APPENDIX 3

Summary of the Projects related to Geophysical Survey

Reference No. P-1, 2 and 3

1. Name of Project: "Projeto Geofisico Brasil-Canada"

2. Executing Organizations: DNPM and GSC (Geological Survey of Canada)

3. Duration: 1975 - 1981

4. Objectives: To train Brazilian engineers, transfer techniques of airborne data acquisition, and to carry out a metallic ore deposit exploration.

5. Covered Area: 5^{o}S-16^{o}S and 48^{o}W-51^{o}W; 375,000 km^2 (1,220 km NS x 330 km EW)

6. Methods: - Airborne magnetic and radiometric survey:
   (1) Quantity: 284,116.5 line-km in total
   (2) Line spacing: 2 km and 1 km
   - Airborne electo-magnetic survey (INPUT).
   - Ground electro-magnetic (EM) survey (INPUT).

7. Given Data: A. "Report to the DNPM, MME, BRAZIL on the General Magnetic and Radiometric Survey of the Projeto Geofisico Brasil-Canada(P-3)"
   Attachments: - Aeromagnetic maps (1:250,000 and 1:750,000), 22 sheets.
   - Airborne radiometric maps (Total, Ur, Th)(1:750,000), 22 sheets.
   B. "Relatorio de encerramento das Actividades do PGBC (P-1)"
   C. "Relatorio de Final Projeto Geofisico Brazil-Canada (P-2)"

8. Results of Geophysical Survey:
   Qualitative and quantitative interpretation had not been made for the areas within the Greater Carajas Program Area. Airborne and ground EM surveys were carried out for the areas with significant aero-magnetic and aero-radiometric anomalies which were detected mainly in the south of the Greater Carajas Program Area.

9. Utilized Data:
   Aeromagnetic and aeroradiometric maps were available in a complete form and found very useful for qualitative and quantitative analysis of the subject area.

Reference No. P-4

1. Name of Project: "Projeto Sul do Para; Levantamento Aerogeofisico Magnetometria e Gamaespetrometria"

2. Executing Organizations: DNPM/NUCLEBRAS

3. Duration: 1974 - 1976

4. Objectives: To carry out metallic and uranium ore deposit surveys and to undertake a study of geological structure.

5. Covered Area: A poligonal area of 182,000 km^2 (between 3°N and 5°30'N, and between 49°30'W and 53°W).

6. Methods: - Airborne magnetic method (whole area).
   - Airborne radiometric method (area: west of 51°W) and line spacing 4 km, NS.

7. Given Data: Final Report in two volumes, including aeromagnetic and aeroradiometric (Th) maps at a scale of 1:250,000.

8. Results of Geophysical Survey:
   The aeromagnetic map suggests that the Grao Para Group may be distributed in this area, which had been considered as a part of the Xingu Complex and is distributed in Serra dos Carajas. There are 30 radiometric anomalies on the aeroradiometric map, which were detected within areas of Devonian rocks.

9. Utilized Data:
   The contouring technique of the aeromagnetic data is no better than that of PGBC, but these data could be used for qualitative interpretation after compiling them with PGBC's data at a scale of 1:1,000,000.

Reference No. P-5

1. Name of Project: "Projeto Integracao Geologico-Geofisica Sul do Para"

2. Executing Organization: DNPM

3. Duration: 1978 - 1979

4. Objectives: To undertake a study of geological structure and to compile a regional geologic map at a scale of 1:500,000.

5. Covered Area: The same as Reference No. P-4.

6. Methods: Re-interpretation of aeromagnetic and radiometric data of Reference No. P-4, and ground magnetic, radiometric and EM surveys as well as geological and photointerpretation works.

7. Given Data: Final Report in one volume.

8. Results of Geophysical Survey:
   Magnetic anomalies are classified into three groups (zones

"A," "B" and "C"). These zones reflect geological units corresponding to those magnetic susceptibility. Radiometric anomalies are also classified into 3 levels, corresponding to each geological unit. As a result, the difference of granite and acidic volcanic rocks are distinguished. (Recommendation) Ground checking for aeromagnetic anomalies within zone "C," which may relate with economical ore deposits, as well as ground magnetic and radiometric and detailed geological and geochemical surveys for other areas with magnetic and radiometric anomalies.

9. Utilized Data: The same as Reference No. P-4.

Reference No. P-6

1. Name of Project: "Projeto Sulfetos de Altamina-Itaituba"

2. Executing Organization: DNPM

3. Duration: 1975 - 1976

4. Objective: To explore sulfide ore deposits within sedimentary rocks in the Amazon Basin.

5. Covered Area: An area of 1,500 km^2, along the Transamazonica Road between the Xingu River and the Tapajos River in the state of Para.

6. Methods: Regional geological, geochemical and ground surveys. The number of radiometric surveys carried out in the project is 1,526.

7. Given Data: Final Report in one volume with a radiometric anomaly map.

8. Results of Geophysical Survey:
Potentials of radiometric minerals contained in defferent rock units were estimated. A heliborne geophysical (including EM and radiometric) survey, with a specification of line spacing of 500 m and flight altitude of 80 m A.G.L. has been recommended.

9. Utilized Data:
The radiometric survey was conducted only along the Transamazonica Road at a very low survey density; therefore, the result of this Project could not be used for the current study.

Reference No. P-7

1. Name of Project: "Projeto Gurupi"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1971 - 1977

4. Objective: Geological mapping.

5. Covered Area: 21,500 km^2.

6. Method: Ground radiometric survey as a supplementary method for geological mapping.

7. Given Data: Final Report in one volume.

8. Results of Geophysical Survey: N.A.

9. Utilized Data: None.

Reference No. P-8

1. Name of Project: "Projeto Tocantinia-Itacaja"

2. Executing Organizations: CNEN/NUCLEBRAS

3. Duration: 1968 - 1970

4. Objective: Uranium ore deposits survey.

5. Covered Area: A total of 37,055 km^2, including the tocantins area to the west of the Rio Tocantins (17,565 km^2) and the Itacaja area to the east (19,490 km^2).

6. Methods: Airborne radiometric survey with flight altitude of 120 m A.G.L., as follows:

	(Total length)	(Flight direction)	(Line spacing)
Tocantinia	16,768 km	EW	1 km
Itacaja	17,841 km	EW	1 km

7. Given Data: Final Report in one volume.

8. Results of Geophysical Survey: N.A.

9. Utilized Data: None.

Reference No. P-9

1. Name of Project: "Projeto Balsas; Reconhecimento Geologico-Radiometrico Preliminar"

2. Executing Organizations: CNEN/CPRM

3. Duration: May, 1971 - August, 1971

4. Objective: Uranium ore deposits survey.

5. Covered Area: 50,500 km^2

6. Method: Carborne radiometric survey with 103 stations.

7. Given Data: Final Report in one volume with a geologic map indicating radiometric values at a scale of 1:500,000.

8. Result of Geophysical Survey:
   No significant radiometric anomalies had been detected.

9. Utilized Data:
   None, since the project covered only a small area and provides very few geophysical data.

Reference No. P-10

1. Name of Project: "Projeto Itapecuru; Reconhecimento Geologico-Radiometrico Preliminar"

2. Executing Organizations: CNEN/CPRM

3. Duration: May, 1971 - August, 1971

4. Objective: Uranium ore deposit survey.

5. Covered Area: 72,000 km^2.

6. Method: Ground radiometric survey.

7. Given Data: Final Report in one volume with a geologic map indicating radiometric values at a scale of 1:500,000.

8. Result of Geophysical Survey:
   Two radiometric anomalies were detected.

9. Utilized Data: None.

Reference No. P-11

1. Name of Project: "Ragiao de Barreirinhas Levantamento Aeromagnetometrico"

2. Executing Organization: PETROBRAS

3. Duration; February, 1969 - August, 1969

4. Objective: Petroleum exploration.

5. Covered Area: Refer to the index map (Plate III-6). The area is in the off-shore of the Atlantic ocean coast.

6. Methods: Airborne magnetic survey at a flight altitude of 400 m A.S.L., flight spacing of 2.5 km (NS) and a total line length of 50,000 line-km.

7. Given Data: Final Report in one volume with a flight path map (1:1,000,000) and six aeromagnetic and tectonic structure maps (1:100,000).

8. Results of Geophysical Survey: N.A.

9. Utilized Data: None.

Reference No. P-12

1. Name of Project: "Projeto Maranhao"

2. Executing Organizations: IRN/SUDENE

3. Duration: 1973 - ?

4. Objective: Natural resources survey.

5. Covered Area: 70,000 km^2 in the Alto Grajau area and 20,000 km^2 in the Gurupi area in the western part of the state of Maranhao.

6. Methods: Airvorne geophysical (magnetic and radiometric) surveys.

7. Given Data: None.

8. Results of Geophysical Survey: N.A.

9. Utilized Data: None.

Reference No. P-13

1. Name of Project: "Estudos Integrados da Iliha de Marajo"

2. Executing Organizations: IDESP/SUDAM

3. Duration; 1971 - 1974

4. Objective: Basic survey for the social and economical development of

the Marajo Island of the state of Para.

5. Covered Area: The entire area of the Marajo Island.
   Planned: 20,000 km^2
   Actual: 16,325 km^2

6. Method: The electrical resistivity method of Schlumberger electrode configuration with a total of 694 stations.
   Maximum of AB (current electrodes separation) is 1,000 m.

7. Given Data: Final Report in two volumes (Vol.1 Text, Vol.2 Attachments).

8. Results of Geophysical Survey:
   The distribution and thickness of the superficial layer and groundwater in the Marajo Island have been defined.

9. Utilized Data: None.

<u>Reference No. P-14</u>

1. Name of Project: "Projeto Xingu-Araguaia; Geologia e geoquimica da area Gradaus Nova Olinda"

2. Executing Organizations: SUDAM/CPRM

3. Duration: October, 1974 - December, 1974

4. Objective: To evaluate mineral resource potentials of the area between the Xingu River and the Araguaia River.

5. Covered Area: An area of about 14,500 km^2 in the southwestern part of the state of Para.

6. Methods: The aeromagnetic method in the pilot area and the ground radiometric survey method.

7. Given Data: Final Report in one volume with no sheets and tables attached thereto.

8. Results of Geophysical Survey:
   Radiometric survey was found effective to distinguish the rocks which are otherwise difficult to distinguish.
   It is recommended to carry out a ground magnetic survey in order to understand the distribution of ultra-basic rocks.

9. Utilized Data:
   Since the geophysical anomaly maps were not available, no date was used for the current study.

Reference No. P-15

1. Name of Project: "Serra dos Carajas (Minerio de ferro)"

2. Executing Organization: DOCEGEO

3. Duration: 1969 - 1972

4. Objective: To explore and exploit iron ore deposits in Serra dos Carajas.

5. Covered Area: No information is available.

6. Method: Aeromagnetic survey.

7. Given Data: No information is available.

8. Results of Geophysical Survey: Ditto.

9. Utilized Data: None.

Reference No. P-16

1. Name of Project: "Serra do Quatipuru

2. Executing Organizations: DOCEGEO/UFPa

3. Duration: January, 1972 - December, 1976

4. Objective: To explore Cu-Ni sulfide and asbestine ore deposits.

5. Covered Area: An area of 45 km along NS and 1-3 km along EW in Santana do Oragnaia in the state of Para.

6. Methods:

Ground Magnetics	379 line-km
IP electrical method	5 line-km
EM method	24 line-km

7. Given Data: Final Report in seven volumes (Vol. 1: Text, Vol. 2 to 7: Attachments)

8. Results of Geophysical Survey:
   After checking IP anomalies by the Em method, four diamond drillings were conducted at each point of IP and EM anomalies.

9. Utilized Data: None.

Reference No. P-17

1. Name of Project: "Serra dos andorinhas"

2. Executing Organization: DOCEGEO

3. Duration: 1973 to 1976

4. Objective: To explore Mn and Au ore deposits.

5. Covered Area: 49°45'W to 50°00'W and 7°15'S to 7°30'S, in the southwestern part of the state of Para.

6. Methods: The airborne magnetic and INPUT method (1,450 line-km) and ground geophysics including magnetics (28.7 km), Crone EM (166.35 km), VLF (28.7 km) and radiometrics (15.5 km) as well as geochemical studies of 4597 speciment (Cu, Pb, Zn, Ni, Cr, Co, Fe, Mn, Ag, and Au).

7. Given Data: Final Report in one volume.

8. Results of Geophysical Survey:
   41 INPUT anomalies were detected and after comparing them with the topography, 21 anomalies were selected.
   For these 21 EM anomalies, ground follow-up surveys, including a geochemical survey, were conducted.

9. Utilized Data: None.

Reference No. P-18

1. Name of Project: "Area Antonio Vicent"

2. Executing Organization: DECEGEO

3. Duration: 1975 - 1976

4. Objective: To explore base metal ore deposits (except for Mn) relating to volcanic rocks of the Uatuma Group.

5. Covered Area: 540 km^2. Refer to the index map (Plate III-6).

6. Method: Re-interpretation of the airborne magnetic data acquired by DOCEGEO in 1972.

7. Given Data: No information is available.

8. Results of Geophysical Survey: Ditto.

9. Utiliaed Data:
   None, since the basic data sucy as aeromagnetic maps, etc.

are not available.

Reference No. P-19

1. Name of Project: "Projeto Cobre Carajas - Jazidas Salobo 3A e 4A"

2. Executing Organizations: DOCEGEO/UFPa

3. Duration: 1974 - 1977

4. Objective: To explore Cu ore deposits in Serra dos Carajas.

5. Covered Area: The Serra dos Carajas area in the southwestern part of the state of Para.

6. Methods: Re-interpretation of aeromagnetic data, geochemical studies of sedimentary materials, and ground geophysics in cluding magnetics, Ip method and radiometrics.

7. Given Data: No information is available.

8. Results of Geophysical Survey: Ditto.

9. Utilized Data:
   None, since the basic data such as maps, etc. are not available.

Reference No. P-20

1. Name of Project: "Projeto Cobre Pojuca"

2. Executing Organization: DOCEGEO

3. Duration: 1977 - 1984

4. Objective: To explore Cu ore deposits at the Pojuca mine in Serra dos Carajas.

5. Covered Area: No information is available.

6. Method Applied: Ditto.

7. Given Data: Ditto.

8. Results of Geophysical Survey: Ditto.

9. Utilized Data: None.

APPENDIX 4

List of Landsat Data Used

Path	Row	Scene ID	Date	Quality	Cloud (%)	Data Used		
				4 5 6 7		Band 5	Band 7	Color
236	62	77182-120045	01 JUL 77	8 8 8 8	10	x	x	
	63	76179-114758	27 JUN 76	5 8 8 8	10	x	x	
	64	76179-114823	27 JUN 76	2 5 8 5	00	x	x	
	65	76179-114848	27 JUN 76	5 5 5 5	00	x	x	
237	62	77183-120627	02 JUL 77	8 8 8 8	40	x	x	
	63	77183-120652	02 JUL 77	8 8 8 8	00	x	x	
	64	77183-120717	02 JUL 77	8 8 8 8	00	x	x	
	65	77183-120742	02 JUL 77	8 8 8 8	00	x	x	
	66	77183-120807	02 JUL 77	8 9 9 9	10	x	x	
238	62	77184-121208	03 JUL 77	8 8 8 8	50		x	
	63	77184-121233	03 JUL 77	8 8 8 8	00		x	
	64	77184-121258	03 JUL 77	8 8 8 8	00		x	
	65	77184-121323	03 JUL 77	8 8 8 8	00		x	
	66	77184-121348	03 JUL 77	8 8 8 8	00		x	
239	62	79175-123223	24 JUN 79	8 8 8 8	10		x	
	63	79175-123248	24 JUN 79	8 8 8 8	00		x	
	64	79175-123313	24 JUN 79	8 8 8 8	00		x	
	65	79175-123338	24 JUN 79	8 8 8 8	00		x	
	66	79175-123403	24 JUN 79	8 8 8 8	10		x	
240	62	77204-122235	23 JUL 77	8 8 8 8	10		x	
	63	77204-122300	23 JUL 77	8 8 8 8	00		x	
	64	77204-122325	23 JUL 77	8 8 8 8	00		x	x
	65	77204-122350	23 JUL 77	8 8 8 8	00		x	
	66	77204-122415	23 JUL 77	8 8 8 8	00		x	x
241	63	79177-124419	26 JUN 79	8 8 8 7	00		x	
	64	77223-122808	11 AUG 77	8 8 8 8	00		x	x
	65	77223-122833	11 AUG 77	8 8 8 8	00		x	
	66	77223-122858	11 AUG 77	8 8 8 8	00		x	
242	63	76203-122025	21 JUL 76	- 8 8 8	00		x	x
	64	76203-122050	21 JUL 76	8 8 8 8	00		x	
	65	76203-122115	21 JUL 76	8 8 8 8	00		x	
	66	76203-122140	21 JUL 76	8 8 8 8	00		x	

PART V

STUDY OF METALLURGICAL INDUSTRY DEVELOPMENT

CONTENTS

1. INTRODUCTION

This Study Report describes results of the Study on the metallurgical industry sector of the Regional Development Plan of the Greater Carajas Program based on the Terms of Reference (TOR, refer to the Annex 1-3 of Part I). The study is a contribution of the Japan International Cooperation Agency (JICA) to the Executive Secretariat of the Greater Carajas Program (SE/PGC).

1-1 Objective

This Study aims to analyze comparative locational advantages of some selected metallurgical industries in the four industrial districts, i.e., Sao Luis, Barcarena, Maraba and Tucurui, which were specified by TOR. In the analyses, hypothetical model plants for the selected metallurgical industries were designed for the purpose of financial evaluation of the appropriate industry for each industrial district.

1-2 Metallurgical Industries to be Studied

The Phase I Study investigated a long-term internationall trade aspect of 13 high potential mineral products. They were bauxite, alumina, aluminum, nickel, ferro-nickel, cobalt, manganese ore, ferro-manganese, copper, copper concentrate, tin, pig-iron and semi-finished steel products. From these 13 products, five metallurgical industries were selected jointly by the Brazilian side and by the JICA Study Team on these criteria: (1) availability of raw material in the Greater Carajas Program Area (the PGC Area), (2) utilization of electric power which will be generated in plenty in the PGC Area and (3) level of value added.

In the course of selection, the Brazilian side indicated the general priority ranking of metallurgical industries, in order, such as: aluminum, pig-iron and semi-finished steel, copper, ferro-manganese, nickel, ferro-nickel and tin. As development of the aluminum and iron-and-steel industries is proceeding in the form of large scale project in other parts of Brazil, the following five metallurgical industries were selected for the Phase II Study:

1) Copper smelting industry
2) Ferro-manganese smelting industry
3) Nickel smelting industry
4) Ferro-nickel smelting industry
5) Tin smelting industry

1-3 Methods

The Study is based on the following analyses:

- collection and evaluation of various written documents as well as site observations of the four industrial districts,

- interviews with federal and local government agencies and other private companies involved in the metallurgical industry,

- interpretation of various plant engineering data which were developed for the design of hypothetical model plants.

- development of various assumptions such as availability of infrastructures, mine-head costs of raw materials, product sales prices and financial conditions, which were used as input data for the calculation of financial internal rate of return for individual industries at each location[1], and

- application of marketing reseach methods to the treatment of by-products.

Figure 1-1 shows the flow-chart of the Study for the metallurgical industry sector. The Study Team for the metallurgical industry stayed in Brazil during July 3 and August 29, 1984 and visited various governmental as well as private institutions (refer to the Annex 1-4 of Part I). The data used in the Study depends on information collected through cooperations and suggestions of these institution such as SE/PGC, National Council for the Non-ferrous and Iron and Steel Industry (CONSIDER), National Department of Mineral Production (DNPM), Companhia Vale do Rio Doce (CVRD), and state or private enterprises concerned with the development of the four industrial districts.

1-4 Composition of the Study Report

This Study Report consists of five chapters and an annex. Following Chapter 1, Introduction, Chapter 2 is devoted to an analysis of present conditions of the five metallurgical industries in Brazil as a general reference for the Phase II Study. The level of production, consumption and export-import as well as production facilities were briefly examined for smelting industries of copper, ferro-manganese, nickel, ferro-nickel and tin. In Chapter 3, a hypothetical model plants was designed for each smelting industry. Information developed in this Chapter such as scale of operation and construction cost at each industrial district were used as input data for the calculation of financial internal rate of return.

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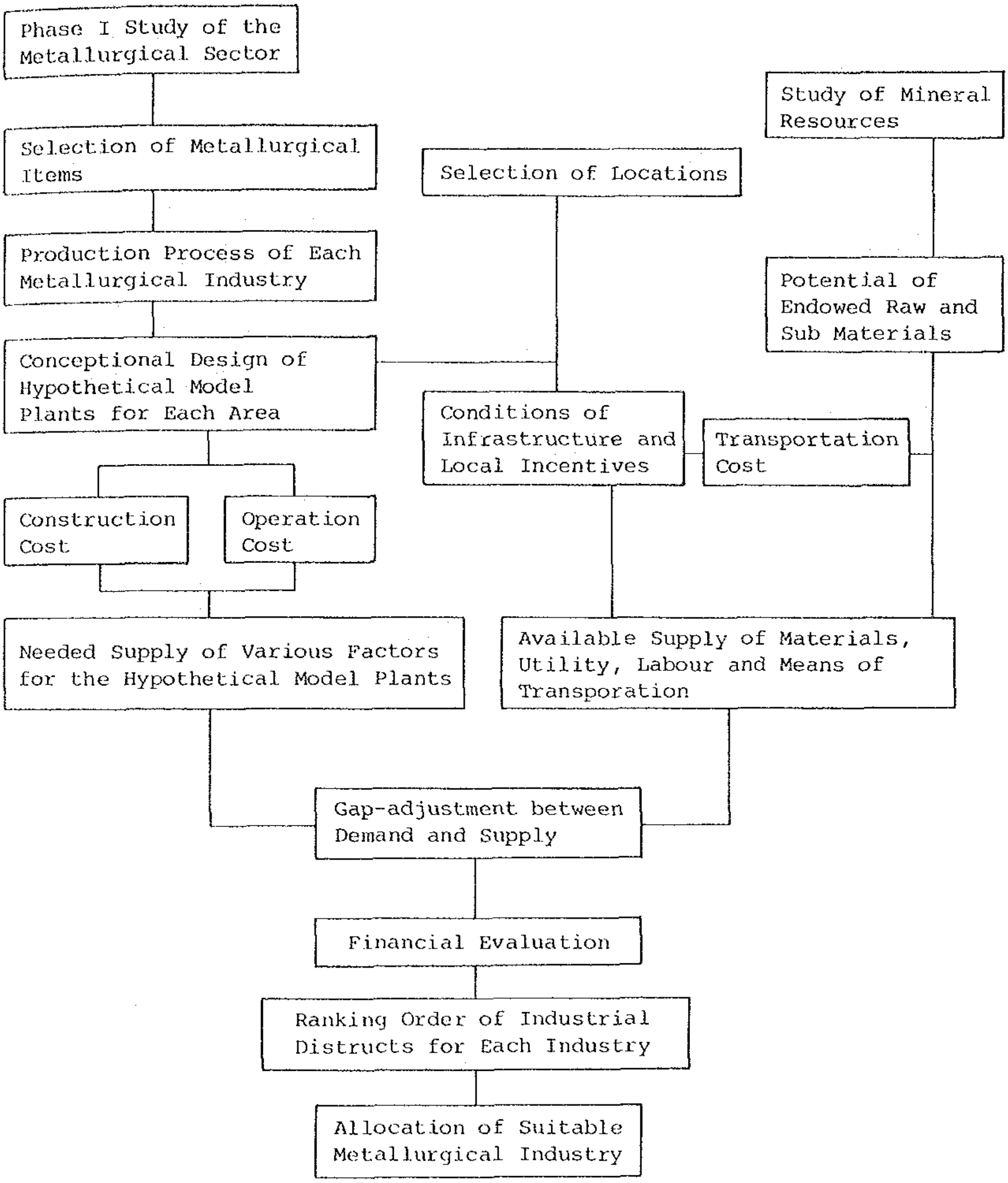
1) The price data in this Report was as of July - August, 1984. The exchange rate used was Cr$ 1,800 - 2,000 per one US$, and 240 Yen per one US$.

Figure 1-1 Flow-chart of Metallurgical Industry Development



Chapter 4 was devoted to the analysis of infrastructure, incentives and financial conditions in each industrial district. Various assumptions with regard to transport infrastructure such as "Tocantins Navigation System" were set forth, and an idea of "Infrastructure Gap Adjustment" in each industrial district was developed. Through the analysis of available incentives, financial conditions such as repayment period and interest rate were also determined in this Chapter.

The results of computed financial internal rate of return, i.e., an indicator showing comparative locational advantages of each industrial district for the five smelting industries, were summarized in Chapter 5. Finally, the results of the study on utilization of sulfuric acid as by-product of copper smelter were shown in the Appendix.

2. PRESENT SITUATION OF SELECTED INDUSTRIES IN BRAZIL

First of all, investigations have been carried out on the present situation of (1) production facilities, and (2) market conditions on the selected five industries, to study the background for the Greater Carajas Program.

Each of these five industries belongs to a plant category specified as electricity-intensive and process-production type metallurgical smelter (and refinery).

There is no plant of these five industries in the Carajas area today.

2-1 Copper Smelting Industry

2-1-1 Production Facilities

Table 2-1 shows plant facilities and operating conditions of Caraiba Metais S.A., which is the only copper smelting company in Brazil.

2-1-2 Market Conditions

Table 2-2 shows recent statistics on market conditions of copper metal in Brazil.

2-1-3 Investigations

(1) Production

The present copper smelting industry in Brazil has only one company, Caraiba Metais S.A., which has two mines and one smelter.

Copper Mines - It seems to be difficult to supply concentrate to the smelter in such quantities as to meet the smelter's present capacity.

Camacari Smelter - It has the production capacity of 100,000 tons/year, and is preparing for commercial start-up. It produced metal to the extent of 4,812 tons in 1982 and 63,083 tons in 1983. A future extension plan calls for it to reach 150,000 tons/year capacity.

(2) Market conditions

(a) Market conditions

The present situation of market conditions estimated from recent statistics is as follows:

Table 2-1 Copper Metal Smelting Company in Brazil

(July, 1984)

Name		CARAIBA METAIS S.A. INDUSTRIA E COMERCIO
Plant Location	Mine	Caraiba (Jaquarari -BA-) Camaqua (Cacapana do Sul -RS-)
	Smelter	Camacari(Aratu -BA-)
Main Product		Electrolytic Copper Metal
Production Capacity		100,000 tons/year (final 150,000 tons/year)
Production Process		Outokumpu OY's Flash Smelting Process and Electrolytic Refining Process
Start-up		1982 (Smelter)
Employee		19,855 (Mines and Smelter)
Raw Materials Origin and Transporation		Caraiba concentrate(50%) → Smelter by road Camaqua concentrate(20%) → Smelter by road and ship Imported concentrate(30%)→ Smelter by ship and ship
Products Shipping		to São Paulo by road

	Production (ton)	Cost of Concentrate (US$)		
		Caraiba	Camaqua	Imported
1982	4,812	CIF 420	CIF 982	FOB 320
1983	63,083	-	-	FOB 415

Annual Input for Production 63,083 (1983) (ton)

Concentrate-167,699	Blister and Imported Cathode - 15,082	Fuel Oil - 37,230
Caraiba 86,628		LPG - 12,458
Camaqua 29,627	Coke - 2,435	Electric Power -
Imported 51,444	Silica - 9,132	319,454 MWh

Source: CONSIDER and DNPM, Mineral Yearbook of Brazil 1983

Table 2-2 Statistics on Copper Metal in Brazil

(Unit : ton)

	1979	1980	1981	1982	1983
Primary Metal Production	-	-	-	4,812	63,083
Primary Metal Domestic Sales	-	-	-	401	66,905
Primary Metal Maker's Stock	-	-	-	4,411	589
Primary Metal Import	190,225	208,232	152,945	204,748	56,442
Primary Metal Import Value(FOB US$ 1,000)	352,728	466,262	282,846	311,867	88,511
Primary Metal Import Unit Price(FOB US$ 1,000)	1.85	2.24	1.85	1.52	1.57
Primary Metal Export	1,655	1,220	801	709	267
Recycled Scrap	----	----	55,866	(-)30,266	55,048
Scrap Import	2,326	3,435	1,483	1,437	442
Secondary Metal Production	53,110	63,000	45,000	57,000	39,920
Secondary Metal Import	-	-	-	-	-
Semi-finished Metal Import	1,949	2,458	3,122	2,252	2,226
Semi-finished Metal Export	5,264	3,223	11,424	10,095	16,146
Semi-finished Metal Export Value(FOB US$ 1,000)	14,693	12,624	25,762	22,837	31,402
Semi-finished Metal Export Unit Price (FOB US$ 1,000)	2.79	3.92	2.25	2.26	1.94
Metal Consumption	----	----	208,500	222,600	150,189
Electric Conductors	----	----	125,517	135,341	----
Rolling Mills	----	----	59,423	65,445	----
Other Sectors	----	----	23,560	21,814	----
User's Stock	----	58,939	51,630	57,330	71,791
Metal Trade Balance(US$ 1,000)	(-)353,134	(-)475,252	(-)279,816	(-)307,196	(-)70,244
Concentrate Import Quantity	-	-	-	10,544	89,158
Concentrate Import Value(FOB US$ 1,000)	-	-	-	3,377	36,953
Concentrate Import Unit Price(FOB US$ 1,000)	-	-	-	0.327	0.414

Major Origin of Imported Metal in 1983

	Chile	Peru	U.S.A	Bahamas	South Africa	Zambia	Zaire
Quantity(ton)	37,950	7,986	1,260	3,835	3,096	1,760	1,538
Value(FOB US$ 1,000)	59,230	12,018	6,954	5,969	5,044	2,688	2,357
Unit Price (FOB US$ 1,000)	1.56	1.50	5.52	1.55	1.63	1.52	1.53

Source: CONSIDER, Statistical Yearbook 1983

Metal consumption: 150,000 - 220,000 tons/year
(fluctuates with market conditions)

Domestic production of primary metal:
Capacity - 100,000 tons/year
(approaching commercial production)

Recycling scrap: 50,000 - 60,000 tons/year

Metal exports: Primary metal - negligible
Semi-finished metal - 10,000 - 15,000 tons/year

Metal imports:
Primary metal - to the extent needed to make up for a shortfall of domestic supply
Secondary metal or scrap - negligible
Semi-finished metal - 2,000 tons/year

(b) Exports

Exports of semi-finished metal has recently increased remarkably. But, the average FOB unit price (US$ 1,800 in 1983) has relatively small price advantage over the import price of primary metal (US$ 1,550 in 1983).

75% of export sales was destined for the U.S.A. in 1983.

(c) Imports

Imports of copper metal and copper concentrate occupy the largest part of import account in Brazilian metal market.

Total amount of metal and ore: US$ 138.751 million FOB
Ratio in total metal and ore imports: 63% (in 1983)

The average unit FOB import price of metal in 1983 was US$ 1,550 (excluding metal from the U.S.A). *This is essentially the same as* the London Metal Exchange (LME) price, US$ 1,560.

(3) Comments

To meet the market demand of primary metal and to improve the foreign exchange position, early expansion and full operation of the Camacari smelter, using domestic ore, will be essential.

Early opening of Carajas copper mines can be an effective means of satisfying these needs.

2-2 Ferro-manganese Smelting Industry

2-2-1 Production Facilities

Tables 2-3, 2-4 and 2-5 show plant facilities and operating conditions of the ferro-manganese smelting industry in Brazil.

2-2-2 Market Conditions

Table 2-6 shows recent statistics on market conditions of ferro-manganese alloy in Brazil.

2-2-3 Investigations

(1) Technical Matters

(a) Facilities and operation

Except Electrosiderurgia Brasileira S.A. (SIBRA) and ALCAN-Aluminio do Brasil S.A. (ALCAN), electric furnaces of this industry are of small electric capacity and of low production efficiency. This can be seen by comparing them with those of the Japanese ferro-manganese industry. Table 2-7 shows the mean value of this industry in Brazil and Japan.

The contents of Table 2-7 indicate that the Brazilian ferro-manganese industry should modernize its equipment in order to improve production efficiency and labor productivity.

(b) Capacity utilization

Capacity utilization rate of this industry was 82% in 1983. The facts that this industry is keeping the capacity utilization rate nearly 80% in these five years, and most of the facilities of this industry were built more than twenty years ago, indicate that an opportunity to make a new capital investment exists on a scrap and build basis.

(2) Market conditions

(a) Market conditions

Present situations of market conditions are estimated as follows from recent statistics.

Production: 280,000 - 290,000 tons/year
(This may be maximum production level.)

Domestic consumption: 130,000 - 150,000 tons/year

Table 2-3 Ferro-Manganese Production Facilities in Brazil

(July, 1984)

Companies	Plant Location	Type of Ferro-manganese	Production Capacity	Number of Electric Furnace	Power (MVA)	Start-up	Employee	Raw Materials Origin and Transportation	Final Products Destination and Transportation
ALCAN - Aluminio do Brazil S.A.	Ouro Preto (MG)	Fe-Si-Mn	(ton/year) 30,000	1	24.0	1940	220 (include Al-member)	Bahia - railway Minas Gerais - road	Rio de Janeiro Minas Gerais Sao Paulo Parana Santa Catarina Rio Grande do Sul - road -
Cia. de Cimento Portland MARINGA	Itapeva (SP)	Fe-Mn (AC)	12,000	1	6.5	1977	123	Urucum (MS) - railway	
		Fe-Si-Mn	8,000	1	6.5				
Cia. PAULISTA de Ferro Ligas	Corumba (MS) Passa Quatro (MG) Passa Vinte (MG)	Fe-Mn (AC)	16,200	3	12.0			Urucum (MS) - railway Minas Gerais - road	Minas Gerais Sao Paulo - road -
	Joceaba (MG)	Fe-Si-Mn	65,520	17	55.9	1961	1,350 (Company Total)		
	Caxambu (MG) Barbacena (MG)	Fe-Mn (MC/BC)	7,200	2	2.4				
PROMETAL - Produtos Metalurgicos S.A.	Aruja (SP)	Fe-Si-Mn	26,400	3	17.7	1953	400	Urucum (MS) - railway Serra do Navio (AP) -railway-ship-road	Minas Gerais Espirito Santo Sao Paulo Rio de Janeiro - road -
		Fe-Mn (MC/BC)	19,080	3	4.2				
PUIATTI & FILHOS Comercia e Industria Ltda.	Barroso (MG)	Fe-Mn (AC)	4,880	2	2.8	1977	23	Minas Gerais-road	Minas Gerais Sao Paulo - road -
Produtos Metalurgicos SAMPAIO LARA Ltda.	Cerquilho (SP)	Fe-Mn (AC)	6,500	1	3.5	1972	150 (include other Ferro-alloys)	Urcum (MS) - railway	Sao Paulo Rio Grande do Sul Santa Catarina Minas Gerais - road -
SIBRA - Eletrosiderurgica Brasileira S.A.	Simoes Filho (BA)	Fe-Mn (AC)	89,200	4	40.2	1970	900	Serra do Navio (AP) -railway-ship	Rio de Janeiro Sao Paulo Minas Gerais - road -
		Fe-Si-Mn	59,500	4	40.2				
Total		Fe-Mn (AC)	128,780	11	65.0				
		Fe-Si-Mn	189,420	26	144.3				
		Fe-Mn (MC/BC)	26,280	5	6.6				
		Grand Total	344,480	42	215.9				

Figure 2-4 Production of Ferro-manganese in Brazil

(Unit: ton)

Manganese Ferroalloys		1979	1980	1981	1982	1983
ALCAN	Fe-Mn(AC)	2,624	-	-	-	-
	Fe-Si-Mn	16,818	20,319	19,404	25,533	27,143
	Total	19,442	20,319	19,404	25,533	27,143
ASSOFUN	Fe-Mn(AC)	-	52	-	-	-
	Total	-	52	-	-	-
CSN	Fe-Mn(AC)	8,696	-	4,570	11,157	-
	Total	8,696	-	4,570	11,157	-
ELECTROMETALUR	Fe-Mn(AC)	-	-	-	-	223
	Fe-Si-Mn	-	-	-	-	1,574
	Total	-	-	-	-	1,797
MARINGA	Fe-Mn(AC)	10,135	12,798	11,900	7,455	8,227
	Fe-Si-Mn	-	-	221	7,060	11,488
	Total	10,135	12,798	12,121	14,515	19,715
PAULISTA	Fe-Mn(AC)	29,494	28,399	17,910	17,438	11,274
	Fe-Si-Mn	32,993	33,225	45,416	57,325	57,170
	Fe-Mn(MC/BC)	-	-	676	2,240	2,213
	Total	62,487	61,624	64,002	77,003	70,657
PROMETAL	Fe-Si-Mn	10,494	17,877	17,518	20,822	17,846
	Fe-Mn(MC/BC)	11,974	12,058	9,009	6,702	7,616
	Total	22,468	29,935	26,527	27,524	25,462
PUIATTI	Fe-Mn(AC)	-	-	-	1,434	1,660
	Total	-	-	-	1,434	1,660
SAMPAIO LARA	Fe-Mn(AC)	-	-	-	2,988	4,266
	Total	-	-	-	2,988	4,266
SIBRA	Fe-Mn(AC)	70,646	87,189	63,807	73,484	67,792
	Fe-Si-Mn	67,198	62,822	60,184	51,908	63,045
	Total	137,838	150,011	123,991	125,392	130,837
Total	Fe-Mn(AC)	121,589	128,438	98,187	113,956	93,442
	Fe-Si-Mn	127,503	134,243	142,743	162,648	178,266
	Fe-Mn(MC/BC)	11,974	12,058	9,685	8,942	9,829
	Grand Total	261,066	274,739	250,615	285,546	281,537

Source: CONSIDER

Table 2-5 Other Informations Related to Ferro-manganese Industry in Brazil

A. Specific Consumption in Brazilian Ferro-maganese Industry

Beneficiated Manganese Ore: 2.4 ton/ton (1982)

Electric Power

Fe-Mn (AC)	: 3,200 KWh/ton	(1983)
Fe-Si-Mn	: 4,600 KWh/ton	

B. Specific Consumption of Ferro-manganese in User-industry (1983)

(kg/ton)

	Fe-Mn (AC)	Fe-Si-Mn	Fe-Mn (MC/BC)
Iron and Steel Industry	4.96	4.34	0.59
Iron Foundry	3.08	0.57	0.86
Steel Foundry	19.89	33.40	2.03

C. Consumption Ratio of Manganese Ore in Brazil (1982)

Ferro-manganese Industry	: 73%
Steel Producing Industry	: 23%
Pig-iron Producing Industry	: 4%

D. Net Sales of Brazilian Ferro-alloy Employee

	1982	1983
Number of Employee	9,019	8,800
Net Sales (Cr$ million)	71,822	234,000
Net Sales per head (US$)	44,930	46,150

Source: CONSIDER

Table 2-6 Statistics on Ferro-manganese Industry in Brazil

(Unit: ton)

	1979	1980	1981	1982	1983
Production	261,066	274,738	250,615	285,546	282,333
Domestic Sales	153,142	175,743	142,463	126,307	133,740
Actual Consumption	149,214	173,402	146,242	129,652	133,093
Apparent Consumption	177,604	200,928	151,151	189,611	108,955
Import	9	1	2	1	0
Export					
Quantity	83,471	73,812	99,466	95,936	173,378
Value (FOB US$ 1,000)	31,406	27,938	36,939	31,542	48,194
Unit Price (FOB US$/ton)	376	379	371	329	278
Export/Production (%)	32	27	40	34	61

Source: CONSIDER, Statistical Yearbook 1983

Table 2-7 Equipment Capacity of Ferro-manganese Industry in Brazil and Japan (1983)

	Brazil	Japan
Fe-Mn (AC)		
Mean Elec. Capa. (MVA/Elec. Furnace)	5.9	27.7
Mean Prod. Capa. (ton/year/Elec. Furnace)	11,707	69,000
Mean Specific Consumption (kWh/ton-product)	3,200	2,400
Fe-Si-Mn		
Mean Elec. Capa. (MVA/Elec. Furnace)	5.6	16.1
Mean Prod. Capa. (ton/year/Elec. Furnace)	7,285	22,995
Mean Specific Consumption (kWh/ton-Product)	4,600	4,000
Fe-Mn (MC, BC)		
Mean Elec. Capa. (MVA/Elec. Furnace)	1.3	2.8
Mean Prod. Capa. (ton/year/Elec. Furnace)	5,256	15,278
Mean Specific Consumption (kWh/ton-Product)	-	1,040
Net Sales of Ferro-alloy		
Per one employee in 1983 (US$)	46,150	291,615

Source: Brazil - CONSIDER, Japan - Japan Ferro-alloy Assosiation.
Japan Chemical Industry Monthly, August, 1982

Import: Nil

Export capacity: max. 150,000 tons/year

(b) Exports

The Brazilian ferro-manganese industry has expanded exports rapidly in the last few years. But as the quantity increased, the FOB export price has decreased remarkably.

	1979	1980	1981	1982	1983
Export quantity (ton)	83,471	73,812	99,466	95,936	173,378
Export unit price (FOB US$/ton)	376	379	371	329	278
Domestic sales price (FOB maker US$/ton)					382

(3) Comments

(a) Production facilities of the industry mainly consist of old, small and inefficient equipment. Nevertheless, they have been constantly used at a high rate of capacity utilization. This situation shows the chance to replace the facilities with larger, more efficient ones.

(b) A favourable tendency for the development of the Brazilian ferro-alloy industry is appearing in a world perspective. Since the oil crisis, the ferro-alloy industry of the world is shifting its production points from high-cost energy parts of existing industrial areas to low-cost energy areas. This tendency is still spreading, gradually and steadily.

(c) A new project of a large smelter of ferro-manganese with ore from the Azul mine in the Carajas Mountains has been planned few years ago. There is a high possibility that it will be revived when there is a favourable turn of the market conditions.

2-3 Nickel Smelting Industry

2-3-1 Production Facilities

Table 2-8 shows an outline of plant facilities and operating conditions of Cia. Niquel Tocantins, which is the only nickel smelting company in Brazil.

Table 2-8 Nickel Metal Smelting Facility in Brazil

(July, 1984)

Company Name	CAMPANHIA NIQUEL TOCANTINS
Plant Location	Niquelandia (GO) and Sao Miguel Paulista (SP)
Production Item	Electrolytic Nickel Metal
Production Capacity	5,000 tons/year (150 tons/year Cobalt)
Production Process	Semi-NICARO Process + Electrowinning Feed Preparation ------ by F.L.Smidth & Co. (Denmark) ↓ Selective Reduction Furnace ------ by Nichols (U.S.A.) ↓ Ammonia Leaching and Basic Nickel Carbonate ------ by Sulzer Brothers (Switzerland) ↓ Sulfate Dissolution and Electrowinning ------ by Outokumpu OY (Finland)
Start-up	1981
Employee	3,424
Raw Materials Origin and Transportation	from Goias by road
Metal Product Shipping	to Sao Paulo by road

Notes:
1. Future expansion plan to 10,000 tons/year has been approved
2. Composition of feed ore

		(%) Ni	Cu	Co	Fe
Silicate type					
	Garnierite	2.0	0.40	0.15	20.0
	Serpentinite	1.2	tr	tr	20.0
Oxide Type					
	Limonite	0.7-1.0	-	-	35.0
Feed adjustment by mixing		1.8			

3. Composition of Basic Nickel Carbonate by NICARO process:

Ni	Co	Cu	Fe
48-50	1.0	0.5	0.2

4. This company is making efforts to adopt new technologies under close cooperations with Outokumpu OY in Finland.
5. By some technical problems, present production level is staying at 40% of plant capacity.

Source: CONSIDER and SE/PGC Report (August, 1983)

2-3-2 Market Conditions

Table 2-9 shows recent statistics on market conditions of nickel metal in Brazil.

We cannot discuss the situation of nickel metal smelting industry alone from above mentioned statistics, because these statistics include metallic nickel and nickel contained in ferro-nickel alloy as primary nickel metal. We have to postulate the metal smelting situation from the disclosed primary nickel balance, considering the nature of the ferro-nickel industry.

2-3-3 Investigations

(1) Technical matters

According to a Report prepared by the Brazilian side (CONSIDER) for the Phase I Study entitled "Survey of Domestic Technological Capacity of the Mining Products Related to the Regional Development Plan of the Greater Carajas Program of the Federative Republic of Brazil", the production rate of this smelter is now at about 40% of capacity due to some technical problems.

(2) Market conditions

(a) Domestic Production - Production of metallic nickel by Cia. Niquel Tocantins is currently counted 4,300 tons/year.

(b) Consumption - The consumption of metallic nickel can be calculated from imports of primary nickel, production of metallic nickel and production of primary nickel in ferro-nickel, as import of ferro-nickel in 1979, 1982 and 1983 were almost zero.

Consumption of metallic nickel: 2,000 - 2,500 tons/year

(c) Imports - Imports of metallic nickel are only to the extent needed to cover a supply shortage from the domestic smelter. Its quantity is supposed to be nearly zero because domestic production of metallic nickel has already reached the level of market demand.

(3) Comments

(a) If the production of Cia. Niquel Tocantins increases, Brazil will be able to stop importing metallic nickel.

Ferro-nickel is already an export product.

(b) New electronic technique and modern special alloys will enlarge the demand of metallic nickel in the near future, in addition to the increase in damand for defense industries, but in the long term forecasts by authorities, the international market of nickel is suggested to be basically weak.

Table 2-9 Statistics on Nickel Primary Metal in Brazil

(Unit: ton)

	1979	1980	1981	1982	1983
Production of metallic nickel	-	-	5	1,388	2,427
Production of primary nickel	2,463	2,504	2,334	4,813	10,741
Primary nickel in ferroalloy	2,463	2,504	2,329	3,425	8,314
Domestic sales of primary nickel	2,424	2,525	1,775	3,335	7,048
Makers inventory of primary nickel	100	79	444	1,622	724
Import of primary nickel	4,579	8,813	6,218	2,133	197
Import of primary nickel FOB US$ 1,000	23,033	55,645	46,517	14,358	1,179
Import unit price FOB US$ 1,000	5.0	6.3	7.5	6.7	6.0
Export of primary nickel	5	6	426	420	3,701
Export of primary nickel FOB US$ 1,000	118	107	2,323	1,894	19,102
Export unit price FOB US$ 1,000	23.6	17.8	5.5	4.5	5.2
Apparent consumption of nickel*	7,907 (899)	11,695 (414)	8,834 (319)	7,013 (224)	7,356 (155)
Trade balance of primary nickel US$ 1,000	-34,069	-61,420	-49,196	-16,238	+15,443
User's comsumption of nickel*			9,842	7,103	7,089
Ni-Ag Alloy			142	153	141
Foundry			1,356	1,067	795
Electroplating			1,605	1,387	1,167
Metallurgy			6,626	4,411	4,915
Others			113	85	71
User's inventory of nickel*		1,573	2,075	749	910

Note: * include import of scrap, semi-finished and other types.
( ) shows their total.

Source: CONSIDER, Statistical Yearbook 1983

The production cost of a laterite nickel smelter is generally higher than that of sulfide nickel smelter because of higher energy cost.

On this matter, detailed information in Volume 4, Progress Report of Phase I Study can be a useful reference.

2-4 Ferro-nickel Smelting Industry

2-4-1 Production Facilities

Tables 2-10 and 2-11 show plant facilities and operating conditions of the ferro-nickel smelting industry in Brazil.

2-4-2 Market Conditions

Table 2-12 shows recent statistics on market conditions of ferro-nickel alloy in Brazil.

2-4-3 Investigations

(1) Technical Matters

(a) Electric Furnace - Average electric capacity and production capacity are 13.1 MVA and 1,840 nickel-tons/year per one furnace. These capacities are smaller than the Japanese average 17.6 MVA and 5,800 nickel-tons/year. Even though the difference of nickel content in raw materials must be taken into consideration, the equipment capacity of old plants needs to be modernized.

(b) Operation Rate - This industry has a surprisingly high operation rate, 113% in 1983.

This value indicates existence of good opportunity to make a new capital investment, whether it is by a new entry or through plant renovation.

(2) Market conditions

(a) Production - The production of ferro-nickel in 1983 reached a record high of 25,991 tons (gross ferro-nickel).

Table 2-10 Ferro-nickel Producing Facilities in Brazil

(July, 1984)

Name		EMPRESA DE DESENVOLVIMENTO DE RECURSOS MINERAIS S.A. (CODEMIN)					MORRO DO NIQUEL S.A.-MINERACAO, INDUSTRIA E COMERCIO- (MONIQUEL)				
Plant Location		Niquelandia (GO)					Pratapolis (MG)				
Production Capacity *		5,000					2,350				
Electric Furnace	Number	2 (closed type)					2 (closed type)				
	MVA	34.0					18.4				
Start-up		1982					1962				
Employee		820					400				
Raw Materials		From Goias by road					From Minas Gerais by road				
Finished Products		To Minas Gerais, Sao Paulo, Rio de Janeiro by road					To Minas Gerais, Sao Paulo, Rio de Janeiro by road				
Actual Production * (ton)		1979	1980	1981	1982	1983	1979	1980	1981	1982	1983
		-	-	-	1,143	5,996	2,668	2,651	2,525	2,491	2,320

* Nickel contained in ferro-nickel

Source: *CONSIDER*

Table 2-11 Other Information Related to Ferro-nickel Industry in Brazil

1. Estimated Specific Consumption of Ferro-nickel Industry in Brazil (per ton Gross Ferro-nickel)

Dried ore	14 ton
Electric Power	8,000 kWh
Charcoal	515 kg
Electrode	80 kg
Lime	150 kg
Fluorite	12 - 15 kg
Oxygen	100 - 120 Nm^3
Caustic Soda	10 - 12 kg

2. Specific Consumption of Ferro-nickel in Brazilian Industries (kg Ferro-nickel/Products-ton)

Iron and Steel Integrated Industry:	0.790
Iron Foundry :	0.290
Steel Foundry :	6.370

Source: SE/PGC Report (August, 1983)

Table 2-12 Statistics on Ferro-nickel Industry in Brazil

(Unit : ton)

	1979	1980	1981	1982	1983
Production					
Gross Ferro-nickel	11,355	11,280	10,744	10,597	25,991
Nickel contained in Ferre-nickel	2,463	2,504	2,329	3,475	8,314
Average Nickel-Content (%)	21.7	22.2	21.7	32.8	32.0
Domestic Sales					
Gross Ferro-nickel	11,200	11,342	8,062	8,225	13,091
Import					
Gross Ferro-nickel	1	402	4,404	6	1
Export					
Gross Ferro-nickel	-	-	1,800	1,529	15,494
Value (FOB US$ 1,000)	-	-	2,273	1,410	18,738
Unit Price for contained Nickel ton (FOB US$ 1,000)	-	-	5.82	2.81	3.78
Export/Production (%)	-	-	16.8	14.4	59.6
Apparent Consumption					
Gross Ferro-nickel	7,907	11,695	8,834	7,013	7,356
Actual Consumption					
Nickel contained in Ferro-nickel	2,964	2,094	1,804	2,291	4,369
(Calculated Gross Ferro-nickel)	(13,659)	(9,432)	(8,313)	(6,984)	(13,653)

Source: CONSIDER, Statistical Yearbook 1983

This figure is considered to be the maximum the industry can supply. The nickel-content of recently produced ferro-nickel shows that production is oriented towards high nickel low-carbon alloys, reflecting the needs of users.

(b) Consumption - Domestic sales each year has been almost the same as actual consumption. The data show that annual domestic consumption is equivalent to 10,000 tons/year ferro-nickel or 3,000 tons/year contained nickel.

(c) Exports - Facing the same situation of ferro-manganese, ferro-nickel industry expanded its exports rapidly in 1983. But the FOB unit price was lower than the international standard price as shown below.

	1981	1982	1983
International standard price (FOB US$ 1,000/nickel-ton)	6.30	5.72	5.67
Brazil export unit price (")	5.12	3.91	3.84

According to present capacity of production facilities, the export capacity of this industry can be estimated as about 5,000 nickel-tons/year, and the level attained in 1983 may be the maximum.

(3) General comments

This industry has a relatively high potential for enlargement of its industrial production capacity due to the following reasons.

(a) It has maintained a high level of production since Empresa de Desenvolvimento de Recursos Minerais S. A. (CODEMIN) began to use new equipment in 1982.

(b) Recent rapid growth of the iron and steel industry in Brazil will increase market demand of this alloy.

(c) Probably there will be no particular serious problem concerning production technique for the laterite nickel ores, except for adjustment of acidity of the ores to prevent attackings of acidic slag to the furnace bricks.

(d) Some foreign enterprises are showing interest, in exploring the resources in Goias and Carajas, to establish new smelters in these areas. But their plans have not been officially approved yet.

2-5 Tin Smelting Industry

2-5-1 Production Facilities

Table 2-13 shows plant facilities and operating conditions of tin smelting industry in Brazil.

2-5-2 Market Conditions

Table 2-14 shows recent statistics on market conditions of tin smelting industry in Brazil.

2-5-3 Investigations

(1) Technical matters

The majority of smelters are producing tin metal by pyrolytic smelting process using electric furnaces and a refining process with dry liquation system. Only Cia. Estanifera do Brazil (SESBRA) has a electrolytic refining process after dry liquation system.

(2) Market conditions

(a) Production - Tin metal production of Brazil ranks fifth in the free world as of 1983, following Malaysia, Thailand, Indonesia and Bolivia. Production is about 5% of world total production.

(b) Market Conditions

Production capacity:	26,000 tons/year
Domestic consumption:	4,000 - 5,000 tons/year
Imports:	nearly zero
Exports:	8,000 - 9,000 tons/year

(c) Export - The trade balance of this metal shows consistently a surplus, and the export value of this metal in 1983 was the second largest in the exported non-ferrous metals, following the aluminium metal.

99.6% of export sales in 1983 was destined for the U.S.A., Canada and Europe.

The ratio of primary metal in the export metal is increasing year after year, while conversely the ratio of others (supposed to be finished goods) is decreasing.

Table 2-13 Tin Smelting Facilities in Brazil

(July, 1984)

Company Name		BERA do Brazil	CESBRA	CIA/BEST/SBM	FLUMINENSE and MINAS BRAZIL	MAMORE	Rhodia S.A.
Plant Location		Santo Amaro (SP)	Volta Redonda (RJ)	Manaus (AM) Sao Paulo (SP) Sao Paulo (SP)	Sao Joao del Rei (MG)	Sao Paulo (SP)	
Production Items		Pyrolytic Metal	Pyrolytic Metal and Electrolytic Metal	Pyrolytic Metal	Pyrolytic Metal	Pyrolytic Metal	
Production Capacity (ton/year)		2,400	7,200	3,000	1,400	12,000	
Production Process		Pyrolytic Smelting by Electric Furnace and Liquation Refining	Pyrolytic Smelting by Electric Furnace and Liquation Refining and Electrolytic Refining	Pyrolytic Smelting by Electric Furnace and Liquation Refining	Pyrolytic Smelting by Electric Furnace and Liquation Refining	Pyrolytic Smelting by Electric Furnace and Liquation Refining	
Start-up		before 1970	before 1970	before 1970	before 1970	before 1970	
Employee		Total of Industry : Mines - 7,606, Smelters - 1,466					
Raw Material Origin and Transportation		from Rondnia Goias by road	from Rondonia by road	from Rondonia by road	from Para by road	from Amazonas Rondonia Para Mato Grosso by road	
Products Shipping		to Sao Paulo Rio de Janeiro by road	to Sao Paulo Rio de Janeiro by road	to Sao Paulo Rio de Janeiro by road	to Sao Paulo Rio de Janeiro by road	to Sao Paulo Rio de Janeiro by road	
Production (ton/year)	1979	280	4,540	1,108	966	3,088	-
	1980	224	3,883	859	379	3,301	-
	1981	487	2,683	565	139	3,765	-
	1982	1,922	2,648	751	187	3,790	-
	1983	1,638	2,785	791	241	7,176	110

Source: CONSIDER

Table 2-14 Statistics on Tin Metal in Brazil

(Unit: ton)

	1979	1980	1981	1982	1983
Primary Metal					
Production	10,132	8,796	7,789	9,298	12,741
Domestic Sales	3,339	3,847	2,647	3,611	3,751
Inventory	560	312	312	364	114
Average Storage Ratio(%)	1.01	1.04	0.93	0.59	0.23
Import	9	20	0	1	0
Export					
Quantity	1,526	2,773	4,747	4,346	8,720
Value (FOB US$1,000)	23,294	46,547	64,516	55,920	110,777
Unit Price (FOB US$1,000)	15.3	16.8	13.6	12.9	12.7
Other Tin Metal					
Export					
Semi-finished	-	40	142	63	1
Value (FOB US$1,000)	-	686	2,012	973	14
Unit Price (FOB US$1,000)	-	17.2	14.2	15.4	14.0
Other Products	3,028	1,004	50	6	10
Value (FOB US$1,000)	46,926	16,517	822	275	262
Unit Price (FOB US$1,000)	14.6	16.5	16.4	45.8	26.2
Sectional Consumption of Tin Metal in Brazil				4,900	3,942
Tin Plate				1,798	1,734
Solders Alloy				1,568	1,534
Bronze				54	28
Oxide and Salt				137	92
Others				1,343	554
Actual Import of Tin ore	7,542	3,605	301	-	-
Trade Balance (FOB US$1,000)	(+)69,986	(+)63,075	(+)67,125	(+)56,907	(+)110,912

Source: CONSIDER, Statistical Yearbook 1983

Recent FOB export unit prices have exactly matched Malaysian market levels:

	1981	1982	1983
Brazilian export price (FOB US$ 1,000/ton)	13.6	12.9	12.7
Malaysian market price (")	14.0	12.9	12.8

Inventory - The average level of primary metal inventory has been extremely low every year; nevertheless total nominal production capacity is more than double actual production. In spite of strong market demand in Brazil for tin metal, ore supply from domestic mines cannot fulfill the smelter's requirements.

The above explanation can be proved by DNPM's statistics for 1982, as follows.

Production of tin concentrate(tin content is about 50%) : 15,250 tons

Year-end stock of tin concentrate : 254 tons

Supply to the smelters : 17,042 tons

(3) Comments

(a) With the rapid increase of tin metal production, this industry is suffering from shortage of raw material supply, while their production capacity of metal is nominally double the level of recent production.

Therefore, early opening of following projected new mines is of high importance.

Projected Mines	Company or Group	Scheduled Start
Pitinga (AM)	Paranapanema	1983
Pela EMA (GO)	Goias Estanho	1983
Serra Branca (GO)	Gondwana	1984
Pedra Branca (GO)	Gondwana	1984
Montenegro (RO)	Brumadinho	1984
Monte Alegre (GO)	Brumadinho	1984

(b) Increase of domestic demand in future will depend on tin-plate demand. Tin-plate industry will increase in scale in tandem with the Brazilian steel industry in the near future.

3. DESIGN OF HYPOTHETICAL MODEL PLANTS

To determine the comparative advantages of each industrial district, an idea, to compare investment efficiencies on conceptional model plants of an identical scale in each industrial district for each individual industry, was introduced into the Study.

The model plants were designed by process engineers of the Study Team who were dispatched from leading companies in each industrial field in Japan.

For selection of production process and production scale, the Study Team considered to (1) world competitive production cost, (2) utilizing electric power as the main energy source, and (3) characteristics of raw material ores.

3-1 General Description

Common assumptions for all model plants are as follows.

3-1-1 Construction Cost

To equalize the base of construction cost for each model plant, the idea of "international construction cost" was applied to the Study.

To obtain one of the available international construction costs, cost estimation method termed "Turn-key base plant exportation by a Japanese contractor" was adopted.

Main equipment of the process is to be procured in Japan, sent to Sao Luis or Barcarena at the expense of ocean freight charges, then sent to each plant site at inland freight costs, and assembled to a perfect plant with equipment and materials procured locally in Brazil.

Equipment and materials locally procured in Brazil were also assumed to be first gathered at Sao Luis or Barcarena, then sent to each construction site with incurrence of inland freight charges.

3-1-2 Construction Period

The construction period for each model plant was estimated by use of the critical path method. Difference was not found in the comparison of construction period for the five industries at any single location.

The construction periods for all model plants at Sao Luis were estimated to be about 36 months from the start of engineering design until the completion of construction.

At Barcarena, the periods were extended to 42 months due to the need for improvement of the soil bearing strength.

At Tucurui and Maraba, the periods were extended to 48 months because of extratime necessary for inland transportation and inavailability of skilled local labor.

3-1-3 Plant Operation Cost

(1) Variable cost

(a) Raw material cost and sub-material cost are discussed in Section 3-2.

(b) Electric power charges follow National Department of Waters and Electric Power (DNAEE) price schedule. KW demand fee plus consumption fee were treated as unit price per MWh in each industry. Obligator loan is not considered, because the cost of transmission cable line between the plant and the main sub-station was already included in plant construction cost.

(c) Industrial water cost was calculated by electric power consumption for the water-intake and water pipeline.

(2) Fixed cost

(a) Personnel expenses

(i) Salary and wages

Estimated average salary and wages per month in Sao Luis are as follows:

	US$/month
Plant manager Superintendent Engineer	1,660
Foreman	350
Operator	185
Worker	85

Locational factor for other industrial distructs:

Barcarena	Sao Luis x 1.05
Tucurui	" x 1.10
Maraba	" x 1.15

Fringe benefits for employees: 20% of salary and wages

(ii) Plant overhead (miscellaneous expenses for routine plant activities)

20% of personnel expenses

(b) Depreciation and amortization

According to accounting information by Industrial Development Institute of Minas Gerais (INDI), the following depreciation periods were assumed.

	(Year)
Process and utilities facilities	5
Building and warehouse	10
Plant indirect cost	20
Outside facilities	30
Intangible fixed assets	5
Interest during construction	5

(c) Maintenance cost

3% of the sum of following items:

Process plant
Utility plant
Offsite facilities within battery limits
Outside facilities

(d) Tax and insurance

1% of undepreciated assets.

3-2 Description of Model Plant

3-2-1 Copper Smelter and Refinery

(1) Production process and plant scale

Smelter:	Mitsubishi Continuous Copper Smelting and Converting Process	
Refinery:	Improved electrolytic refining process	
Plant capacity:	99.99% or more copper cathode	100,000 tons/year
	98% sulfuric acid	150,000 tons/year
	electrolytic gold	2.7 tons/year

(2) Process flow sheet

Refer to Figure 3-1.

(3) Plant lay-out

Refer to Figure 3-2.

(4) Process description of smelter

The scope of the process is as follows:

(a) Raw materials storage and feed preparation
(b) Mitsubishi furnaces
(c) Gas cooling and cleaning facilities
(d) Anode plant
(e) Oxygen plant
(f) Acid plant
(g) Auxiliary facilities

(a) Raw materials storage and feed preparation

Storage

Copper concentrates, silica, limestone and coal are delivered to the storage area. The storage capacity for concentrate is approximately 40,000 tons and that for silica is approximately 9,000 tons.

Reverts from the smelter area are transported by truck to the crushing plant and processed to the required size, and then stored in the shed.

Drying of material

Copper concentrate and coal must be dried in order to be fed pneumatically to the smelting furnace through lances as well as to reduce consumption of fuel in smelting.

The materials are dried in a combined rotary and flash dryer to a moisture content of 0.5%.

The dried materials are collected by two-stage cyclones and bag filters and then stored in the dry bin. The heat source of this dryer is mainly fuel oil and supplementary furnace off-gases. A separate rotary dryer reduces the moisture of silica, limestone fluxes and converting furnace slag (C-slag).

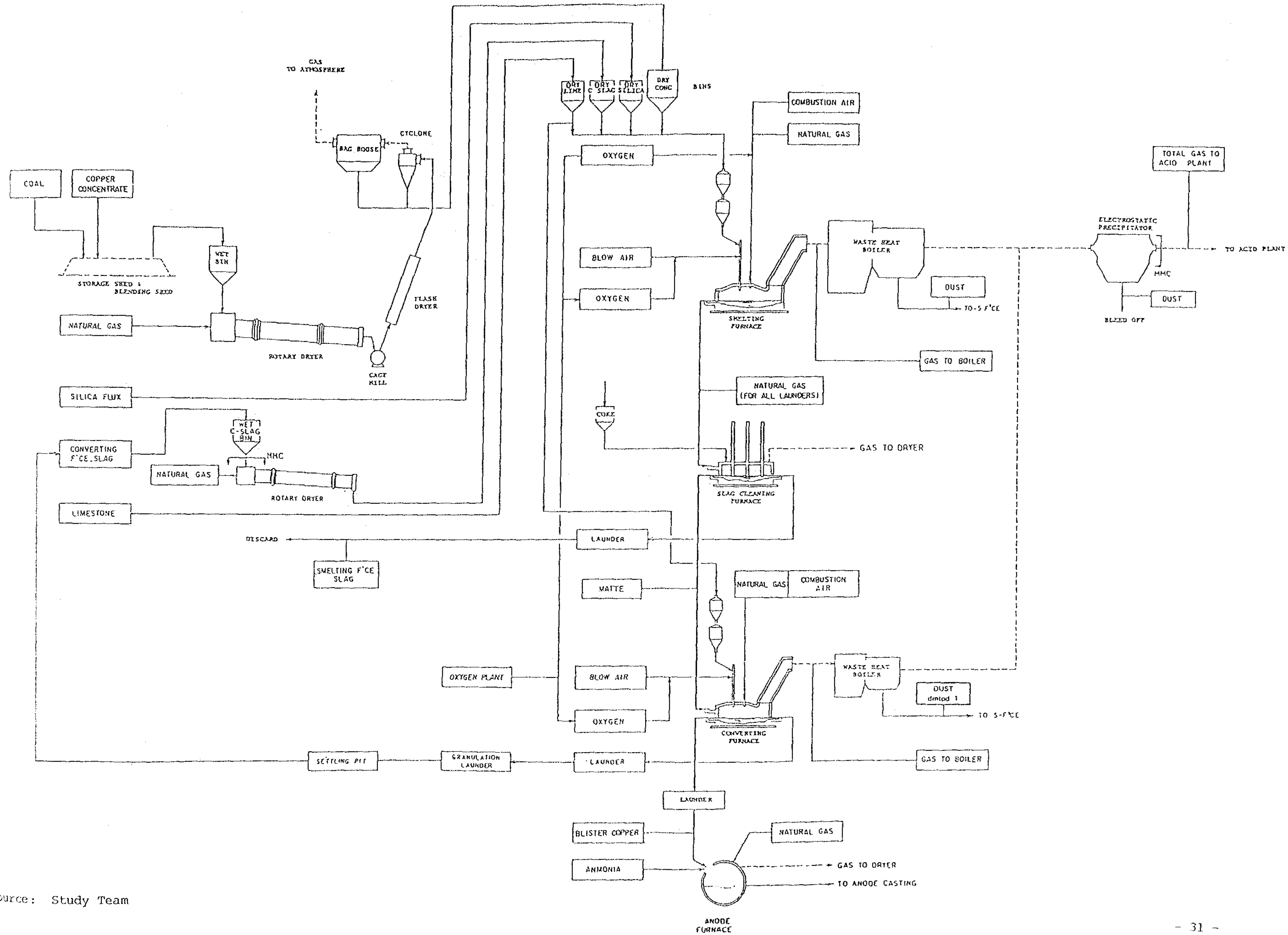
(b) Mitsubishi furnaces

Smelting

The dried concentrates and fluxes are distributed to the smelting furnace feed hoppers, from which they are pneumatically charged to the feeding lances. The materials are then injected through the lances with oxygen enriched air, at 50% oxygen (O_2).

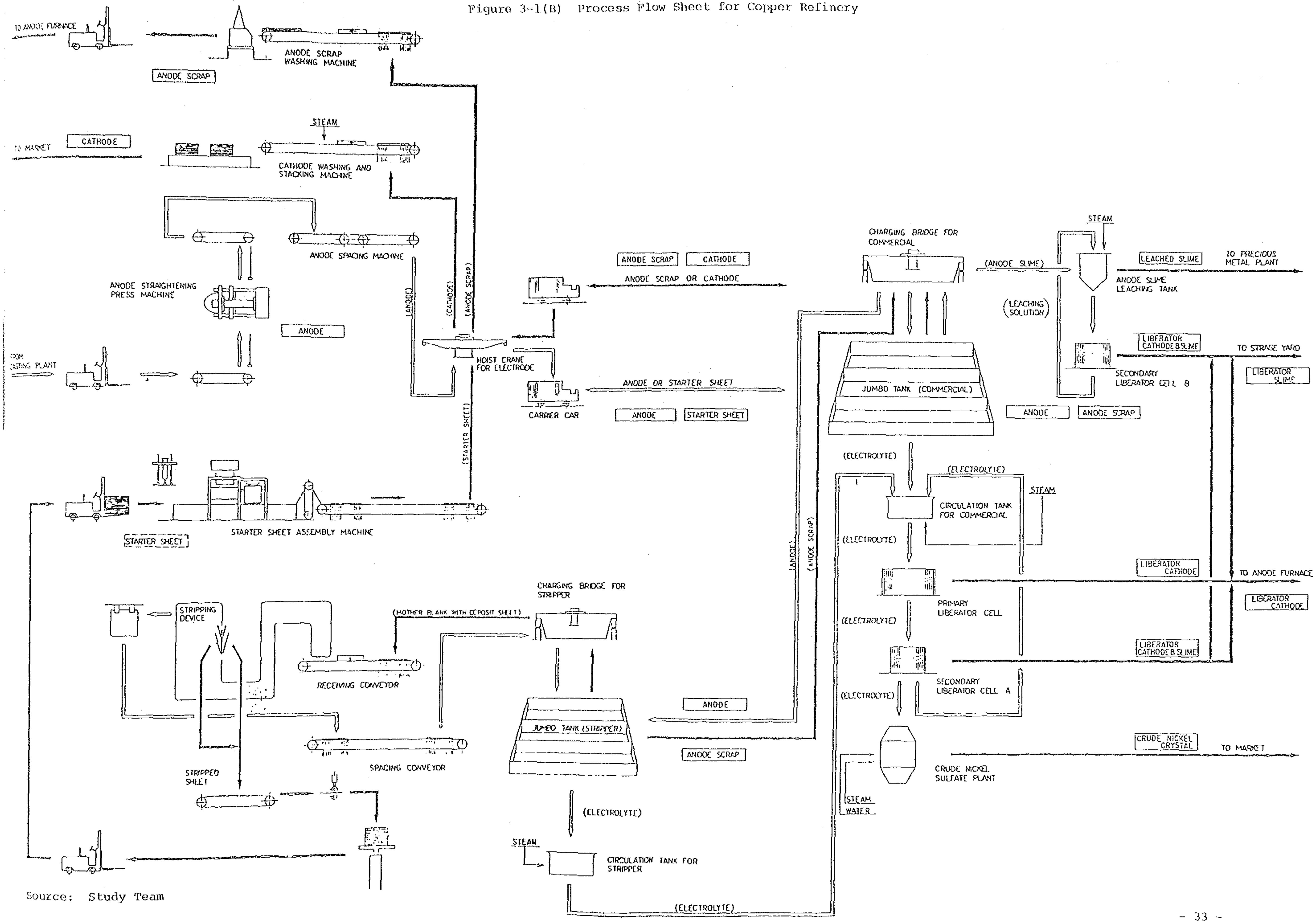
In the smelting furnace, the materials are injected through a thin slag layer directly into the matte and the sulfide minerals, the major constituents of the concentrate, are rapidly melted into the matte.

Figure 3-1(A) Process Flow Sheet for Copper Smelter



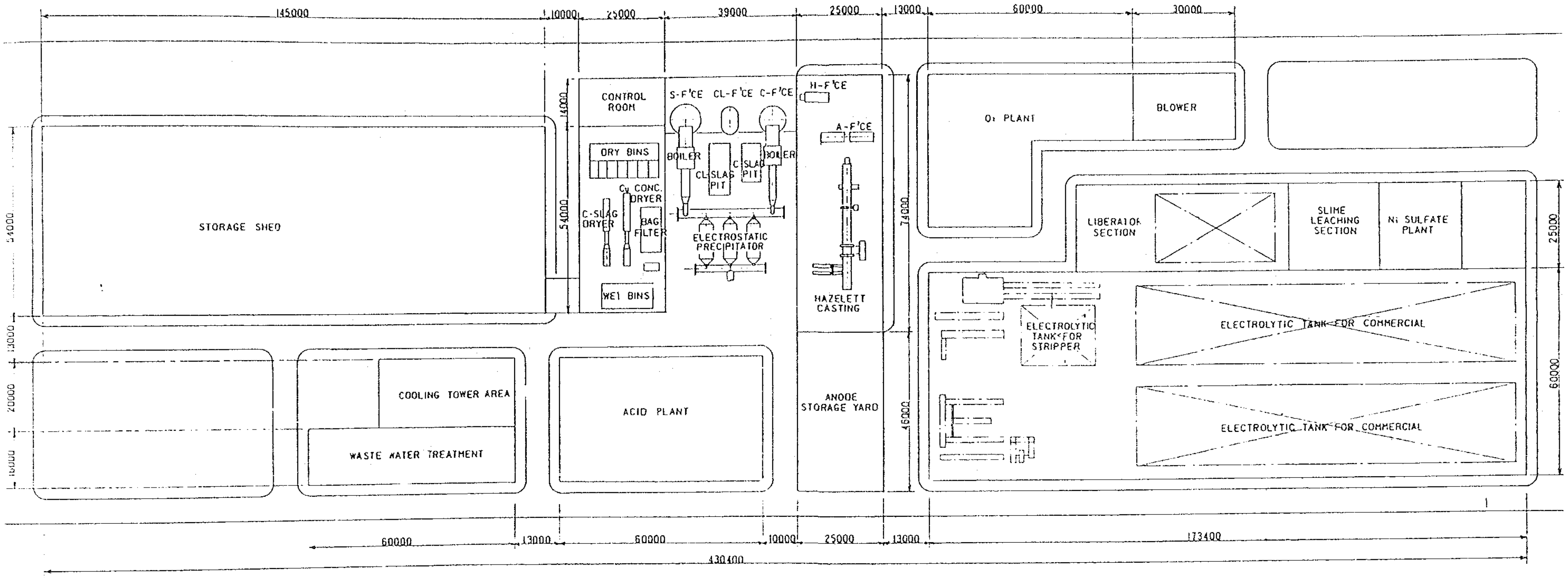
Source: Study Team

Figure 3-1(B) Process Flow Sheet for Copper Refinery



Source: Study Team

Figure 3-2 Plant Lay-out for Copper Smelter and Refinery



Source: Study Team

The molten bath in the furnace consists of a matte covered with a thin slag layer. Thereby a high oxygen efficiency is ensured for the top blowing.

The molten product, a mixture of matte (65% copper (Cu)) and slag, overflows continuously from the furnace to the slag cleaning furnace through a heated launder. The off-gas is sent to a waste heat boiler through a furnace uptake.

Slag cleaning

The mixture of matte and slag is separated into matte and slag in the slag cleaning furnace, an electric furnace, which provides quiescent conditions permitting the matte to be separated from slag.

The discard slag continuously overflows from the furnace and is granulated with water, while the matte is continuously siphoned out and sent to the converting furnace. The off-gas is sent to the concentrate dryer.

Converting

The matte containing 65% Cu flows continuously from the slag cleaning furnace through a heated launder thus eliminating ladle transfers of molten matte, slag and metal as required in conventional processes involving converter aisle operations.

Iron and sulfur are eliminated by blowing air enriched to about 27% O_2 into the furnace through lances in the same manner as the smelting furnace and controlling the slag composition at 17% calcium oxide (CaO) and 15% Cu.

The slag containing about 15% Cu is transferred to a water granulation stage and then is returned to the smelting furnace after drying. The off-gas is sent to a waste heat boiler through the furnace uptake. The blister copper containing about 98.5% Cu is continuously siphoned out and sent to holding furnace through a launder.

Computer control

For the Mitsubishi Process, a computer is used to control blast air, flux ratio and temperature.

The matte and slags are automatically sampled and analyzed using a X-ray fluorescence analyzer. The analyzed values are fed directly to the computer and control parameters are adjusted when necessary.

(c) Hot gas cooling and cleaning facilities

Smelting and converting furnace

Hot off-gasses from the smelting and converting furnaces are cooled in separated waste heat boilers. The boilers are designed to cool gases from 1,200°C to 350°C. The heat of off-gases is recovered as saturated steam at 55 kg/cm² Gauge.

Cooled gas from each boiler is fed to an electrostatic precipitator (E.P.) and the cleaned gas is sent to the acid plant after dust removal. Dust from the boiler are returned to the smelting furnace.

Slag cleaning furnace and holding furnace

The furnace off-gas is sent to the concentrate dryer at which the sensible heat of gas is utilized to dry the concentrate, and dedusted by a cyclone.

(d) Anode plant

Fire refining

The blister copper produced in the converting furnace is continuously received in a holding furnace through a launder. The blister copper is then sent to an anode furnace by a ladle.

Fire refining of copper involves two key operations: oxidation of impurities such as sulfur etc., in the molten blister copper, followed by reduction of the excess cuprous oxide (Cu_2O) formed in the first operation. The oxidation is carried out by blowing air under the molten copper surface through tuyeres. After oxidation, reducing of copper oxide is achieved by blowing gaseous ammonia through tuyeres in the molten bath.

Anode casting

After the fire refining of copper, the molten copper from the anode furnace is cast into molds on a casting wheel. Constant feeding of copper into each mold is carried out by an automatic weighing and feeding system.

Off-gas treatment

Furnace off-gas is usually sent to the concentrate dryer.

Off-gas generated during oxidation step contains a relatively high concentrate of sulfur dioxide (SO_2) gas. Therefore, gas is treated in the absorbing tower.

(e) Oxygen plant

95% oxygen used at smelter is produced at the oxygen plant. Oxygen is mainly used for metallurgical reaction passing through lances as oxygen-enriched air. Another use is for miscellaneous use. Oxygen pressure at the point of use is required to be 3.0 kg/cm² for lances and 5.0 kg/cm² for miscellaneous use.

(f) Acid plant

Gas cleaning and cooling section

The SO_2 gas, passing through waste heat boiler and dry electrostatic precipitator, is led to venturi scrubber to remove impurities in the gas, to humidify and to reduce the gas temperature.

The SO_2 gas, after passing through the venturi scrubber, is led into a gas cooler and 1st & 2nd wet electrostatic precipitators.

The gas is cooled down in the gas cooler to an adequate temperature for the contact acid section, and harmful matters such as acid mist, dust, etc., in the gas are removed in the wet electrostatic precipitator in order to maintain the catalyst activity and the catalyst life.

Contact acid section

Purified SO_2 gas is introduced to the drying tower, where moisture in the gas is absorbed by circulating acid.

The dried SO_2 gas is pressurized by the main gas blower and heated up by 1st and 2nd heat exchangers to the adequate temperature in order to convert SO_2 to SO_3 easily.

The heated SO_2 gas enters the catalyst beds of converter, where SO_2 is converted to SO_3 by reacting with a part of oxygen in the SO_2 gas by the aid of vanadium pentoxide catalyst.

Overall conversion efficiency of more than 99.7% is accomplished. SO_3 converted in the 1st, 2nd and 3rd catalyst beds is absorbed in 1st absorption tower and SO_3 converted in the 4th catalyst bed is absorbed in 2nd absorption tower after respective heat recoveries.

(g) Auxiliary facilities

Auxiliary facilities of the process consist of following facilities

1) Water cooling facilities
2) Waste gas treatment
3) Waste water treatment

(5) Process description of refinery

(a) Commercial section

Cell (large tank is divided into small portions hereinafter referred to as "cells")

The total of 640 electrolytic cells are installed in the commercial section. The commercial section is divided into two blocks and each block is further divided into 20 large tanks, each tank consists of 16 cells respectively. The working unit per day for charging and discharging of electrodes in 4 tanks or 64 cells.

Cell construction

One of the most unique features embodied in the design in the Study is an application of large tanks of steel structure with complete side-to-side electrolyte circulation.

The steel tanks are first lined stainless steel and then PVC liners are applied as protective layers.

Electrolyte is supplied for each tank and circulates smoothly from one end to the other end through the cells.

All the cells are installed on the ground level, which makes it possible to lower the height of the building in order to lower the construction cost.

Electrolyte circulation system

The flow rate of electrolyte to each tank is about 270 ℓ/min. Electrolyte circulates from one end to the other end of the tanks. The uniform distribution of electrolyte and supply of additional reagent as well as heat supply are realized rationally.

The temperature of electrolyte is 60°C at the inlet and 57 - 58°C at the outlet of the tanks.

Electrolyte filtering system

Filters which are installed in the circulation area remove the slime particles suspended in circulating electrolyte.

Lining of circulation tank and piping, etc.

Circulation tanks are of steel-reinforced concrete structure and lined with stainless steel. PVC pipes are used for circulation pipings.

Additive reagent feeding system

The type and quantity of addition reagents are the important factors for electrolysis. The following addition reagents are recommended based on actual experience.

1) Thiourea
2) Glue

The addition reagents for one-day use will be first dissolved in a dissolution tank and then diluted in a feeding tank. The solution is then continuously fed into electrolyte at a constant rate.

Slime treatment system

The anode slimes which are settled on the bottom of a cell are sucked up by an automatic slime removal device attached to the charging bridge without decanting electrolyte, and transported through a slime pipe into a slime collecting tank. The slimes are then pumped up to the slime leaching section.

Thyristor rectiformer

Two thyristor-rectiformers supply electric current to the commercial section. The rectiformer is designed to have about 10% extra capacity both in current and voltage to enable a possible increase of the current density in the future.

(b) Stripper section

The stripper section are divided into 4 blocks, which consist of 12 stripper cells. A stripper cell has the same dimensions as a commercial cell. The design basis for cell construction, circulation system, electrolyte filtering system, circulation tank, addition reagents feeding system, slime treatment system, thyristor-rectiformer, circuit breaker, etc., are identical to those of the commercial section.

(c) Mechanical equipment section

The major machinery and equipment to be installed will be as follows:

1) Anode straightening press machine
2) Anode spacing machine
3) Anode scrap washing machine
4) Starter sheet preparation machine
5) Cathode washing and stacking machine
6) Charging bridge for commercial
7) Hoist crane for electrode
8) Carrier car
9) Loop making machine
10) Suspension bar conveyor

11) Automatic stripping machine
12) Traverser
13) Charging bridge for stripper

(d) Electrolyte purification system

Electrolyte purification is carried out in the ordinary liberator system. The copper sulfate method is one of the electrolyte purification methods, but such a method is not adopted in the Study because the market of copper sulfate crystal is not known.

The facilities for electrolyte purification system consist of the primary and secondary liberators which eliminate impurities in electrolyte. Nickel in the electrolyte is eliminated as crude nickel sulfate crystal in the nickel sulfate plant.

(e) Anode slime leaching section

The slimes delivered from the slime collecting tank are first received in the slime thickening tank, where the slime slurry is concentrated. The slimes are then sent to the slime leaching tank and blended with electrolyte.

The mixed solution is then heated by steam. Copper in the slimes is oxidized and dissolved into solution by airation. The slimes thus decopperized are washed, filtered and dried.

(f) Anode scrap treatment

All anode scraps generated at the tankhouse is returned to the smelter for remelting and casting into anode.

(6) Material balance

Smelter	Refer to Table 3-1
Refinery	Refer to Table 3-2

(7) Personnel requirement

Refer to Table 3-3.

(8) Construction cost

Refer to Table 3-4.

(9) Operation cost factors

Raw material	
Copper concentrate	271,800 tons/year

Table 3-1 Material Balance for Copper Smelter

Material Balance for Smelting Furnace

Material	Weight	Element (%)							
	(tons/hr)	Cu	Fe	S	SiO_2	CaO	MgO	$A\ell_2O_3$	C
<u>Charge</u>									
Copper Concentrate	35.4	40.8	14.3	7.9	15.3	0.6	1.2	3.1	4.0
Pyrite	7.1	-	44.4	48.9	4.2	-	-	0.6	-
Silica Flux	1.0	-	-	-	98.0	-	-	-	-
Limestone	0.2	-	-	-	-	54.0	-	-	-
O-slag	5.9	15.0	46.9	-	-	17.0	-	-	-
Coal	1.1	-	-	-	-	-	-	-	-
<u>Discharge</u>									
Matte	23.7	65.0	12.0	22.0	-	-	-	-	-
Slag	22.4	0.6	36.7	-	30.0	6.0	1.9	5.1	-

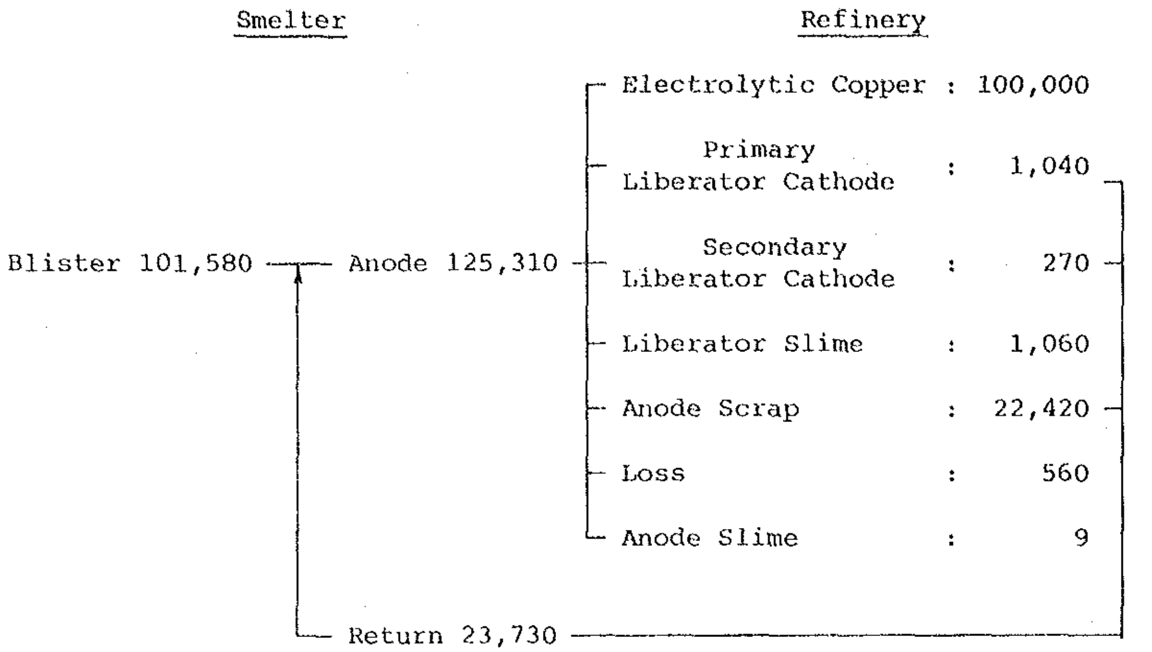
Material Balance for Converting Furnace

Material	Weight	Element (%)						
	(tons/hr)	Cu	Fe	S	SiO_2	CaO	MgO	$A\ell_2O_3$
<u>Charge</u>								
Matte	23.6	65.0	12.0	22.0	-	-	-	-
Limestone	1.9	-	-	-	-	54.0	-	-
<u>Discharge</u>								
Blister Copper	14.4	99.4	-	0.5	-	-	-	-
C-slag	5.9	15.0	46.9	-	-	17.0	-	-

Source: Study Team

Table 3-2 Material Balance for Copper Refinery

(Unit: ton/year (Cu))



Source: Study Team

Table 3-3 Estimated Requirement for Plant Operation Group
(Copper Smelter and Refinery)

	Plant Manager	Super-intendent	Engineer	Foreman	Operator	Worker
Smelter		1	5	11	137	
Refinery	1	1	2	6	34	30
Utility		1	4	9	47	
Maintenance and Others		1	3	3	22	

Note: Personnel number of administration and others
25% of plant operation group

Source: Study Team

Table 3-4 Hypothetical Model Plant (Copper Smelter and Refinery) Estimated Construction Cost

(Unit: US$ 1,000)

	Sao Luis	Barcarena	Tucurui	Maraba
Land price	11	9	8	7
Land preparation	390	390	390	390
Plant direct cost (A)				
Process plant	97,373	97,373	97,373	97,373
Utility plant	11,273	11,273	11,273	11,273
Offsite facilities	16,804	16,804	16,804	16,804
Plant direct cost (B)				
Spare parts	2,933	2,933	2,933	2,933
Cata and Chemicals	833	833	833	833
Temporary works	6,273	6,273	6,273	6,273
Plant indirect cost				
Construction equip.	12,545	12,545	12,545	12,545
Ocean freight and ins.	6,398	6,398	6,398	6,398
Inland freight and ins.	467	467	4,974	3,731
License, Engineering and Services	18,818	18,818	18,818	18,818
Indirect field expenses	5,018	5,018	5,018	5,018
Other facilities				
Transmission cable	405	243	405	1,944
Waterintake and pipeline	2,333	1,733	1,133	3,833
Housing colony	-	13,000	-	12,000
Project management	1,881	1,881	1,881	1,881
Pre-operating expenses	9,676	9,830	9,869	0,470
Contingency	29,015	30,873	29,539	31,729
Interest during const.	24,740	30,240	28,635	35,095
Initial working capital	10,245	10,048	10,427	10,087
Total Capital Requirement	257,431	277,342	265,529	288,435

Source: Study Team

Sub-materials		
Pyrite	54,700	tons/year
Silica flux	7,900	"
Limestone	1,800	"
Coal	8,200	"
Supplies		
Graphite electrode (US$2,254/ton)	65	tons/year
Refractories (US$540/ton)	400	"
Lance pipe (US$2,084/ton)	60	"
Utilities		
Electric power	122,730	MWh/year
Industrial water	32,637	tons/year
Steam	109,820	tons/year

Other factors

Refer to Section 3-1-3.

(10) Study on raw materials

(a) Technical study

Salobo III deposit in the Carajas Mountains is expected to be used as the source of copper ore. The expected composition of concentrate deduced from examination results of floatation enrichment is as follows:

Concentrate (expected)

Cu	40.8%	Au	10 g/ton
S	7.9	Ag	6 g/ton
Fe(sulfide)	6.9	Mo	0.27%
Fe(total)	14.3	Ni	100 ppm
C (graphite)	4.0	Co	100 ppm
SiO_2	15.3	As	100 ppm
$A\ell_2O_3$	3.1		
CaO	0.6		
MgO	1.2		

As the main component of Salobo III deposit is bornite and chalcocite, sulfur content is far less than in sulfide ore.

Therefore, pyrite addition is required to maintain the heat balance in the smelter.

(b) Cost study

(i) Mine-head cost of copper concentrate

According to the market conventions in international copper trade, mine head cost is estimated as follows by the Non-ferrous Metal Division of CVRD.

(0.75 x Cu content x Price of LME Wire-bar Metal) + Contained Gold Price and Platinum Price = US$ 551.78/ton

(ii) *Transportation cost of copper concentrate*

Copper concentrate is assumed to be produced at the Salobo mine. It will be transported from Salobo to the Carajas railway terminal by road. This transportation cost was estimated with following assumptions:

Distance : 64 km (128 km for return)
Vehicle : 30 ton dump truck x 5
average speed: 40 km/h
price : US$ 417,000/one truck
Interest : 12% per year
Depreciation and repayment: 5 years
Fuel : 10 kg/h/vehicle
Fuel cost : US$ 385/ton
Personnel cost : 20 driver x US$ 300/month
Transportation volume : 271,800 tons/year (824 tons/day)

Resulted cost is about US$ 3.0/ton.

Transportation cost to the plant site (US$/ton)

1) Sao Luis

Salobo - Carajas terminal (truck 64 km)	3.0
Carajas - Sao Luis (Railway 890 km)	21.0
Loading and unloading charge (US$ 1 x 2)	2.0
Sao Luis terminal - plant site (truck 5 km)	0.5
	26.5

2) Barcarena

Salobo - Carajas terminal (truck 64 km)	3.0
Loading charge	1.0
Carajas - Maraba (railway 150 km)	7.6
Maraba - Barcarena plant site (refer to Section 4-1-6(1))	23.2
	34.2

3) Tucurui

Salobo - Carajas terminal (truck 64 km)	3.0
Loading charge	1.0
Carajas - Maraba (railway 150 km)	7.6
Maraba - Tucurui plant site (refer to Section 4-1-6(1))	17.0
	28.6

4) Maraba

Salobo - Carajas terminal (truck 64 km)	3.0
Carajas - Maraba (railway 150 km)	7.6
Loading and unloading charge	2.0
	12.6

(iii) Pyrite

Pyrite shall be obtained by importation or from the coal mine rejects in the state of Santa Catarina.

Price estimation (US$/ton)

Mine head cost (Canada)	5
Ocean freight	40
Handling charge	5
CIF Sao Luis or Barcarena	50

Sao Luis plant site	50
Barcarena plant site	50
Tucurui plant site (via Barcarena by barge)	76
Maraba plant site (via Sao Luis by railway)	72

(iv) Silica Flux

Silica Flux is assumed to be available in each place except Barcerena. Barcarena shall be supplied from Tucurui by truck (transportation cost by barge - US$ 30/ton - is expensive). Mine head cost and transportation cost by road (20 km) were estimated as US$ 3 and US$ 4 respectively.

Sao Luis plant site	US$ 7/ton
Barcarena plant site (via Tucurui, US$15/ton by truck)	22/ton
Tucurui	10/ton
Maraba	10/ton

(v) Limestone

Limestone is assumed to be available in each place. Mine head cost and transportation cost (50 km) were assumed as US$ 8/ton and US$ 7/ton respectively.

(vi) Coal

Coal was assumed to be supplied from coal mines in Santa Catarina. CIF price at plant site was assumed as follows:

Sao Luis	US$ 75/ton
Barcarena	US$ 85/ton
Tucurui	US$ 110/ton (via Barcerena, by barge)
Maraba	US$ 96/ton

3-2-2 Ferro-manganese Smelter

The smelter has two production units, the ferro-manganese unit and the ferro-silicomanganese unit, conforming to the general rule of ferro-alloy industry.

(1) Production process and plant scale

Production process :	Ordinary type closed electric furnace with Sederberg electrode	
Production capacity:	High carbon ferro-manganese (Fe-Mn(A/C))	72,600 ton/year
	Ferro-silicomanganese (Fe-Si-Mn)	48,200 ton/year

(2) Process flow sheet

Refer to Figure 3-3.

(3) Plant lay-out

Refer to Figure 3-4.

(4) Process description

(a) Main facilities and equipment of process plant

(i) Sintering unit

Manganese-ore (fine) and charcoal (fine) storage, charging, drying, mixing, sintering, sieving, and sintered ore storage facilities.

Dust collecting equipment.

Capacity 460 tons/day

(ii) Raw material storage and treating unit

Manganese-ore storage, charging, drying, crushing and sieving facilities.

Coke drying and storage facilities.

Ferro-manganese slag crushing equipment.

Raw materials for ferro-manganese and ferro-silicomanganese blending facilities.

Capacity

Raw material for Fe-Mn	600 tons/day
Raw material for Fe-Si-Mn	550 tons/day
Coke drying	110 tons/day
Slag crushing	130 tons/day

(iii) Electric furnaces

	Fe-Mn (A/C)	Fe-Si-Mn
Transformer	40,000 kVA	40,000 kVA
Load	24,000 kW	26,000 kW
Mean load	23,000 kWD	25,000 kWD
Working days	330 days/year	330 days/year
Production Capacity	72,600 tons/year	48,200 tons/year

(iv) Products treating unit

Casting and pouring equipment - two sets
Cooling, crashing and sizing facilities - two sets

Capacity

Fe-Mn	220 tons/day
Fe-Si-Mn	150 tons/day

(v) Gas purification and water treatment

Gas purification and storage equipment.
Waste water treating equipment.

(b) Process operation

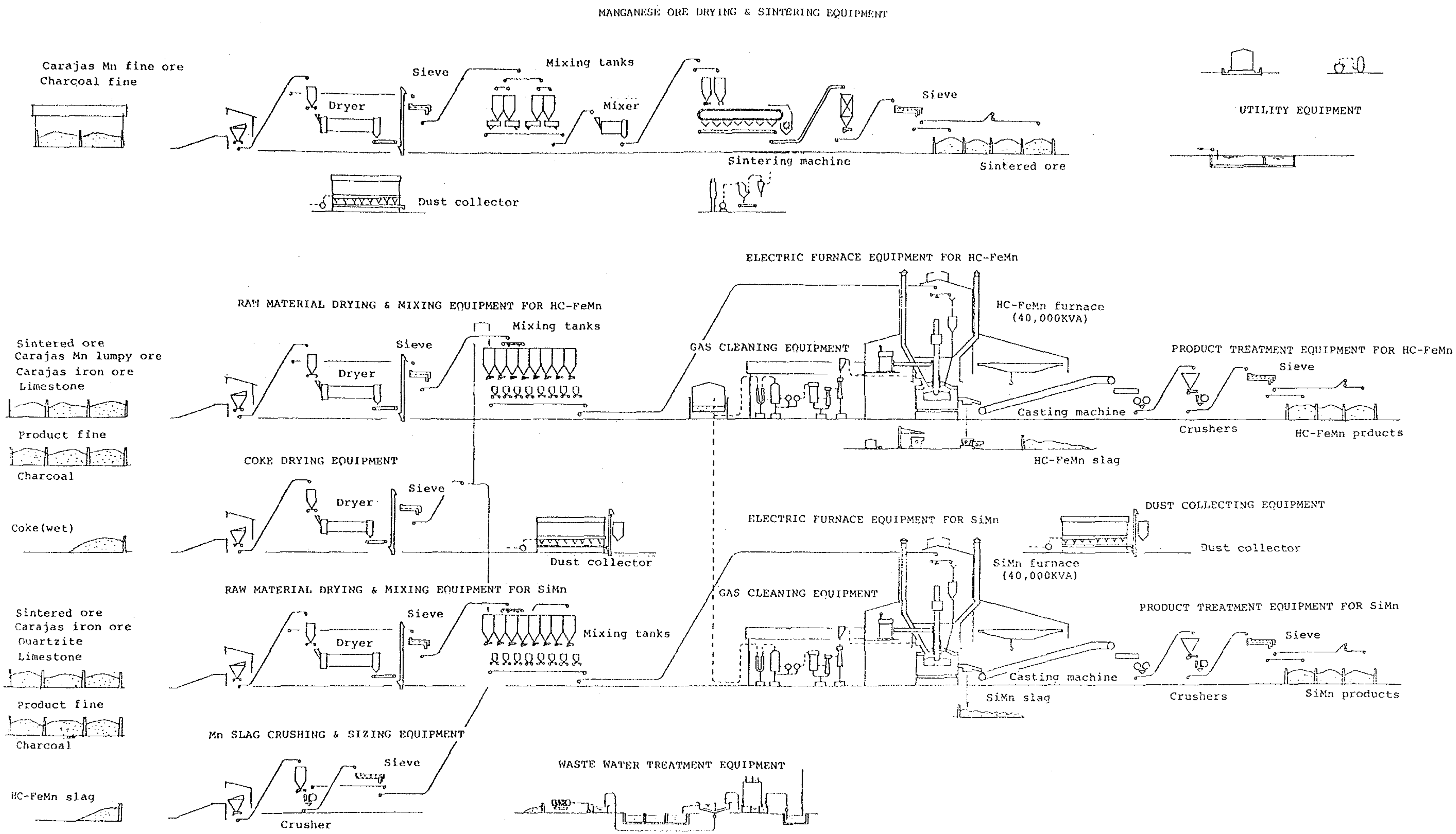
(i) Pretreatment of raw materials

The raw materials to be fed into the electric furnace must be controlled regarding moisture content and size distribution to get stable operation of the furnace. Manganese ore and charcoal are treated with dryer, crusher and sizing sieve. The under-size raw materials are sent to sintering unit as a sinter feed. For the operation of a large-scale furnace, the most important factor is to keep stable furnace conditions. Usually the rate of sintered ore in the feed materials should be high for this purpose.

(ii) Blending of raw materials

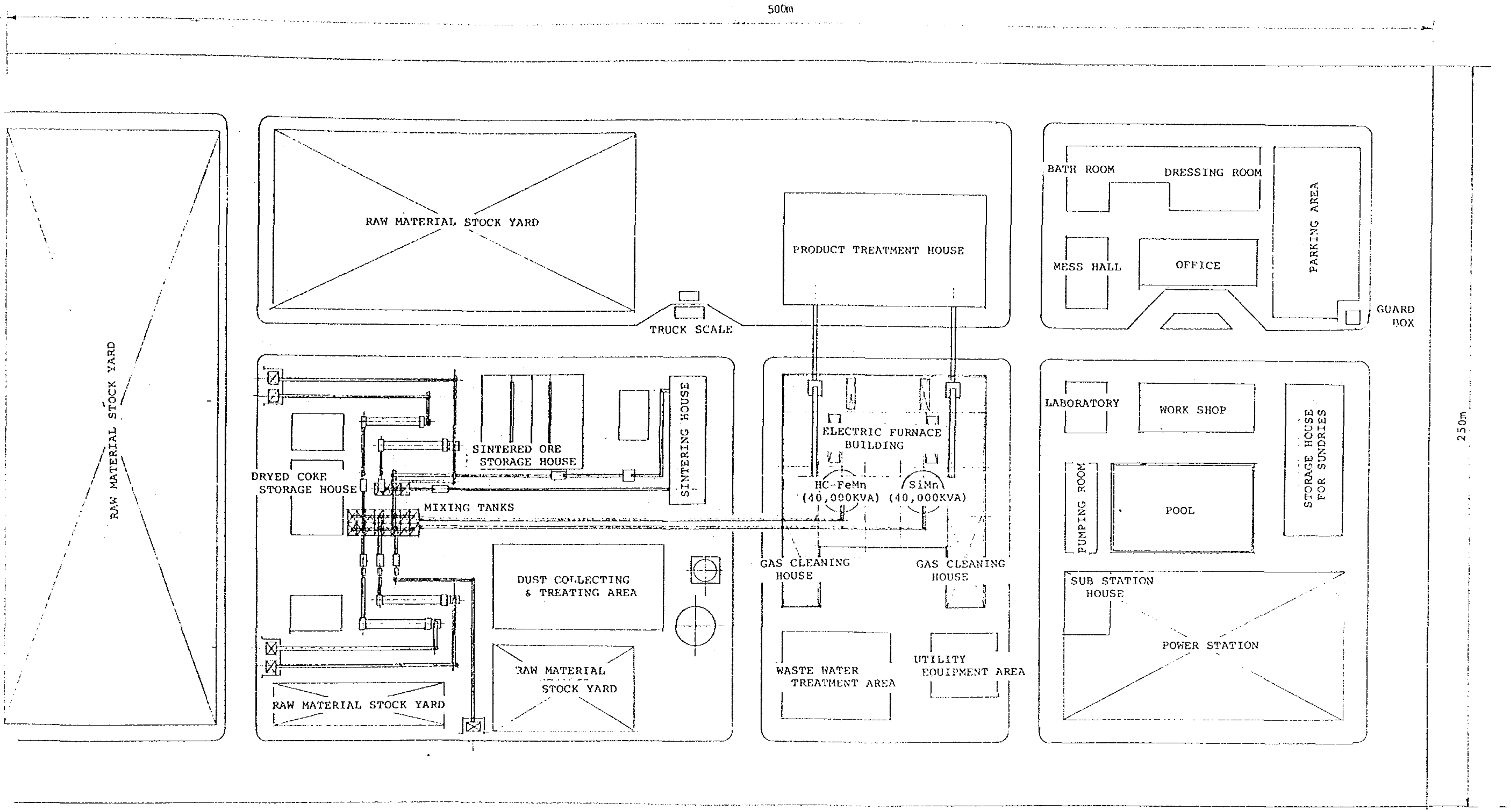
Blending of raw materials is performed so that metal and slag may reach their target composition after reduction in electric furnace. The critical factor of this step is the ratio of the reduction agent. According to operating conditions of electric furnace, it must be carefully controlled to get the optimum conditions.

Figure 3-3 Process Flow Sheet for Ferro-manganese Smelter



Source: Study Team

Figure 3-4 Plant Lay-out for Ferro-manganese Smelter



Source: Study Team

(iii) Furnace operation

After turning on the electric current, mixed feed materials is fed into furnace, and operation is started. The rated load is attained by adjusting voltage and electrode position. A large-scale furnace is usually provided with a choke feed system for its raw material feed, and tapping operation takes place every four or five hours. Important factors for furnace operation are as follows:

1) Control of electrode

The electrode is of the Sederberg type which receives carbon paste from the upper opening and bakes up the paste to solid electrode with Joul's heat of electric current. Balancing of the baking amount with the consumed quantity is important to prevent the electrode problems.

2) Control of electrode position

Metal and slag are formed and accumulated inside the furnace by the continuous reduction. They are tapped out from the furnace bottom at the regular intervals.

Control of electrode position and electrode length are necessary to keep a stable reduction zone in the furnace, to maintain a constant reductive reaction.

3) Control of slag composition

Composition of slag (Mn, CaO/SiO_2, MgO and $A\ell_2O_3$ content) must be well controlled in relation to the stable operation.

(iv) Tapping operation (Casting operation)

Accumulated metal and slag are taken out by tapping operation at regular intervals. This activity consists of tap hole opening, separation of metal and slag, casting of metal, discharge of slag, plugging of tap hole, and after settlement.

(v) Products treatment

Fe-Mn and Fe-Si-Mn products are crushed and sieved to adjust the size after removal from casting mould. Under-mesh particles are returned to the electric furnace.

(vi) Slag treatment

Slag of Fe-Mn (A/C) is used as one of raw materials for Fe-Si-Mn. Slag of Fe-Si-Mn is disposed of as waste.

(vii) Gas treatment and disposal water treatment

Gas from the electric furnace is washed in a scrubber and sent to the drying section of raw materials as fuel. Remaining gas is burned by the flare-stack.

Waste water from the scrubber is treated to separate solid particles prior to discharge. Solid particles are collected as effluent sludge and returned to the sintering unit.

(viii) Analysis

Raw materials, products and slags are to be analysed at the regular intervals.

(5) Material balance

Refer to Figure 3-5.

(6) Personnel requirement

Refer to Table 3-5.

(7) Construction cost

Refer to Table 3-6.

(8) Operation cost factors

Raw material

Manganese ore	201,800 tons/year
Iron ore	10,200 "

Sub-materials

Silica	36,200 tons/year
Limestone	27,600 "
Charcoal	23,000 "
Coke	36,300 "

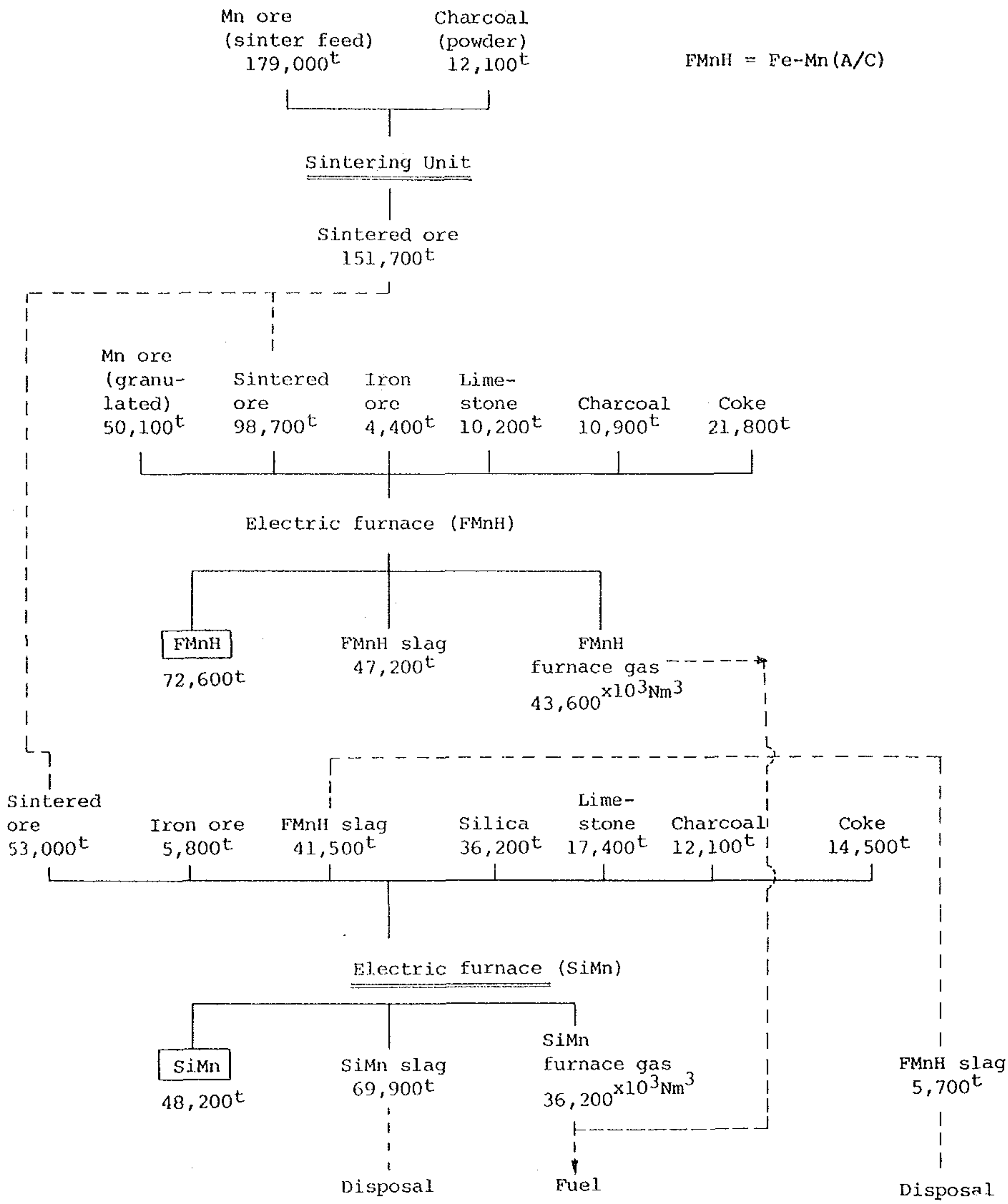
Supplies

Electrode paste (US$ 900/ton)	1,690 tons/year
Chemicals	US$ 41,700/year
Others consumables	US$ 217,800/year

Utilities

Electric power	446,440 MWh/year
Industrial water	2,059,200 tons/year

Figure 3-5 Material Balance for Ferro-manganese Smelter (Ton/Year)



Source: Study Team

Table 3-5 Personnel Requirement for Ferro-Manganese Smelter

	Plant Manager	Super-intendent	Engineer	Foreman	Operator	Worker
	1					
Production department						
Engineering department		3	12	25	140	20
Maintenance department						
Admi. and other parts		25% of plant operation group				

Source: Study Team

Table 3-6 Hypothetical Model Plant (Ferro-manganese Smelter) Estimated Construction Cost

(Unit: US$ 1,000)

	Sao Luis	Barcarena	Tucurui	Maraba
Land price	5	4	3	3
Land preparation	162	162	162	162
Plant direct cost (A)				
Process plant	34,763	34,763	34,763	34,763
Utility plant	13,613	13,613	13,613	13,613
Offsite facilities	13,575	13,575	13,575	13,575
Plant direct cost (B)				
Spare parts	1,306	1,306	1,306	1,306
Cata and Chemicals	417	417	417	417
Temporary works	3,098	3,098	3,098	3,098
Plant indirect cost				
Construction equip.	6,195	6,195	6,195	6,195
Ocean freight and ins.	2,700	2,700	2,700	2,700
Inland freight and ins.	265	253	2,426	1,700
License, Engineering and Services	15,488	15,488	15,488	15,488
Indirect field expenses	2,478	2,478	2,478	2,478
Other facilities				
Transmission cable	495	297	495	2,376
Waterintake and pipeline	1,667	1,227	635	2,526
Housing colony	-	6,240	-	5,760
Project management	1,239	1,239	1,239	1,239
Pre-operating expenses	2,474	2,599	2,570	2,288
Contingency	14,991	15,848	15,174	16,453
Interest during const.	12,590	14,620	16,995	18,425
Initial working capital	9,302	9,590	9,381	9,679
Total Capital Requirement	136,823	145,712	142,713	154,244

Source: Study Team

Other factors

Refer to Section 3-1-3.

(9) Study on raw materials

(a) Technical study

The expected composition of Azul detritic washed ore in the Carajas Mountains, in percentage, is as follows.

Granulated (6 mm over)

Mn	P	S	Fe	CaO	Na_2O	Al_2O_3
45.5	0.07	0.036	3.5	0.30	0.15	9.8

MgO	K_2O	SiO_2	As	Ba	L.O.I.
0.30	1.50	2.7	20 ppm	0.25	16.0

Sinter Feed (6mm under)

Mn	P	S	Fe	CaO	Na_2O	Al_2O_3
43.0	0.07	0.036	4.7	0.03	0.08	10.8

MgO	K_2O	SiO_2	As	Ba	L.O.I.
0.40	1.20	3.5	20 ppm	0.25	18.0

As the content of Al_2O_3 is somewhat higher than in the usual case, additional use of magnesite may be necessary if the melting point of slag becomes higher in actual operation.

(b) Cost study

(i) Mine-head cost of manganese ore

Manganese ore of Azul mine is shoveled by open cut, sent to dressing facilities in the Carajas terminal area by wire rope way, and after being washed is sent out to users by railway.

Mine head cost (include washing cost) has been estimated as US$ 60/ton on an average for granule and fine by mining authorities.

(ii) Transportation cost of manganese ore

In same manner as copper concentrate (the volume is almost same), the transportation cost of manganese ore to each plant site can be arranged as follows.

1) Sao Luis

Azul mine - Sao Luis (Railway 890 km)	US$ 21.0/ton
Loading and unloading charge	2.0
Sao Luis terminal - plant site (truck 5 km)	0.5
	US$ 23.5/ton

2) Barcarena

Azul mine - Maraba (railway 150 km)	US$ 7.6/ton
Loading charge	1.0
Maraba - Barcarena plant site (refer to Section 4-1-6(1))	23.2
	US$ 31.8/ton

3) Tucurui

Azul mine - Maraba (railway 150 km)	US$ 7.6/ton
Loading charge	1.0
Maraba - Tucurui plant site (refer to Section 4-1-6(1))	17.0
	US$ 25.6/ton

4) Maraba

Azul mine - Maraba (railway 150 km)	US$ 7.6/ton
Loading, unloading and transfer charge	2.1
	US$ 9.7/ton

(iii) Iron ore

Iron ore shall be supplied from the Carajas iron ore mine. Iron ore can be transported from Maraba station to Tucurui and Barcarena at the same cost as manganese ore, considering it as a part of the manganese ore.

Price estimation

Mine head cost	25	US$ 25/ton
Sao Luis plant site	25 + 23.5	48.5
Barcarena plant site	25 + 31.8	56.8
Tucurui plant site	25 + 25.6	50.6
Maraba plant site	25 + 9.7	34.7

(iv) Silica flux

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

(v) Lime stone

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

(vi) Charcoal

Charcoal price is estimated as US$ 50/ton in each plant site from the present market price.

(vii) Coke

Coke shall be imported. The price can be estimated CIF Sao Luis or Barcarena as US$ 100/ton. Therefore, price estimation considering bulk density to be 0.7 is as follows.

Sao Luis plant site (with handling charge)	US$ 105/ton
Barcarena plant site (with handling charge)	105
Tucurui (via Barcarena, by barge)	128
Maraba (via Sao Luis, by railway)	126

3-2-3 Nickel Smelter

(1) Production process and plant scale

Production process : Ammonia leaching process

Production capacity :

99.8% up nickel briquette	12,024 tons/year
Mixed sulfide	3,880 tons/year
Ni 28.5%, Co 11.4%	

(2) Process flow sheet

Refer to Figure 3-6.

(3) Plant lay-out

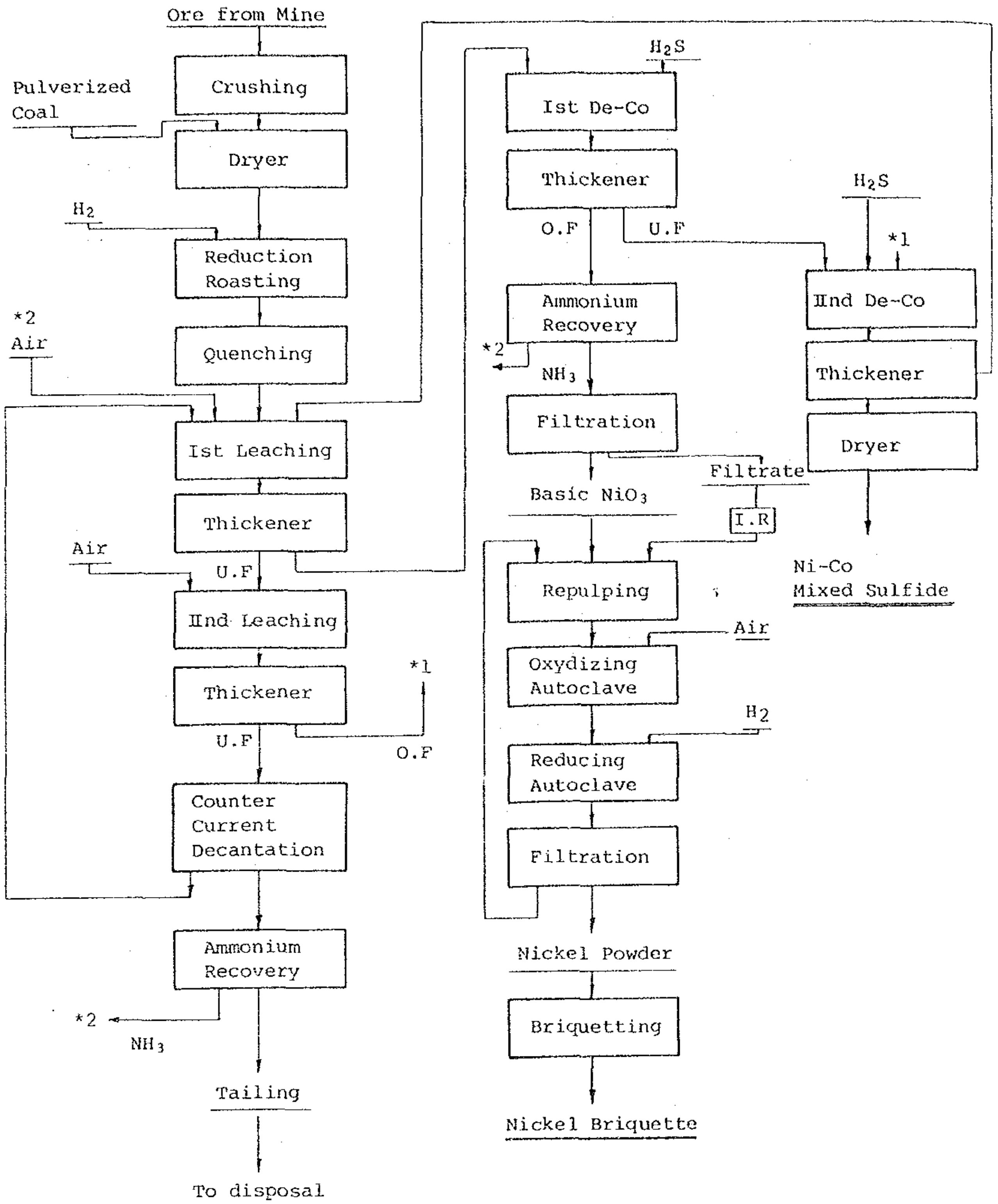
Refer to Figure 3-7.

(4) Process description

A model plant is made up of the following operational facilities:

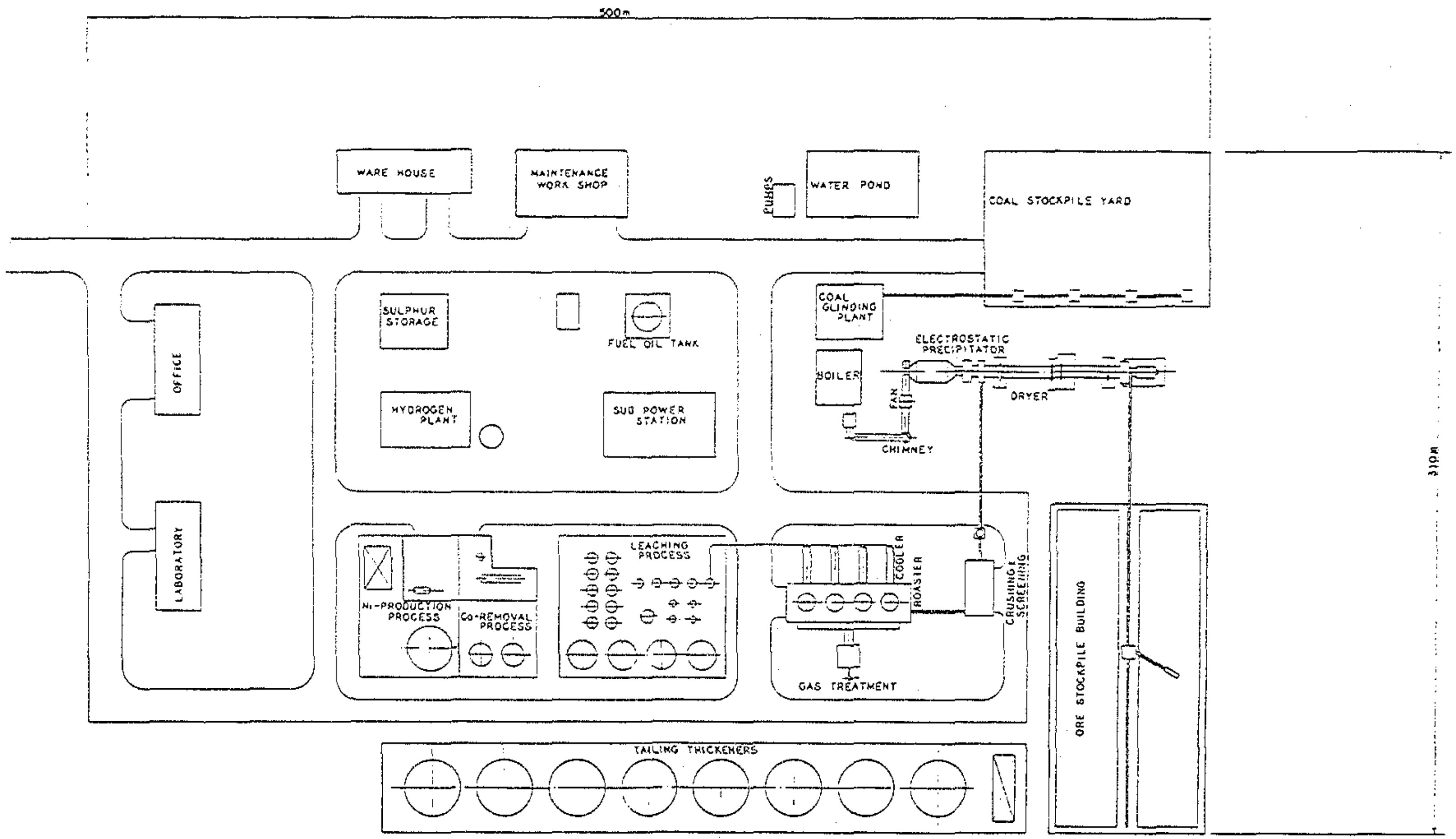
Drying and stockpiling
Crushing and grinding
Roasting
Leaching and washing
Cobalt removal
Basic nickel carbonate precipitation
Ammonia recovery
Nickel metal production
Auxiliary facilities

Figure 3-6 Flow Sheet for Nickel Smelter



Source: Study Team

Figure 3-7 Plant Lay-out for Nickel Smelter



Source: Study Team

(a) Pretreatment

The plant is designed to treat 1,105,990 dry tons of 1.55% nickel-bearing ore per year.

Trucks from the mine site dump the ore through a stationary grizzly and the ore is carried by a series of conveyors to a stacker and onto a 50,000 ton stockpile. Ore is reclaimed from the stockpile on a 24 hour basis by front-end loaders and fed by a series of conveyors to ore dryer feed bins. The ore drying facility consists of 5 m diameter by 50 m long rotary pulverized coal fired co-current dryers.

The dryer has its own feed, discharge and dust collection system. Dryer discharge at about 2.5% free moisture is conveyed to a screen house.

Ore from screening is stored in silos which feed mills. Each mill system is designed to handle 50 tons per hour of fresh feed and reduce the feed material to 85% minus 200 mesh. Ground ore is mechanically/air separated and conveyed to the roaster feed silos.

(b) Reduction roasting

Reduction of the laterite ore is carried out in four multiple hearth roasters each 8 m in diameter. The ore is mixed with the reductant oil in keneaders prior to being fed into the top of the roasters. Roaster operation is basically controlled by reductant and temperature profiles. Gases leaving each roaster are passed through a cyclone and into a common header to electrostatic precipitators. The collected dust is recycled partway up each roaster. Roaster discharge is cooled to 150°C with calcine coolers. As well as cooling, these facilities transfer the ore to the leaching unit.

(c) Leaching

Calcine from the coolers is quenched with recycle ammonium carbonate solution from the second stage of cobalt removal to produce a slurry containing about 20% solids. The leaching section is a two-stage countercurrent leach. The calcine is leached in ammonium carbonate solution. The slurry from the first stage leach circuit is magnetically flocculated and then transferred to the first stage leach thickener.

The thickener overflow containing 12 g/ℓ of nickel is split with a portion being introduced into the second stage cobalt removal feed tank which is eventually recycled to the quench tank, while the remaining solution is sent to nickel recovery via the first stage cobalt removal circuit. The first stage leach thickener underflow is repulped with first stage wash thickener overflow and pumped to the second stage leach tanks. The overflow from the second stage leach thickener is fed together with a part of the first leach thickener overflow to the second stage cobalt removal. The second stage leach thickener underflow proceeds to the countercurrent decantation wash circuit where underflows are repulped with the advancing thickener overflows.

Whole process described above reduces the soluble nickel and cobalt in the slurry to 0.15 g/ℓ and 0.048 g/ℓ respectively. Solution leaves the leach and wash circuit as product liquor from the first leach thickener overflow and with the underflow of the last wash thickener.

The underflow from the wash thickener proceeds to the tailing still for recovery of the ammonia and carbon dioxide contained in the solution fraction of the slurry.

(d) Cobalt removal

The cobalt removal circuit consists of two stages. The first stage removes cobalt and copper from the product nickel stream to low levels to meet the nickel metal specifications. The second stage controls the amount of cobalt in the leach circuit and provides the means of physically recovering it as the mixed sulfide. Leach liquor from the first thickener is passed through a pipeline reactor where hydrogen sulfide is added.

The reaction takes place in seconds and produces a cobalt-free solution and mixed sulfide with a high nickel to cobalt ratio. The sulfide is thickened in a thickener with the overflow going through clarifying polish filter. Thickener underflow is recycled to the feed and a portion is drawn off and fed to the second stage along with solution from the second stage leach.

In the second stage the ratio of nickel to cobalt in the final sulfides is reduced to approximately 2 to 1. The mixed sulfides from the second stage thickener underflow are dried indirectly. Dryer discharge is indirectly cooled with water and the sulfides transferred to a bin for final packaging in boxes.

(e) Ammonium recovery

The ammonia and carbon dioxide from the preheated solution are stripped in the boil column by distillation with live steam. The nickel precipitates simultaneously as nickel carbonate.

The 4 basic nickel carbonate precipitation columns are 3.6 m diameter with sixteen bubble cap trays. During the precipitation of the carbonate, impurities such as manganese and magnesium precipitate as well, forming a hard scale and eventually plugging up the columns. To allow for this, one column out of the four is temporarily out of use for cleaning.

Column discharge is flashed before going to a thickener. The overflow is passed through an ion exchange circuit to recover the nickel values not precipitated. Thickener underflow is filtered and washed for sulfur removal. The nickel carbonate cake produced is dissolved in an ammonium sulfate solution.

The small amount of carbonate cake which will not readily dissolve is separated from the solution by setting in a thickener. The thickener underflow is recycled to cobalt removal.

There are two autoclaves, larger flash tanks, briquette machine and sintering furnace.

(5) Material balance

Refer to Table 3-7.

(6) Personnel requirement

Refer to Table 3-8.

(7) Construction cost

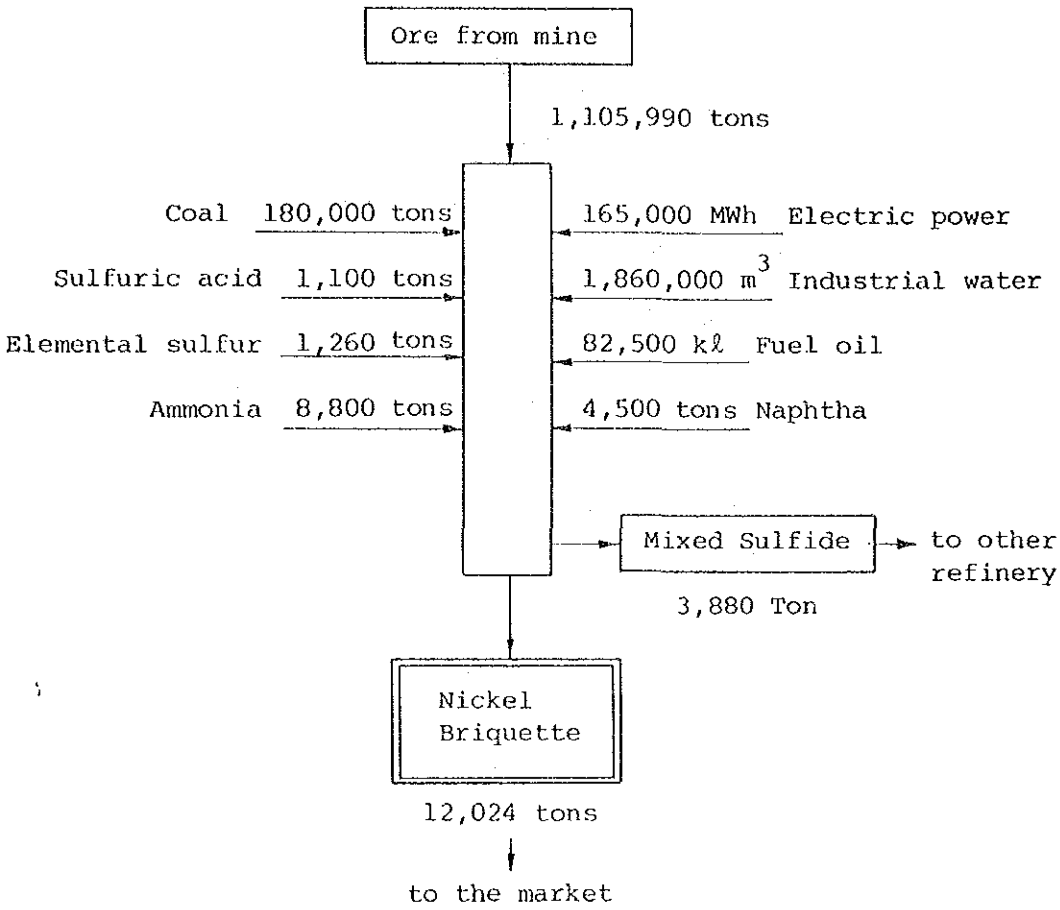
Refer to Table 3-9.

(8) Operation cost factors

Raw material	
Raw nickel ore (dry)	1,105,990 tons/year
Sub-materials	
Pulverized coal	180,000 tons/year
Fuel oil	82,500 kℓ/year
Naphtha	4,500 tons/year
Sulfuric acid	1,100 tons/year
Elemental sulfur	1,260 tons/year
Ammonia	8,800 tons/year
Utilities	
Electric power	165,000 MWh/year
Industrial water	1,860,000 tons/year
Supplies	
Steel balls (US$ 1,500/ton)	280 tons/year
Other miscellaneous cost	10% of sum of above costs

Table 3-7 Nickel Smelter Material Balance

A. Material Balance (per year)



B. Metal Balance (dry ton per year)

	Dry ton/y	Content of metal (%)		Contained metal	
		Ni	Co	Ni	Co
Ore from Mine	1,105,990	1.55	0.10	17,143	1,106
Ore to dryer	1,072,810	1.57	0.10	16,894	1,089
Rejected rock	33,180	0.75	0.05	249	17
Nickel briquette	12,024	99.8	0.1	12,000	11
Mixed sulfide	3,880	28.5	11.4	1,106	442
Tailings	933,340	0.41	0.07	3,788	636

Source: Study Team

Table 3-8 Estimated Personnel Requirement of Nickel Smelter

	General Manager	Assist. Manager	Super-intendent	Assist. 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	15	10	50	
Engineering Section				1	5	5	40	
Transportation and Other Services				1		1	5	40

Source: Study Team

Table 3-9 Hypothetical Model Plant (Nickel Smelter) Estimated Construction Cost

(Unit: US$ 1,000)

	Sao Luis	Barcarena	Tucurui	Maraba
Land price	7	6	5	4
Land preparation	260	260	260	260
Plant direct cost (A)				
Process plant	49,125	49,125	49,125	49,125
Utility plant	12,750	12,750	12,750	12,750
Offsite facilities	7,542	7,542	7,542	7,542
Plant direct cost (B)				
Spare parts	1,671	1,671	1,671	1,671
Cata and Chemicals	833	833	833	833
Temporary works	3,471	3,471	3,471	3,471
Plant indirect cost				
Construction equip.	6,942	6,942	6,942	6,942
Ocean freight and ins.	4,048	4,048	4,048	4,048
Inland freight and ins.	295	275	2,236	1,677
License, Engineering and Services	17,354	17,354	17,354	17,354
Indirect field expenses	2,777	2,777	2,777	2,777
Other facilities				
Transmission cable	405	243	405	1,944
Waterintake and pipeline	1,667	1,227	635	2,526
Housing colony	-	6,240	-	5,760
Project management	1,388	1,388	1,388	1,388
Pre-operating expenses	6,361	6,644	6,717	5,659
Contingency	17,534	18,419	17,724	18,860
Interest during const.	14,730	14,640	14,890	24,415
Initial working capital	23,953	24,544	24,550	23,971
Total Capital Requirement	173,113	180,399	175,323	192,977

Source: Study Team

(9) Study on raw materials

(a) Technical study

Vermelho deposit of nickel ore in the Carajas Mountains is expected to be used as raw material resource for the nickel smelter. The mineral investigations for this deposit are still being conducted. According to the information suggested by authorities, chemical composition of the ore has been assumed as follows.

Assumed Composition of Raw Material

Basic information → Assumed Composition

Composition \ Type	Garnierite	Limonite
Ni	1.8%	1.21%
Fe_2O_3	22.0	49.0
MgO	20.0	2.7
Co	570 ppm	1,200 ppm

Assumed Composition	
Ni	1.55%
Fe	33
Co	0.1
Moisture	35
Loss of Ignition	10

Cobalt content affects the dimensions of cobalt removal unit in the process.

(b) Cost study

(i) Mine-head cost of nickel ore

According to information of average trading prices in 1983 at plant sites in the states of Goias and Minas Gerais, which were Cr$ 1,622/ton and Cr$ 2,125/ton respectively, mine head price of a new nickel mine was assumed to be Cr$ 1,500/ton (US$ 2.6/ton) as the expected price.

(ii) Transportation cost of nickel ore

Transportation route of nickel ore from Vermelho to the consumption area is assumed as follows.

To Sao Luis

Vermelho - Carajas railway terminal
by road 95 km

Carajas - Sao Luis terminal
by railway 890 km

Sao Luis terminal - Plant site
by road 5 km

To Barcarena

Vermelho - Maraba river port
by road (via state road PA-150) 230 km

Maraba - Barcarena plant site
by Tocantins Navigation 500 km
Refer to Section 4-1-6(1).

To Tucurui

By same manner as Barcarena
Tocantins Navigation 200 km

To Maraba
Vermelho - Plant site
directly by truck (via state road PA-150) 230 km

To send the ore to Maraba, road transportation by dump truck is cheaper than a combination of road and railway under the following assumptions and calculations.

a) Vermelho - Maraba

Road 230 km
Dump truck: 300PS, 30 ton, average speed 40 km/h, 56 vehicles, 24 hr operation, drivers 112 men, salary US$ 300/month, fuel 0.01 ton/hr/vehicle, unit price of fuel US$ 385/ton, price of vehicle US$ 417,000/one vehicle, loan interest rate 12% per year - five year depreciation and repayment.

Calculated transportation cost US$ 7.944/ton

b) Vermelho - Carajas railway terminal - Maraba

Road 95 km
Dump truck: same dimensions as above, 23 vehicles, drivers 70 men

Calculated transportation cost US$ 3.403/ton

Railway 150 km
Railway tariff US$ 7.61/ton

Total transportation cost US$ 11.013/ton

Therefore, the route to Tucurui, Barcarena and Maraba was chosen as the combination of road and Tocantins Navigation. But to Sao Luis, as wagon operation and ore loading at Maraba station seems to be difficult, utilizing of Carajas terminal facilities was taken into consideration.

For the summary of above study, estimated haulage to each plant site will be as follows.

Sao Luis plant site

Vermelho - Carajas	US$ 3.4/ton
Carajas - Sao Luis	21.0
Handling charge	2.0
Railway - Plant site	0.3
	US$ 26.7/ton

Barcarena plant site

Vermelho - Maraba port	US$ 7.9/ton
Maraba port - Barcarena plant site (refer to Section 4-1-6(1))	16.4
	US$ 24.3/ton

Tucurui plant site

Vermelho - Maraba port	US$ 7.9/ton
Maraba port - Tucurui plant site (refer to Section 4-1-6(1))	9.6
	US$ 17.5/ton

Maraba plant site

Vermelho - Maraba plant site	US$ 7.9/ton

iii) Coal

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

iv) Fuel oil

Fuel oil is assumed as oleo conbustivel (Sp.gr. 0.8), and estimated cost including the as follows including the transportation cost,

Sao Luis	US$ 203/ton
Barcarena	214
Tucurui	239
Maraba	221

v) Sulfuric acid

Market price of sulfuric acid in the U.S.A. is US$ 70 - 90/ton at present stage and production cost is estimated as US$ 50 - 70/ton. If the price of sulfuric acid is estimated on an import basis, it will be as follows.