Sao Luis	US$ 150/ton
Barcarena	150
Tucurui	200
Maraba	250

vi) Elemental sulfur

Elemental sulfur was assumed to be imported from Canada or Mexico. Estimated price is as follows.

Sao Luis	US$ 120/ton
Barcarena	120
Tucurui	145
Maraba	138

vii) Naphtha

Naphtha is assumed as oleo diesel (Sp. gr. 0.7), and the cost was estimated as follows including delivery charge.

Sao Luis	US$ 450/ton
Barcarena	450
Tucurui	475
Maraba	468

viii) Ammonia

Ammonia shall be supplied from the state of Sao Paulo. According to DNPM's price statistics, the price was supposed to be US$ 157/ton FOB Sao Paulo. Plant site price in each industrial district will be as follows under considerations of transportation cost using high-pressure vessel.

Sao Luis	US$ 250/ton
Barcarena	260
Tucurui	300
Maraba	350

3-2-4 Ferro-nickel Smelter

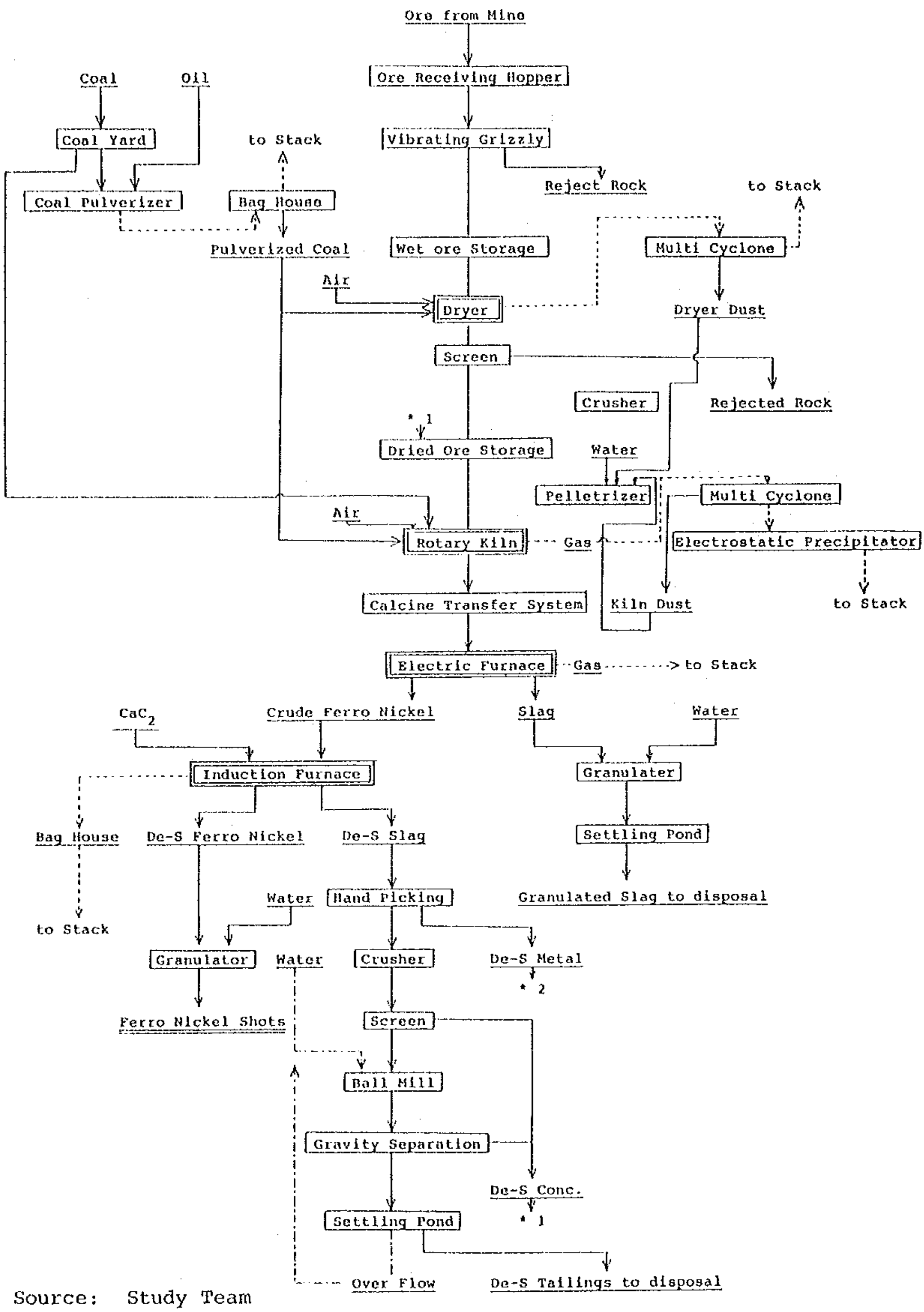
(1) Production process and plant scale

Production process : ELKEM process
Plant capacity:
As contained nickel (Ni), 12,000 tons/year
As ferro-nickel (Fe-Ni) shot, 48,000 tons/year

(2) Process flow sheet

Refer to Figure 3-8.

Figure 3-8 Flow Sheet for Ferro-nickel Smelter



Source: Study Team

(3) Plant lay-out

Refer to Figure 3-9.

(4) Process description

Ore Preparation

Ore preparation includes upgrading and drying. Ore from the mine is dumped into the receiving hopper by the belt feeder, which feeds the vibrating grizzly with 30 cm openings. Large boulders, barren of nickel, are discharged onto a reject pile and discarded. Grizzly undersize is conveyed to the covered 50,000 ton wet ore storage building and stockpiled. The ore upgrading and wet ore stockpiling is scheduled to operate 200 days per year, two shifts per day, in accordance with the mine operation.

The ore is reclaimed by front-end loaders into the dryer feed bins. Drying of the ore is carried out in a 4.5 m diameter by 35 m long co-current pulverized coal fired dryer. The moisture content of the ore is reduced from 30% to 20% in the dryer. The ore is only partially dried so that it is not too dusty during subsequent handling.

The partially dried ore is then screened on the double deck screens, to further reject over 5 cm barren rock for upgrading, with the over 2 cm portion being crushed in a cone crusher and joining the minus 2 cm ore stream. The partially dried ore storage building has a capacity of 20,000 tons, in which a stacker lays the ore in layers for ore blending. The dryer operates 330 days per year, three shifts per day. Off gas from the dryer is dust-collected through the multiclones and is discharged to the atmosphere.

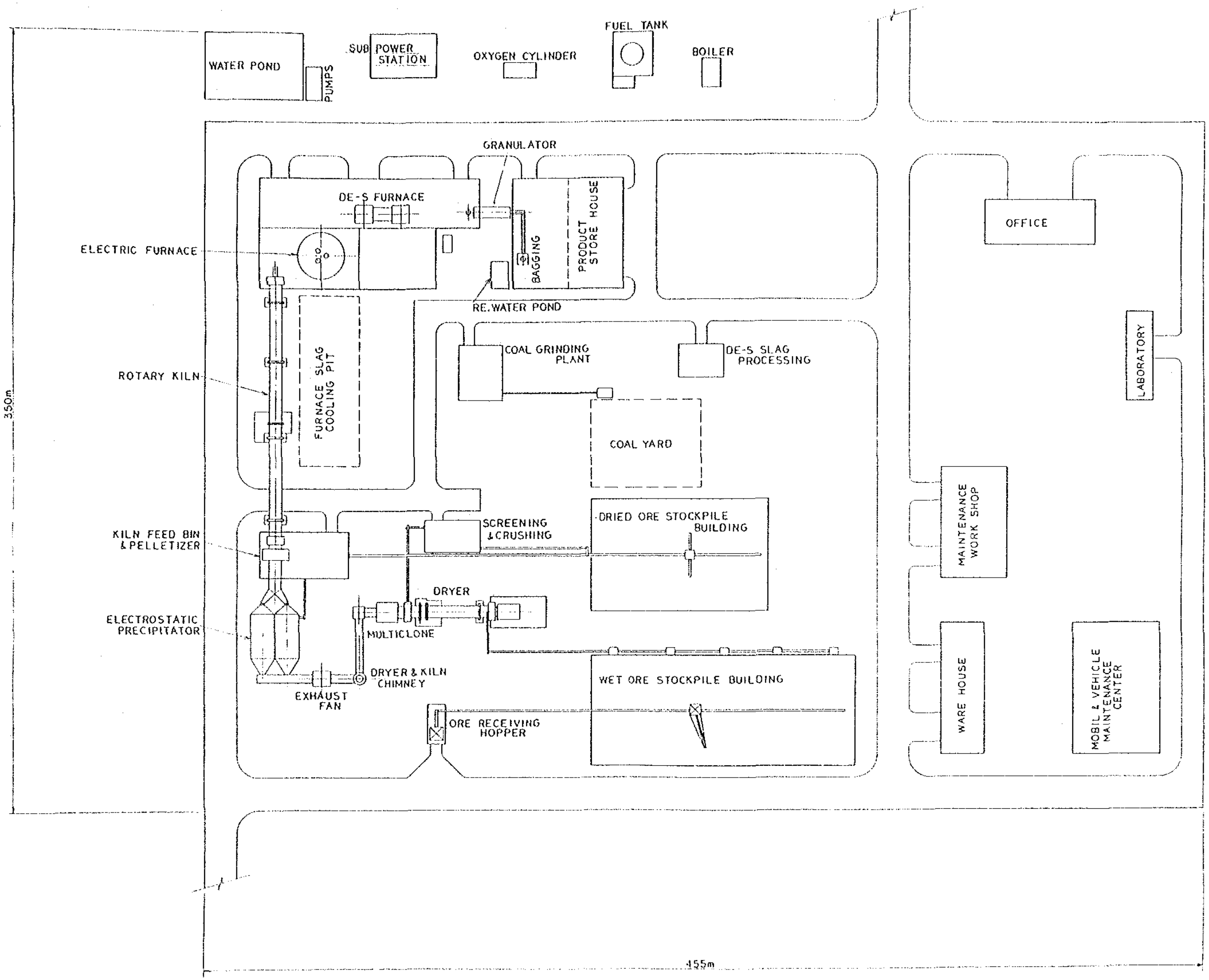
In the ore preparation operation ore is upgraded from 2.0% Ni to 2.2% Ni.

Reduction

The partially dried ore in the storage building is reclaimed by front-end loaders, which cut the stockpile perpendicularly for further blending.

The reduction kiln is a 5.2 m diameter by 115 m long counter-current pulverized coal fired rotary kiln. In the midsection of the kiln, scoop feeders are installed, through which bituminous lamp coal is added as reductant. As the ore travels from the feed end to the discharge end of the kiln, it is dehydrated and preheated. In the reducing atmosphere, produced by the decomposition and partial combustion of the lump coal which is added in the midsection of the kiln, the ore is pre-reduced. Sensible heat is supplied by the pulverized coal burner installed at the discharge end of the kiln, and the additional heat is generated by injecting air through four kiln-mounted air ports to burn combustibles arising from the reduction zone, with the kiln discharge temperature being around 900°C.

Figure 3-9 Plant Lay-out for Ferro-nickel Smelter



Source: Study Team

Off-gas from the kiln passes through the multiclones, followed by the electrostatic precipitation, and the dust-eliminated off-gas is discharged to the atmosphere.

Kiln-dust, thus collected, and dryer multiclone dust, 8 - 10% by weight of the ore treated, is pelletized and recycled to the rotary kiln.

Smelting

The hot reduced calcine goes into a surge bin below the discharge of the kiln and is discharged into refractory-lined air-tight containers. The containers are hoisted up by a crane to discharge the calcined ore into one of the nine refractory-lined furnace feed bins, each of which is equipped with a bin cover to keep the furnace feed bin air-tight, in order to prevent reoxidation of the reduced ore. Crane operation is completely automatic, with a sensor set in each furnace feed bin selecting the bin which should be charged next, and delivering signals to the crane. The electric furnace is round with a diameter of 20 m. It utilizes three 2 m diameter self-baking electrodes to deliver up to 43 MW to the charge. The furnace is so charged that the molten slag is covered with the unmolten charge, so as to achieve the stable furnace operation and minimum heat loss, with energy comsumption of 470 kWh per ton of charge.

The crude ferro-nickel is tapped from the electric furnace into pre-heated refractory lined, stainless steel ladles with 30 ton capacity, which subsequently serve as refining vessels. The metal tapping temperature is 1,450°C. The furnace slag is skimmed approximately every four hours, granulated with pressure water and discarded.

Refining

An ASEA-SKF ladle furnace, consisting of an arc furnace roof, three 250 mm diameter graphite electrodes and induction stirrer, receives the ladle containing 30 tons crude ferro-nickel. The metal is reheated by applying electrode power at 2 MW for 5 minutes. Calcium carbide is added as desulfurizing agent and the strong induction stirring accelerates the desulfurizing reaction between the solid agent and the metal. The metal is desulfurized well within specifications in 30 minutes. After a metal sample is taken for sulfur analysis and the slag is removed, the metal is deoxidized by aluminum lumps.

Shot Making

The refined ferro-nickel is transported to the shot-making area, consisting of a tilter, a metal launder, a shot-making pond, a rotating table net conveyors, a dryer, screens product silos, a product packer and a product storage house.

A flow rate control of the metal and the rotating table produces good pebble-shaped ferro-nickel granules, which are packed in 2 ton flexible containers and shipped to stainless steel makers.

Desulfurization Slag Processing

Every ton of the nickel contained in the ferro-nickel produces 208 kg desulfurization slag (de-S slag), containing 28 kg nickel and 25 kg sulfur. To reclaim the metal values in the de-S slag, it is processed to eliminate sulfur, which would cause uneconomical sulfur build-up in the system. Through hand-picking, crushing, wet grinding, screening and gravity-separation, 96% of the nickel contained in the de-S slag is reclaimed and recycled to the system, while sulfer is discarded in the form of gravity-separation tailings.

(5) Material balance

Refer to Table 3-10.

(6) Personnel requirement

Refer to Table 3-11.

(7) Construction cost

Refer to Table 3-12.

(8) Operation cost factors

Raw material		
Raw nickel ore	(dry base)	663,800 tons/year
Ni	2.0%	
Fe	15%	
Loss of Ignition (L.O.I)	10%	
Sub material		
Coal		104,777 tons/year
Calcium carbide		888 tons/year
Aluminium		50 tons/year
Liquid oxygen		500 km³/year
Utilities		
Electric power		323,076 MWh/year
Fuel oil		900 kℓ/year
Industrial water		3,800,000 m³/year
Supplies		
Electrode casing (US$ 833/ton)		59 tons/year
Electrode paste (US$ 900/ton)		763 tons/year
Graphite electrode (US$ 2,254/ton)		49 tons/year
Refractories (US$ 504/ton)		480 tons/year

Other miscellaneous cost

10% of sum of above costs.

Table 3-10 Material Balance for Ferro-nickel Smelter

			DMTPY	% Ni	TPY Ni	REMARKS
Pre-treatment	Processed	Ore from Mine	663,800	2.0	13,276	
	Produced	Ore	621,476	2.1	13,051	
		Reject Rock	34,895	0.5	175	to disposal
		loss			50	
					(13,276)	
Dryer & Ore Sizing	Processed	Ore	621,476	2.1	(13,051)	
	Produced	Dried Ore	578,682	2.2	12,731	
		Dried Dust	5,923	2.2	131	recycled to R/K
		Reject Rock	34,895	0.5	175	to disposal
	loss				14	
					(13,051)	
Potary Kiln	Processed	Dried Ore	578,682	2.2	12,731	
		Dryer Dust	5,923	2.2	131	via pelletizer
		Kiln Dust	44,618	2.2	982	
		De-S Conc	1,185	17.7	210	from De-S Slag processing
			(630,408)		(14,054)	
	Produced	Calcine	528,411	2.5	13,058	
		Kiln Dust	44,618	2.2	982	recycled to R/K
	loss				14	
					(14,054)	
Electric Furnace	processed	Calcine	528,411	2.5	13,058	
		De-S Metal	622	17.9	111	from De-S Slag processing
			(529,033)		(13,169)	
	produced	Crude Ferro-nickel	49,356	25.0	12,339	
		E/F Slag	449,389	0.2	809	to disposal
	loss				21	
					(13,169)	
Induction Furnace & Shot Making	processed	Crude Ferro-nickel	49,356	25.0	12,339	
	produced	Ferro-nickel	48,000	25.0	12,000	
		De-S Slag	2,493	13.4	333	
	loss				6	
					(12,339)	
De-S Slag Processing	processed	De-S Slag	2,493	13.4	333	
	produced	De-S Metal	622	17.9	111	recycled to E/F
		De-S Conc	1,185	17.7	210	recycled to R/K
		De-S Tailings	686	1.8	12	to disposal

Source: Study Team

Table 3-11 Estimated Personnel Requirement for Ferro-nickel Smelter

(unit : man)

	General Manager	Assist. G.M.	Super-intendent	Assit. Superintendent	Engineer	Foreman	Operator Technician	Worker
Administration Office				1	5	15		
Accounting Section				1	3	7		
Purchasing Section	1	2		1	5	10		
Plant Operation Group			1	6	10	5	50	
Engineering Section				1	5	5	40	
Transportation and Other Services				1		2	3	30

Source: Study Team

Table 3-12 Hypothetical Model Plant (Ferro-nickel Smelter) Estimated Construciton Cost

(Unit: US$ 1,000)

	Sao Luis	Barcarena	Tucurui	Maraba
Land price	6	5	4	4
Land preparation	208	208	208	208
Plant direct cost (A)				
Process plant	59,625	59,625	59,625	59,625
Utility plant	5,625	5,625	5,625	5,625
Offsite facilities	10,208	10,208	10,208	10,208
Plant direct cost (B)				
Spare parts	1,762	1,762	1,762	1,762
Cata and Chemicals	417	417	417	417
Temporary works	3,773	3,773	3,773	3,773
Plant indirect cost				
Construction equip.	7,546	7,546	7,546	7,546
Ocean freight and ins.	3,843	3,843	3,843	3,843
Inland freight and ins.	281	281	2,122	1,592
License, Engineering and Services	18,865	18,865	18,865	18,865
Indirect field expenses	3,018	3,018	3,018	3,018
Other facilities				
Transmission cable	495	297	495	2,376
Waterintake and pipeline	1,750	1,050	350	3,500
Housing colony	-	6,240	-	5,760
Project management	1,509	1,509	1,509	1,509
Pre-operating expenses	2,526	3,166	3,102	2,316
Contingency	18,219	19,116	18,371	19,792
Interest during const.	15,355	18,730	17,980	17,990
Initial working capital	15,411	15,844	14,165	15,490
Total Capital Requirement	170,442	181,128	172,988	185,219

Source: Study Team

(9) Study on raw materials

(a) Technical study and cost study for nickel ore.

The source and composition of raw material ore for the ferro-nickel smelter is assumed as same as for nickel metal smelter.

The cost situation of ore transportation will also be on same basis.

Detailed assumptions and calculations are given in Section 4-1-6(1).

(b) Coal

Refer to Section 3-2-1,(10),(b),(vi).

(c) Calcium carbide

Calcium carbide for the induction furnace shall be assumed to be supplied from south areas by ship. Using the average plant site price in July 1984, US$ 395.6/ton, prices were estimated for each plant site as follows.

Sao Luis	US$ 400/ton
Barcarena	410
Tucurui	435
Maraba	420

(d) Aluminium

Metallic aluminium is assumed to be available both in Sao Luis and Barcarena. According to market price of January to April, 1984, average Cr$ 2,000/kg FOB (US$ 2.08/kg), US$ 2,080/ton was assumed as unit price at all plant sites. Transportation charge is negligible small to the metal price.

(e) Fuel oil

Refer to Section 3-2-3,(9),(b),(iv).

(f) Liquid oxygen

Liquid oxygen cost was estimated as to be produced by a small air separation unit. It was assumed as US$ 0.53/m^3 in each industrial district. The majority of the production cost of oxygen is the electric power cost.

3-2-5 Tin Smelter and Refinery

(1) Production process and plant scale

Production process

Smelter:	Three-stage smelting by two electric furnaces and liquating process
Refinery:	Electrolytic refining process
Production capacity	Electrolytic tin 7,000 tons/year

(2) Process flow sheet

Refer to Figure 3-10.

(3) Plant lay-out

Refer to Figure 3-11.

(4) Process description of smelter

(a) Plant Equipment

(i) Raw materials handling and storage facilities

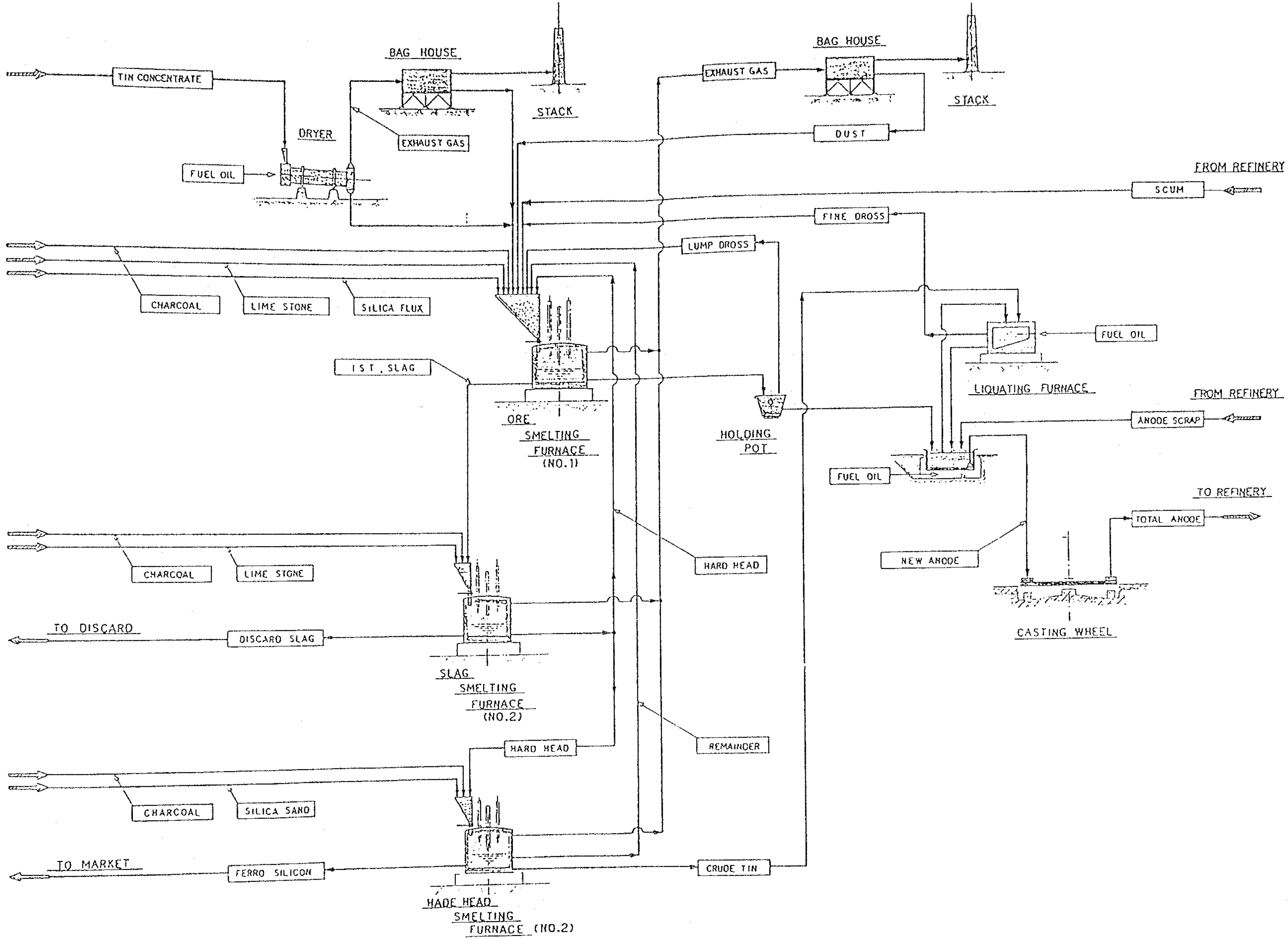
The rotary drier is 1.95 m in diameter and 12 m in length with a capacity to dry 13 tons/hr of concentrate from 12% to 6% moisture by firing of fuel oil.

(ii) Ore smelting furnace (#1 Furnace)

A stationary type 2,600 kVA electric furnace is used for ore smelting. The furnace is 3.1 m in diameter and 2.8 m in height inside brickwork. The furnace bottom and lower portion of the side wall are lined with magnesite-chrome bricks and the upper portion of the side wall is lined with fireclay bricks (SK 34). The furnace roof is of cooling jacket structure. The bottom is of special structure so as to prevent "floating" of bricks by penetration of tin metal.

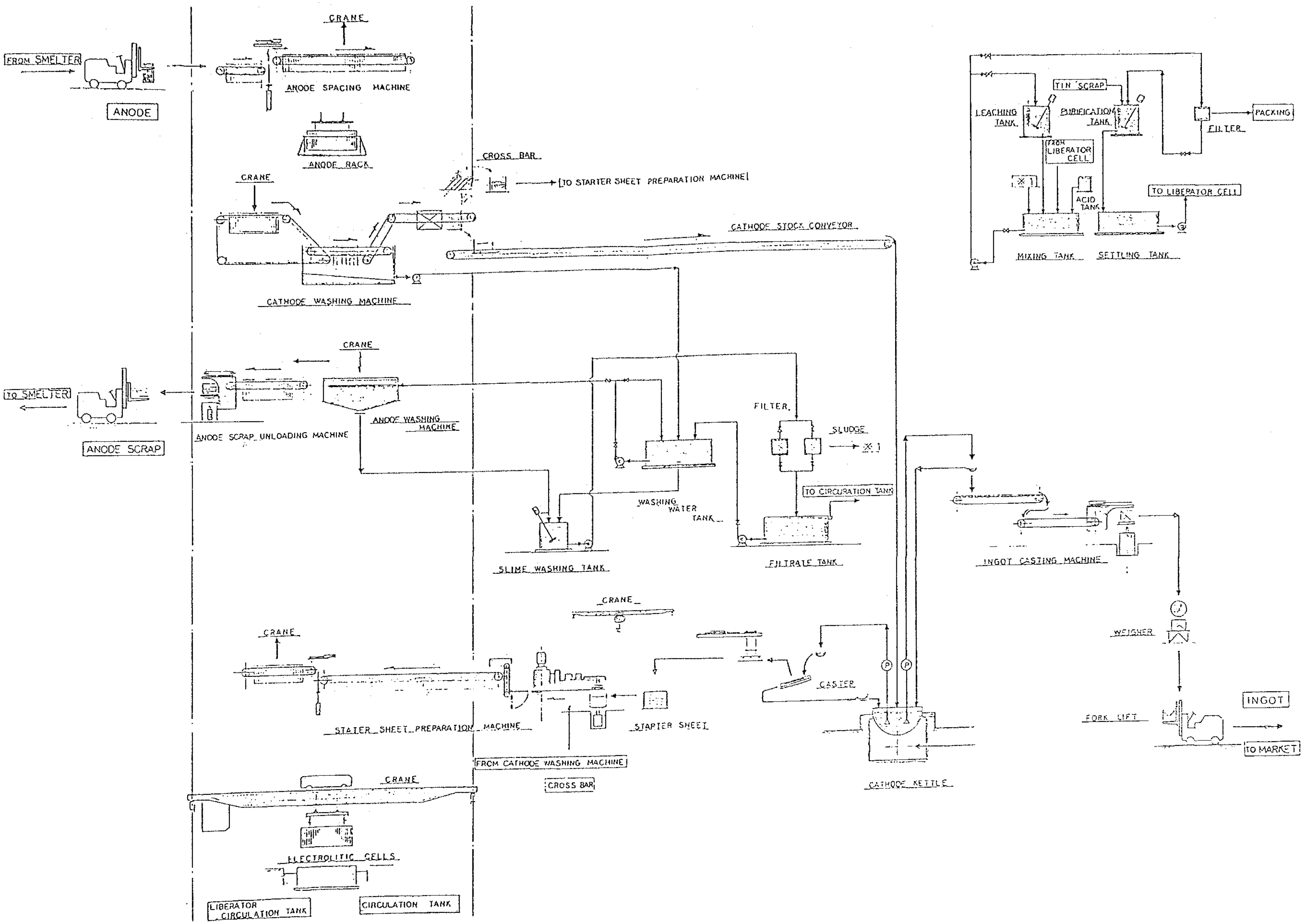
The furnace is equipped with three artificial graphite electrodes each with 400 mm diameter respectively (electrode slipping is done automatically). The voltage supplied to the electrodes is controlled manually depending upon the furnace conditions. The furnace flue is a side-take with fireclay brick construction. The flue is partly provided with cooling jackets.

Figure 3-10(A) Process Flow Sheet for Tin Smelter



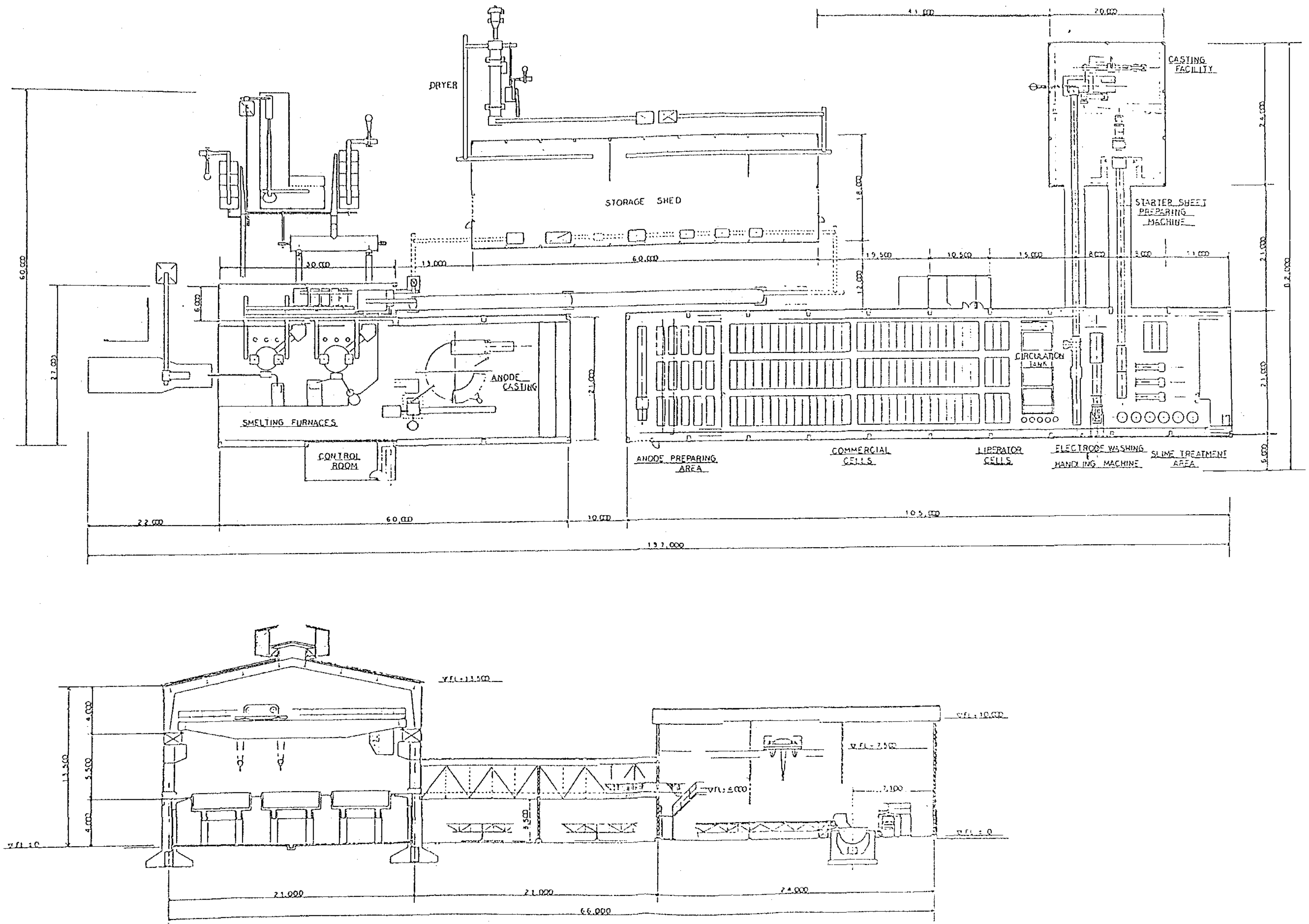
Source: Study Team

Figure 3-10(B) Process Flow Sheet for Tin Refinery



Source: Study Team

Figure 3-11 Plant Lay-out for Tin Smelter and Refinery



Source: Study Team

(iii) Slag smelting and hard-head smelting furnace (#2 furnace)

A stationary electric furnace with a 2,400 kVA transformer capacity is used alternately for slag smelting and hard-head smelting. The furnace is 3.0 m in diameter and 2.8 m in height inside brickwork. The furnace construction is identical to the ore smelting furnace except the side wall, which is lined with silica bricks.

(iv) Liquating furnace

The internal dimensions of the furnace are 1.3 m wide, 2.3 m long and 0.75 and 1.75 m high. The furnace is constructed of fireclay bricks with the hearth made of cast iron.

(v) Anode casting facilities

The crude tin and anode scraps are fed to a 30-ton capacity anode kettle. The anode kettle is heated by firing of fuel oil.

The molten crude tin is then sent to the casting wheel by a pump with a 300 ℓ/min. capacity. The casting wheel is a non-stop Walker-type wheel, mounted with 16 cast-iron molds. The wheel is 10 m in diameter. The cast anodes are then removed from the wheel by an automatic take-off machine and delivered out of the casting plant.

(vi) Power supply

Electric power is received at 66,000 V and distributed as follows:

Electric furnace	5,000 kVA
Motors, etc.	1,000 kVA
(Electrolytic refinery)	(420 kVA)

The voltages for the respective uses are as follows:

Motors over 200 HP	3,300 V
Other motors	440 V
Lighting	240 V
Instrumentation	48 V

(vii) Water supply

The maximum instantaneous consumption, which is expected when the slag smelting is in operation and the #2 furnace is being tapped, is approximately 1,000 tons/hr.

(b) Process description

(i) Feed preparation

Tin concentrate is first dried in a rotary dryer. The dried concentrate is then stored in the dried concentrate storage shed. The dust recovered in the bag house is mixed and stored with the dried concentrate.

Silica flux, limestone and charcoal are received and stored in the respective storage shed.

The smelter reverts are fed directly into a discharge hopper.

A predetermined one-day charge of each raw material is weighted and fed into the respective hopper by a belt feeder. The charge materials are then conveyed to a mixture hopper above the ore smelting furnace (#1 furnace).

The hard-head recycled to the ore smelting furnace is sent to a hard-head bin.

The charge materials to the slag smelting furnace (#2 furnace) for both slag and hard-head smelting are sent to the respective hoppers above the furnace.

(ii) Ore smelting

In the ore smelting stage, the tin content in concentrate is reduced by charcoal to produce crude tin.

The expected compositions of the products from the ore smelting furnace are as follows:

Crude tin

Sn: 97 - 99%   Fe: 0.4 - 0.8%

Slag

Sn: 25.0%   Fe: 1.60% SiO_2: 25.5%   CaO: 7.0%

The melting point of the slag would be approximately 1,100 - 1,150°C.

Approximately 70% of the blended charge is first fed from the mixture hopper into the furnace. The fed materials are then spread evenly in the furnace. The recycled hard-head and dross are then fed evenly over the blended charge. The furnace is then heated up and when the charge materials are melted down, 20% of the charge is fed and when this is melted, the remaining 10% of the charge is fed.

The total amount of one-batch charge is 18.0 tons including 10.7 tons of concentrate. The smelting of one-batch charge takes 4.7 hours for smelting and 1.3 hours for charging, rabbling and tapping (total operating time: 6 hours).

Power consumption in this furnace is approximately 780 kWh/ton concentrate.

There are two different operations in the treatment of the molten product tapped from the furnace. When the #2 furnace is in slag smelting operation, the melt is introduced to a "separator", where the crude metal remains and the slag overflows into a ladle. The slag is then charged in molten state to the slag smelting furnace. The crude metal is sent to a holding pot and after removal of dross, sent to an anode kettle. On the other hand, when the #2 furnace is not in slag smelting operation, the molten product is separated to slag and metal in the forehearth. The slag is then granulated with water, while the metal is received in a ladle to be transferred to the holding pot.

(iii) Slag smelting

The products from this stage are discard slag and tin-iron alloy (hard-head).

The expected composition of the products are as follows:

Hard-head

Sn: 69.5% Fe: 28.7%

Slag

Sn: 1.0% Fe: 10.0% SiO_2: 40.0% CaO: 23.0%

The melting point of the slag is 1,350 - 1,400°C.

The first slag produced in the ore smelting stage is charged together with charcoal and limestone. One-batch operation is scheduled in accordance with the operating time of the ore smelting stage. The smelting takes 4.2 hours and charging, rabbling, tapping waiting, etc., 1.8 hours, the total operating time being 6 hours.

Power consumption in this furnace is approximately 550 kWh/ton slag.

The molten product is discharged from the furnace into the forehearth, in which the melt is separated to slag and hard-head. The hard-head is granulated with water, approximately 80% of it is recycled to the ore smelting stage and the remaining 20% is sent to the hard-head smelting stage.

(iv) Hard-head smelting

The products from this stage are ferro-silicon and crude tin.

The expected composition of the products is as follows:

Crude tin

Sn: 90% Fe: 60%

Slag

Fe: 77% Si: 16% Sn: 3.5%

The operating temperature of this stage would be 1,450 - 1,500°C.

The granulated hard-head is fed into the furnace together with charcoal and silica sand. The total time required for one-batch operation is 6 hours (smelting 4.5 hours and charging rabbling and tapping 1.5 hours).

Power consumption in this furnace is approximately 2,100 kWh/ton hard-head.

The crude tin is cast into ingots and then sent to the liquating furnace.

(v) Liquating

In this liquating furnace, fuel oil is fired to heat the fed materials at 400 - 500°C. Tin metal melts down along the sloped hearth and flows out of the furnace. Iron and other impurities with higher melting points remain in the furnace as fine dross. The crude metallic tin is sent to the anode kettle.

(vi) Anode casting

The crude tin produced in the ore smelting furnace, liquating furnace and anode scraps sent from the refinery are fed into the anode kettle and cast at 300 - 350°C. The anode scrap ratio in the refinery is expected to be 25% and the total amount of anodes cast is approximately 29 tons/day. The weight of one anode is 280 kg.

(vii) Gas and dust handling

The off-gases from the #1 and #2 furnaces pass through respectively the dust chamber, cooled flue and balloon flue to be then sent to the bag house for dust removal.

The dust collected in the bag house are pelletized together with the dust recovered from the gas trains and recycled to the ore smelting furnace.

(5) Process description of refinery

(a) Refinery equipment

(i) Preparation of anodes

The anodes are first transported by a forklift truck to the anode spacing machine located at the inlet of the tankhouse to be spaced at a 110 mm pitch. The anodes thus spaced are then transferred by a 3 ton crane to the two-stage anode racks in one cell lot. The number of anode stored on the racks is 1,200, which corresponds to 30 cell lots.

(ii) Electrolytic cells

The electrolytic cells are constructed of reinforced concrete lined with 10 - 20 mm asphalt with the internal dimensions of 1,200 mm W x 4,750 mm L x 1,300 mm H. The commercial section consists of 6 blocks, each with 15 cells. Each block is provided with a circuit-breaker respectively. The capacity of the rectifier is 5,000 A, 30 V, 150 kW.

(iii) Anode washing machine

The anodes are removed from the cells every 6 days together with cathodes for washing-off of the slimes and then returned back to the cells. The anode washing machine consists of the slimes washing section, anodes collecting and unloading section (used when anodes are discharged as anode scraps), washing water filtering and recycling section, and slimes discharge section.

The scrap anodes, the anodes after 30-day electrolysis, are washed, collected and sent to the anode casting area by a forklift truck.

(iv) Cathode washing machine

The cathodes unloaded on the cathode washing machine are washed on the conveyor, collected in one cell lot and, after cross bars are mechanically pulled off, conveyed to the electrolytic tin casting area.

(v) Casting of refined tin

Cathodes conveyed from the tankhouse are melted in the cathode kettle provided with the burner facilities, which automatically control the melt temperature at 300 - 350°C, and cast into 36 kg ingots by the constant feed casting machine. The casting machine is of endless belt type equipped with an automatic scraper and cooling device. The ingots are automatically stacked in 5 stacks and 5 rows to be transported by a forklift truck and then weighed.

(vi) Slimes treatment facilities

The slimes filtered off from the anode washing solution are fed to the 6.6 m^3 leaching tank together with the liberated solution and sulfuric acid. The leached solution is filtered and fed to the 4.5 m^3 purification tank and sent to the liberator section circulation tank. The leaching tank and the purification tank are provided with ventilation equipment for possible generation of poisonous arsine gas.

(vii) Liberator section

The liberator section consists of 9 cells, which are identical to the commercial cells. The capacity of the rectifier is 4,000 A, 25 V, 100 kW. The electrolyte circulation is independent of the commercial section. Anodes are 6% antimonial lead plates.

(b) Process description of refinery

In electrolytic refining, tin dissolves electrochemically from anodes into electrolyte and then deposits onto cathodes. This electrochemical reaction takes place by passage of electric current between the electrodes.

Most of the impurities contained in anode, such as arsenic, bismuth, antimony, copper, etc., which are electrochemically much nobler than tin, remain on the surfaces of anodes as slimes without dissolving into electrolyte. Lead, which is nobler than tin but close to tin in electrode potential, once dissolves but then promptly reacts with sulfuric acid in the electrolyte to form insoluble lead sulfate and enter the slimes. Iron is less noble than tin but goes eventually into the slimes.

The operation of the electrolytic refinery may be summarized as follows.

- The commercial section consists of 90 cells, each receiving 40 anodes and 41 cathodes respectively. Electrode connection is of Walker type. The typical composition of electrolyte will be Sn^{2+} 20 g/ℓ, Sn^{4+} 5 g/ℓ, total H_2SO_4 70 g/ℓ and total H_2SiF_6 50 g/ℓ. Glue and β-naphthol are added to the electrolyte to stabilize electro-deposition. The electrolyte is fed to the cells at 35°C, circulated at 40/min./cell.

- The anode life will be 30 days and the cathode life 6 days. When the cathodes are removed, the anodes are also picked up together from the cell and cleaned for removal of slimes and returned to the cell.

- The current circuit is connected in series between each pair of electrodes and in parallel between each cell. The current density is 60 A/m^2 and the current efficiency is 93%.

- The slimes removed from the anodes are sent to the liberator section. In the liberator section, tin contained in the slimes is first leached with sulfuric acid. The impurities in the leached solution are then cemented with tin and the resulted pure solution is subjected to electro-winning of tin. The commercial section consists of 9 cells, having an isolated rectifier.

- The tankhouse is operated in a two day - one cycle schedule. The operation in the first day is mainly composed of the exchange of electrodes and that in the second day is the casting of refined tin and manufacture of starter sheets.

- The cathodes are washed and, after cross bars are pulled off, stacked in each cell lot and conveyed to the casting plant.

- The cathodes are melted during the third shift and cast into ingots on the following day. The operating temperature during casting is controlled automatically at 300 - 350°C and each ingot weight is 36 kg.

- Starter sheets are manufactured by flowing molten tin over the mirror-finished surface of the water-cooled steel plate, which is inclined. Exchange of electrodes for the liberator cells is done every six days.

Following table summarizes the major design and operating conditions of the tankhouse.

Major Design and Operating Conditions for Tank House

Commercial Section	
Number of tank sections	6
Cells per section	15
Electrodes per cell	40 anodes, 41 cathodes
Electrode spacing (mm)	110
Starter sheet dimensions (mm)	1,000 x 1,000
Current density (A/m^2)	60
Total deposition current (A)	4,800
Current efficiency (%)	93
Plant utilization (%)	97
Cell voltage (V)	0.2

Anode cycle (days)	30
Cathode cycle (days)	6
Average cathode weight (kg)	40
Anode scrap ratio, VS anode (%)	25
Power per ton of tin (kWh)	90
Anode weight (kg)	230
Anode dimensions (mm)	970 x 970
Cell dimension (mm)	$4,750^{L} \times 1200^{W} \times 1,300^{H}$
Rectifier capacity	$5,000^{A} \times 30^{V}$
Slime production ratio, VS cathode (%)	0.8
Chemicals addition (kg/ton cathode)	
H_2SO_4	20
H_2SiF_6	10
Reagents addition (kg/ton cathode)	
Glue	2.0
β-naphthol	0.5
Electrolyte composition (g/ℓ)	
H_2SO_4	70
H_2SiF_6	50
Electrolyte temperature (°C)	35

Liberator Section

Number of cells	9
Electrodes per cell	40 anodes, 41 cathodes
Electrode spacing (mm)	110
Starter sheet dimensions (mm)	1,000 x 1,000
Current density (A/m^2)	40
Total deposition current (A)	3.200
Current efficiency (%)	85
Cell voltage (V)	2.2
Cathode cycle (days)	6
Anode weight, Pb anode (kg)	285
Cell dimensions (mm)	285
Rectifier capacity	$4,000^{A}$ x 25^{V}
Electrolyte composition (g/ℓ)	
SN^{2+}	45 - 5
H_2SO_4	200 - 300
Electrolyte temperature (°C)	35

(6) Material balance

Refer to Figures 3-12 and 3-13.

(7) Personnel requirement

Refer to Table 3-13.

(8) Construction cost

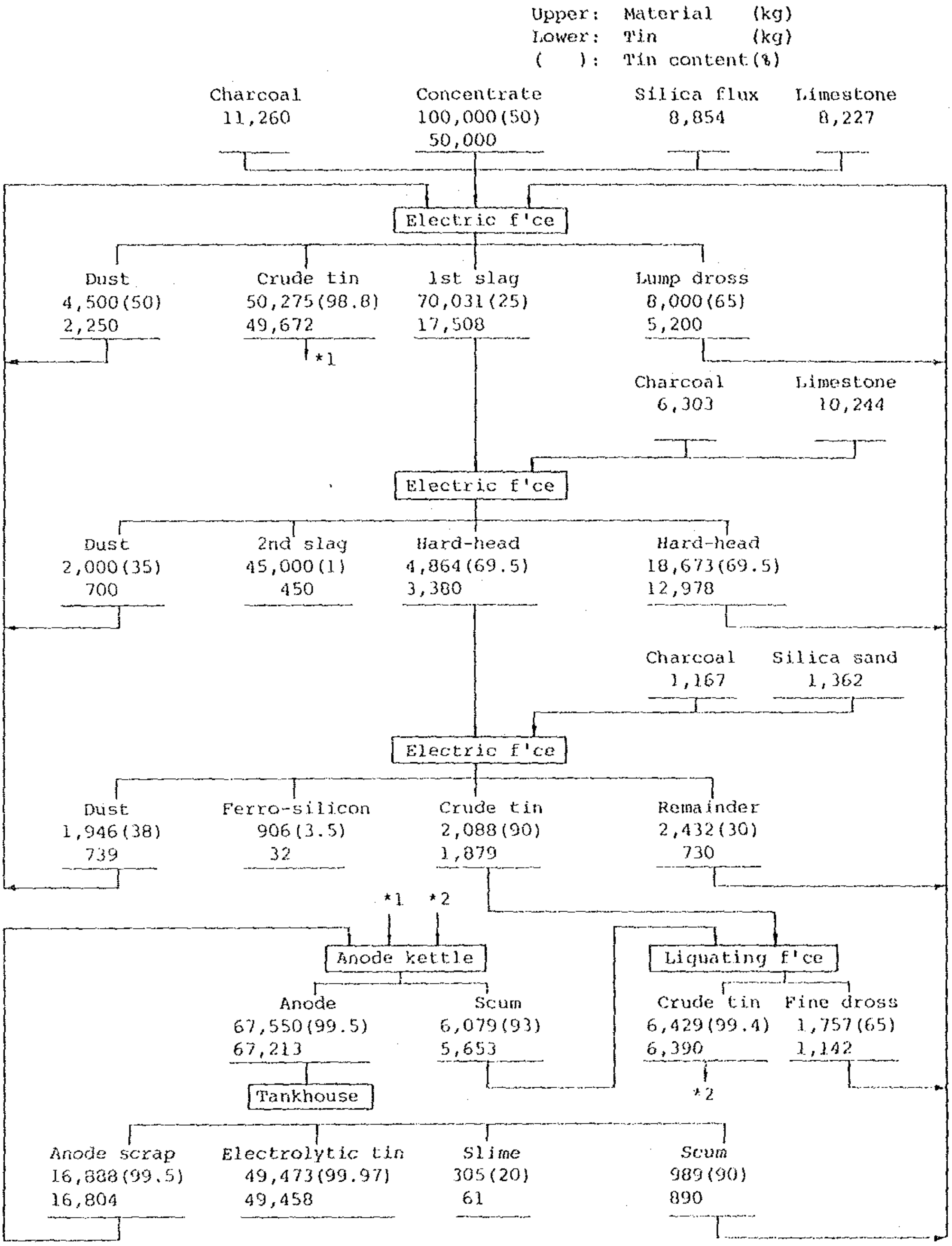
Refer to Table 3-14.

(9) Operation cost factors

Raw materials

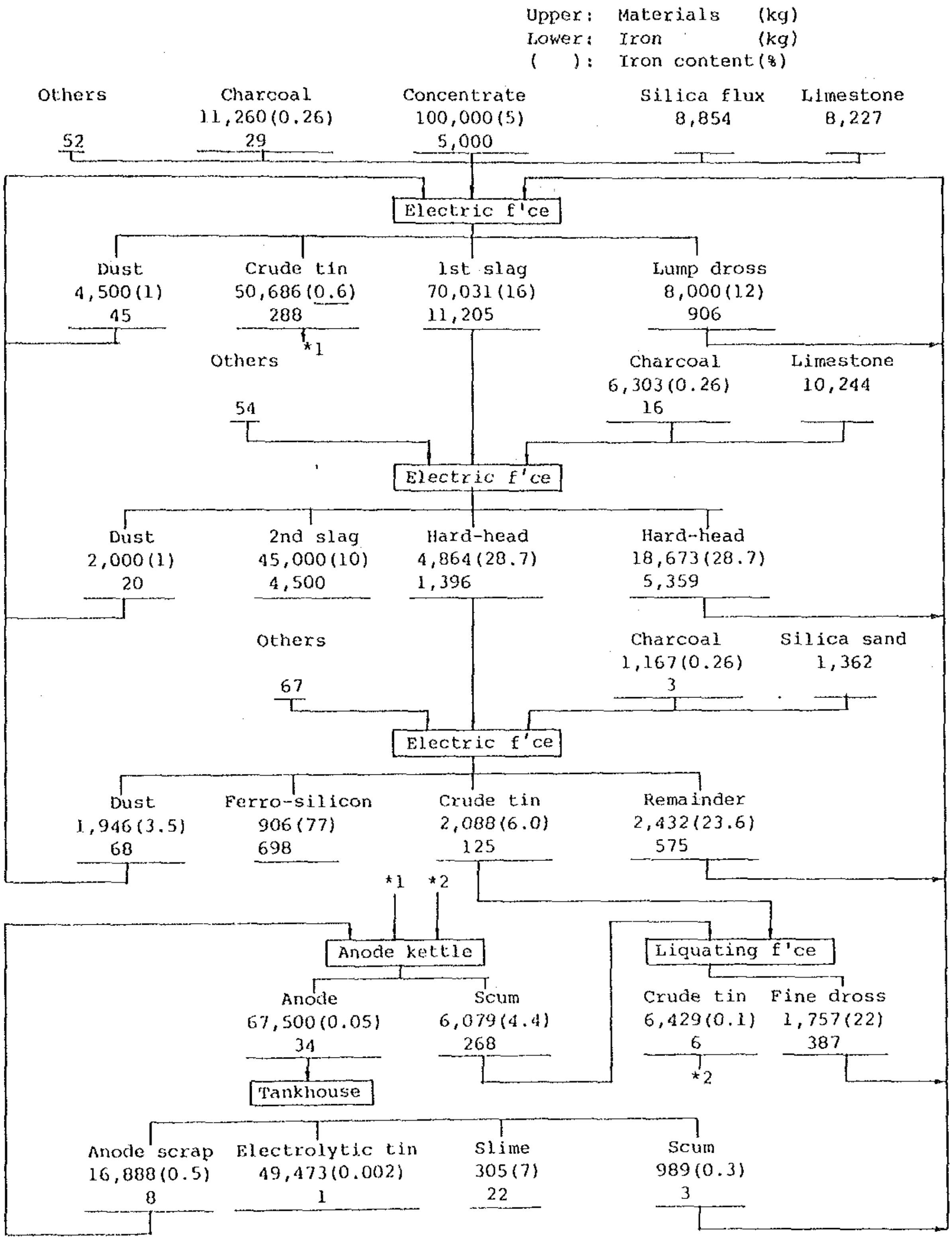
Tin cancentrate (dry base) 14,149 tons/year

Figure 3-12 3-Stage Process Material Balance (Tin)



Source: Study Team

Figure 3-13 3-Stage Process Material Balance (Iron)



Source: Study Team

Table 3-13 Estimated Personnel Requirement for Tin Smelter and Refinery

	Manager	Superintendent	Engineer	Foreman	Operator	Worker
Production Department	1					
Production Section		1	5	14	58	30
Utility Section		1	3	6	15	
Engineering Section		1	3	2	10	
Maintenance Section		1	2	5	10	
Administration Accounting Purchase	20% of Production Department					

Source: Study Team

Table 3-14 Hypothetical Model Plant (Tin Smelter and refinery) Estimated Construction Cost

(Unit: US$ 1,000)

	Sao Luis	Barcarena	Tucurui	Maraba
Land price	5	4	4	3
Land preparation	177	177	177	177
Plant direct cost (A)				
Process plant	12,224	12,224	12,224	12,224
Utility plant	2,602	2,602	2,602	2,602
Offsite facilities	2,965	2,695	2,695	2,695
Plant direct cost (B)				
Spare parts	480	480	480	480
Cata and Chemicals	417	417	417	417
Temporary works	890	890	890	890
Plant indirect cost				
Construction equip.	1,779	1,779	1,779	1,779
Ocean freight and ins.	873	873	873	873
Inland freight and ins.	191	191	1,477	1,085
License, Engineering and Services	4,448	4,448	4,448	4,448
Indirect field expenses	712	712	712	712
Other facilities				
Transmission cable	405	243	405	1,944
Waterintake and pipeline	993	627	233	1,852
Housing colony	-	4,680	-	4,320
Project management	356	356	356	356
Pre-operating expenses	6,476	6,506	6,483	6,453
Contingency	5,399	6,026	5,479	6,537
Interest during const.	4,510	5,260	6,840	7,200
Initial working capital	24,350	24,007	23,663	27,296
Total Capital Requirement	70,252	75,467	72,507	84,613

Source: Study Team

Sub-materials

Charcoal	2,680 tons/year
Limestone	2,640 tons/year
Silica flux	1,270 tons/year
Silica sand	200 tons/year

Utilities

Electric power	20,993 MWh/year
Industrial water	1,345,000 tons/year
Fuel oil	480 tons/year

Supplies

Electrode (US$ 2,254/ton)	163 tons/year
Refractories (US$ 319/ton)	109 tons/year
Clay (US$ 100/ton)	240 tons/year
Bag (200ø x 2,500L)(US$ 40/bag)	100 bags

Other expenses US$ 100,000/year

(10) Study on Raw Materials

(a) Technical study on raw material ore

Antonio Vicente deposit in the Carajas Mountains is expected to be used as the source of raw material cassiterite. Investigations are in preliminary stage. Tin-oxide(SnO_2) content was assumed to be 65% from the informations of adjacent deposits such as Serra do Mocambo, Serra do Velho Guilherme, Serra do Sao Francisco, etc.

(b) Cost study of raw materials

(i) Mine head cost of cassiterite

Mine head cost of cassiterite was assumed to be US$ 7,440/kg according to "Anuario Mineral Brasileiro" (DNPM) 1983.

(ii) Transportation cost of cassiterite

Transportation of cassiterite was assumed to be done by road transportation due to the location of Antonio Vicente.

The expected course is as follows.

Antonio Vicente - Sao Felix do Xingu 50 km

Sao Felix do Xingu - PA-150 cross junction (PA-279) 240 km

Cross junction - Maraba (PA-150) 205 km

In the same calculation manner as previous, the transportation cost by road will be US$ 19.1/ton under next assumptions.

30 ton dump truck 1 (price, US$ 417,000)

15 ton dump truck 1 (price, US$ 167,000)

Drivers 10 men.

From Maraba river port to Tucurui and/or Barcarena, the transportation fee had better be treated as general cargo of commercial barge, as the volume per one day is only 43 tons. Using the present commercial tariff of barge transportation between Barcarena and Tucurui (US$ 25/ton) on Rio Tocantins, the cost is calculated as follows.

Maraba - Tucurui (200 km)

US$ 17/ton + Handling charge US$ 6/ton US$ 23/ton

Maraba - Barcarena (500 km)

US$ 42/ton + Handling charge US$ 6/ton US$ 48/ton

(iii) Charcoal

Refer to Section 3-2-2,(9),(b),(vi).

(iv) Limestone

Refer to Section 3-2-1,(10),(b),(v).

(v) Silica flux

Refer to Section 3-2-1,(10),(b),(v).

(vi) Silica sand

The condition is assumed to be same as silica flux. Mine head cost was estimated as US$ 2/ton according to DNPM's "Price Bulletin 49".

Estimated cost is;

Sao Luis plant site	US$ 6/ton
Barcarena plant site	US$ 21/ton
Tucurui	US$ 9/ton
Maraba	US$ 9/ton

(vii) Fuel oil

Refer to Section 3-2-3,(9),(b),(iv).

4. STUDY ON INFRASTRUCTURE, INCENTIVES AND PLANT LOCATION FACTORS IN EACH INDUSTRIAL DISTRICT

4-1 Infrastructure

4-1-1 General Description

The location of each plant site expected to be used in each industrial district is shown in Figures 4-1 to 4-4. As for supply capacity of physical infrastructure, which support industrial activities of production plants with service for transportation, power supply, water supply, communication system, labor, etc., existing capacity plus authorized planned capacity were considered as available supply. Before proceeding to description of available infrastructure of each industrial district, some of the major assumptions with regard to infrastructure are set forth as following:

- Carajas Railway; the Carajas railway shall be fully completed to the Carajas terminal station. The data for transport tariff were provided by CVRD.

- Road maintenance; road to be used for transportation in connection with the industrial districts shall be kept available for use in all seasons. Transportation costs were estimated by the Study Team.

- Power generation and transmission; power generation shall be available from the Tucurui Dam to assure electric power supply. A power transmission line shall be completed as the present network plan of Eletronorte, so that the plant may connect a branch line at the main switchyard of each industrial district.

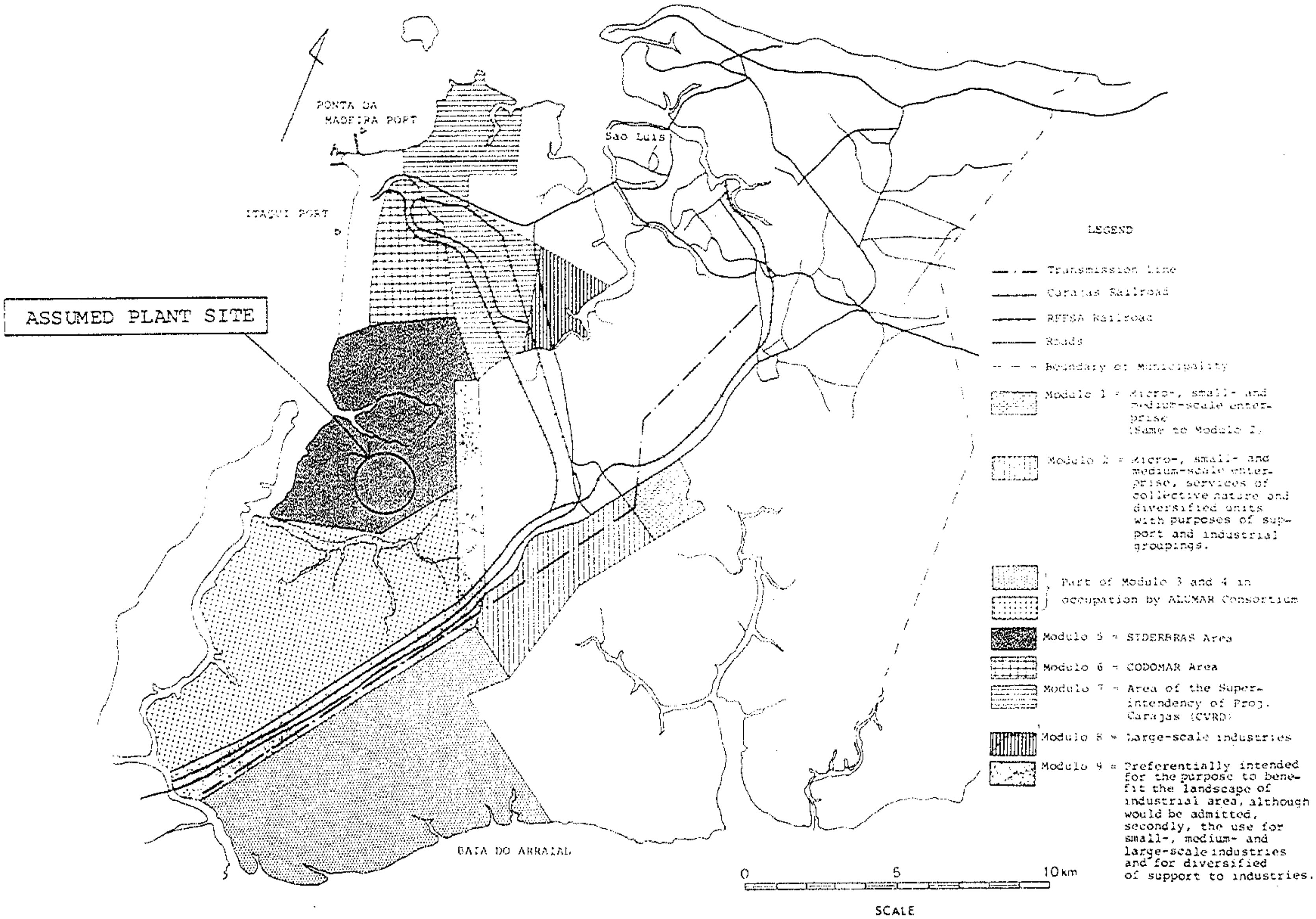
4-1-2 Sao Luis Industrial District

The plant site expected to be used is M-5 of Fugure 4-1, and 5 km from mineral terminal of Carajas Railway (EFC), 5 km from main sub-station of Eletronorte and also 5 km from the supply point of industrial water by Maranhao Water and Drainage Company (CAEMA)'s water pipeline.

(1) Transportation facilities

All kind of raw material ore from the Carajas Mountains are to be sent to the Mineral Terminal in Itaqui Port by EFC. Then they will be sent to plant site by dump trucks. With Itaqui Port, EFC and a well paved road network, Sao Luis has no problem concerning transportation of raw materials, sub-materials and final products.

Figure 4-1 Assumed Plant Site in Sao Luis



Source: Study Team

(2) Power supply

Eletronorte's planned supply capacity at the Sao Luis main sub-station, 600 MVA, is enough to supply required energy to any plant under study.

(3) Water supply

CAEMA's present supply capacity, 1,300 m^3/hr, is enough to supply industrial water to any kind of plant in this Study. The copper smelter requires more than 4,000 m^3/hr, but almost all of this amount is cooling water for furnaces, etc. and can be substituted by sea-water. The smelter will be provided with water intake and pipeline for the sea-water.

(4) Communication system

Telecommunications Company of Maranhao (TELEMA) and Brazil State Telecommunication Company (EMBRATEL) can easily supply 20 circuits, i.e., 15 circuits for city calls and 5 circuits for inter-state calls.

(5) Population and labor supply

Population of Sao Luis: 449,432 (in 1980)

Average salary and wages for plant employee in July, 1984 are as follows:

	Cr$/month
General worker	126,858
Driver	268,760
Carpenter/Brick layer	208,293
Machine operator	195,583
Electric technician	272,875
Foreman	556,164
Engineer	2,615,158

Average payment for construction worker in May, 1984 are as follows:

	Cr$/hour
Welder	698 - 1,396
Carpenter	708 - 931
Operator of heavy equipment	850 - 1,200
Machine setter	1,100 - 1,675

4-1-3 Barcarena Industrial District

The plant site expected to be used is 3 km from Aluminio Brasileiro S.A. (ALBRAS) and main sub-station of Eletronorte. This location is 5 km from new Vila do Conde Port, and near to river side of Rio Para (refer to Figure 4-2).

(1) Transportation facilities

To send raw material ores from the Carajas Mountains to Barcarena, river transportation by barge on Rio Tocantins is essential. The ores shall be carried to Maraba by EFC or road, and transferred to barge transportation.

For transferring ores from railway to river port at Maraba, the following items shall be provided:

- Railway wagon dumping device at Maraba station
- Receiving and stocking hoppers of ores
- System for charging ores onto dump trucks

Thus, ores can be mobilized to river port of Maraba by dump trucks.

For port facilities at Maraba river port, these items shall be provided:

- Warehouse for ore
- System for loading ores onto barges
- Port, harbour and auxiliary facilities

Thus, ores can be transported by barge to Barcarena on Rio Tocantins via the Tucurui navigation canal.

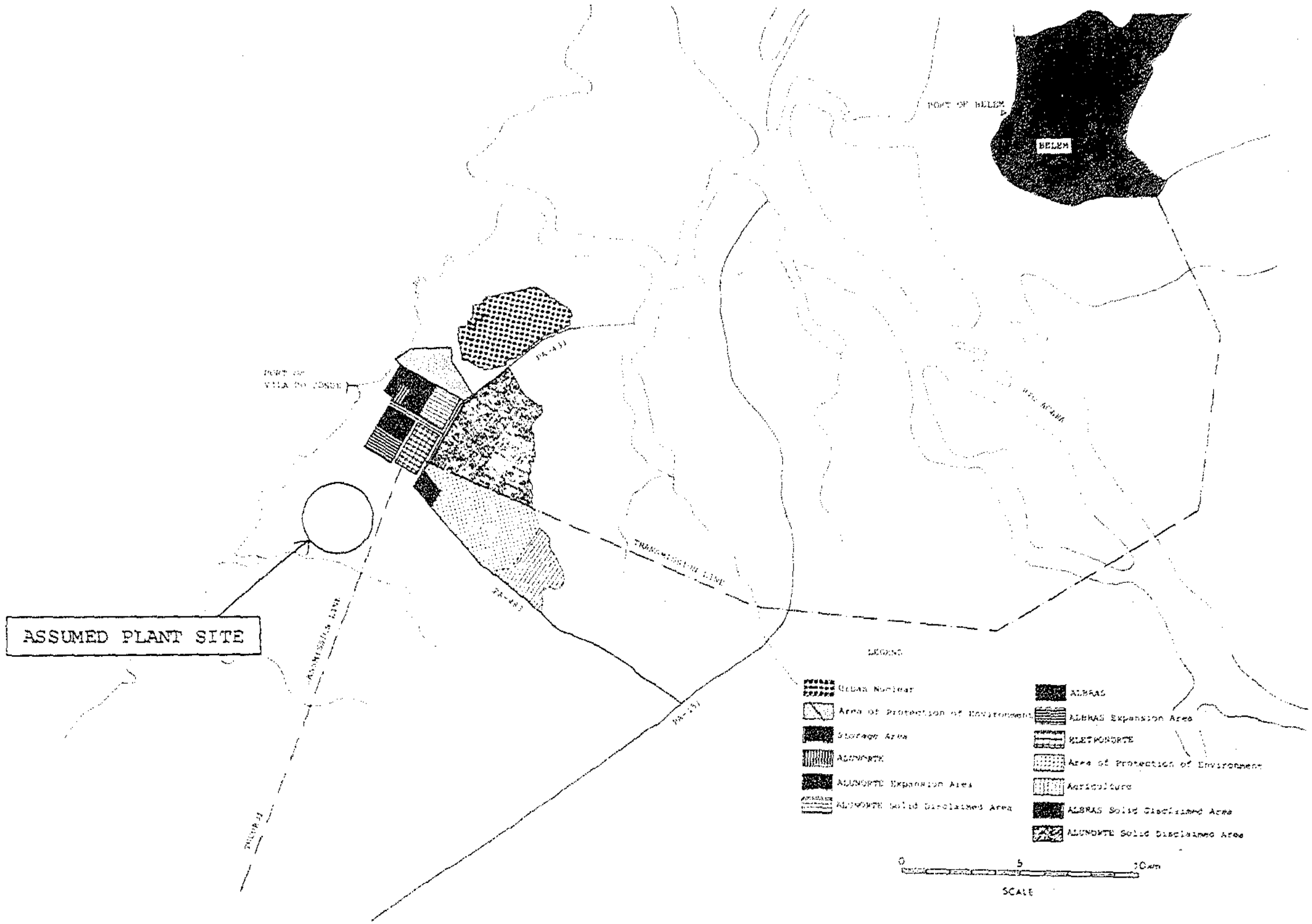
The detour transportation by bulk carrier on the sea way via Itaqui Port or Ponta da Madeira to new Vila do Conde Port is evaluated to be less economical than the Tocantins way.

As for unloading of ores from barge, the existing Barcarena port facilities are not suitable for large quantity of bulk ores on a barge. A combination of floating dock type barge yard and front-end shovel loader is most effective to handle a large quantity of ores in a short time. A new unloading port shall be constructed near the plant site. For other materials and consumables, especially products for exportation, existing Barcarena port can offer favorable conveniences.

(2) Power supply

Eletronorte's planned supply capacity at Barcarena main sub-station, 750 MVA, is enough to supply required energy to any plant under study.

Fgiure 4-2 Assumed Plant Site in Barcarena



Source: Study Team

(3) Water supply

There is no system in this area to supply industrial water. The plant must be provided with its own water intake facility and pipeline. Pipeline length is about 3 km.

(4) Communication system

The planned network capacity by Brazil Telecommunication Company (TELEBRAS), ENBRATEL and Telecommunication Company of Para (TELEPARA) is enough to ensure the required telecommunication circuits for the plants.

(5) Population and labor supply

It seems to be difficult to obtain the required number of plant employees in this area. It will be necessary to recruit employees in Belem or other town and provide them with living accommodations.

Average salary and wages for plant employees is estimated as 105% of payment level in Sao Luis due to inconvenience of living conditions. Average payment for construction workers in July, 1984 are as follows.

	(Cr$/hour)
General worker	766
Bar bender	995
Carpenter	995
Welder	995
Electrician	1,128
Pipe fitter	1,128

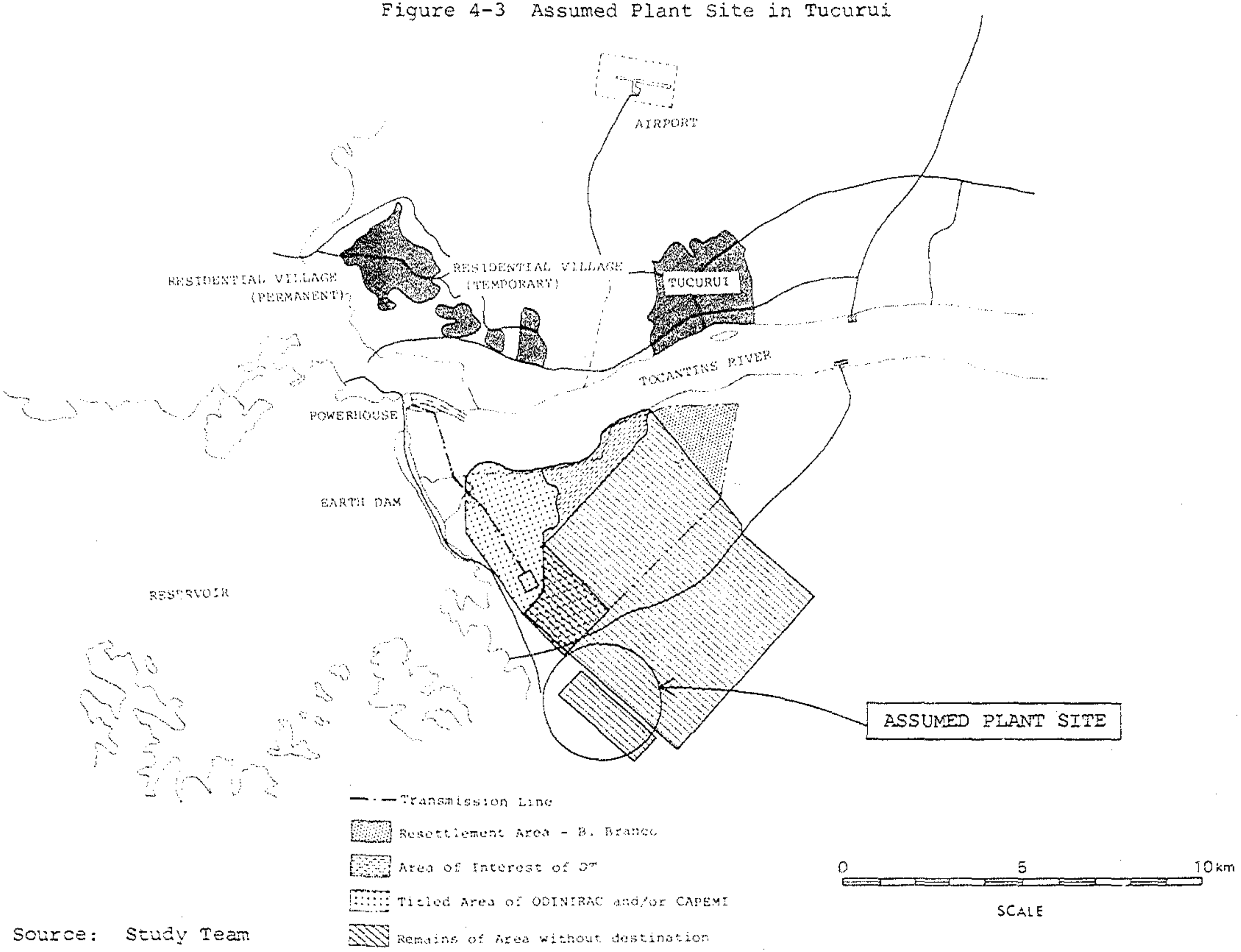
4-1-4 Tucurui Industrial District

The plant site expected to be used is 5 km from the main sub-station of Eletronorte, 1 km from the water-intake point, and 5 km from the existing port (refer to Figure 4-3).

(1) Transportation facilities

The same conclusion as for Barcarena can be applied to transportation of ores to Tucurui plant site. For unloading of ores, the existing Tucurui port is not convenient. New port facilities shall be established near the plant site similar to Barcarena's case. The existing port shall be utilized for receiving materials and consumables as well as shipping products.

Figure 4-3 Assumed Plant Site in Tucurui



Source: Study Team

(2) Power supply

Eletronorte's planned supply capacity at Tucurui main sub-station, 100 MVA, is smaller than other main sub-stations, but still enough to supply required energy to any plant under study.

(3) Water supply

Conditions are same as at Barcarena. The length of the water pipeline is about 1 km.

(4) Population and labor supply

Population of new and old Tucurui is 67,265 as of 1980. It seems to be difficult to secure plant employees in this area. It will be necessary to recruit employees from other towns or cities. In Tucurui, it is not necessary to provide new residential accommodations owing to the existence of Eletronorte's township.

The average salary and wages for plant employees is estimated as 110% of payment level in Sao Luis due to social conditions. The average payment for contruction workers is estimated as 130% of the payment level in Barcarena due to social conditions and technical specialities.

4-1-5 Maraba Industrial District

The plant site expected to be used is 24 km from the main sub-station of Eletronorte, and 10 km from water-intake point (refer to Figure 4-4).

(1) Transportation facilities

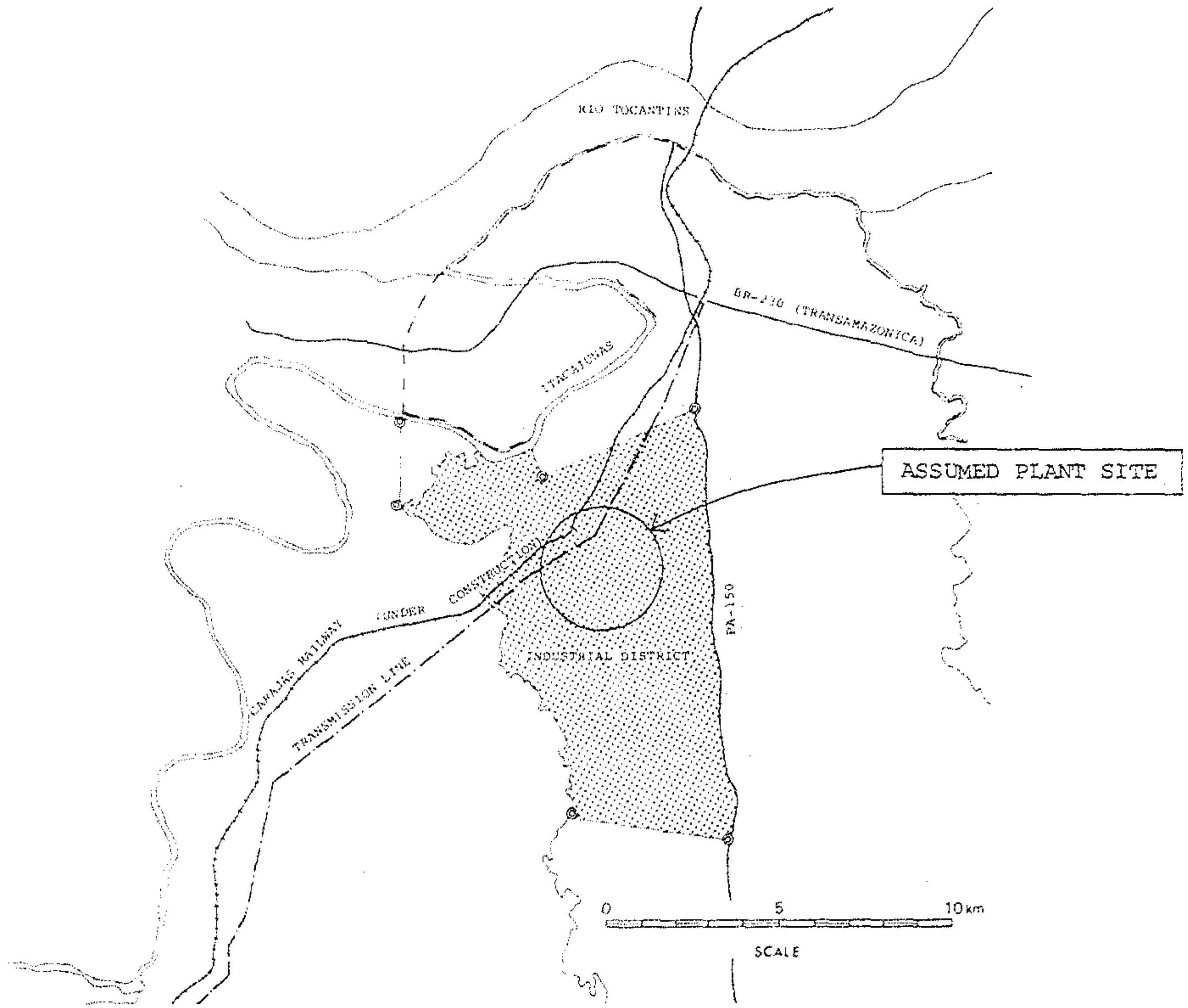
Maraba is the key point for development of Carajas resources. EFC crosses Rio Tocantins at Maraba, and river transportation of ores to Tucurui and Barcarena will start here.

Tucurui and Barcarena cannot obtain their metallurgical raw materials from the Carajas Mountains without "Maraba Transfer" and "Tocantins Navigation" in industrial scale and economical price. "Maraba Transfer" and "Tocantins Navigation" are the most important economic infrastructure for Tucurui and Barcarena to be centers of industrial development. "Maraba Transfer" and "Tocantins Navigation" shall be discussed in next section 4-1-6 as a gap adjustment item.

(2) Power supply

Eletronorte's planned supply capacity at Maraba main sub-station, 300 MVA, is enough to supply required energy to any plant under study. The distance from the main sub-station to plant site, 24 km, is quite far compared to that of other industrial districts, and the installation cost for a transmission cable line is proportionally larger. This is one of the demerits of the Maraba plant site.

Figure 4-4 Assumed Plant Site in Maraba



Source: Study Team

(3) Water supply

Conditions are same as at Barcarena and Tucurui. The length of the water pipeline, 10 km, is also one of the demerits of Maraba plant site.

(4) Communication system

The planned network capacity by TELEBRAS, ENBRATEL and TELEPARA is enough to ensure the required telecommunication circuits for plants under study.

(5) Population and labor supply

The population of Maraba is about 72,530 as of 1980 but most plant employees shall be recruited from other industrial zones. It is also necessary to provide living accommodations for these employees.

The average salary and wages for plant operation employees are estimated as 115% of the payment level in Sao Luis due to social factors and payment rule for interstate movement. Average payment for construction workers is estimated as 150% of the payment level in Sao Luis due to social conditions and technical specialities.

4-1-6 Gap Adjustment of Infrastructure

The gap here means a shortage of available supply capacity to meet the volume required by the production plant. There is a gap between the available supply of power, water and materials resulting from insufficient network of infrastructure and the volume needed for the production in a model plant. This gap is adjusted by the plant itself, providing extra power, water and materials which need to perfectly execute process of production . This provision results in constructing supplementary facilities for the production line, and thus the cost of the gap adjustment must be added to the construction cost of the model plant.

(1) Power supply

(a) Necessary gap adjustment schedule

(i) Sao Luis

Eletronorte cost	Plant cost
No.II Switchyard 500 kV → 230/69 kV	5 km → Plant sub-station Bush

(ii) Barcarena

Eletronorte cost	Plant cost	
Vila do Conde Switchyard ⦶	3 km ——→	Plant sub-station
500 kV ——→ 230/69 kV	Forest and bush	

(iii) Tucurui

Eletronorte cost	Plant cost	
Tucurui Switchyard ⦶	5 km ——→	Plant sub-station
500 kV ——→ 230/69 kV	Across river Forest and bush	

(iv) Maraba

Eletronorte cost	Plant cost	
Maraba Switchyard ⦶	24 km ——→	Plant sub-station
500 kV ——→ 230/69 kV	Across river Forest and bush	

(b) Estimated gap adjustment cost

(Unit: US$ 1,000)

	Sao Luis	Barcarena	Tucurui	Maraba
Copper smelter and refinery	405	243	405	1,944
Ferro-manganese smelter	495	297	495	2,376
Nickel smelter	405	243	405	1,944
Ferro-nickel smelter	495	297	495	2,376
Tin smelter and refinery	405	243	405	1,944

(2) Water supply

(a) Quality of water

Data of water analysis at Sao Luis and Barcarena showed that the hardness of river water is low (permanent hardness: 20 - 30 mg/l as $CaCo_3$) and no trouble is expected in using it as cooling water for machines and equipment. As Tucurui and Maraba are up-stream of Barcarena on Rio Tocantins, no difference can be assumed for four industrial districts on water quality which will affect construction cost and operation cost of water treatment facilities.

(b) Necessary gap adjustment schedule

	Sao Luis	Barcarena	Tucurui	Maraba
Copper smelter and refinery	(Water volume: 4,000 m^3/hr)			
Water intake pump	150 kW	150 kW	150 kW	150 kW
Water transfer pump	440 kW	390 kW	340 kW	570 kW
Water pipeline	850 mmø x 5 km	850 mmø x 3 km	850 mmø x 1 km	850 mmø x 10 km
Ferro-manganese smelter	(Water volume: 260 m^3/hr)			
Water intake pump	10 kW	10 kW	10 kW	10 kW
Water transfer pump	30 kW	27 kW	23 kW	40 kW
Water pipeline	300 mmø x 5 km	300 mmø x 3 km	300 mmø x 1 km	300 mmø x 10 km
Nickel smelter	(Water volume: 240 m^3/hr) Same as Ferro-manganese			
Ferro-nickel smelter	(Water volume: 480 m^3/hr)			
Water intake pump	18 kW	18 kW	18 kW	18 kW
Water transfer pump	40 kW	35 kW	31 kW	52 kW
Water pipeline	400 mmø x 5 km	400 mmø x 3 km	400 mmø x 1 km	400 mmø x 10 km
Tin smelter and refinery	(Water volume: 200 m^3/hr)			
Water intake pump	8 kW	8 kW	8 kW	8 kW
Water transfer pump	25 kW	22 kW	20 kW	32 kW
Water pipeline	300 mmø x 5 km	300 mmø x 3 km	300 mmø x 1 km	300 mmø x 10 km

(c) Estimated gap adjustment cost

(Unit: US$ 1,000)

	Sao Luis	Barcarena	Tucurui	Maraba
Copper smelter and refinery	2,333	1,733	1,133	3,833
Ferro-manganese smelter	1,667	1,227	635	2,526
Nickel smelter	1,667	1,227	635	2,526
Ferro-nickel smelter	1,750	1,050	350	3,500
Tin smelter and refinery	993	627	233	1,852

4-1-7 Maraba Transfer and Tocantins Navigation

Selection of means of transportation is crucial so as to carry a great deal of raw materials, sub-materials and products. Means of transportation should be examined for the following three key routes:

(a) carriage of raw material ores between the Carajas Mountains and the four industrial districts,

(b) carriage of sub-materials such as coke, coal, etc. between the origin of the sub-materials and the four industrial districts, and

(c) carriage of products between the four industrial districts and ports of shipment.

In the Sao Luis industrial district, raw material ores are carried by the Carajas railway; sub-materials are unloaded at Itaqui Port; and, products are shipped at Itaqui Port as well. In the Maraba industrial district, raw material ores are carried by the Carajas railway; sub-materials are first unloaded at Itaqui Port, then carried by the Carajas railway toward Maraba; and, products are carried by the Carajas railway toward Itaqui Port where products are shipped.

In the Tucurui industrial district, unlike Sao Luis and Maraba, both transshipment from the Carajas railway onto barge at Maraba Port and the barge navigation of the Tocantins river are necessary for the carriage of raw material ores. Sub-material are first unloaded at Vila do Conde Port, then carried up the Tocantins river by barge; products are carried down the Tocantins river by barge and shipped at Vila do Conde Port. In the Barcarena industrial district, same as Tucurui, the carriage of raw material ores need the transshipment at Maraba Port and the barge navigation on the Tocantins river. Both sub-materials and products are directly unloaded or shipped at Vila do Conde Port.

The above conditions of transportation in four industrial districts conclude that both the provision of new facilities for transshipment at Maraba Port (Maraba Transfer) and the barge navigation on the Tocantins river (include a navigation canal at the Tucurui Dam) (Tocantins Navigation) are essential to operate the all model plants in the Phase II study.

The idea of "Maraba Transfer" is as follows:

- Transfer of ores from a railway station to river port at Maraba, and river transportation of ores by barge, shall be possible after completion of concerning facilities.

The idea of "Tocantins Navigation" is as follows:

- Barge navigation shall be possible between Maraba and Barcarena in all seasons by assuring five meters water depth by removing rocks and dredging the river bed.

- A navigation canal at the Tucurui Dam shall be completed and in service.

However, the required investment for the construction of these facilities is very huge and it is not practical to include it in plant construction cost. Moreover, the construction of "Tocantins Navigation" and "Maraba Transfer" would greatly benefit the PGC Area by transporting various goods other than raw material ores. Therefore, construction of these facilities is assumed to be done by the public sector or alternative enterprises and operation cost of this service shall be charged to the receiving plant as transportation cost of raw material. The transportation costs between Maraba - Tucurui and Maraba - Barcarena were estimated as follows.

To send Carajas origin ores to Tucurui and/or Barcarena through "Maraba Transfer" and "Tocantins Navigation" will require following facilities:

At Maraba

1) Railway wagon dumping device at Maraba station

2) Stock and discharge hoppers

3) System for loading ore onto dump trucks

4) Dump trucks to carry ore to river port

5) Ore stock yard at port side

6) Equipment to load ore onto barges

7) Port, harbour and auxiliary facilities

At Tucurui and Barcarena

1) Ore unloading port, harbour and auxiliary facilities

2) Ore unloading equipment

3) Ore stock yard at port side

4) System to move ore to plant warehouse

For river navigation

1) Pusher boats

2) Bulk carrier barges

Nickel ore and tin concentrate will be transported by dump truck from the point of origin to Maraba port.

The dimensions of above facilities depend on the volume of ore handled.

Estimated dimensions and cost are as follows.

At Maraba station:

1) 2 wagon (180 tons)/set rotary drum up-setter, high support structure with hopper and chute, side railway with small locomotive engine.

   Estimated cost for Cu smelter (824 tons/day) or Fe-Mn smelter (612 tons/day): US$ 1,042,000.

2) 30 tons, 405 PS dump truck with accessories

   Estimated cost: US$ 417,000 per one set

   Required number for Cu smelter or Fe-Mn smelter: 1 set

At Maraba river port:

1) Stock yard with roof and ore loading system:

   Estimated cost for Cu smelter and Fe-Mn smelter

   Stock capacity 2,000 tons
   Loading capacity 500 tons/hr US$ 526,000

   Estimated cost for Ni smelter (3,351 tons/day)

   Stock capacity 6,000 tons
   Loading capacity 1,000 tons/hr US$ 1,450,000

Estimated cost for Fe-Ni smelter (2,012 tons/day)

Stock capacity 4,000 tons
Loading capacity 800 tons/hr US$ 1,068,000

2) Water level adjustable dock yard type harbour:

Estimated cost

for Cu, Fe-Mn smelter	: US$ 4,167,000
for Ni smelter	: US$ 9,668,000
for Fe-Ni smelter	: US$ 7,119,000

At Tucurui and Barcarena

Ore unloading harbour, same type as Maraba, with unloading system.

Estimated cost

for Cu, Fe-Mn smelter	: US$ 4,167,000
for Ni smelter	: US$ 9,668,000
for Fe-Ni smelter	: US$ 7,119,000

Pusher boat

Draft 2.3 m, 620 x 2 = 1,240 PS, pushing speed 8.5 knots, normal speed 10.5 knots, 160 tons pusher

Estimated cost: US$ 1,344,000/boat

Barge

Draft 3 m, flat ore deck 1,000 ton bulk carrier.

Estimated cost: US$ 630,000/barge

Pusher and barge team

One team consists of one pusher and two barges.
One team transports 2,000 tons ore per one navigation.
mean speed is 6.5 km/hr for upstream navigation and 10.5 km/hr for downstream navigation.

The number of required pusher-barge team and navigation hour per one round trip are as follows:

	Trip hours	Cu, Fe-Mn	Ni	Fe-Ni
Maraba - Tucurui	72 hr(3 days)	2 team	5 team	3 team
Maraba - Barcarena	144 hr(6 days)	3 team	10 team	7 team

Under the assumption of following conditions,

1) Depreciation

Dump truck	5 years
Pusher boat and barge	12 years
Other facilities	30 years

2) Interest

12% per year

3) Personnel expenses

US$300 per month per one man

Maraba up-set in station	3 men
dump truck	2 men
Port facilities	10 men

4) Return on investment (ROI), on facilities investment: 10% of initial investment per year.

5) Return on investment, on pusher and barge: 10% of annual fixed cost per year.

6) Utility cost

Pusher	: Fuel oil 168 kg/hr, US$ 385/fuel oil ton
Ore handling at port	: 5 kWh/ton
Dump truck	: Fuel oil 10 kg/hr, US$ 385/fuel oil ton
Ore handling at station	: 1 kWh/ton

The calculation results for handling cost and transportation cost at "Maraba Transfer" and "Tocantins Navigation" are shown below:

Handling Cost and Transportation Cost

(Unit: US$/ton)

	Cu	Fe-Mn	Ni	Fe-Ni	Sn
Ore transfer from railway to river port	1.5	1.5	-	-	-
Operation at loading port	3.6	3.6	2.0	2.4	**3.0
Transportation cost					
Maraba - Tucurui	8.8	8.8	5.9	6.1	*17.1
Maraba - Barcarena	15.0	15.0	12.7	14.5	*42.0
Operation at unloading port					
Tucurui, Barcarena	3.1	3.1	1.7	2.1	**3.0
Cost from Maraba station					
to Tucurui	17.0	17.0	9.6	11.5	23.0
to Barcarena	23.2	23.2	16.4	19.9	48.0

* Proportional to existing tariff rate between Barcarena and Tucurui (US$25/ton).

** For tin ore, the existing Barcarena and Tucurui ports are usable for unloading. Existing handling charge is used.

4-2 Incentives

Any project, which is executed in the Greater Carajas Program Area, is eligible various incentives provided by the Superintendency for the Development of Amazonia (SUDAM) or the Superintendency for the Development of Nordeste (SUDENE). These incentives can be summarized as follows.

4-2-1 Tax Incentives

(1) Income Tax : 10 years exemption

(2) Industrialized Products Tax (IPI) : Reduction or exemption

(3) Marketing Tax (ICM) : Reduction or exemption

(4) Import tax of plant facility : Exemption

(5) Export tax of products : Exemption

4-2-2 Financial Incentives

(1) Raising of capital

Raising of 30 - 75% of required investment through the Amazonia Investment Fund (FINAM) (SUDAM) as capital participation, or maximum 60% of required investment through the Northeast Investment Fund (FINOR) (SUDENE) as capital participation with a charge of 4% per year is possible.

(2) Loan facilitation

SUDENE will facilitate a long term loan or credit guarantee by Bank of the Northeast of Brazil (BNB) or National Bank of Economic Development (BNDE).

4-2-3 Fiscal Incentives

Approval for accelerated depreciation/amortization shall be given on the basis of negotiation.

4-2-4 Local Incentives

(1) Sao Luis

Industrial Development Company of Maranhao (CDIMA) will serve (a) land purchase, (b) site preparation, (c) oxidation lagoon and (d) other support for industrial development.

Maranhao Water and Drainage Company (CAEMA) will supply industrial water and potable water for the plants.

(2) Barcarena

Barcarena Development Company (CODEBAR) offers a township for plant employee.

(3) Tucurui and Maraba

Industrial Development Company of Para (CDIPARA) will serve land purchase for the newcomer enterprises.

4-3 Plant Location Factors

The design basis of the plant was assumed as follows for all four industrial districts, except earth bearing strength as at Barcarena where soil improvement will be required for installing heavy equipment.

Seismic factor	: 0
Wind velocity	: 40 m/sec.
Ambient temperature	: 30°C
Relative humidity	: 80%
Rainfall	: 3,000 mm/year Max. one day 120 mm
Cooling water intake temperature	: 25°C

5. FINANCIAL EVALUATION OF COMPARATIVE ADVANTAGES

5-1 Introduction

For the financial evaluation, Financial Internal Rate of Return (FIRR) was adopted as a measure of comparison. FIRR is one of parameters of financial analysis for measuring efficiency of capital investment. It indicates a rate of yield on invested capital after recovery of principal and interst.

Mine head prices of ores were assumed to be the present market level in Brazil because the mines are not yet opened for all items except manganese ore. Given the present price conditions of products in international trade markets, a reasonable value of FIRR was not obtained. Therefore the present price conditions of products were adjusted to some extent in order to obtain a reasonable value of FIRR.

5-2 Assumption on Financial Evaluation

Financial analysis has been carried out using the program which nas been developed for multi-purpose financial evaluations.

Assumptions on data input were as follows:

- Product inventory	1/12 of annual production volume
- Material inventory	1/12 of annual consumption of raw material and sub-materials
- Sales expenses	2% of sales revenue
- Income tax	
Exemption	10 years
After 10 years	50% of taxable income
- Dividends	Nothing
- Accounts receivable	1/12 of annual sales revenue
- Accounts payable	1/12 of annual raw material and sub-material cost
- Depreciation	Refer to Section 3-1-3,(2),(b)
- Financial resources	
Share capital	30%
Long term debt	70%

Interest rate:	12% per year
Grace period:	5 years
Repayment:	10 years equal payment of principal and interest

- Raw material cost and unit sales price of product
  Refer to Table 5-1

- Other input data — Refer to Section 3-1 and Section 3-2

5-3 Results of Financial Evaluation

5-3-1 Three Main Factors and Case Classification

In considering the FIRR values, the following three factors can be considered to affect the results.

- Factor A: The proportion of the freight charge in the overall raw material cost

- Factor B: Costs for infrastructure gap adjustments included in the construction costs (costs of facilities outside the factory, such as electric power transmission lines, water intake and pipelines and company housing, and their related facilities)

- Factor C: Regional differences in construction and operation costs (differences in inland transportation costs included in construction and operation costs, interest incurred during construction work, personnel expenses and others)

Factor A and C are peculiar to certain areas, while the discrepancies caused by Factor B can be equalized with the development of the infrastructure. Supposing that the discrepancies caused by Factor B can be uniformized by the implementation of social development policies, the results achieved will enable a comparison to be made of the locational advantages of each industrial district under Factor A and C.

A comparison between Maraba, which has the most advantageous position in Factor A, and Sao Luis, which has the most advantageous position in Factor C, will indicate which of the two factors, A or C, will be more critical in the Greater Carajas Program Area. Factor B in TUcurui is similar to that in Sao Luis because of the benefits derived from the dam construction work of Eletronorte power station, so that locational advantage or disadvantage in Tucurui over Sao Luis can be compared under the influences of Factor A and C. The Factor B component in Barcarena can be considered as similar to that of Sao Luis except for the cost incurred in constructing company housing. Therefore, a revision of construction cost of company housing as a gap

Table 5-1 Input Data of Raw Material Cost and Unit Sales Price of Product

(Unit: US$/ton)

	Sao Luis	Barcarena	Tucurui	Maraba
Copper concentrate				
Mine head cost	522	552	552	552
Haulage cost	27	35	29	12
Manganese ore				
Mine head cost	60	60	60	60
Haulage cost	24	32	26	10
Nickel ore				
Mine head cost	3	3	3	3
Haulage cost	27	24	18	8
Tin concentrate				
Mine head cost	7,440	7,440	7,440	7,440
Haulage cost	40	67	42	19
Copper metal FOB at port	1,800	1,800	1,800	1,800
Haulage to port	-	-	25	18
Sulfuric acid ex-plant price	52	52	52	52
Gold ex-plant price	$11,254 \times 10^3$	$11,254 \times 10^3$	$11,254 \times 10^3$	$11,254 \times 10^3$
Ferro-manganese FOB at port	550	550	550	550
Haulage to port	-	-	25	18
Ferro-silicomanganess FOB at port	600	600	600	600
Haulage to port	-	-	25	18
Mixed sulfide ex-plant price	3,284	3,284	3,284	3,284
Contained nickel in Ferro-nickel				
FOB at port	5,600	5,600	5,600	5,600
Haulage to port	-	-	25	18
Tin metal FOB at port	17,500	17,500	17,500	17,500
Haulage to port	-	-	25	18

Source: Study Team

adjustment, makes a comparison between Barcarena and Sao Luis possible with regard to Factor A and C.

It should be noted that Maraba and Tucurui have a locational disadvantage in Factor C over Barcarena and Sao Luis, because almost all materials, except raw material ores, have to be transported over a long distance via ports of either Sao Luis or Barcarena.

On the basis of the above considerations, comparative advantages of four industrial districts were calculated for each smelter on the Base Case in which the current data were input, and on the Gap Adjusted Case in which Factor B in Maraba, Tucurui and Barcarena was revised to level similar to that of Sao Luis.

5-3-2 Comparative Advantages of the Four Industrial Districts

As described in Section 5-1, a number of assumptions have been made concerning the raw material price and the product selling price, so that the resultant FIRR values have meaning when comparing the four industrial districts in terms of one industry, but cannot be used when comparing different industries at one industrial district. To avoid confusion, therefore, and to make it possible to compare the results mutually on the same basis, the results of Barcarena, Tucurui and Maraba were expressed as a percentage with the results of Sao Luis used as a base of 100.

The obtained results are shown in Table 5-2 (Base case) and Table 5-3 (Gap Adjusted Case).

For most industries in the Base Case and the Gap Adjusted Case, Sao Luis is ranked at the top and Barcarena as number two indicating that Tucurui and Maraba, which are located well inland, are inferior in terms of construction and operation costs to the coastal regions.

For the ferro-nickel (Fe-Ni) industry in the Base and Gap Adjusted Cases, Maraba is graded as number two and Barcarena as the lowest, the reason being that the location of Maraba is superior to that of Tucurui and Barcarena. For a transport scale of some 600,000 tons per year, there are no advantages in using the Tocantins Navigation system to the Fe-Ni plants of Tucurui and Barcarena. For the nickel industry, however, Barcarena is ranked second in the Base Case and first in the Gap Adjusted Case, indicating that the Tocantins Navigation system makes Factor A less effective than Factor C for nickel smelting at Barcarena which is the farthest from the mine when the transport scale overs one million tons per year.

Tin smelting in Tucurui is number two in the Base Case and the lowest in the Gap Adjusted Case. Tucurui enjoys the most favorable conditions in terms of gap adjustment of the infrastructure at present. In addition, construction costs of the process plant in the tin smelting is relatively low. Therefore, the construction costs of auxiliary facilities outside the plant, i.e., a part of gap adjustment

Table 5-2 Relative FIRR (Indicated by Point Score System)
(Base Case)

	Sao Luis	Barcarena	Tucurui	Maraba
Copper	100 (1)	86.85 (2)	78.14 (4)	84.29 (3)
Fe-manganese	100 (1)	92.37 (2)	75.28 (4)	81.63 (3)
Nickel	100 (1)	94.87 (2)	84.36 (4)	90.44 (3)
Fe-nickel	100 (1)	60.72 (4)	66.67 (3)	89.01 (2)
Tin	100 (1)	86.33 (3)	88.53 (2)	78.30 (4)

Table 5-3 Relative FIRR (Indicated by Point Score System)
(Gap Adjusted Case)

	Sao Luis	Barcarena	Tucurui	Maraba
Copper	100 (1)	93.80 (2)	78.14 (4)	91.29 (3)
Fe-manganese	100 (1)	98.67 (2)	75.28 (4)	88.52 (3)
Nickel	100 (2)	101.4 (1)	84.35 (4)	95.66 (3)
Fe-nickel	100 (1)	65.11 (4)	66.67 (3)	95.50 (2)
Tin	100 (1)	96.09 (2)	88.53 (4)	89.84 (3)

Source: Study Team

cost, occupy a relatively high proportion in the total construction cost. This situation is more conductive to the success of a tin industry in Tucurui than to one in Maraba or Barcarena in the Base Case, but the position of the industry turns down to the substantive order in the Gap Adjusted Case where the situation is relatively the same for each location.

5-3-3 Conclusions

(1) General

The comparative advantages of metallurgical industries development in terms of investment efficiency are shown in the Base Case table (Sao Luis registered the highest ranking for all industries). The Gap Adjusted Case table indicates that coastal zones enjoy more beneficial conditions than the inland areas, even after the infrastructural base has been laid for the entry of smelting industries. In both tables, Barcarena recorded the second highest score except for the Fe-Ni industry. One measure that thus may be taken by Para is to develop the transport infrastructure between the inland areas and Barcarena along the Tocantins river to send mineral ores from mountain area to Barcarena industrial district.

(2) Copper, ferro-manganese and tin smelters

From the results of Gap Adjusted Case, comparing the points of Sao Luis (or Barcarena) and Maraba, it is supposed that the merit of transportation cost of Maraba (Factor A) cannot compensate for the demerit of Factor C.

Transportation cost of ore is a relatively small part in the raw material cost at the copper smelter and the tin smelter. In such a process industry Factor C has a heavy weight for the production cost. At the ferro-manganese smelter it accounts for a considerable part of the raw material cost, but the influence of Factor C is still larger than that of Factor A. The break-down of estimated production cost at the 7th year (full capacity operation) shows this fact as follows.

Break-down of Production Cost
(Ferro-manganese smelter)

	Sao Luis	Maraba	Difference
Total production cost	100	101.5	
Raw material cost	20.2(8.1)	15.1(3.0)	-5.1(-5.1)
Sub material cost	9.1	10.6	+1.5
Utility cost	15.8	15.8	
Direct fixed cost	6.5	7.8	+1.3
Deprication (after gap adjustment)	26.0	27.9	+1.9
Interest on loan	16.1	17.9	+1.8
Others	6.3	6.4	+0.1

Note: ( ) shows the transportation cost
A negative value indicates an advantage in Factor A, and a positive value indicates a disadvantage in Factor C.

(3) Nickel and ferro-nickel smelters

It is obvious that transportation cost of ore dominates the raw material cost in these two industries from Table 5-1.

Even in such "transportation cost sensitive" industries as nickel and/or ferro-nickel smelter, it is difficult for Maraba to hold a superior position relative to Sao Luis both in the Base Case and the Gap Adjusted Case. The advantage of Maraba in Factor A is still less affective to the FIRR than that of Sao Luis in Factor C. However, Maraba gets the second ranking in the ferro-nickel smelter in the both cases. This means that the influence of the advantage of Maraba in Factor A is larger than that of Barcarena in Factor C and that of Tucurui in Factor B, at the base of 600,000 tons per year transportation scale of ore.

Barcarena is ranked the last in the ferro-nickel smelter in the both cases. This means that a transportation scale of 600,000 tons per year on the Tocantins Navigation is not sufficient to reduce transportation cost of raw material for the ferro-nickel smelter in Barcarena in order to overcome the handicaps in Factor A. Otherwise, Barcarena is ranked second in the Base Case and first in the Gap Adjusted Case in the nickel smelter. This means that a transportation scale over one million tons per year on the Tocantins Navigation is enough to generate an advantage in Factor A regarding raw material cost for the nickel smelter in Barcarena.

(4) Allocation of smelters

Because Sao Luis, Barcarena, Tucurui and Maraba are supposed to be developed as bases for social development through industry, and if at least one industry is to be allocated to each industrial district, one combination which has the highest total of FIRR values, that is, the greatest total score can be chosen from all possible combinations.

The most profitable combination selected from either the Base Case or Gap Adjusted Case is as follows.

Sao Luis	Copper smelter and Ferro-manganese smelter
Barcarena	Nickel smelter
Tucurui	Tin smelter
Maraba	Ferro-nickel smelter

This comparative study has been carried out by converting the FIRR values into relative score points, so that the results can be used only for comparison of the range of advantages and the degrees of difference in the investment returns. If the choice is to be made on the basis of some investment criteria (for example, a project having a FIRR value of 10% or less is judged to be unworthy of the investment), these relative terms are insufficient. It is difficult to make the choice with such criteria because at the present time, with mines not having been fully developed, there are too many uncertain factors affecting raw material prices, with variations in product prices in the market being difficult to forecast. The resultant FIRR values are therefore very difficult to analyse, making firm conclusions difficult. Conversely, these relative terms are used to avoid confusion, and it must be realized that ideas based on an investment criteria such as absolute values of FIRR will not suit the scope of works for the present Study.

APPENDIX. STUDY ON UTILIZATION OF SULFURIC ACID (BY-PRODUCT)

Sulfuric acid is produced as a by-product at the rate of 150,000 tons/year by the copper smelter. This is a relatively high, as commercial production. This by-produced sulfuric acid is 98% content, and chemically pure for industrial use.

A-1 General Description of Sulfuric Acid

A-1-1 Raw Material

Elemental sulfur (brimstone), pyrite and SO_2 in industrial effluents are the three main sources of present sulfuric acid. According to statistics from the British Sulphur Corp. the world raw material ratio of sulfuric acid is as follows at 1982.

Elemental Sulfur	Pyrite	Others
59.35%	21.50%	19.14%

In Japan, statistics of Sulfuric Acid Association (for 1983) are showing as follows.

Elemental Sulfur	Pyrite	Smelter SO_2	Others
25.54%	10.85%	59.10%	4.4%

A-1-2 Production Process

The production process of sulfuric acid today almost all cases uses the catalytic oxydation process with Vanadium pentoxide catalyst. 98.5% of sulfuric acid in Japan was produced by this process in 1983.

A-1-3 Uses of Sulfuric Acid

The trend of the composition of demand in world market is as follows (in percent; from International Fertilizer Association (IFA) statistics and other information):

	1975	1979	1980	1981	1982
Fertilizer use	50.7	55.2	58.1	56.2	62.0
Other industrial use	49.3	44.8	41.9	43.8	38.0

In Japan, main consumption markets of sulfuric acid were as follows as of 1983.

N-fertilizer	8.5%
P_2O_5-fertilizer	21.1
Textile	9.8
Inorganic chemicals	24.0
Organic chemicals	1.0
Plastics & adhesives	1.2
Steel industry	1.4
Mining & metallurgy	1.0
Paper & pulp	1.9
Others	15.5
Export	10.8

A-1-4 Cost and Price

According to a Japanese periodical research report for the production cost of chemical industry, the production cost of sulfuric acid in a 300,000 - 500,000 tons/year plant in the U.S.A and Japan can be calculated by the following equations in relation to the raw material cost (as of 1980).

The raw material cost occupies very large portion of the production cost in sulfuric acid industry. The equations correspond to the existing plant, which has almost finished the depreciation for plant assets, and newly constructed plant, which has to bear a large initial depreciation for the plant construction costs.

The equations are also classified in accordance with the source of raw material, namely elemental sulfur, pyrite and effluent SO_2 gas.

From elemental sulfur (specific consumption: 0.33 ton elemental sulfur/product ton)

<u>Existing Plant</u>

U.S.A. Raw material cost ÷ 0.91 = Production cost (unit: US$)

Japan Raw material cost ÷ 0.98 = Production cost (unit: Yen)

Newly constructed plant

U.S.A. Raw material cost ÷ 0.68 = Production cost (unit: US$)

Japan Raw material cost ÷ 0.81 = Production cost (unit: Yen)

Note: CIF Brazil price of elemental sulfur was US$ 140/ton at March 1984.

From Pyrite (Specific consumption: 0.75 ton pyrite/product ton)

Existing plant

Japan Raw material cost ÷ 0.94 = Production cost (unit: Yen)

From smelter SO_2 and other source of Sulfer

No information

The price trend has been as follows, in U.S. dollars per ton.

	1975	1979	1980	1981	1982	1983
U.S.A. (93% equivalent)		50.8	60.4	85.0	88.7	87.3
Japan (98%, US$ 1=240 YEN)	50.9	55.7	63.3	67.4	68.8	69.1

A-1-5 Transportation Cost

Transportation cost of sulfuric acid in Japan by tank lorry, railway and ship are as follows.

10 ton tank lorry US$ 26.25/ton/100 km

30 ton tank railway wagon US$ 10.7/ton/100 km

1,000 ton tank ship (15 knots)

Construction cost US$ 1,533,000

Crew member 7 men

Fuel cost 4.3 kℓ/day bunker A oil.

Depreciation 10 years, Interest rate 12% per year.

US$ 45.6/ton for 4,500 km distance (15 days)

A-2 Present Situation in Brazil

Figure A-1 shows the material balance for sulfuric acid in Brazil (as of 1982).

The following comments can be made on the basis of this material balance.

(1) Brazil has a insufficient supply of raw material source for producing sulfuric acid.

Its self-sufficiency is only

$$\frac{163 + 52 + (2{,}014 \times \frac{62}{62+929})}{2{,}320} = 14.7\%$$

By-produced acid will be welcomed by the domestic market.

(2) Brazil is importing raw material brimstone (elemental sulfur) instead of product acid to compensate for the insufficient supply of acid. This is a common way to keep transportation cost low because 0.33 part of brimstone yields to 1.0 part of acid. Furthermore, transportation of product acid is dangerous.

(3) There is no space in Brazilian consumption market for a large supply volume of sulfuric acid of 150,000 tons/year except fertilizer use.

(4) Most sulfuric acid used for fertilizer in Brazil is used for P_2O_5 (phosphoric acid type)-fertilizer.

Table A-1 shows the production and consumption of fertilizer in Brazil in Fertilizer Year 1978. The following comments can be pointed out.

(1) The main N-fertilizer related to sulfuric acid demand is ammonium sulfate. Ammonium sulfate is being replaced by urea in the recent application fields in Brazil, and for the Brazilian soil ammonium sulfate is not suitable because of its acidifying character except in special cases.

(2) Brazil is importing a large quantity of ammonium phosphate and ammonium sulfate. This means that Brazil has a shortage of domestically produced ammonia. Domestic ammonia is preferably consumed not for ammonium sulfate but for ammonium nitrate and ammonium phosphate. It is not adequate to think of N-fertilizer as an objective of sulfuric acid supply.

Figure A-1 Material Balance on Sulfuric Acid in Brazil (1,000 tons/year)

		Brimston	Pyrite	Others
Domestic sulfur	137	(62	59	17)
Imported sulfur	929	(929	-	-)
Total Sulfur	1,066	(991	59	17)
Non acid use	-160			
	906			
H_2SO_4	2,229	(2,014	163	52)

Imported H_2SO_4	91
Total H_2SO_4 (Supplied)	2,320

Consumption of H_2OS_4 2,331
- Fertilizer use 1971
  - N 140
  - P_2O_5 1,831
- Non-fertilizer use 360

Source: FAO Statistics in 1982.

Table A-1 Fertilizer Production and Consumption in Brazil (1978 - 1979 Fertilizer Year)

	Production	Import	Export	Consumption
N-Fertilizer (N ton)			Total 1,900	
* Ammonium Sulfate	11,801	160,781		172,582
Ammonium Nitrate	107,042	2,868		109,910
Urea	32,925	164,315		197,240
* Ammonium Phosphate	88,943	73,923		162,866
Other Complex Fertilizer	32,341	3,253		33,694
* Ammonium Sulfate Nitrate	-	20,125		20,125
Sodium Nitrate	-	4,792		4,792
Calcium Cyanamide	-	163		163
Other Nitrogen Fertilizer	-	4,500		4,500
			Total	779,500
P_2O_5-Fertilizer (P_2O_5 ton)			Total 3,500	
* Single Superphosphate	238,858	16,089		254,947
* Concentrated Superphos phate	419,670	116,143		535,813
* Ammonium Phosphate	284,353	201,649		486,002
Other Phosphate Fert.	21,653	1,400		23,053
* Other Complex Fert.	112,396	153		109,049
Ground Rock Phosphate	108,914	-		108,914
Basic Slag	-	1,782		1,782
				1,656,200

* Relating substance to sufuric acid

K_2O Fertilizer (K_2O ton)	1,085,000
Total Fertilizer Consumption (N ton + P_2O_5 ton + K_2O ton)	3,520,700

Source: FAO Statistics

A-3 Preliminary Selection

From the investigations summarized in sections A-1 and A-2, the following rules for preliminary selection can be made for the finding the supply markets of by-produced sulfuric acid.

(1) Sulfuric acid shall be preferably utilized at near place of production, rather than at a long distance away.

(2) Sulfuric acid shall be used in the P_2O_5-fertilizer production field.

A-4 Present Situation of P_2O_5-fertilizer and Related Products

Single super phosphate, double super phosphate, triple super phosphate, mono-ammonium phosphate, di-ammonium phosphate and N.P.K. compounds are the main P_2O_5-fertilizers made using sulfuric acid. On the other hand, phosphate rock, sulfuric acid and phosphoric acid are the main raw materials for the P_2O_5-fertilizers.

A-4-1 Phosphate Rock

Production and imports of phosphate rock in Brazil from 1975 to 1981 as shown in FAO statistics show that the recovery from phopsphate rock mines in Brazil has been rapidly increased to meet the increasing domestic demand.

(1,000 tons)

	1975	1976	1977	1978	1979	1980	1981
Production	345	463	605	1,069	1,695	2,921	2,764
Import		1,434	1,617	1,156	754	772	467

Generally phosphate rock is supplied with P_2O_5 content 30 - 36% (B.P.L - Bone Phosphate of Lime-value: 65 - 80%) after concentration dressing. The international market price of phosphate rock was FOB US$ 50 - 52/ton (Morocco), and US$ 39 - 40/ton (Florida) at BPL 68% in 1981 - 1982.

A-4-2 Phosphoric Acid

Phosphoric acid is made from phosphate rock and sulfuric acid and is mainly used as an intermediate of P_2O_5-fertilizers. The camacari smelter of Caraiba Metais S.A. has a phosphoric acid plant of 165,000 tons/year to utilize its by-produced sulfuric acid.

Brazil is still importing phosphoric acid as shown by FAO statistics:

(1,000 tons)

	1978	1979	1980	1981
Import	569.2	591.2	794.0	280.2

The market price of phosphoric acid (85%) is FOB US$ 606/ton (Chem. Mark. Rep.) in the U.S.A. and CIF Port Alegre US$ 609/ton (DNPM) in the Brazilian domestic market.

A-5 Conclusion of the Preliminary Market Study

First, a phosphoric acid plant shall be provided at the copper smelter as in the case of the existing Camacari smelter. In this case, plant capacity will be 65,000 tons/year as P_2O_5 (gross 162,500 tons/year 40% solution), and construction cost is estimated as US$ 13,500,000. The product phosphoric acid shall be sent to existing P_2O_5-fertilizer industry in the south industrial area. The market demand is enough large and, in addition, use of this phosphoric acid has the merit of reducing imports of foreign origin phosphoric acid, thereby improving Brazil's balance of trade and foreign exchange position.

For the second stage, when supply of ammonia become available in PGC Area, a P_2O_5-fertilizer plant (Di-ammonium phosphate or triple super phosphate) can be taken up in planning.

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