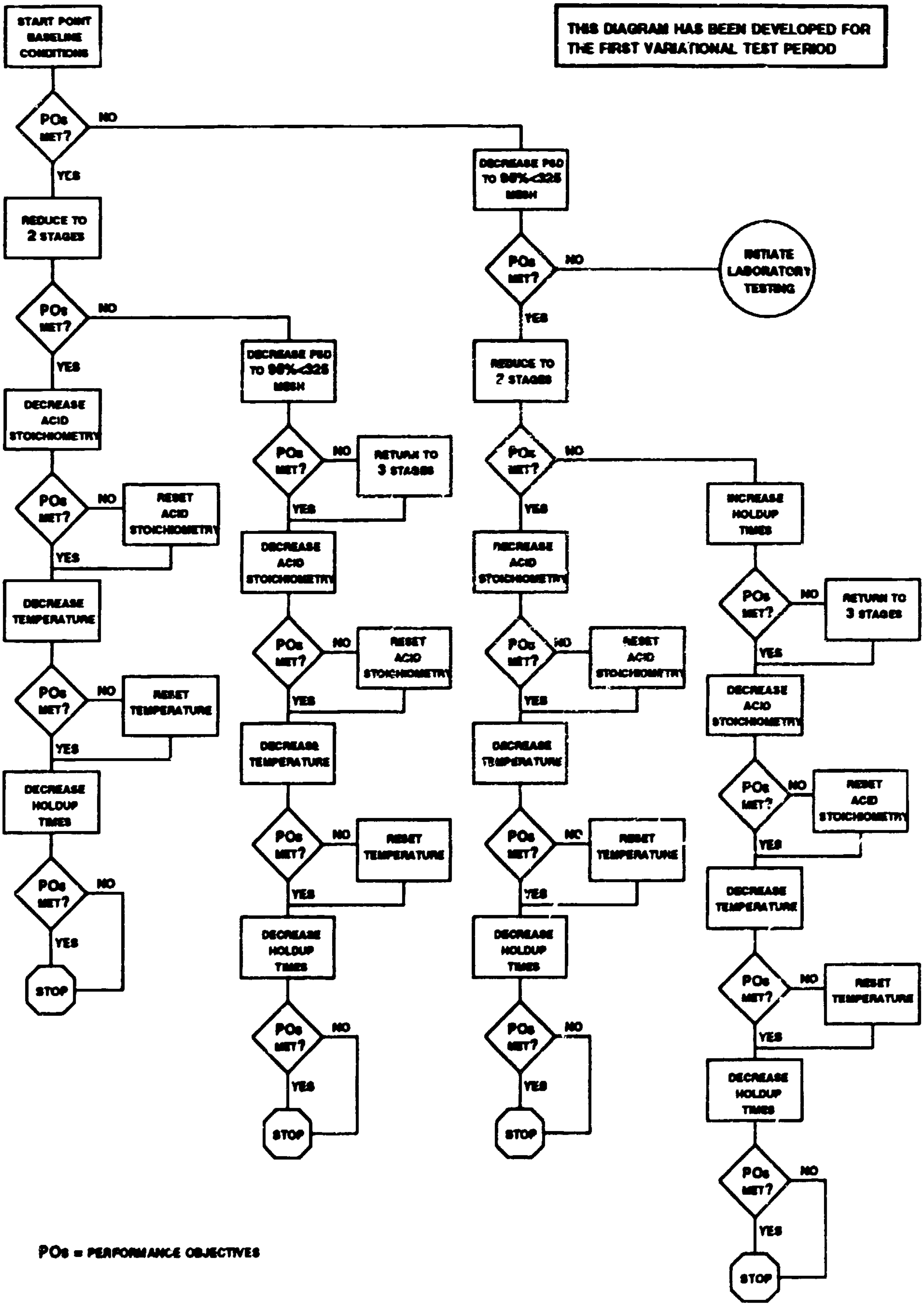
Table 4-11. Wavelengths for ICPES and Flame AA Elemental Analysis

Element	ICPES		Flame AA	
	Wavelength (nM)	Sensitivity (mg/l)	Wavelength (nM)	Sensitivity (mg/l)
Ag	328.1	0.005	328.1	0.06
Al	308.2	0.45	324.7	1
As	193.7	0.03	193.7	0.02
Ba	493.4	0.02	553.6	0.04
Be	313.0	0.0005	234.9	0.03
Ca	317.9	0.1	422.7	0.08
Cd	226.5	0.003	228.8	0.03
Co	228.6	0.05	240.7	0.2
Cr	267.7	0.05	357.9	0.3
Cu	324.7	0.02	324.7	0.1
Fe	259.9	0.05	248.3	0.1
K	766.5	0.25	766.5	0.04
Mg	279.1	0.25	285.2	0.01
Mn	257.6	0.02	279.5	0.05
Mo	202.0	0.09	313.3	0.4
Na	330.2	0.03	589.6	0.02
Ni	231.6	0.15	232.0	0.2
Pb	220.3	0.05	283.3	0.5
Sb	206.8	0.03	217.6(231.1)	0.5
Se	196.0	0.08	196.0	0.005(Hydride)
Te	214.3	0.1		
Ti	334.9	0.15		
Tl	190.8	0.04	276.8	0.5
V	292.4	0.08	318.4	0.8
Zn	213.8	0.02	213.9	0.02
Sn	242.9	0.1 (Fe Interference)	286.3	4

Table 4-12. Measurement of Anions and Non-Metallic Elements

Element/Anion	Method	Reference
C (Total Carbon)	Leco Furnace (Infrared)	Leco Instrument Manual
Cl^- (Chloride)	Extraction/Ion Chromatography	EPA 300
Cr^{+6} (Chromium)	Extraction/Colorimetric	SW-846 7196A
CN^- (Cyanide)	Distillation/Colorimetric	SW-846 9012
F^- (Fluoride)	Distillation/Fluoride Electrode	APHA 4500-F
NH_3 (Ammonia)	Distillation/NH_3 Electrode	APHA 4500-NH_3
NO_3 (Nitrate)	Extraction/Ion Chromatography	EPA 300
P (Phosphorus,Total)	Dissolution/Colorimetric	APHA 4500-P
S (Sulfur, Total)	Leco Furnace (Infrared)	Leco Instrument Manual
Si (Silicon)	Dissolution/Colorimetric	APHA-Si

Figure 4-1. Test Program Decision Diagram - Acid Extraction



POs = PERFORMANCE OBJECTIVES

Figure 4-2. Test Program Decision Diagram - Metals Recovery

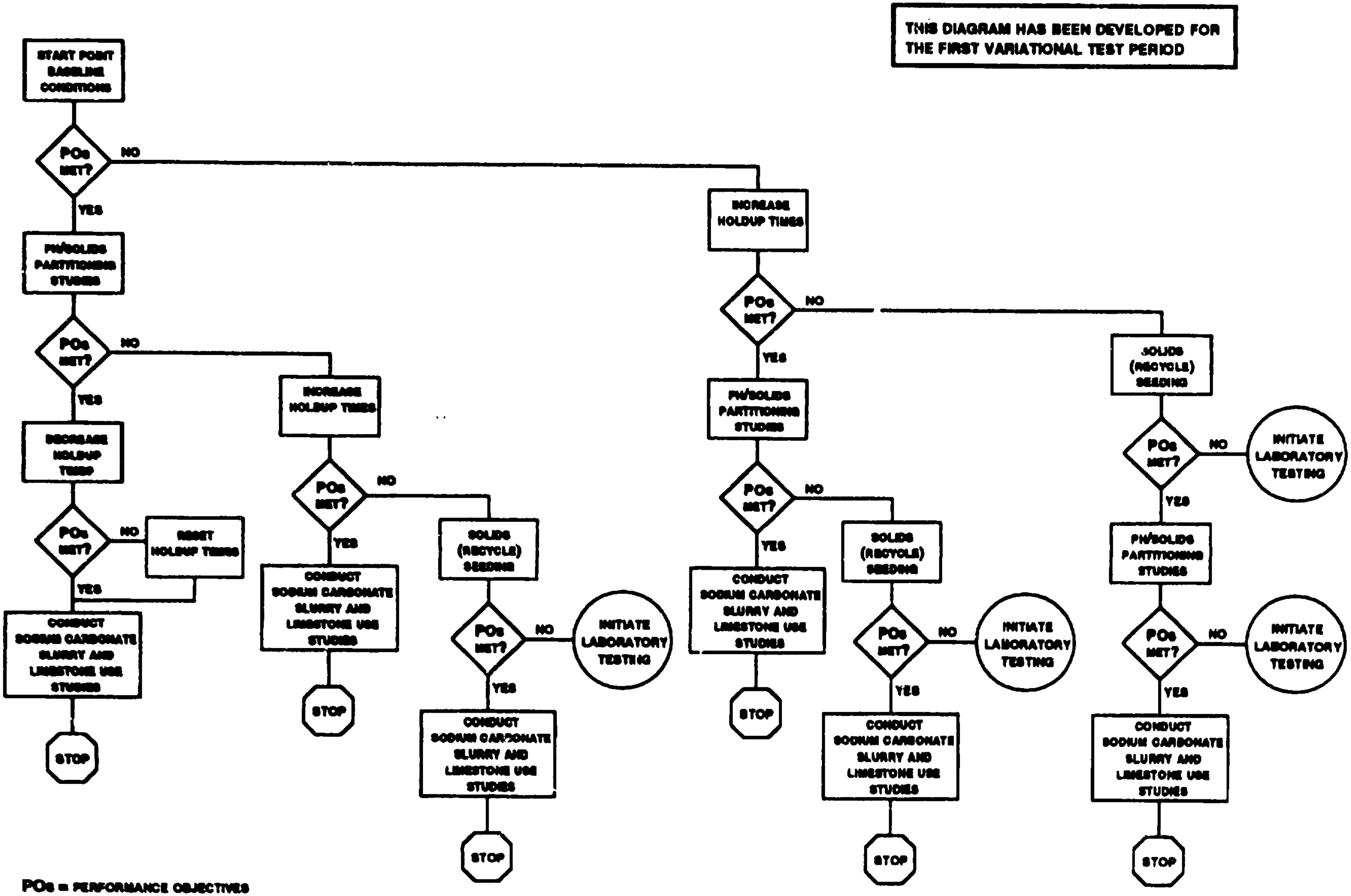
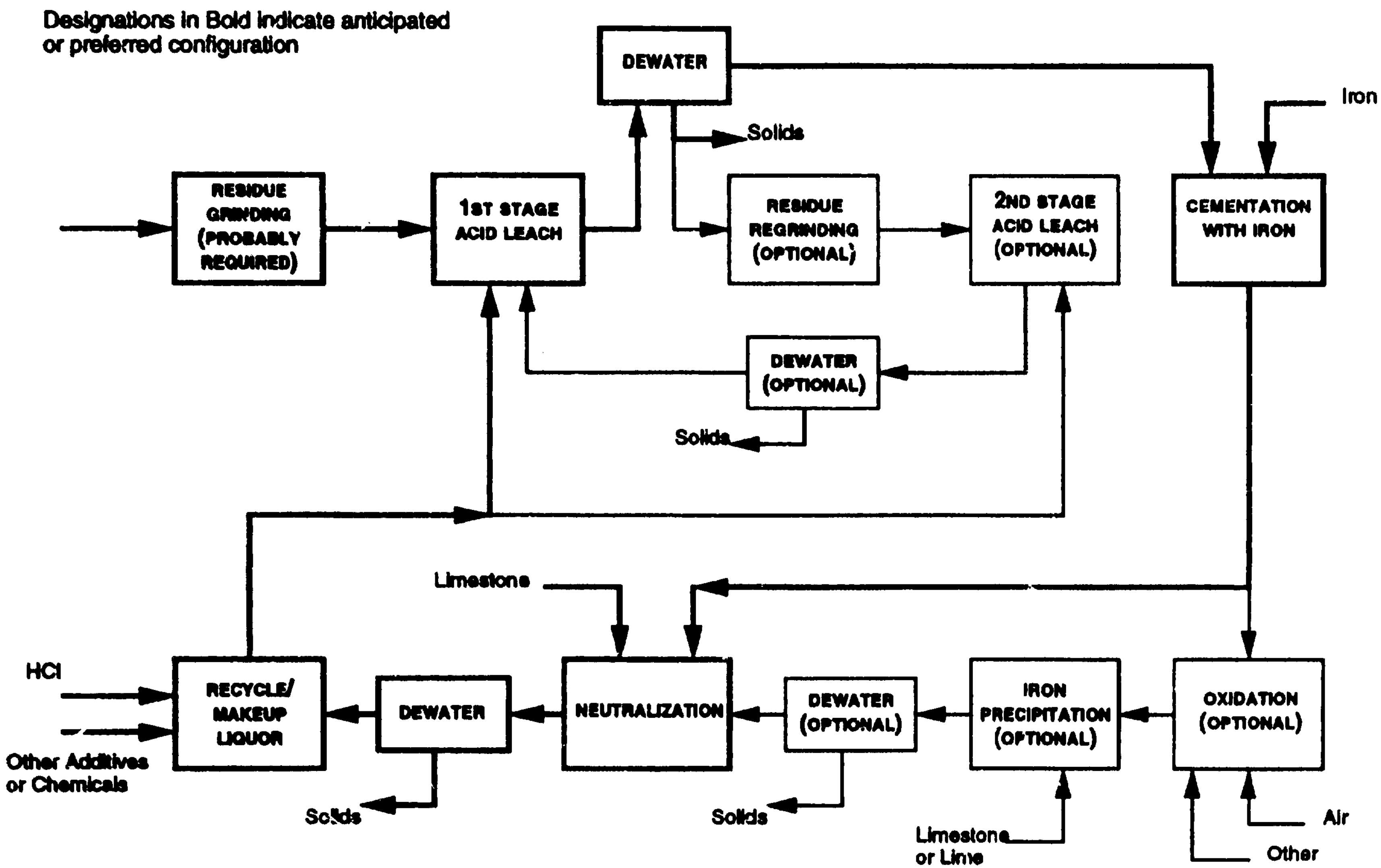


Figure 4-3. Residue Treatment Laboratory Batch Test Configuration



Note: This is a test configuration diagram, not a process flow diagram

Figure 4-4A. Test Program Decision Diagram - Residue Treatment (Part 1)

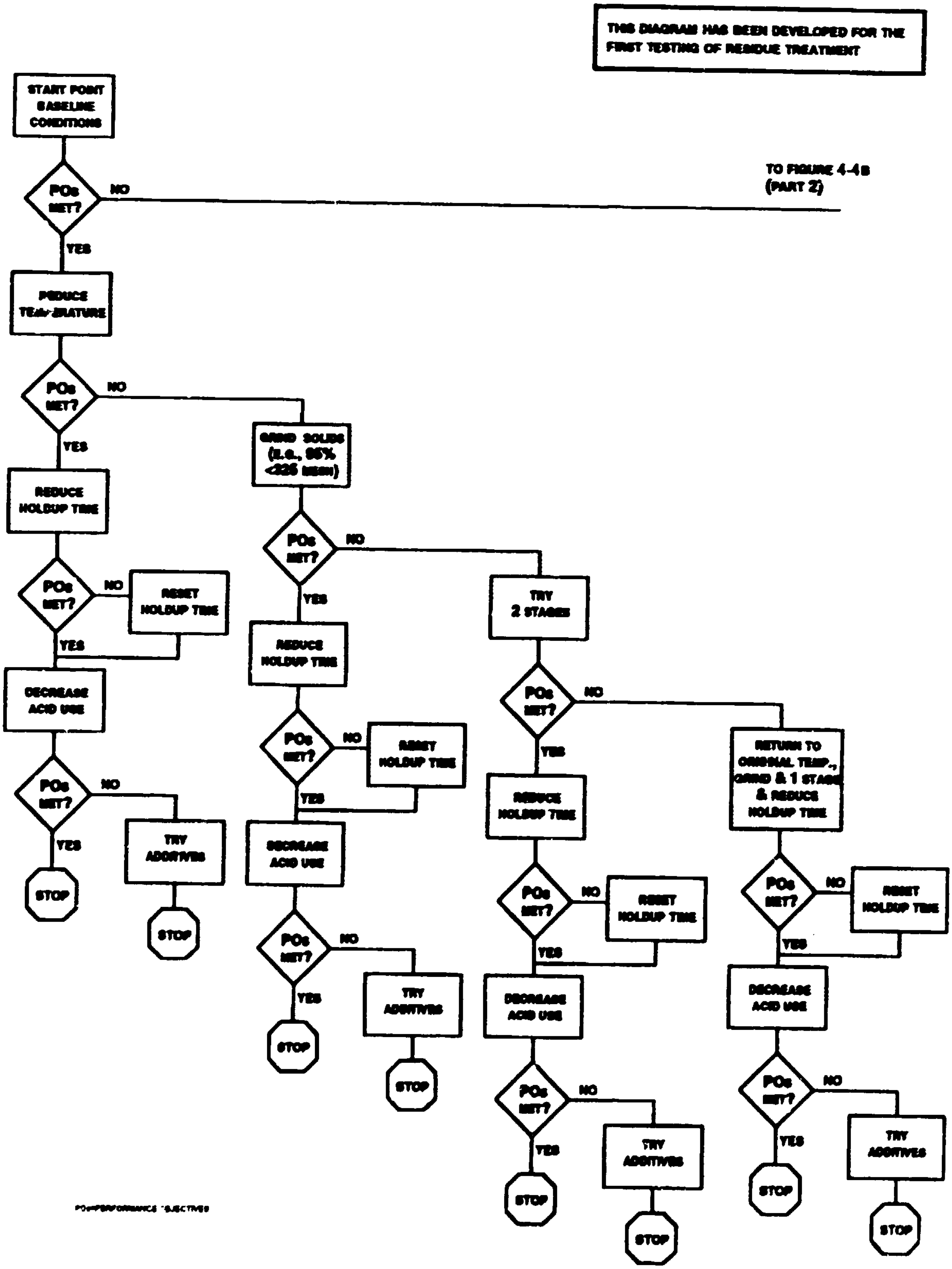
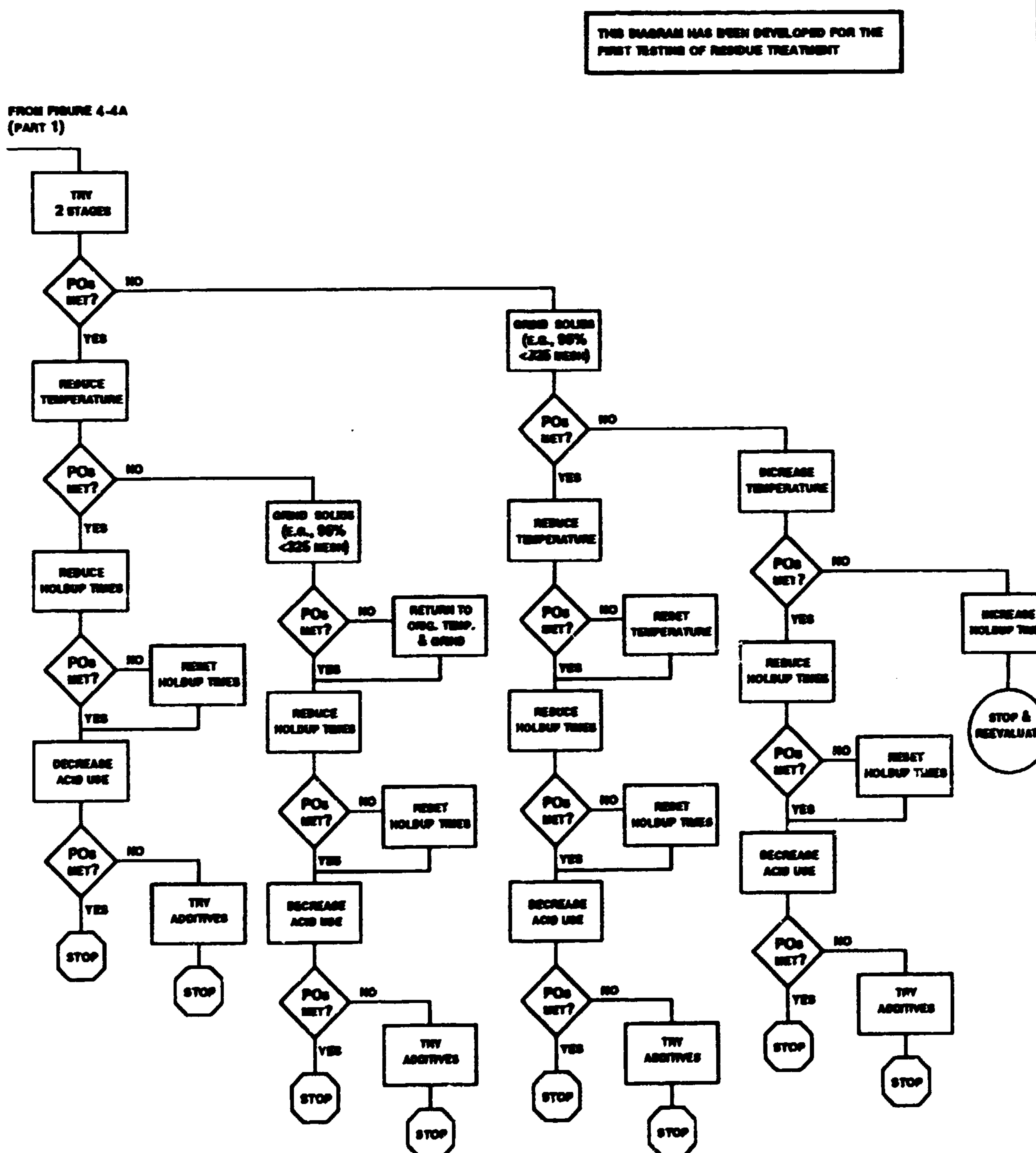


Figure 4-4B. Test Program Decision Diagram - Residue Treatment (Part 2)



PO=PERFORMANCE OBJECTIVES

SECTION 5: ENGINEERING DESIGN

5.0 Engineering Design

5.1 Design Drawings and Specifications

All drawings and specifications are contained in appendixes 1. 2. 3. and 4.

5.2 Cost Estimate Summary

Prices in USD exchange rate is the Hungarian National Bank's mean rate of 12 December, 1995. Customs fee and charges: 23, 5%.

5.2.1 Process Equipment

(This cost includes: purchase price, packing, shipping to the construction/assembling contractor's site of imported and home machines and equipment, insurance, cost of material management).

5.2.1.1 Solid material preparation area: $ 100, 263.

5.2.1.2 Acid extraction area: $ 200, 346.

5.2.1.3 Metal recovery area: $ 300, 437.

5.2.1.4 Steel structure skids, 21,1 tons: $ 68, 580.

5.2.2 Assembling, Fitting of Process Equipment

This cost includes fitting and assembling of all machines and vessels on the skids, assembling the pipelines, pipe hangers and supports, complete pipe fitting, hydrostatic tests, functional tests per assembly units) $ 377,110.

5.3 Electric Power Transmission

(Cost components: installation of all electric equipment, fittings, cables, complete electric fitting work, functional tests per units of assembly) $ 70, 810.

5.4 Instrumentation

(The costs include: purchase price of instruments and auxiliary material; for installation, complete fitting work, functional tests per units of assembly) $ 113,745.

5.5 Transportation of the Complete Assembled Plant to the Site: $ 11, 215, - $ 1,688.950.

6.0 Estimate of Further Costs

6.1 Arrangement of the site, creation of utilities connections 60,000.

6.2 Participation at and carrying out of test run $ 60,000.

6.3 Modifications as required upon test run experiences (10% on points 1 - 4 above) $ 167,775, -
Total: $1,976,725.

GLOSSARY

Galvanic Sludge -	Sludges containing waste products (especially metals) from metals plating as etching operations.
PFCD -	Process flow and control diagram
PFD -	Process Flow diagram
P & ID -	Piping and instrumentation diagram
Pilot Plant -	A fully operational version in smaller scale of a proposed operating facility. The pilot plant is intended as a test bed for industrial scale process testing and modification. For this project, the pilot plant is intended to be used in continuing operation as a transportable satellite of the full scale plant after process proving.
SCFM -	Standard cubic feet per minute
TBD -	To be developed
TDS -	Total dissolved solids
TSS -	Total suspended solids

ERRATA

Sections 5.2.1 et seq are replaced as follows:

5.2.1. Process equipment
(The cost include: purchase price, packing, shipping to the construction/assembling contractor's site of imported and home machines and equipment, insurance, costs of material management)

5.2.1.1.	Solid material preparation Area 100	263.705,-
5.2.1.2.	Acid extraction Area 200	346.035,-
5.2.1.3.	Metal recovery Area 300	437.755,-
5.2.1.4.	Steel structure skids, 21,1 tons	68.580,-

5.2.2.	Assembling, fitting of process equipment (The cost includes fitting and assembling of all machines and vessels on the skids, assembling the pipelines, pipe hangers and supports, complete pipe fitting, hydrostatic tests, functional tests per assembly units)	377.110,-
5.2.3.	Electric power transmission (Cost components: installation of all electric equipment, fittings, cables, complete electric fitting work, functional tests per units of assembly)	70.810,-
5.2.4.	Instrumentation (The costs include: purchase price of instruments and auxiliary material for installation, complete fitting work, functional tests per units of assembly)	113.745,-
5.2.5.	Transportation of the complete assembled plant to the site	11.215,-
	Costs of the complete pilot plant equipment	1.688.950,-

5.2.6.	Estimate of further costs	
	6.1. Arrangement at the site, creation of utilities connections	60.000,-
	6.2. Participation at and carrying out of test run	60.000,-
	6.3. Modifications as required upon test run experiences (10 % on points 1-4 above)	167.775,-
	TOTAL:	1.976.725,-

Section 6 is deleted