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19403

TECHNO-ECONOMIC PROFILE

ON

BATTERY RECYCLING

JULY 1991

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1.0 EXECUTIVE SUMMARY

The lead-acid accumulator is the principle source of secondary lead in developed countries. Adverse operating conditions, partly the result of the fluctuating price of primary (and hence of secondary) lead but principally that of increasingly stringent environmental requirements have greatly reduced the number of secondary smelters operating in the United Kingdom and in the USA during the last decade. Compliance with such requirements continues to impose rapid change on the technology of secondary lead smelting. Several new processes are under development but only the 'Engitec' appears to have progressed to the stage at which reasonably detailed operating data are available.

The minimum viable size for a new recycling plant under European conditions is at least 50,000 tonnes/y and possibly as high as 80,000 tonnes/y of used batteries. No country of the Arabian Peninsula approaches this battery generation rate. The combined battery supply available from Saudi Arabia, United Arab Emirates Kuwait, Qatar, Bahrain and Oman would be needed to keep the smallest commercially available plant in full continuous production - an 'Engitec' plant rated at 30,000 t/y input of batteries (5t/h) and producing 18,000 t/y of refined lead. Inclusion of Iran and Iraq implies a possible additional 18,700 t/y of batteries.

None of the companies supplying technology is willing to give detailed quotations without knowing the required capacity and the precise location of the proposed plant, since the latter dictates the level of the environmental constraints. Only Engitec was willing to give any indication whatsoever of plant capital cost. Some operating and economic data on the products of the Engitec process are, however, available.

The cost of a 5 t/h Engitec plant for battery breaking, paste desulphurisation and sodium sulphate production is given as approximately $3.8 million, with a further $800,000 for installation. It requires a building of 450-500m² area with a headroom of 12-13m. The capital cost of melting, refining and casting facilities with their associated filters adds a further $1,020,000 plus installation costs; an additional 900m² of area would be needed. No special civil engineering features have been specified, but lead containment measures are a general requirement.

The gross margin between typical current prices for recovered metal ($560/tonne) and Engitec's published cost of treatment ($315/tonne) for a 25 t/h plant working at 80% capacity is approximately $245. A 5 t/h plant would not benefit from such a scale of operation; the margin cannot be quantified but would presumably be smaller. A 5 t/h planting working three shifts, 7 days/week, represents an annual input of 30,000 t/y of batteries equivalent to 18,000 t/y lead. This might ignoring capital and building charges, and depending on market conditions, providing full capacity working, represent a maximum annual surplus based on published margins, of $4.4 million.

2.0 PRODUCT DEFINITION

2.1 Description of Product and Specification

The products of battery breaking and smelting operation and their typical recovered specifications are:

Metallic Lead (55%-65% of input weight with better than 95% recovery yield).
93-96% (99.97% after refining). Almost 40 different alloys are made by some producers to meet customers' individual specifications. They contain 0.4%-12% Sb, the bulk being Pb 1.7% Sb, Pb-Ca alloys contain 0.08% Ca.

Ebonite (2½% of input weight with better than 95% recovery yield)
Better than 88%. Metallic lead and lead compounds < 0.18%. Impurities < 2.5%. Moisture (surface) < 9%.

Polypropylene (5% input weight with better than 95% recovery yield)
97-99% (nominal Pb content 200 ppm).

Desulphurised Lead Paste (38.5% of input weight with 70-72% recovery yield)
Humidity content 9-12%. Total metal content 66-68%. Sb < 0.5%, allowing production of soft lead. Sulphur content < 1.1% (using sodium hydroxide) as desulphurising agent.

Sodium Sulphate
Anhydrous, detergent quality, odourless, 99.5% purity b.w., 0.01% insoluble in water. Sodium chloride 0.01%. Moisture 0.2%. Bulk density 1.400-1.600 kg/m^3.

PVC Separators

Sent for disposal.

Mixed Plastics Waste

Sent for disposal.

Other Products (wastes)

There is essentially no market for the 10% sulphuric acid which plants could provide.

2.2 Overall Recovery Ratios

Input from Typical Wet Battery	(% Weight)	Yield	Output (% Weight)
Electrolyte	20		
Lead Sulphate	19.4	70-72%	Desulphurised Lead Paste - 28%
Lead Oxides	19.1		
Metallic Lead	27.7	> 95%	Metallic lead - 55-65%
Ebonite	2.5	> 95%	Ebonite - 2.5%
Polypropylene	5.0	> 95%	Polypropylene - 5.0%
Separators	4.9		
Miscellaneous	1.4		

3.0 TECHNOLOGY REVIEW

3.1 Review of Options

3.1.1 Background

World production of refined lead in 1989 was approximately 5.8 million tonnes, of which almost 2.4 million came from secondary sources. World wide, some 41.4% of refined lead comes from secondary sources.

TABLE 1 USE OF LEAD BATTERIES IN DEVELOPED COUNTRIES

Country	Total Usage (tonnes)	Lead in Batteries (tonnes)	Battery Consumption (%)
France	264,000	160,000	60.6
West Germany	364,800	178,500	48.9
Italy	259,000	109,000	42.1
Japan	405,693	278,894	68.7
United Kingdom	336,400	102,200	30.3
USA	1,182,566	1,012,155	85.6

Source: Metallatastistik, Metallgesellschaft Aktiengesellschaft, 77th Ed., 1990

The lead acid accumulator is extensively recycled. In the early 1980's over 90% of the lead used in storage batteries was reclaimed within five years of manufacture. The high recovery rate for antimony results from co-recovery in battery lead. Considerations of cost, operation, safety, and economics of recycling have precluded large-scale substitution and, for the foreseeable future, the lead-acid system will probably predominate for the SLI (Starting, Lighting and Ignition) accumulators which consume about 70% of the battery lead. Batteries for electric vehicles (Motive Power Batteries) consume about 15% and those for Uninterruptible Power Supplies about 10% of battery lead.

Historically, the financial credit given for failed battery has contributed substantially towards the cost of a new one. Though this is no longer so it is often convenient for a purchaser to leave an old unit at the point of sale of the new one. When sufficient have been collected they are sold on to a scrap dealer, who offers them to a lead smelter. Batteries not accepted by vendors may go to a landfill; this has given rise to schemes designed to maximise recovery through legal or fiscal measures. This trend seems likely to increase, with possible increases in the flow of secondary lead for recycling.

3.1.2 The Traditional Battery Recycling Process

Traditionally, batteries were recycled by many small and a few larger companies using relatively simple plants with no universal technology base. Most secondary lead smelters were pyrometallurgical, using blast, reverberatory, or rotary furnaces to treat battery plates and terminals from outside breaking operations, with no control over the disposal of cases or acid.

The toxicity of lead presents special environmental problems and from the mid-1960's pressure grew to reduce emission to air and water and to reduce blood lead concentrations in employees and nearby residents. Environmental legislation now classifies batteries as 'Hazardous

Materials' and controls to the processing, handling and storage of batteries. Other perturbations arose from poor market conditions: in 1990 the LME cash price for lead varied from a low of £312/tonne to a high of £815, and the settlement price from £325 to £654/tonne. The UK price of battery plates fell from £130-160/tonne (Jan. 4) to £95-110 (Oct. 18) and of whole batteries from £100-110 (Mar. 22) to £70-75 (Dec. 13). In June 1991 the price of battery plates is £90-100/tonne and of batteries £45-55.tonne. Recovery of battery lead fell from 90% in 1979/1980 in the USA to 58% in 1985. From 1982 to 1986 the number of US smelters fell from 60 to 24. Failure to meet emission standards, or the cost of so doing, was probably the overriding factor in several closures. As the costs to the secondary smelter of environmental compliance increase scrap prices will tend to fall. The backward link to the acceptance of spent batteries is clear.

3.1.3 Current Technology

There are now only three UK secondary smelters, i.e. Enthoven (1 plant) and Britannia (2 plants). Enthoven annually treats some 2 million spent batteries (almost 40% of UK arisings) to produce 53,000 tonnes of lead and 1,500 tonnes.y of polypropylene. A further 9,000 tonnes/y of lead arises from other scrap. The plant, based on proprietary equipment, aims to contain all toxic material for recycling to the furnaces.

3.1.3.1 FLOWSHEET

A battery breaker comminutes feed into metallic lead, lead paste, polypropylene, and miscellaneous case materials. Liberated acid passes to the effluent treatment plant. Lead-bearing materials (grids and leady paste) pass to the charge preparation building (maintained under negative air pressure), and are mixed with dross (purchased and own in-plant arisings), coke breeze, cast iron borings (to assist in slag formation), and soda ash for charging to the rotary furnaces.

The type of furnace is not especially critical. Rotary furnaces are easier than reverberatory to make environmentally secure, and accept a wider range of feedstock. The two rotary furnaces at Enthoven are each of 25 tonnes nominal capacity and burn oil or gas. Effluent gases are cleaned by dry bag filtration, and the fume is recirculated. Molten metal is refined in enclosed lead kettles maintained under suction, alloyed as necessary, and cast into slugs or bars (for 1 tonne bundles) or 3 tonne ingots for storage on-site against possible flow disruptions.

3.1.3.2 ECONOMICS

Availability of Raw Material

The life of an automobile battery in Europe varies between 3.5 and 5.5 years. The average is probably close to 60 months although the average in the climatic conditions of the middle east may be as low as 24 months giving rise to a market 2.5 times of the equivalent European market. Over capacity in the UK battery-breaking and smelting business, may account for the prevailing secrecy. There is surprisingly little international trade in batteries, reflecting the low price of lead. Some 4-8,000 tonnes/y are exported to the Far East at prices $50-66/tonne (30-40) greater than the relevant UK price.

Despite recent moves to lower antimony contents in battery lead (1.7-1.8% in low maintenance types compared with the 6% formerly used) there is a shortfall of antimony, attributable to a reduction in the supply of scrap type metal. The no-maintenance, sealed, Pb-Ca types have only about 5% of the market.

Cost of Feed Material

The average price paid for batteries is currently $115-150/tonne (£70-90), based on a mix of large and small units, which are mot classified into drained or undrained. Since they contain 50-60% of their weight as lead this is about one third of the LME lead price.

Viable Size of Plant

Enthoven believes that 25,000 tpy may not be a viable size plant under current European conditions and environmental restrictions. A realistic minimum of 40,000 tpy reflects the reduced numbers of UK smelters (9 in 1980 and 2 in 1991).

Labour Needs

Employment in the Enthoven plant is 195, for some 60,000 tpy total lead. The charge preparation, filter baghouse, and furnace room together employ only 4 and the strip mill a further 2 men.

Capital Cost of Plant

In the mid 1980's Enthoven reconstructed irs plant. The MA battery breaker and the strip mill each cost approximately $1.65 million. The total cost of the feed treatment plant, rotary furnaces and filter baghouses was then given as $17.5 (£10.6) million on a developed site already owned by the company. Slightly less than half of this related to environmental protection. Civil engineering works (foundations and buildings) formed about 30% of the total cost.

3.1.3.3 Changes in the Industry

The industry in the UK (and, by inference, in other developed countries) is mature and fragile. The invisible barriers, largely environmental, are considerable but do not necessarily apply in countries outside the EEc, North America and Japan.

3.1.3.4 Possible Changes in Technology

Industrial sources consider that environmental pressures will cause high-temperature smelting to be abandoned in the foreseeable future; water pollution will replace stack emissions as the prime environmental concern. Alternative systems are being developed or installed but may not be competitive under present conditions. They are:

The Engitec Process:

Engitec supplies equipment for the recovery, smelting and refining of non-ferrous metals, scrap and residues. It specialises in battery-treatment processes and supplies turnkey plants and carries out feasibility studies, basic and process engineering, detailed design, procurement, erection, start-up and personnel training. Engitec is highly regarded in the industry, although its solutions are thought expensive. Since 1982 it has supplied and installed plants for complete or partial battery treatment in Yugoslavia, Germany, Italy, Brazil, Canada, USA and UK. Installations include smelting equipment for scrap from batteries; treatment of recovered ebonite (20t/d); lead paste desulphurisation, and electrowinnig of lead paste (10,000 t/y). The Engitec process is described in Section 4.1 (below). For reasons given in 3.3 it is the recommended technology.

Other New Battery-Smelting Processes:

Other new processes under development or installed include the RSR, Ginatta, Bergsoe, Oliforno, Metaleurop, Mercedes-Benz, and Isasmelt processes. Details are given in Appendix 1. None however can be regarded as proven technology of the capacity likely tc be required.

3.2 Review of Production Scale Ranges and Factors Governing Them

The country in which it is proposed to locate the new battery processing plant has not been disclosed. The numbers of vehicles in the countries of the Arabian Peninsula are given in Table 2 with the United Kingdom for comparison.

TABLE 2 VEHICLES IN USE IN ASIA, 1989

	Cars	Commercial Vehicles		Total
Arab Emirates	260,000	150,000		410,000
Bahrain	90,000	6,000		96,000
Kuwait	580,000	210,000		790,000
Oman	145,010	107,024		252,034
Qatar	105,000	47,500		152,500
Saudi Arabia	1,842,500	1,645,000		3,487,500
			Total	5,461,034
United Kingdom	22,427,725	3,309,705		25,737,430

Source: Society of Motor Manufacturers and Traders

Battery recycling is a continuous process operation and a plant rated at 5t/h input should process a total of 30,000 t/y based on 3 shifts of 8hrs/day, 7 days/wk, 48 weeks per year at an overall productivity of say 75%.

Looking at the market to supply this feed, the Arab Emirates alone would be expected to generate only some 2562.5 tonnes/y of scrap batteries, calculated on the basis of a life of 24 months and 80 units/tonne. The inclusion of arisings form Bahrain, Oman, Qatar and Kuwait would raise this total to almost 12,334 t/y. This is equivalent to 5t/h unit working at only 41% of capacity. However the assumption of 24 months for battery life and the assumption of recovering nearly 100% of batteries need to be substantiated for the particular market envisaged.

The inclusion of Saudi Arabia howver, would provide a futher 21,796 t/y of batteries and thus a total supply of 34,130 t/y. Inclusion af Iran and Iraq could provide a further 18,700 t/y of batteries.

3.3 Recommended Production Technology

A modern process which appears to match the probable required capacity and is the Engitec 5t/h plant, incorporating CX1 and CX2 stages, together with a rotary furnace.

However, battery smelting is not 'off the shelf' technology, and it is likely that, depending on the degree of environmental control specified, several companies listed in Section 3.4 could supply a suitable plant in response to a serious enquiry which provided complete details of the proposed capacity and location.

3.4 Suppliers of Technology

Engites Impianti spa
Viale E. Jenner, 51
20159 Milano
Italy
Tel: 2-607-2741 Fax: 2-688-2178

Ginatta SA
Via Brofferio 1
I 10121 Torino
Italy
Tel: 11-94-93-493 Fax: 11-94-93-387

Lurgi GmbH
Post Box 11 12 31
D 6000 Frankfurt am Main
Germany
Tel: 69-5808 0 Fax: 69-5808-3888

MA Industries
Peachtree City
GA, USA
MIM Technology Marketing Ltd
Botany Road
Northfleet
Kent DA11 9BG
UK
Tel: 0474-351188 Fax: 0474-320064

Monometer Furnaces
Monometer Business Park
Tollesbury
Maldon
Essex CM9 8SJ
UK
Tel: 0621-869342 Fax: 0621-868522

RSR Corporation
1111 West Mockingbird Lane
Dallas
Texas 75247
USA
Tel: 214-631-6070 Fax: 214-631-6146

4.0 THE PRODUCTION PROCESS

4.1 Description and Flowsheet of Recommended Technology

The Engitec Process:

The Engitec CX system crushes whole undrained batteries (apart from steel cases or strapping, which must be removed prior to charging) with a maximum diagonal dimension of 800mm and with up to 15% of industrial batteries of an assumed composition (based on US and Canadian data) as below:

Electrolyte	20.0%
Lead sulphate	19.4%
Lead oxides	19.1%
Lead metal	27.7%
Ebonite	2.5%
Polypropylene	5.0%
Separators	4.9%
Miscellaneous	1.4%

Mechanical screening and a rising current hydrodynamic separator then separate by density into polypropylene, lead and a fraction which contains ebonite and separator material.

Paste slurry is desulphurised with waste acid and 50% sodium hydroxide solution for a reaction time of about 1h. Sodium hydroxide is preferred to sodium carbonate because the hydroxide content of commercial caustic soda can be specified accurately whereas commercial sodium carbonate varies in quality. Plant operating data indicate that the desulphurised paste contains less than 0.6% sulphur and 0.5% antimony. Product sodium sulphate is pH adjusted, filtered and treated by evaporation and crystallisation to yield a

Fig. 1

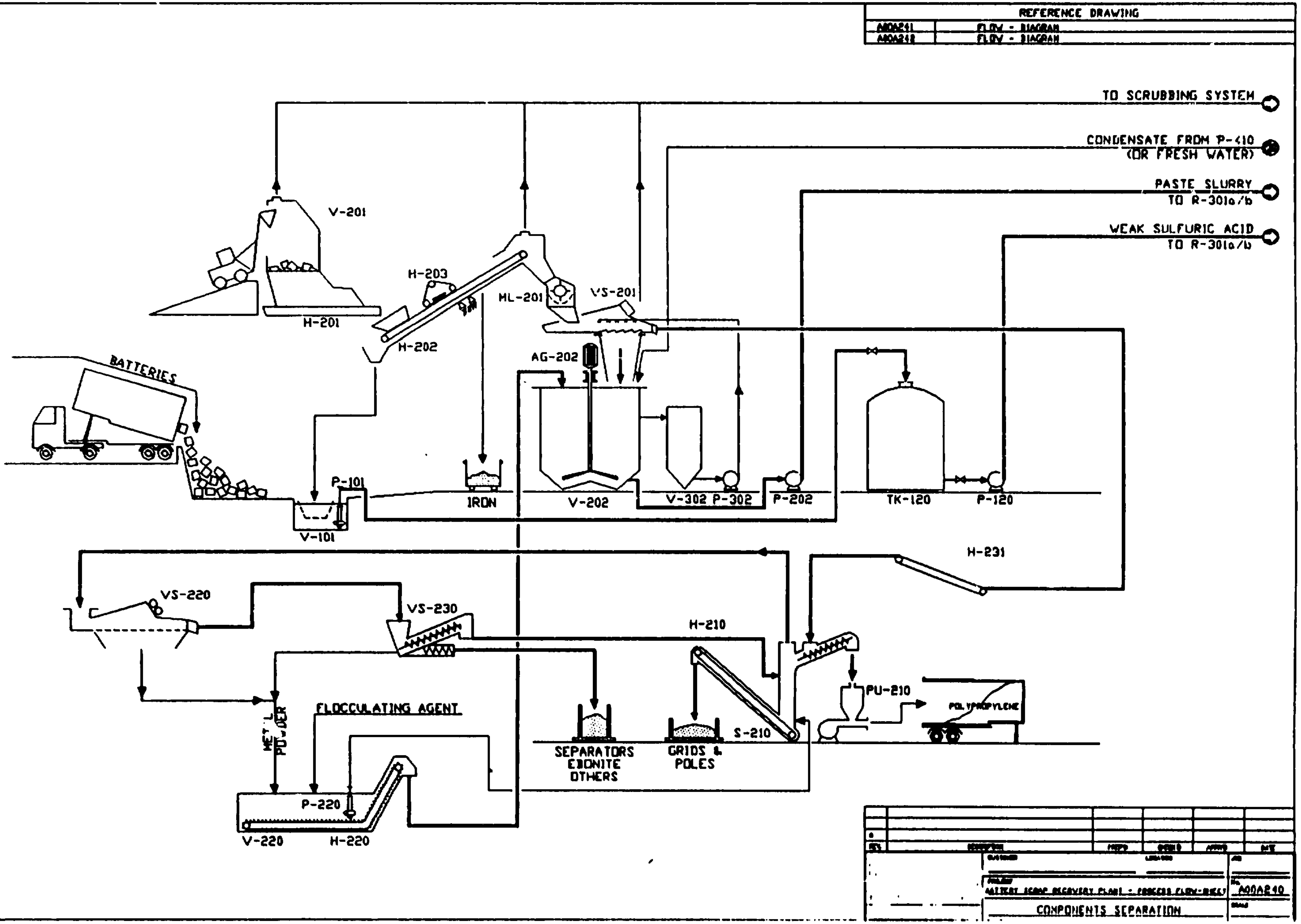
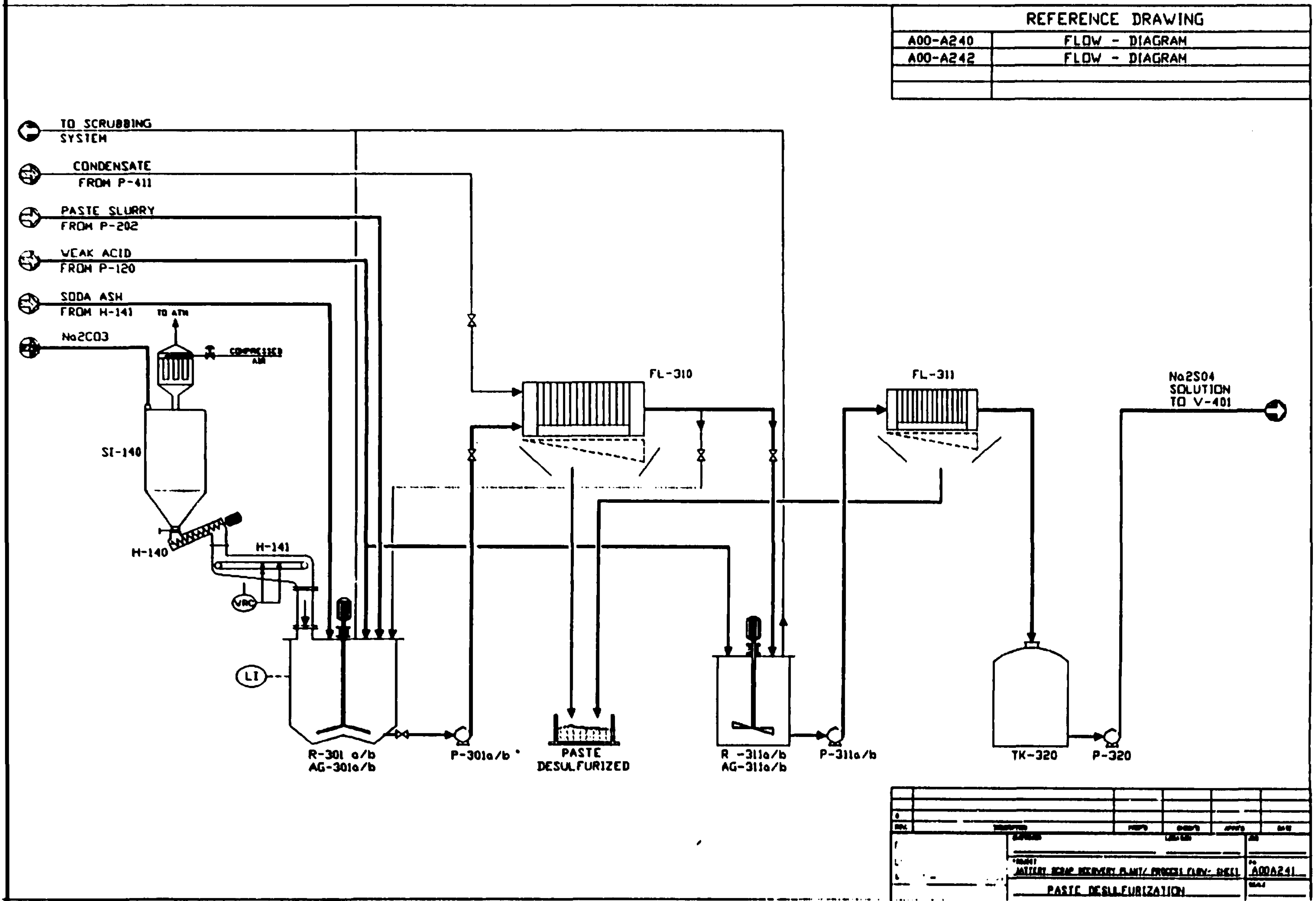
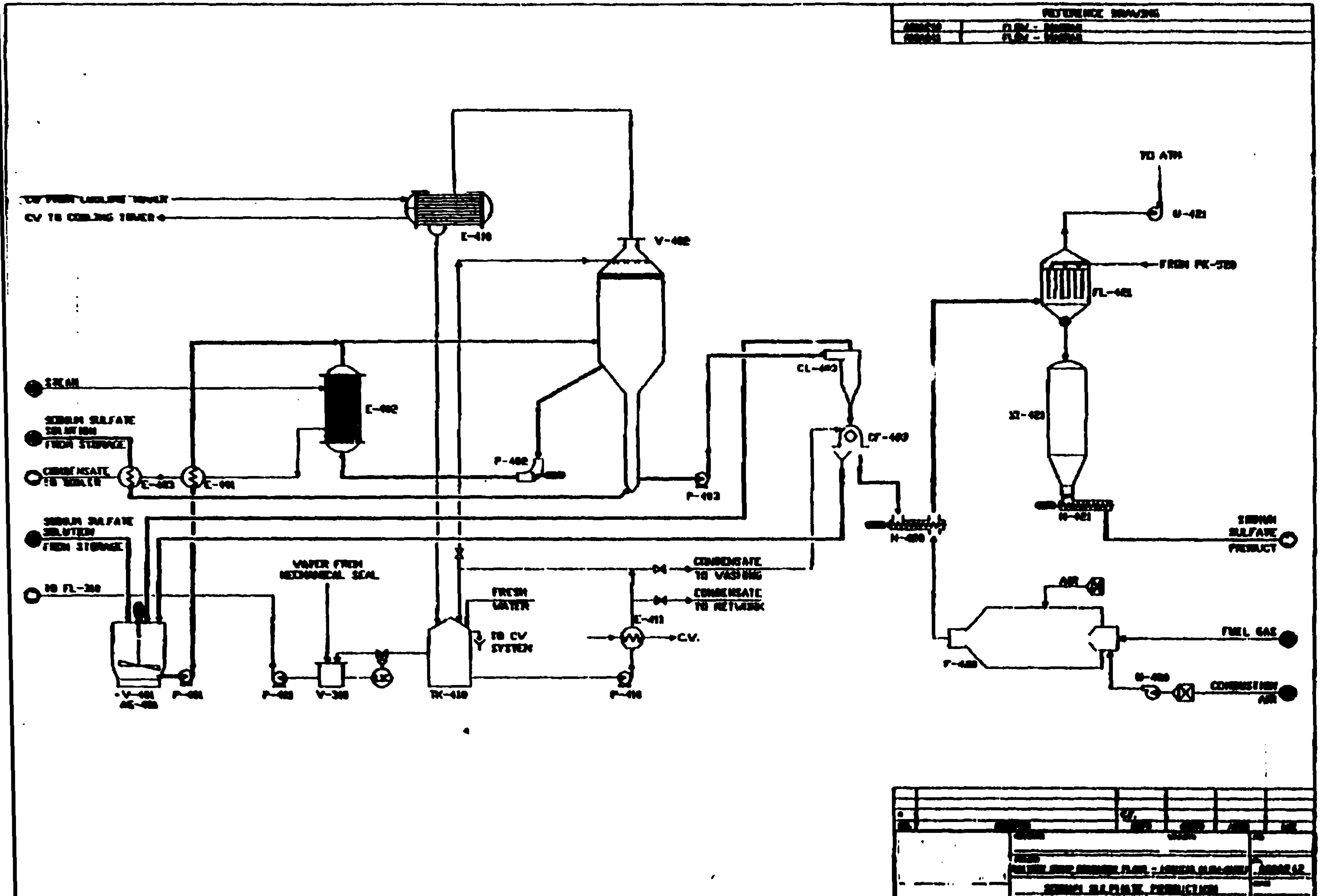

REFERENCE DRAWING
FLOW - DIAGRAM
FLOW - DIAGRAM
TO SCRUBBING SYSTEM
CONDENSATE FROM P-410
(OR FRESH WATER)
PASTE SLURRY
TO R-301a/b
WEAK SULFURIC ACID
TO R-301a/b
V-201
H-201
H-203
H-202
ML-201
VS-201
AG-202
BATTERIES
P-101
V-101
IRON
V-202
V-302
P-302
P-202
TK-120
P-120
H-231
VS-220
VS-230
H-210
PU-210
POLYPROPYLENE
METAL POWDER
FLOCCULATING AGENT
SEPARATORS
EBONITE
OTHERS
GRIDS & POLES
S-210
P-220
V-220
H-220
A00A240
COMPONENTS SEPARATION

Fig. 2



REFERENCE DRAWING
A00-A240 FLOW - DIAGRAM
A00-A242 FLOW - DIAGRAM
TO SCRUBBING SYSTEM
CONDENSATE FROM P-411
PASTE SLURRY FROM P-202
WEAK ACID FROM P-120
SODA ASH FROM H-141
TO ATM
Na2CO3
COMPRESSED AIR
SI-140
H-140
H-141
VRC
LI
R-301 a/b
AG-301a/b
P-301a/b
FL-310
PASTE DESULFURIZED
R -311a/b
AG-311a/b
P-311a/b
FL-311
TK-320
P-320
Na2SO4 SOLUTION TO V-401
A00A241
PASTE DESULFURIZATION


REFERENCE DRAWING
CW FROM COOLING TOWER
CW TO COOLING TOWER
E-410
V-402
TO ATM
FROM PK-350
FL-401
STEAM
E-402
SODIUM SULFATE SOLUTION FROM STORAGE
CONDENSATE TO BOILER
E-403
E-401
P-402
P-403
CL-403
CF-403
SD-403
SODIUM SULFATE SOLUTION FROM STORAGE
TO FL-310
WATER FROM MECHANICAL SEAL
FRESH WATER
TO CV SYSTEM
CONDENSATE TO WASHING
CONDENSATE TO NETWORK
E-411
C.V.
AIR
FUEL GAS
COMBUSTION AIR
SODIUM SULFATE PRODUCT
V-401
AG-401
P-401
P-400
V-300
TK-410
P-410
SODIUM SULFATE PRODUCTION

recyclable mother-liquor and product crystals, which are sold as detergent grade.

Claimed advantages over traditional breaking systems include the separation of lead oxide/sulphate from metallic grids and poles permitting rotary furnace melting of the latter categories at low temperature for hard lead and separate smelting of the desulphurised paste for soft lead. The separation of polypropylene from other casing and separator materials maximises revenues from polymers and minimises disposal costs for the fraction containing ebonite, PVC and paper. Desulphurisation of paste reduces furnace sulphur content by 90%, thus reducing consumption of fluxing agents, enhancing furnace productivity by approximately 30% compared with sulphurised paste, and reducing solid wastes by 75%. A reduction in furnace temperature of 100-150°C reduces energy consumption by some 10%.

Production Ranges

Basic Production capacities for the CX system represent charging rates of 5, 15 or 25 tonnes/h of whole, undrained batteries, with possible extension to 40t/h. One, two, or three shift operation is possible to achieve plant production rates of 50,000-75,000 tonnes/annum of metallic lead.

Production and Product Quality

The following typical calculations are based on a 25 tonne/h plant with fully automated controls at 80% of full-rated capacity, using sodium hydroxide as the desulphurisation agent. The calculated materials balance for crushing, screening, and separation systems is:

Recovery yield (as % of quantities notionally charged):

Desulphurised paste	70-72%
Ebonite	Better than 90%
Metallic Lead	Better than 95%
Polypropylene	Better than 95%

Product purity:

Desulphurised paste	Humidity content 9-12%. Total metal content 66-68% as is. Sb , 0.5% allowing production of soft lead. Sulphur content , 1.1% (using sod. carbonate) or < 0.7% (using sodium hydroxide).
Ebonite	Better than 95%
Metallic Lead	93-96%
Polypropylene	97-99% (nominal Pb content 200 ppm.
Sodium sulphate	Anhydrous, detergent quality, odourless, 99.5% purity b.w. 0.01% insoluble in water. Sod. chloride 0.01% Moisture 0.2% Bulk density 1,400-1,600 kg/m^3.

Product Applications:

Desulphurised paste	Treatable in suitable furnace, with a claimed 30% increase in productivity, 10% energy saving, and 75% saving in fluxing agents.
Ebonite	Usable as fuel, either alone or with oil or natural gas.
Metallic Lead	Can be upgraded from original 97% purity by crushing, washing and extrusion to 99,5% for use, after suitable

	blending, in a range of plastics with tailor made properties. Though not suitable for battery cases it is acceptable, for about 40-50% of the cost of primary polypropylene, in low grade applications such as appliance handles and imitation terracotta pots.
Sodium sulphate	Detergents.

4.2 Outline List of Machinery and Equipment

(Serial numbers refer to Figs. 1-2)

Raw Material Storage Section

V	101	Drained Electrolyte Pump
P	101	Electrolyte Sump Pump
TK	120	Electrolyte Storage Pumps
P	120	Electrolyte Pumps
FL	101	Electrolyte Filter Press
SI	140	Soda Ash Bin
H	140	Screw Conveyor
H	141	Weighing Belt

Battery Components Separation Section

V	201	Feeding Hopper with Hood
H	201	Vibrating Feeder
H	202	Belt Conveyor
H	203	Magnetic Separator
ML	201	Batter Scrap Mill
VS	201	Paste Separation Screen
V	202	Paste Slurry Tank
AG	202	Stirrer for V 202
P	202	Paste Slurry Pump
FL	310	Filter Press

V	302	Clarified Water Tank
P	302	Recirculating Pump
H	231	Overscreen Conveyor
S	210	Hydroseparation grids + PP
H	210	Grids Conveyor
VS	220	Dewatering Screen
S	221	Dewatering Tank
V	220	Metal Powder Settler
P	220	Recirculating Pump for S 210
H	221	Flocculating Agent System

Paste De-Sulphurisation

R	301a/b	Desulphurisation Reactors
AG	301a/b	Stirrers for R 301a/b
P	301a/b	Filter Press Feeding Pump
V	302	Clarified Washing Water Tank
P	302	Clarified Water Circulating Tank
FL	310	Paste Filter Press
V	310	Washing Water Tank
R	311a/b	Neutralisation Stirred Reactor
AG	311a/b	Stirrers for R 311a/b
FL	311	Refining Filter
TK	320	Sodium Sulphate Solution Tank
P	320	Sodium Sulphate Solution Tank
P	321	Sodium Sulphate Volumetric Pump

Sodium Sulphate Crystallisation and Drying

V	401	Brine Feed Tank
AG	401	Stirrer for V 401
P	401	Brine Feed Pump
E	401a/b	Brine Feed Preheater
E	402	Liquor Circulation Heater
V	402	Crystalliser
P	402	Liquor Circulation Pump
P	403	Thickened Slurry Pump
CL	403	Hydrocyclone
CF	403	Product Centrifuge

E	410	Steam Condenser
J	410	Inert Gas Ejector
TK	410	Condensate Storage Tank
P	410	Condensate Pump
E	411	Condensate Cooler
P	411	Condensate Wash Pump
H	420	Drying Feed Conveyor
F	420	Combustion Chamber
U	420	Combustion Air Fan
FL	421	Product Gas Filter
U	421	Exhausted Gas Fan
SI	421	Product Storage Silos
H	421	Product Conveyor to Loading System

Utilities

PK	500	Cooling Tower System
PK	510	Steam Generation System (including water softening)
PK	520	Compressed Air System
PK	540a/b/c	Sump Pumps

Gases and Hygiene Air Treatment Plant

PK	530	Pollutant Stream Collecting and Scrubbing

Melting and Casting Equipment

Rotary Furnace
Refining Kettle
Filter Package
Mould Ingot Casting Machine

4.3 Budget Cost Estimate for Machinery and Equipment

The approximate capital cost of a 5t/h CX plant (Stages 1 & 2), treating 10,000 t/year of undrained batteries in one 8h shift, 250 days per year, is given below.

Capacity may be increased by increasing utilisation to the designed 24h/day.

Capital Costs: (excluding site and civil engineering costs and including auxiliaries, pollution control and engineering/design fees).

5t/h CX plant, Stage 1 & 2	$ 3,800,000
3.5m short body rotary furnace	$ 290,000
Refining kettles, (2 off, 15 tonne)	$ 230,000
Filter Package	$ 415,000
Mould Ingot Casting Machine	$ 85,000
Total	**$ 4,820,000**

4.4 Erection Costs

5t/h CX plant, Stage 1 & 2	$ 800,000
Furnace, refining and casting facilities	Not supplied

4.5 Size of Required Site

5t/h plant, Stage 1 & 2	450-500m²
(Headroom	12-13m)
Furnace, refining and casting facilities	900m²
Warehouse	140m²
Office	140m²
Hardstanding	1200m²
Total	**2,880m²**

4.6 Details of Buildings and Special Civil Works Required

No particular civil engineering features are specified. Lead containment, however, requires provision for maintaining buildings under negative air pressure.

4.7 Raw Materials and Consumable Items

(All costs are given per tonne of recovered lead).

ITEM	UNIT	UNIT CONSUMPTION	UNIT COST ($US)	TOTAL COST ($US)
Fuel, natural gas	cu.m	91.16	0.12	10.90
Combustion Oxygen	kg	115.90	0.09	10.70
Electricity	kwh	146.70	0.07	10.16
Coal	kg	25.38	0.11	2.80
Antifoaming agent	kg	0.0014	8.46	0.01
Flocculant	kg	0.068	4.52	0.31
Na Carbonate	kg	95.00	0.21	19.95
Na Hydroxide	kg	1.411	0.29	0.41
Iron turnings	kg	9.20	0.15	1.38
Sulphur	kg	1.327	0.31	0.41
Refining Oxygen	kg	0.97	0.09	0.09
Ca Hydroxide	kg	0.179	0.08	0.01
Charcoal	kg	0.179	0.28	0.05
Scrap Batteries	tonne	1.67	132.5	221.27

4.8 Utility Requirements

Electricity	kwh	146.70	0.07	10.27
Fuel, natural gas	cu.m	91.16	0.12	10.90

4.9 Normal Annual Maintenance, Spare Parts and Costs

Maintenance materials $US 13.22/tonne

4.10 Manpower Requirements

Below is a typical manpower breakdown for the size of the plant suggested:-

General Manager	1
Sales Manager	1
Accountant/book-keeper	1
Secretary	1
Production Engineer	1
Foreman	1
Maintenance Fitter	1
Operatives	10
Total Labour	17 single shifts or 30 double shifts

A typical cost breakdown is:

ITEM	UNIT	UNIT CONSUMPTION	UNIT COST ($US)	TOTAL COST ($US)
Direct Labour	hr	1.435	14.23	20.42
Indirect Labour	hr	0.236	14.23	3.36
Service and maintenance labour	hr	0.449	17.31	7.80
Total labour cost/tonne				31.58

4.11 Pre-production Cost Items

No identifiable pre-production cost will arise provided that senior management and production engineers are recruited from the industry and technical support is negotiated within the capital cost of the equipment supply.

4.12 Typical Early Years Production Levels

A typical early years production build up may assume the following:

Year	Shift	Rated Capacity
1	1	50%
2	2	70%
3	3	80%

4.13 Required Construction Period

The overall construction period would be:-

Design	4 months
Equipment Manufacture	6 months
Shipping	2 months
Site Works	6 months
Commissioning	2-3 months
Total Time	20-21 months

4.14 Environmental Aspects

The battery recycling industry is under acute environmental pressure. The economics of lead processing are considerably affected by environmental requirements for gaseous and liquid effluents. The cost of complying with environmental and workplace standards is seen as the greatest problem faced by the US domestic lead industry. Process effluents may represent only one half of the environmental burden, the remainder comprising fugitive emissions from flue dust handling, from reception, unloading, transport and handling of raw materials in the plant, and from vehicle movement. Control of fugitive emissions may well be more costly than process emission control.

Such factors may affect the capital cost of a plant by millions of dollars. It is impossible to specify the capital cost of a plant without a complete knowledge of the required capacity, probable operating level (% of maximum capacity), and applicable environmental requirements. Without such information few, if any, manufacturers will provide even an estimate of the capital costs.

The plant described in this profile is claimed to meet modern environmental requirements, and should in theory be capable of being sited anywhere. However, the possibility of accidental leakage/spillage dictates that a concrete base should be so designed as to trap any leakage of sulphuric acid, so preventing contamination of ground water. The ideal location will obviously be as far as practicable from residential areas.

5.0 COMPARATIVE EUROPEAN PRODUCTION COSTS

5.1 Production Cost Breakdown

Cons Items	Unit	Unit Consump. Trad	Unit Consump. CX	Unit Cost ($US)	Total Cost Trad ($US)	Total Cost CX ($US)
Direct Labour	h	1.518	1.435	14.23	21.60	20.42
Indirect Labour	h	0.375	0.236	14.23	5.34	3.36
Service and Maintenance Labour	h	0.682	0.449	17.31	11.80	7.80
Fuel, Natural Gas	cu.m	129.16	91.16	0.12	15.50	10.90
Combustion Oxygen	kg	136.35	115.90	0.09	12.59	10.70
Electricity	kwh	137.25	146.70	0.07	9.50	10.16
Coal	kg	40.50	25.38	0.11	4.50	2.80
Antifoaming Agent	kg		0.0014	8.46		0.01
Flocculant	kg		0.068	4.62		0.31
Na Carbonate	kg	24.50	95.00	0.21	5.20	19.95
Na Hydroxide	kg	1.44	1.411	0.29	0.42	0.41
Iron Turnings	kg	70.75	9.20	0.15	10.60	1.38
Sulphur	kg	1.35	1.327	0.31	0.42	0.41
Refining oxygen	kg	0.99	0.97	0.09	0.09	0.09
Ca hydroxide for acid neutr.	kg	1.70		0.08	0.13	
Ca hydroxide for SO_2 scrubber	kg	2.00		0.08	0.15	
Slag & residue disposal	kg	348	146	0.09	31.32	13.14
Maintan. mats.	$US	14.31	13.22			

	Trad	CX
Total Production Expenses ($US/tonne)	135.76	122.32
Total Cost/tonne batteries charged	132.5	132.5
Total Cost/tonne lead produced	268.26	254.82
Na sulphate recovery (80%)		17.45

6.0 INTERNATIONAL PRICES OF PRODUCED ITEMS

6.1 Recent and Present 'Market' Prices of Products

Refined lead:	US$ 569.25/tonne plus premium depending on alloying additions.
Secondary polypropylene	US$ 495/tonne or less
Sodium sulphate:	US$ 222.75 (detergent grade)

APPENDIX 1

The RSR Process

In 1980 RSR operated five conventional battery treatment plants in the USA to produce battery paste, polypropylene, hard rubber (used as a source of carbon reducing agent in the furnaces), 99.98% lead bullion and antimonial lead alloys with 0.3-20% Sb. By 1990 RSR had published details of what it claims is the first full-scale (the Engitec CX3 process is still at the laboratory stage) plant to recover electrowon lead cathode from battery scrap, using a patented desulphurisation process. A plant to produce 36,000 tonnes of electrowon lead was in the final design stages. The RSR process has stages broadly in common with Engitec's. Differences arise in the RSR three-stage desulphurisation of the paste and in its later treatment, i.e. solubilisation for H_2SiF_6, to yield a lead fluosilicate electrolyte for electrowinning. Power consumption for electrowinning is expected to be 600Kwh/tonne.

The RSR electrowinning process has yet to generate data based on industrial scale operation, and no economic data are available. RSR also promotes reverberatory - electric furnace technology for battery smelting, but no economic data are given. RSR is not interested in selling technology, but is willing to consider joint venture operations.

The Ginatta Process

Ginatta processes batteries at Santena, Torino by cutting off the battery bases (the only mechanical operation) to expose the plates to an electrolyte in which the plates are subjected to a voltage of 14.5V between poles and plates for about 6 hours; such activation of the plates precedes anodic dissolution in lead fluoborate at 3V and a current density of up to 400 A/m^2. Cathodes of about 1,5000kg of 99.9% PB are produced. Electrolyte composition is adjusted through a bleed and stripping regime. Primary pastes from the cases and secondary pastes from plate dissolution are first converted to lead carbonate, which is then dissolved in recycled electrolyte from the stripping tanks before electrowinning of the lead. Battery cases are processed by grinding, screening and washing.

Ginatta stresses that the process is particularly suitable for small plants, so minimising the need for transport of spent batteries; that room temperature operation minimises emissions; that no slag is generated; that all battery components are recovered, and that energy consumption is very low (1,000 kwh/tonne of lead). However, no capacities, process details or economic data are given.

The Bergsoe Process

From 1975 onwards Paul Bergsoe and Son A/S has smelted whole batteries at Golstrup, Denmark, eliminating the dangerous and unpleasant task of breaking battery cases. The process employs a water-jacketed shaft furnace.

No capital or operating costs are available.

The Oliforno Process

Accumulatoren Fabrik, of Oerlikon, Switzerland, operates a secondary lead facility that treats whole batteries in a kiln. The process is reported to produce more flue dust than the Bergsoe Process.

No capital or operating costs are available.

The Metaleurop Process

At Oker, Germany, Metaleurop annually processes some 65,000 tonnes of wet batteries to produce polypropylene granules, soft lead, lead-calcium and antimonial lead from battery scrap, lead residues and scrap lead, using a rotary kiln and a short rotary furnace. The metallics are relatively impure (87.5%Pb for the metals and 69.8% for the oxides) and have a high proportion (2-8%) of oxides and organic materials. A detectable loss is the 1% Pb contained in the ebonite. The polypropylene has 100 ppm surface lead, 0.07% chlorine and 0.04% total other polymers, and is ready saleable.

The battery treatment plant operates in two 8-hr shifts, five days per week, with 3 men/shift for the entire plant (including polypropylene upgrading and effluent treatment), plus a supervisor during one shift. A total staff of 23, including foreman supervision, is required to run the refinery, together with the foundry and shipping. Published data claim an effective utilisation of 65% in 1988, with 75% expected in 1989.

<u>Operating Data</u>

Capacities

Total Input (scrap as delivered)	70,000 tonne/y
Feed rate	30 tonne/h
Shift performance	150-170 tonne/shift
Waste water handling	70m³/h max.
Polypropylene grain production	3,000 tonne/y

Operation time

Working days		220 d/y
Shifts		10 shifts/week
Working time		16 h/d
Staff	Salaried Personnel	1
	Wage Earners	10

Consumables	
Electricity	27kwh/tonne
Lime	8
Flocculant	2.4 kg/t
Polyelectrolyte	23 g/t
Water	2.2 m^3/t

The plant appears to utilise the equipment of the former Harz Smelter Plant, whose shaft furnaces ceased operation in the mid-1970's, and it cannot be regarded as an efficient, purpose-built secondary smelter. In particular, the sulphur of the battery acid generates large quantities of slag, whose disposal is problematical.

The Mercedes-Benz Process:

Mercedes Benz is investigating techniques for furnace processing of entire batteries; the process requires feed free from PVC, and is clearly not applicable to existing units.

The Isasmelt Process:

Britannia Refined Metals, a subsidiary of MIM Holdings Limited is installing the CSIRO patented lance system (ISASMELT) technology at its plant at Northfleet, England. The plant, which will not be operational until late 1991, utilises the CX process for battery breaking and desulphurisation, and ISASMELT to smelt lead concentrates, including battery paste, to produce soft lead, an antimonial alloy, and an environmentally acceptable discard slag. Capacity will increase from 10,000 to 30,000 tonnes/y of secondary ingot. The aims are to minimise sulphur emissions to atmosphere, minimise lead emissions, eliminate soda additions, produce a leach-resistant slag, and achieve low operating costs.

Since this process uses CX technology its only novel feature would appear to be the CSIRO lance which, despite a decade of development, must be regarded as still untried technology, for which (at least for lead) no data or costs are available.