BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

2/1/19 January 1979

RECORD

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS

Amdel Report

No. 1254

COPPER SMELTER COST ESTIMATES

Bureau of Mineral Resources
Record 1982/32

by

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COPPER SMELTER COST ESTIMATES

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J.R. Tuffley

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THE AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES

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Preface

This Record consists of a report commissioned by BMR from a consultant as part of BMR's mineral resource studies.

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BMR would welcome discussion with anyone using information from this report in carrying out their own feasibility studies.

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SUMMARY

Background

As part of a continuing programme of compiling capital and operating costs for treatment processes within the mineral industry, the Bureau of Mineral Resources, Geology and Geophysics requested Amdel to derive these costs for three sizes of copper smelter using the flash smelting technique.

Objectives

The aim of the investigation was to derive capital and operating costs for copper flash smelters with capacities of 25,000, 75,000 and 150,000 tonnes of blister copper per annum respectively.

Summary of Work Done

A description of the flash smelting process was obtained from published descriptions of operating plants. Design calculations were carried out to obtain flow rates, mass balances and heat balances. These figures were used to calculate the size of all items of equipment, and to estimate the direct labour requirement and the requirements for power, water, fuel oil and fluxes.

Operating costs were then derived using a standard factored method in which overheads and maintenance are related to direct labour costs and capital investment respectively. Capital costs were derived from published information on the total installed costs of smelters, rather than by costing individual items. The main reason for this was the relative inaccuracy which could have been introduced in estimating the cost of the largest individual item, viz, the flash smelting furnace.

Conclusions

1. The total capital costs of the three smelters, including acid plants, are as follows:

Tonnes Cu per Annum	Capital Cost $m
25,000	35
75,000	94
150,000	164

2. The total production costs, excluding the cost of the concentrates, are as follows:

Tonnes Cu per Annum	Production Costs $/Annum	$/Tonne Cu
25,000	12,668,000	506.73
75,000	26,897,000	358.63
150,000	44,185,000	294.56

Note: It should be noted that the above figures could change quite significantly for the case of a smelter located in a remote area.

1. INTRODUCTION

As part of a continuing programme of compiling capital and operating costs for treatment processes within the mineral industry, the Bureau of Mineral Resources, Geology and Geophysics requested Amdel to derive these costs for three sizes of copper smelter using the flash smelting technique. Costs were required for smelters producing 25,000, 75,000 and 150,000 tonnes of blister copper per year.

Approval to proceed with the project was given in Purchase Order No. J72173 dated 1 December 1978.

2. BASIS

One major consideration with present-day copper smelters is the disposal of waste gases containing sulphur dioxide. In conventional copper smelters, the gases produced contain insufficient sulphur dioxide for economic manufacture of sulphuric acid. However, one of the advantages of the flash smelting process is that it produces higher grade exhaust gases, and an acid plant is often an integral part of the smelter. This in turn results in the need for a smaller and less expensive stack for disposal of the gases. It has been assumed in this study that an acid plant will be installed.

Other assumptions are as follows:

1. The smelter is situated relatively close to the coast and transport.

2. The smelter will operate continuously and an operating year is 330 days.

3. The feed received at the smelter is moist chalcopyrite flotation concentrates in which the major sulphide impurity is pyrite.

4. The concentrates contain no unusual impurities which would necessitate additional processing stages.

5. The chemical analysis of the concentrates is: 25% Cu, 29% Fe, 33% S, 8% SiO_2 and 2% CaO.

Costs have been derived for the smelter only. The costs of providing a township, road or railway, power and water supplies, etc, have not been included.

3. PROCESS DESCRIPTION

A flowsheet illustrating the processes described in this section is presented in Fig. 1.

Flash smelting is a continuous process which combines the roasting and smelting stages of conventional copper smelting plus some converting all in the one smelting unit. The heat generated by the exothermic oxidation reactions is used in smelting, and any deficiency in the heat balance is compensated for by a small amount of additional fuel or by the use of oxygen in the combustion air. Reactions taking place within the flash smelter are as follows:

$$2CuFeS_2 \rightarrow Cu_2S + \tfrac{1}{2}S_2 + 2FeS$$

$$FeS_2 \rightarrow FeS + \tfrac{1}{2}S_2$$

$$\tfrac{1}{2}S_2 + O_2 \rightarrow SO_2$$

$$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$$

and in the settling unit:

$$2FeO + SiO_2 \rightarrow Fe_2SiO_4$$

$$3FeO + \tfrac{1}{2}O_2 \rightarrow Fe_3O_4$$

The concentrates and fluxes are blended and fed to a rotary dryer where the moisture content is reduced to less than 0.2%. The dried feed is then conveyed to the smelter feed bins located above the flash smelting unit. Concentrates and preheated air are fed into the furnace through burners. The furnace itself consists of two vertical chambers, the first being the reaction chamber while the second serves as a furnace uptake through which the exhaust gases pass into a waste heat boiler followed by an electrostatic precipitator.

The vertical chambers are connected by a low horizontal one in which the molten material separates into matte and slag layers. The matte (assumed to contain 60% copper) is tapped for converting to blister copper, while the slag passes to a slag cleaning process. The latter may take one of two forms. In one method the slag is cooled slowly, crushed and ground, and residual copper sulphides are recovered by flotation.

In the second method, the molten slag is treated further in one or two electric furnaces to achieve a high degree of separation of matte and slag, and obtain a final slag containing 0.4% approx. The electric furnaces may be separate from the main furnace, or they may be an integral part of the total furnace structure as illustrated in Fig. 1. This design was used in the second flash smelter constructed by Western Mining Corporation Limited at Kalgoorlie. Slag cleaning by the electric furnace method has been assumed in this study. Slag from the converters is also returned to the electric furnaces for cleaning.

Gases from the furnace and the converters pass through electrostatic precipitators and are then processed in the sulphuric acid plant. Gases from the rotary dryer are cleaned in a separate electrostatic precipitator and then discharged to atmosphere. All dusts collected in electrostatic precipitators are returned to the flash smelting unit.

4. DESIGN CALCULATIONS

Mass balance calculations for the three sizes of smelter are set out in Appendix A. The figures contained in Appendix A were used for sizing the major items of equipment and determining operating requirements. The schedules of equipment, the requirements of power, direct labour, raw materials and utilities, and the total production costs for copper productions of 25,000 tonnes/a, 75,000 tonnes/a and 150,000 tonnes/a are given in Appendices B, C and D respectively.

However, the production costs do not include the cost of the concentrates. If the smelter is treating concentrates from a mine owned by the same company, the concentrates have a value equal to or exceeding the costs of mining and concentrating. On the other hand, a custom smelter must purchase concentrates at a price related to the world copper price.

5. TOTAL CAPITAL INVESTMENT

The combined flash smelting and electric slag cleaning furnace with its ancillaries is the largest single item and represents a major portion of the total project cost. Because it is a large complex item, the estimation of its cost to any reasonable degree of accuracy presents a problem. Accordingly, a different approach has been taken to capital cost estimation.

The total capital costs of seven copper smelters constructed since 1972 have been obtained from the E & MJ Surveys of Mine and Plant Expansion from 1973 to 1978. All capacities and costs have been converted to tonnes and Australian dollars respectively, the latter at the rate of $1 Aust. = $1.13 US (December 1978). Costs have also been updated to 1978 figures by using the Chemical Engineering Plant Cost Index. A graph of capital cost versus capacity is given in Fig. 2.

Most of these are conventional smelters, but the point in the graph with a circle around it represents a flash smelter with an acid plant. Flash smelters generally have lower capital costs than conventional ones, but the graph shows that the cost of a flash smelter plus acid plant is of the same order as the cost of a conventional smelter without acid plant. Accordingly, the total capital costs of the three smelters in this study (including acid plants) have been taken from the graph in Fig. 2 and are tabulated below:

Tonnes Cu per Annum	Capital Cost $m
25,000	35
75,000	94
150,000	164

A breakdown of costs into nine sections has been given by Sharma, Beck and George (1975). This breakdown is listed in Table 1 for each of the three sizes of smelter.

6. CONCLUSIONS

1. The total capital costs of the three smelters, including acid plants, are as follows:

Tonnes Cu per Annum	Capital Cost $m
25,000	35
75,000	94
150,000	164

2. The total production costs, excluding the cost of the concentrates, are as follows:

Tonnes Cu per Annum	Production Costs	
	$/Annum	$/Tonne Cu
25,000	12,668,000	506.73
75,000	26,897,000	358.63
150,000	44,185,000	294.56

Note: It should be noted that the above figures could change quite significantly for the case of a smelter located in a remote area.

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APPENDIX A

MASS BALANCE CALCULATIONS

The following assumptions have been made:

1. The dry concentrate contains 25% Cu, 29% Fe, 33% S, 8% SiO_2.
2. The overall recovery of copper is 99%.
3. The cleaned slag contains 0.4% Cu.
4. A siliceous flux containing 90% SiO_2 is used.
5. The matte grade is 60% Cu. This means that the matte contains 75.1% Cu_2S and 24.9% FeS. The matte composition is therefore 60.0% Cu, 15.8% Fe and 24.2% S.
6. 97% of the sulphur in the concentrates reports in the gases passing to the acid plant. The remainder is lost in slag, blister copper, etc.
7. A 98% conversion of sulphur dioxide to sulphuric acid is obtained.

(All quantities in tonnes/a unless otherwise stated)

Smelter Capacity, Tonnes/a Cu	25,000	75,000	150,000
a. Feed to Flash Smelting Unit			
Copper in concentrates (99% recov.)	25,250	75,750	151,500
Concentrate required	101,000	303,000	606,000
Contained sulphur	33,330	99,990	199,980
Contained iron	29,290	87,870	175,740
Total SiO_2 required to form Fe_2SiO_4	15,690	47,070	94,140
SiO_2 in concentrates	8,080	24,240	48,480
Additional SiO_2 required	7,610	22,830	45,660
Siliceous flux (90% SiO_2)	8,460	25,370	50,740
Flux to dryers (see later section)	4,530	13,600	27,200
Total dry weight of new feed	105,530	316,600	633,200
Plus say 10% H_2O on dry weight	10,550	31,660	63,320
b. Air Requirements (flash smelter)			
Copper in matte	25,000	75,000	150,000
Total matte	41,660	125,000	250,000
Iron in matte	6,580	19,750	39,500
Sulphur in matte	10,080	30,250	60,500
∴ Iron oxidised to FeO in flash smelter	22,710	68,120	136,240
Oxygen required	6,490	19,460	38,920
Sulphur oxidised in flash smelter	23,250	69,740	139,480
Oxygen required	23,250	69,740	139,480
Total oxygen	29,740	89,200	178,400
Volume of oxygen, std m^3/a	20.8×10^6	62.4×10^6	124.8×10^6
Volume of air required, std m^3/a	99.0×10^6	297.1×10^6	594.2×10^6
Volume of exit gases, std m^3/a	94.5×10^6	283.5×10^6	567.0×10^6
Volume of SO_2, std m^3/a	15.8×10^6	47.3×10^6	94.6×10^6
% SO_2 (v/v)	16.7	16.7	16.7
Allow 20% dilution of gases for cooling:			
Total gases to acid plant, std m^3/a	113.4×10^6	340.2×10^6	680.4×10^6
% SO_2 (v/v)	14.3	14.3	14.3

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Smelter Capacity, Tonnes/a Cu	25,000	75,000	150,000
c. Flash Smelter Slag			
FeO in slag	29,200	87,580	175,160
SiO_2 required	12,160	36,480	72,960
SiO_2 in concentrates	8,080	24,240	48,480
∴ SiO_2 in flux	4,080	12,240	24,480
Flux to flash smelter	4,530	13,600	27,200
∴ Slag weight:			
FeO	29,200	87,580	175,160
Slag forming compounds in conc.	13,130	39,390	78,780
Fluxes	4,530	13,600	27,200
Sub Total	46,860	140,570	281,140
Copper in slag (0.4%)	190	560	1,120
Total	47,050	141,130	282,260
d. Converter Slag (after cleaning)			
FeO in slag	8,460	25,390	50,780
Flux to converters	3,930	11,770	23,540
Sub Total	12,390	37,160	74,320
Copper in slag (0.4%)	50	150	300
Total	12,440	37,310	74,620
Total slag production	59,490	178,440	356,880
e. Air Requirements (converter)			
Iron in matte	6,580	19,750	39,500
Oxygen required	1,880	5,640	11,280
Sulphur in matte	10,080	30,250	60,500
Oxygen required	10,080	30,250	60,500
Total oxygen	11,960	35,890	71,780
Volume of oxygen, std m^3/a	8.4×10^6	25.1×10^6	50.2×10^6
Volume of air required, std m^3/a	39.8×10^6	119.5×10^6	239.0×10^6
Allow 100% excess			
Total air required, std m^3/a	79.6×10^6	239.0×10^6	478.0×10^6
Volume of exit gases, std m^3/a	78.4×10^6	235.1×10^6	470.1×10^6
Volume of SO_2, std m^3/a	6.8×10^6	20.5×10^6	41.0×10^6
% SO_2 (v/v)	8.7	8.7	8.7

Smelter Capacity, Tonnes/a Cu	25,000	75,000	150,000
f. Acid Production			
Total sulphur in gases	32,330	96,990	193,980
Volume of SO_2, std m^3/a	22.6×10^6	67.9×10^6	135.8×10^6
Total volume of gases, std m^3/a	172.9×10^6	518.6×10^6	1037.1×10^6
% SO_2 (v/v)	13.1	13.1	13.1
Acid production (98% conversion)	97,030	291,090	582,180

APPENDIX B

SMELTER CAPACITY 25,000 TONNES/a

1. Schedule of Major Items of Equipment

Section/Item	No.	Size
Charge Preparation		
Concentrate and flux storage bins	5	40 tonnes capacity
Rotary dryer	1	2 m dia. × 20 m
Exhaust fan	1	3600 std m^3/..
Electrostatic precipitator	1	3600 std m^3/h
Smelting		
Smelter feed bins	2	40 tonnes capacity
Flash smelting furnace	1	101,000 tonnes/a conc.
Air preheater	1	12,500 std m^3/h to 500°C
Blowers	3	5000 std m^3/h
Waste heat boiler (forced circulation)	1	8000 kg/h steam
Electric slag cleaning furnaces	2	1000 kva
Slag granulation facilities	1	60,000 tonnes/a
Converters	3	3 m dia. × 4 m
Overhead cranes	2	30 tonne capacity
Electrostatic precipitators:		
Flash smelter	1	15,000 std m^3/h
Converters	1	24,000 std m^3/h
Acid Plant		
Standard contact acid plant	1	100,000 tonnes/a

2. Schedule of Power Requirements

Item	No.	Power/Unit, kW	kWh/day
Rotary dryer and fan	1	35	840
Conveyors	8	5	960
Blowers (air preheaters)	3	100	7,200
Slag cleaning furnaces	2	1000	48,000
Converters (incl. blowers)	3	30	2,160

Item	No.	Power/Unit, kW	kWh/day
Overhead cranes	2	120 (installed)	1,730 (operating)
Acid plant	1	20 kWh/tonne	5,880
Blowers on stack	2	50	2,400
			69,170
Miscellaneous			830
Total			70,000

3. Direct Labour Requirements

The direct operating labour requirements are as follows:

Shift Operators	No.
Foreman	1
Feed bin attendant	1
Dryer operator	1
Flash and electric furnace operators	3
Matte tappers	2
Slag tappers	2
Control room operator	1
Converter operators	6
Crane drivers	2
Crane chasers	2
Boiler attendant	1
Electrostatic precipitator attendants	2
Acid plant operators	3
Total	27 × 4 shifts = 108

Day Labourers	No.
Slag disposal	2
Fork lift drivers	2
General labourers	8
Total	12

4. Raw Material and Utilities Requirements

Siliceous flux: 8,460 tonnes/a

Power: 70,000 kWh/day
or 23.1×10^6 kWh/a

Fuel oil:

Rotary dryer	960 tonnes/a
Air preheaters	2,070 tonnes/a
	3,030 tonnes/a

Water:

Fresh	220 megalitres/a
Cooling (recycled or from sea)	5,500 megalitres/a

Steam: Nil - plant is self sufficient

5. Total Production Costs

The total production costs are summarised as follows:

Item	Cost $/annum	Cost $/tonne Cu
1. Raw material and utilities		
Siliceous flux 8460 tonnes/a @ $8/t	67,680	2.71
Power 23.1 × 10^6 kWh/a @ 3¢/kWh	693,000	27.72
Fuel oil 3030 tonnes/a @ $80/t	242,400	9.70
Water (fresh) 220 megalitres/a @ 20¢/kl	44,000	1.76
Total raw material and utilities	1,047,080	41.89
2. Direct labour		
Shift operators 108 @ $11,000/a	1,188,000	47.52
Day labourers 12 @ $10,000/a	120,000	4.80
Total direct labour	1,308,000	52.32
3. Maintenance		
8% of capital (see Table 1)	2,800,000	112.00
4. Supervision		
20% of direct labour	261,600	10.46
5. Operating supplies		
10% of direct labour	130,800	5.23
6. Direct Manufacturing Costs (Items 1 to 5)	5,547,480	221.90
7. Payroll overhead		
20% of direct labour	261,600	10.46
8. Plant overhead		
125% of direct labour	1,635,000	65.40

Item	Cost	
	$/annum	$/tonne Cu
9. Process control		
25% of direct labour	327,000	13.08
10. Indirect Manufacturing Costs (Items 7 to 9)	2,223,600	88.94
11. Depreciation		
8% of capital	2,800,000	112.00
12. Property taxes and insurance		
1% of capital	350,000	14.00
13. Fixed Manufacturing Costs (Items 11 and 12)	3,150,000	126.00
14. Total Manufacturing Costs (Items 6, 10 and 13)	10,921,080	436.84
15. Administrative expenses		
3% of manufacturing cost	327,630	13.10
16. Distribution and marketing expenses		
10% of manufacturing costs	1,092,110	43.69
17. Research and development		
3% of manufacturing costs	327,630	13.10
18. Non-Manufacturing Costs (Items 15 to 17)	1,747,370	69.89
19. Total Production Costs (Items 14 and 18)	12,668,450	506.73

APPENDIX C

SMELTER CAPACITY 75,000 TONNES/a

1. Schedule of Major Items of Equipment

Section/Item	No.	Size
Charge Preparation		
Concentrate and flux storage bins	5	80 tonnes capacity
Rotary dryer	1	3 m dia. × 30 m
Exhaust fan	1	11,000 std m^3/h
Electrostatic precipitator	1	11,000 std m^3/h
Smelting		
Smelter feed bins	4	50 tonnes capacity
Flash smelting furnace	1	303,000 tonnes/a conc.
Air preheater	1	37,500 std m^3/h to 500°C
Blowers	4	10,000 std m^3/h
Waste heat boiler (forced circulation)	1	24,000 kg/h steam
Electric slag cleaning furnaces	2	3000 kva
Slag granulation facilities	1	180,000 tonne/a
Converters	3	4 m dia. × 7 m
Overhead cranes	2	50 tonne capacity
Electrostatic precipitators:		
Flash smelter	1	45,000 std m^3/h
Converters	1	70,000 std m^3/h
Acid Plant		
Standard contact acid plant	1	300,000 tonnes/a

2. Schedule of Power Requirements

Item	No.	Power/Unit, kW	kWh/day
Rotary dryer and fan	1	75	1,800
Conveyors	8	5	960
Blowers (air preheaters)	4	150	14,400
Slag cleaning furnaces	2	3000	144,000
Converters (incl. blowers)	3	60	4,320

Item	No.	Power/Unit, kW	kWh/day
Overhead cranes	2	230 (installed)	3,310 (operating)
Acid plant	1	20 kWh/tonne	17,640
Blowers on stack	2	100	4,800
			191,230
Miscellaneous			1,770
Total			193,000

3. Direct Labour Requirements

The direct operating labour requirements are as follows:

Shift Operators	No.
Foreman	1
Feed bin attendant	1
Dryer operator	1
Flash and electric furnace operators	3
Matte tappers	2
Slag tappers	2
Control room operator	1
Converter operators	9
Crane drivers	2
Crane chasers	2
Boiler attendant	1
Electrostatic precipitator attendants	2
Acid plant operators	3
Total	30 × 4 shifts = 120

Day Labourers	No.
Slag disposal	2
Fork lift drivers	2
General labourers	10
Total	14

4. Raw Material and Utilities Requirements

Siliceous flux: 25,370 tonnes/a

Power: 193,000 kWh/day
or 63.7×10^6 kWh/a

Fuel oil:

Rotary dryer	1,065 tonnes/a
Air preheaters	6,200 tonnes/a
	7,265 tonnes/a

Water:

Fresh	660 megalitres/a
Cooling (recycled or from sea)	16,500 megalitres/a

Steam:	Nil - plant is self sufficient

5. Total Production Costs

The total production costs are summarised as follows:

Item	Cost	
	$/annum	$/tonne Cu
1. Raw material and utilities		
Siliceous flux 25,370 tonnes/a @ $8/t	202,960	2.71
Power 63.7 × 10^6 kWh/a @ 3¢/kWh	1,911,000	25.48
Fuel oil 7,265 tonnes/a @ $80/t	581,200	7.75
Water (fresh) 660 megalitres/a @ 20¢/kl	132,000	1.76
Total raw material and utilities	2,827,160	37.70
2. Direct labour		
Shift operators 120 @ $11,000/a	1,320,000	17.60
Day labourers 14 @ 10,000/a	140,000	1.87
Total direct labour	1,460,000	19.47
3. Maintenance		
8% of capital (see Table 1)	7,520,000	100.27
4. Supervision		
20% of direct labour	292,000	3.89
5. Operating supplies		
10% of direct labour	146,000	1.95
6. Direct Manufacturing Costs (Items 1 to 5)	12,245,160	163.28
7. Payroll overhead		
20% of direct labour	292,000	3.89
8. Plant overhead		
125% of direct labour	1,825,000	24.33

Item	Cost $/annum	Cost $/tonne Cu
9. Process control		
25% of direct labour	365,000	4.87
10. Indirect Manufacturing Costs (Items 7 to 9)	2,482,000	33.09
11. Depreciation		
8% of capital	7,520,000	100.27
12. Property taxes and insurance		
1% of capital	940,000	12.53
13. Fixed Manufacturing Costs (Items 11 and 12)	8,460,000	112.80
14. Total Manufacturing Costs (Items 6, 10 and 13)	23,187,160	309.17
15. Administrative expenses		
3% of manufacturing costs	695,610	9.27
16. Distribution and marketing expenses		
10% of manufacturing costs	2,318,720	30.92
17. Research and development		
3% of manufacturing costs	695,610	9.27
18. Non-Manufacturing Costs (Items 15 to 17)	3,709,940	49.46
19. Total Production Costs (Items 14 and 18)	26,897,100	358.63

APPENDIX D

SMELTER CAPACITY 150,000 TONNES/a

1. Schedule of Major Items of Equipment

Section/Item	No.	Size
Charge Preparation		
Concentrate and flux storage bins	8	100 tonnes/capacity
Rotary dryers	2	3 m dia. × 30 m
Exhaust fan	2	11,000 std m^3/h
Electrostatic precipitator	2	11,000 std m^3/h
Smelting		
Smelter feed bins	4	100 tonnes/capacity
Flash smelting furnace	1	606,000 tonnes/a conc.
Air preheater	1	75,000 std m^3/h to 500°C
Blowers	8	10,000 std m^3/h
Waste heat boilers (forced circulation)	2	24,000 kg/h steam
Electric slag cleaning furnaces	2	6000 kva
Slag granulation facilities	1	360,000 tonnes/a
Converters	3	4 m dia. × 10 m
Overhead cranes	2	60 tonne capacity
Electrostatic precipitators:		
Flash smelter	1	90,000 std m^3/h
Converters	1	140,000 std m^3/h
Acid Plant		
Standard contact acid plant	1	600,000 tonnes/a

2. Schedule of Power Requirements

Item	No.	Power/Unit, kW	kWh/day
Rotary dryers and fans	2	75	3,600
Conveyors	12	5	1,440
Blowers (air preheaters)	8	150	28,800
Slag cleaning furnaces	2	6000	288,000
Converters (incl. blowers)	3	100	7,200

Item	No.	Power/Unit, kW	kWh/day
Overhead cranes	2	270 (installed)	3,900 (operating)
Acid plant	1	20 kWh/tonne	35,280
Blowers on stack	2	150	7,200
			375,420
Miscellaneous			3,580
Total			379,000

3. Direct Labour Requirements

The direct operating labour requirements are as follows:

Shift Operators	No.
Foreman	1
Feed bin attendant	1
Dryer operators	2
Flash and electric furnace operators	3
Matte tappers	2
Slag tappers	2
Control room operator	1
Converter operators	9
Crane drivers	2
Crane chasers	2
Boiler attendant	1
Electrostatic precipitator attendants	2
Acid plant operators	4
Total	32 × 4 shifts = 128

Day Labourers	No.
Slag disposal	2
Fork lift drivers	2
General labourers	12
Total	16

4. Raw Material and Utilities Requirements

Siliceous flux:	50,740 tonnes/a
Power:	379,000 kWh/day or 125.1×10^6 kWh/a

Fuel oil:	
Rotary dryers	1,145 tonnes/a
Air preheaters	12,395 tonnes/a
	13,540 tonnes/a
Water:	
Fresh	1,320 megalitres/a
Cooling (recycled or from sea)	33,000 megalitres/a
Steam:	Nil - plant is self sufficient

5. Total Production Costs

Item	Cost	
	$/annum	$/tonne Cu
1. Raw material and utilities		
Siliceous flux 50,740 tonnes/a @ $8/t	405,920	2.71
Power 125.1×10^6 kWh/a @ 3¢/kWh	3,753,000	25.02
Fuel oil 13,540 tonnes/a @ $80/t	1,083,200	7.22
Water (fresh) 1320 megalitres/a @ 20¢/kl	264,000	1.76
Total raw material and utilities	5,506,120	36.70
2. Direct labour		
Shift operators 128 @ $11,000/a	1,408,000	9.39
Day labourers 16 @ $10,000/a	160,000	1.06
Total direct labour	1,568,000	10.45
3. Maintenance		
8% of capital (see Table 1)	13,120,000	87.47
4. Supervision		
20% of direct labour	313,600	2.09
5. Operating supplies		
10% of direct labour	156,000	1.05
6. Direct Manufacturing Costs (Items 1 to 5)	20,664,520	137.76
7. Payroll overhead		
20% of direct labour	313,600	2.09
8. Plant overhead		
125% of direct labour	1,960,000	13.07

Item	Cost	
	$/annum	$/tonne Cu
9. Process control 25% of direct labour	392,000	2.61
10. Indirect Manufacturing Costs (Items 7 to 9)	2,665,600	17.77
11. Depreciation 8% of capital	13,120,000	87.47
12. Property taxes and insurance 1% of capital	1,640,000	10.93
13. Fixed Manufacturing Costs (Items 11 and 12)	14,760,000	98.40
14. Total Manufacturing Costs (Items 6, 10 and 13)	38,090,120	253.93
15. Administrative expenses 3% of manufacturing costs	1,142,700	7.62
16. Distribution and marketing expenses 10% of manufacturing costs	3,809,010	25.39
17. Research and development 3% of manufacturing costs	1,142,700	7.62
18. Non-Manufacturing Costs (Items 15 to 17)	6,094,410	40.63
19. Total Production Costs (Items 14 and 18)	44,184,530	294.56

TABLE 1: BREAKDOWN OF CAPITAL COSTS FOR THREE CAPACITIES

Item		Costs, $m		
	%	25,000	75,000	150,000
Furnaces, converters, and ancillaries	49.5	17.3	46.5	81.2
Acid plant	26.8	9.4	25.2	43.9
Engineering design and procurement	6.5	2.28	6.11	10.7
Materials handling and drying	5.2	1.82	4.89	8.53
Stack	4.6	1.61	4.33	7.54
Flue system	4.1	1.44	3.86	6.72
Plant buildings	1.5	0.52	1.41	2.46
Electrical facilities	1.5	0.52	1.41	2.46
Instrumentation	0.3	0.11	0.29	0.49
Total	100.0	35.0	94.0	164.0

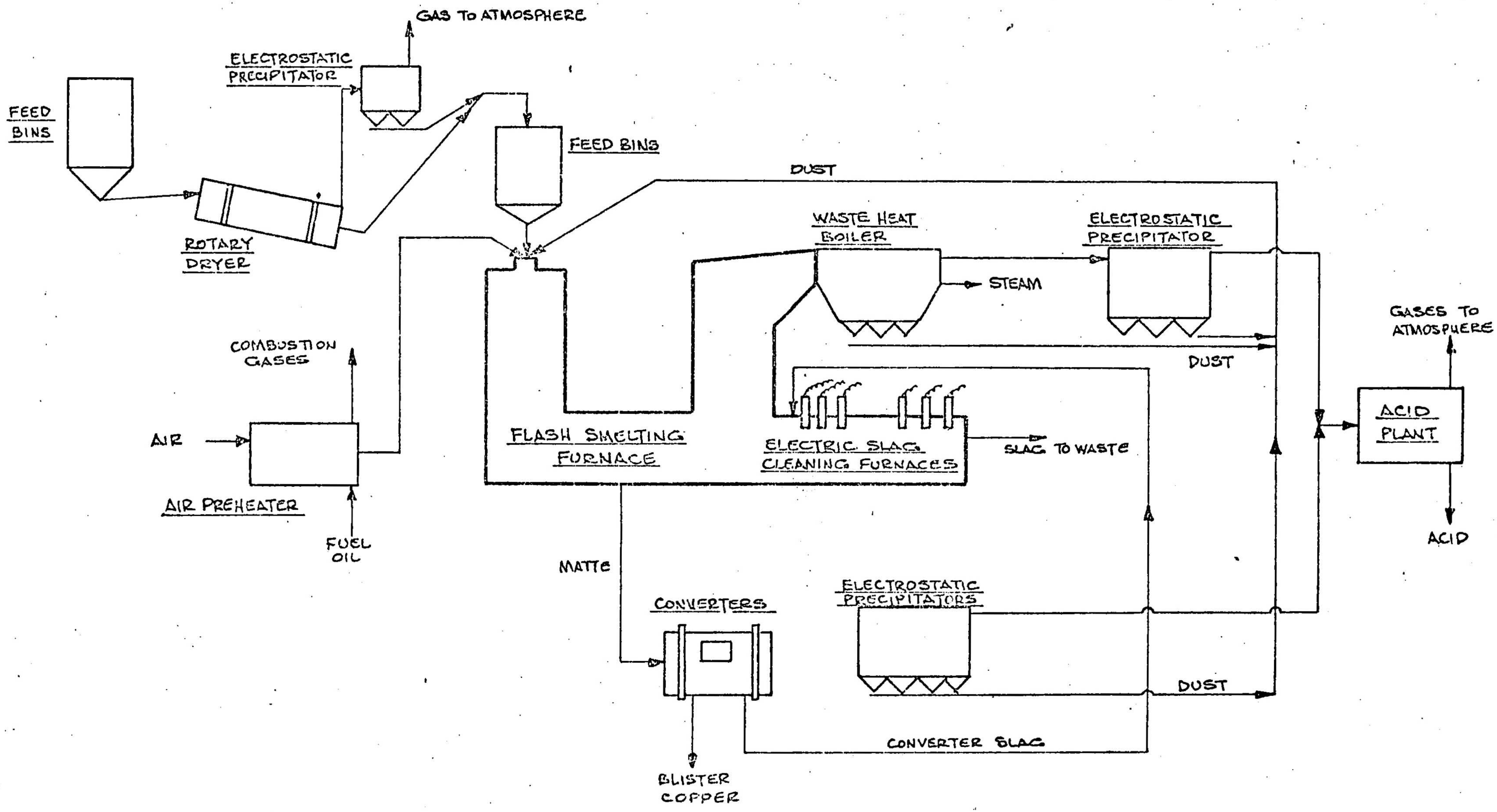

FIG.1: FLASH SMELTING FLOWSHEET

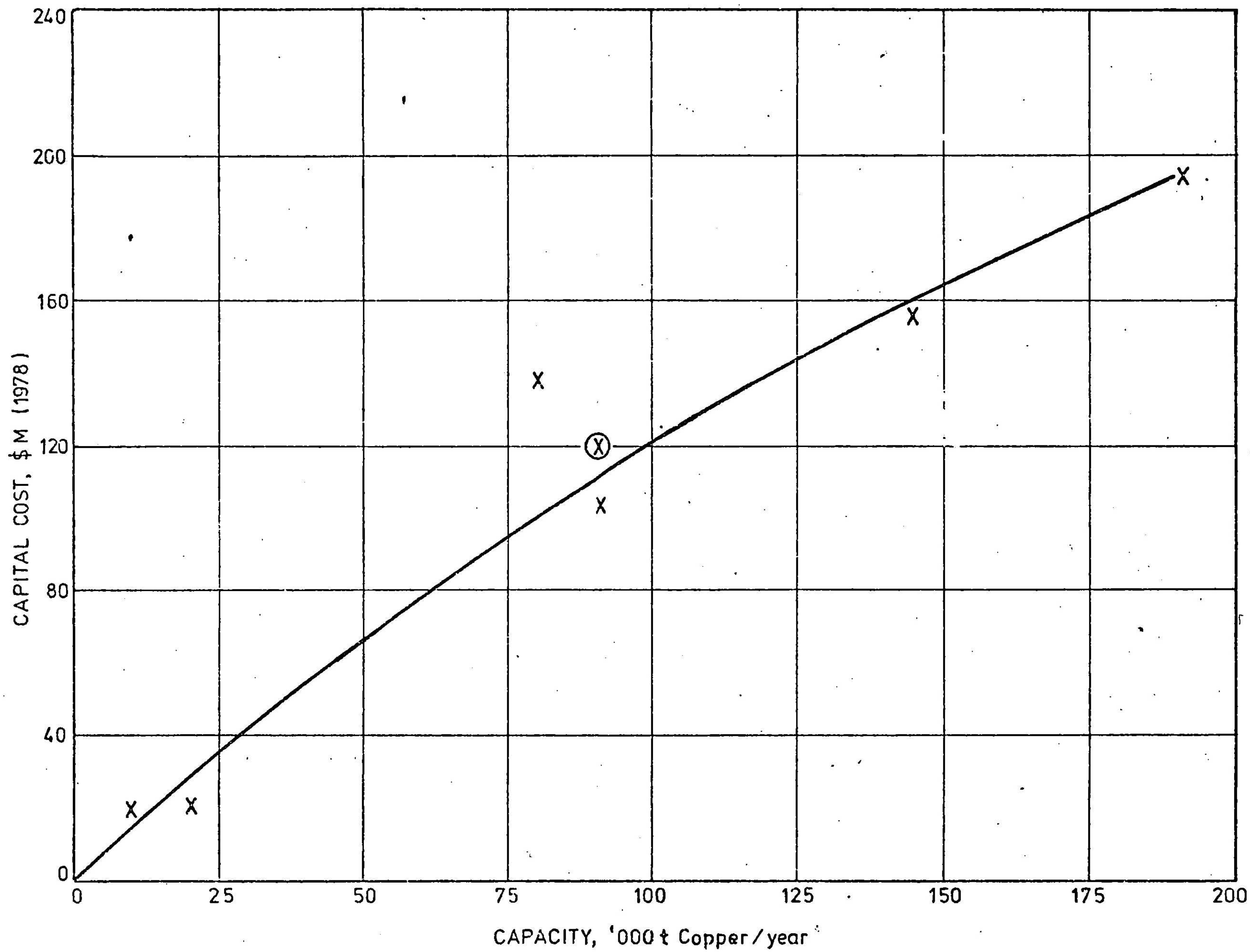

FIG. 2 : CAPITAL COST OF COPPER SMELTERS