9-3 Influence Exerted by Various Factors on the Estimated Cost

9-3-1 Scale Merit

The copper refining industry is a typical example of an installation-intensive business and 30% of the cost is fixed. The costs corresponding to various production scales with facilities using the same system are presented in Table III-9-3-1, starting from an annual production capacity of 60,000 T/Y.

Table III-9-3-1 Variation of Cost According to Production Scale

Production Scale (T/Y)	Estimated Refining Cost (US¢/Lb)	Share
60,000	6.45	1.00
120,000	5.78	0.90
180,000	5.50	0.85
240,000	5.33	0.83

It is rather difficult to attain scale merit in a copper refining plant because once the size of the anode is determined, the plant area increases proportional to the production scale. In case of expanding production scale from 60,000 T/Y to 200,000 T/Y, however, it is possible to cut the cost by 10 to 20%, by adopting an entirely different system instead of simply multiplying the production scale with the same system. Considerable rationalization can be attained through modifications in the system, e.g., use of jumbo tanks, mother blanks of stainless steel or titanium, etc.

9-3-2 Influence of Electricity Cost

The electricity cost represents approximately 10% of the total refining cost. Furnaces of the ordinary type using fuel oil are adopted in the blister melting process, because steam is required in the electrolysis plant. The share of the electricity cost can be increased further, therefore, by engineering the system in such a way as to use as much electricity as possible.

Variations in the production cost according to variations of electricity cost for a plant with a production scale of 60,000 T/Y shown in Table III-9-3-2.

Table III-9-3-2 Variation of Production Cost According to Electricity Cost

Electricity Cost (US¢/KWH)	Estimated Refining Cost (US¢/Lb)	Share
1	6.02	0.93
2	6.23	0.97
3	6.45	1.00
4	6.67	1.03

The influence exerted by variation of the electricity cost on the production cost is minor because the share represented by the electricity cost in the production cost is small. For example, even when the electricity cost is reduced from 3US¢/KWH to 1US¢/KWH, the production cost is cut by only 10%.

10. International Competitiveness of Estimated Cost

The estimated cost calculated in section 9-2 of this report is rather high compared with the target value set in section 9-1-1. The peculiarities of each factor composing the production cost are as follows:

- The share of fixed costs is very high, being of the order of 30%.
- The share of electricity cost is very low, being approximately 10% in the case of 3US¢/KWH.

The following measures are required in order to further reduce the production cost.

(1) The construction cost should be cut as much as possible. The calculations in this study are carried out assuming prices prevailing in Japan plus a mere 25%. It is assumed that reduction in the construction cost will be possible through local procurement of machinery.

(2) The plant should be designed considering some expansion in production scale concurrently with rationalization of the production system.

(3) The project should be planned considering fund raising methods and depreciation methods as advantageous as possible.

(4) Cut in energy costs. The possibility of cutting energy costs should be examined using as much electricity as possible in the blister melting process, which currently uses fuel oil, and in the generation of steam for the electrolysis plant.

The most important factor in determination of the profitability of this project is the purchasing terms (refining charge and recovery stipulated in the terms). Therefore, it is fundamentally important to purchase the blister copper as advantageously as possible in pursuit of the mutual benefits to South American countries. On the other hand, it is also indispensable to materialize transportation costs on par with those of custom ore refineries in Japan and Europe in order to attain advantageous ore purchasing terms.

It is quite possible to establish a copper refining industry in Paraguay, located in the center of South America, by studying carefully the relevant factors, principally the ore purchasing conditions. It is needless to say that it is indispensable to obtain the understanding of the countries of the region concerned, by explaining the importance of this project. Adequate timing for implementation of the project is extremely important also from the point of view of collection of invested capital and therefore it should be decided after a careful study because the copper market is subject to major fluctuations.

11. Problematic Points Related to This Study

This study assumes the construction of a model plant adopting the usual copper refining process. The production cost of the plant is estimated assuming various conditions. However, it is necessary to improve the accuracy of the study by determining further concrete conditions. The factors which should be in mind a more concrete form are as follows.

(1) Purchasing terms for blister copper

Discussion of profitability under terms actually proposed by some suppliers. It is not an exageration to say that everything depends on the ore purchasing terms.

(2) Transportation cost

Discussion of means for materialization of transportation costs on par with custom refineries of other areas, including study of land transportation routes, referring to concrete example of raw material sources and product sales destinations.

(3) Construction costs

Discussion of means for reducing the construction costs as much as possible, including the possibility of procuring machinery and materials in Paraguay and from South America.

Other factors which should be considered are listed below.

- Fund raising plan

  Discussion of the most advantageous fund raising method and cash flow.

- Marketing of products and byproducts

  Discussion of concrete marketing conditions, e.g., destination, prices, specifications, etc.

- Market survey

  Discussion of investment timing based on world supply and demand trends.

- Materials

  Discussion of conditions related to the purchase of principal materials, e.g., quality, price, etc.

- Process

  Design of the production process able to make use of local conditions, based on concrete results of analysis of raw materials.

- Utilities

  Discussion of utility supply plan, particularly evaluation of the electricity price, based on a concrete process design.

IV. Zinc

1. General Description of Zinc

Zinc is a metal characterized by the following properties.

- Corrosion resistance
- High ductility
- Easy formation of alloys with other metals
- Easy casting

Zinc is used as a coating material for iron and steel as protection against corrosion and as a material in alloys and castings. In particular, more than a half of demand is for protection of iron and steel against corrosion and therefore, the zinc industry is closely related with the iron and steel industries. On the other hand, with regard to die castings, principally of parts used in the automotive industry, these are being replaced partially by alternative products of aluminum and plastic. Demand for zinc itself has remainded unchanged, however, due to the development of applications in other fields. Moreover, further expansion in demand can be expected through development of new applications for this metal. The production of zinc has been stagnant or declining in recent years due to the oil shock and subsequent worldwide economical recession, and is in fact below the peak level. In particular, in the hydrometallurgical process, the most important among zinc refining processes, there is a substantial cost difference between countries such as Japan, where the unit cost of electricity is expensive, and countries like Canada, where it is cheap. This energy problem, together with the environmental pollution control problem, is bringing about a considerable change in the production mechanisms of the international zinc market.

2. Market and Price Trends for Zinc

The worldwide consumption of zinc reached 6.3 million tons in 1979 but declined thereafter. In 1981 the consumption of this metal totalled 5.9 million tons. It is presumed that this decline has been caused by the oil shock and the subsequent stagnation of the world economy but the same consideration is applicable to copper and other metals too. The principal consumers of zinc are the Soviet Union, the U.S. and Japan.

The principal zinc ore producing countries are Canada, the Soviet Union, Peru, etc., while the principal metal zinc producing countries are the Soviet Union, Japan, Canada, etc. In other words, Canada is an exporter of both ore and metal, while Peru is a zinc ore exporting country and Japan a zinc ore importing country. The Soviet Union, which is one of the principal consumers of this metal, produces metal as well as ore, but in the case of the U.S., domestic consumption of zinc is covered by importing both metal and ore.

Statistical data on production of ore, production of metal and consumption of zinc are given in Tables IV-2-1, IV-2-2 and IV-2-3. Zinc negotiated on the market is classified into Prime Western Grade Zinc, Special High Grade Zinc, Electrolytic Zinc, etc., according to the refining process adopted for production. Electrolytic zinc and special high grade zinc are of high grade, surpassing 99.9% purity, while prime western grade zinc is rather low grade.

Zinc is a typical example of an international commodity whose price is determined by the supply-and-demand balance on the world market. The London Metal Exchange

(LME), the Producer Price (P.P.), the independent price of the U.S., etc., are examples of mechanisms for determining the price of zinc on the world market. The evolution of the LME zinc price in recent years is indicated in the Table II-2-4.

Table IV-2-1 World Mine Production Of Zinc

Metric Tons

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
United States	433.8	434.3	453.4	426.0	433.0	448.2	337.0	293.8	368.0	334.0
Canada (a)	1,128.4	1,226.3	1,126.8	1,055.0	1,039.4	1,299.9	1,245.0	1,204.1	1,058.5	1,093.8
Mexico	271.8	271.3	262.7	220.8	219.9	265.6	244.9	245.4	238.2	216.8
Guatemala	-	-	-	-	-	1.0	0.5	0.5	0.1	0.9
Honduras	23.3	19.7	24.3	26.0	30.0	26.5	24.3	19.8	16.0	18.0
Nicaragua	-	-	-	-	-	10.1	3.6	-	-	-
Total North America	1,857.3	1,951.6	1,867.2	1,727.8	1,722.3	2,051.3	1,855.3	1,763.6	1,680.8	1,663.5
Argentina	44.5	40.7	37.2	34.9	34.0	39.2	37.0	37.1	33.5	34.9
Bolivia (c)	39.7	49.6	48.6	48.7	49.2	63.6	59.6	49.6	50.2	48.0
Brazil	17.8	24.6	36.2	30.0	36.0	50.5	60.2	68.5	70.0	67.1
Chile	-	-	-	-	-	3.9	2.1	1.8	1.1	1.0
Colombia	-	-	-	-	-	0.1	0.1	0.1	0.1	0.1
Ecuador	-	-	-	-	-	1.9	1.2	0.7	2.7	3.6
Peru	357.5	413.6	397.1	383.1	359.9	475.8	457.4	490.7	487.5	496.9
Other South America	-	-	-	-	-	-	0.1	0.1	-	-
Total South America	459.5	528.3	519.1	496.7	479.1	635.0	617.7	648.6	645.1	651.6
Austria	15.7	17.3	16.3	17.4	17.6	22.0	24.8	22.8	19.1	18.1
Finland	49.9	58.6	59.3	52.7	59.2	61.3	53.2	54.5	58.4	53.6
France	13.3	13.3	14.3	13.9	31.7	41.8	40.0	36.6	36.8	37.4

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Germany, F.R. (b)	121.0	122.8	116.0	116.0	114.8	146.0	121.0	117.1	120.8	102.4
Greece	18.7	20.0	25.1	16.0	30.4	18.0	26.0	23.2	24.0	26.8
Greenland	..	30.0	101.2	90.9	88.4	76.6	82.4	87.3	92.1	78.5
Ireland	94.9	68.8	66.3	66.6	61.2	116.3	176.0	212.1	228.7	117.0
Italy	102.6	93.7	77.9	81.8	78.5	79.3	74.0	66.3	58.4	38.1
Norway	14.5	19.2	22.0	24.0	29.1	29.6	29.6	28.4	27.7	28.5
Spain	91.2	94.4	94.7	85.3	84.6	96.1	143.2	144.2	179.2	172.8
Sweden	109.7	118.5	113.7	111.3	122.4	140.0	167.3	169.2	167.3	180.9
United Kingdom	-	-	-	-	-	3.0	1.5	-	4.4	9.6
Yugoslavia	96.7	97.4	94.7	110.3	90.0	112.4	103.8	101.7	94.2	90.7
Total Europe	728.3	754.0	801.5	786.2	807.9	942.4	1,042.8	1,063.4	1,111.1	954.4
Burma	8.2	7.7	5.6	5.8	3.6	1.7	2.5	2.9	3.9	3.6
Cyprus	-	-	-	-	-	0.3	-	-	-	-
India	12.7	13.6	16.7	21.7	25.0	35.5	39.3	43.0	32.2	28.0
Iran	47.5	32.5	42.4	95.0	36.0	61.5	45.0	25.0	25.0	24.0
Japan	281.1	263.9	240.7	254.4	260.0	275.6	274.5	243.3	238.[illegible]	242.0
Republic Of Korea	35.9	48.1	42.3	45.7	55.5	68.8	66.3	62.4	56.1	60.0
Philippines	4.6	5.4	7.8	10.4	10.5	12.4	9.5	9.7	6.8	5.8
Thailand	-	-	-	-	-	-	-	1.0	-	-
Turkey	19.2	24.7	31.6	26.6	30.0	50.2	38.1	24.9	20.4	24.0
Total Asia	390.0	371.2	387.1	459.6	420.6	506.0	475.2	412.2	382.5	387.4

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Algeria	17.0	14.4	10.2	14.0	16.0	3.1	4.2	4.7	8.2	11.8
Congo	2.7	3.3	3.3	4.0	3.6	5.2	4.8	-	-	-
Morocco	22.0	20.5	14.0	18.8	18.0	11.2	5.1	5.7	6.1	8.2
Namibia	-	-	-	-	-	38.3	36.6	29.0	25.4	39.6
Republic Of South Africa	2.4	18.7	37.4	67.0	81.5	72.4	68.7	56.5	81.7	86.6
South West Africa	44.5	52.6	44.9	45.6	48.0	-	-	-	-	-
Tunisia	10.2	15.9	11.4	6.3	7.0	7.1	7.4	8.0	9.1	7.3
Republic Of Zaire	111.1	100.0	81.3	80.4	90.0	73.3	83.8	73.0	67.2	76.0
Zambia	96.7	106.4	80.5	67.3	48.8	51.1	60.5	53.7	37.1	33.3
Total Africa	308.3	331.8	283.0	303.4	312.9	261.7	270.1	230.6	234.8	262.8
Australia	502.2	442.4	425.0	463.2	466.6	491.5	473.2	529.1	495.2	504.1
U.S.S.R.*	800.0	899.7	949.6	1,029.8	1,031.8	1,039.8	1,029.8	1,019.8	999.8	999.5
Bulgaria*	79.1	79.8	79.8	80.0	84.0	80.0	78.0	80.0	78.0	78.0
Czechoslovakia*	9.3	8.9	9.1	9.5	12.0	9.4	8.8	9.1	9.0	8.6
Germany, D.R.*	5.0	3.0	-	-	-	-	-	-	-	-
Hungary*	3.5	4.0	2.7	2.2	2.4	3.0	2.8	3.1	2.8	2.7
Poland*	222.2	209.5	199.5	189.9	216.0	220.9	230.9	236.9	216.7	190.5
Rumania*	55.3	59.9	59.9	59.9	59.9	50.0	51.0	50.0	48.0	47.6
China*	109.7	109.7	129.7	135.0	132.0	149.9	149.9	155.0	149.9	150.1
North Korea*	149.7	159.6	162.4	160.0	168.0	149.9	144.9	135.0	130.0	130.2
Vietnam	-	-	-	-	--	10.0	10.0	10.0	10.0	10.0
Total	1,434.5	1,534.1	1,592.7	1,666.3	1,706.1	1,712.9	1,706.1	1,698.9	1,644.2	1,617.2

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
World Total (d)	5,133.0	5,471.0	5,947.3	5,440.0	6,235.1	6,118.3	5,967.2	5,817.3	5,698.5	5,536.9

Source : American Bureau of Metal Statistics Inc., U.S. Bureau of Mines, Metallgesellschaft AG, World Bureau of Metal Statistics and various other sources.

(a) Statistics Canada.

(b) Includes production from pyrites.

(c) Exports.

(d) In addition there is production in Chile, Colombia, Ecuador, New Zealand, and Portugal; the total of these countries is estimated to be about 2,000 tons in 1976.

* Conjectural.

Table IV-2-2. World Production Of Slab Zinc

Metric Tons

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
United States	694.2	623.9	574.8	404.4	486.1	454.2	441.4	525.6	369.8	341.8
Canada	476 1	532.4	426.2	426.9	472.2	494.8	495.3	580.4	591.5	618.5
Mexico	87 4	73.5	133.3	148.9	143.9	174.3	173.1	161.6	145.4	129.7
Total North America	1,257 7	1,229.8	1,134.3	980.2	1,102.2	1,123.3	1,109.8	1,267.6	1,106.7	1,090.0
Argentina	40.8	35.7	37.2	39.6	40.0	29.0	23.9	36.7	25.4	26.9
Brazil	16 2	22.3	30.7	31.4	43.4	47.0	56.1	63.5	78.3	91.9
Peru	67 1	67.1	69.0	63.7	72.0	67.0	62.9	68.4	63.8	129.0
Total South America	124.1	125.1	136.9	134.7	155.4	143.0	142.9	168.6	167.5	247.8
Portugal	-	-	-	-	-	-	-	-	2.0	4.0
Austria	16 9	17.0	16.4	16.3	16.5	16.8	22.0	23.2	22.1	23.6
Belgium	286.3	276.5	288.6	218.1	234.6	273.6	232.8	252.5	247.5	247.1
Finland	81.1	79.9	91.3	109.5	110.6	138.0	132.9	146.6	146.7	139.8
France	261.4	259.3	276.6	181.0	233.2	238.3	231.2	249.0	258.8	257.0
Germany, F.R. (a)	356.3	394.9	400.0	294.6	304.6	354.7	306.7	355.5	365.2	366.4
Italy	155.7	190.0	184.2	179.7	191.2	169.3	177.6	202.7	206.3	180.9
Netherlands	49.3	30.5	78.2	116.0	125.4	109.4	135.2	153.8	169.4	177.3
Norway	73.3	80.9	72.4	60.9	62.8	69.7	71.6	77.8	79.0	80.3
Spain	98.9	106.4	130.0	138.0	163.9	152.6	177.0	185.9	151.7	188.7
United Kingdom	73.8	83.8	84.3	53.4	41.6	81.4	73.6	76.6	86.7	58.4

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Yugoslavia	48.6	55.3	86.4	97.9	140.5	98.8	95.1	98.8	84.4	96.1
Total Europe	1,501.6	1,574.5	1,708.4	1,465.4	1,624.9	1,702.6	1,655.7	1,822.4	1,819.8	1,819.6
India	25.2	20.8	21.1	25.7	26.3	36.0	61.9	63.3	43.6	57.0
Japan	804.6	842.7	849.7	698.1	741.9	778.2	767.8	789.3	735.0	670.0
Republic Of Korea	10.5	12.6	11.5	20.9	27.3	31.6	59.0	80.8	75.6	86.2
Turkey	-	-	-	-	-	16.1	17.3	17.2	13.1	17.2
Total Asia	840.3	876.1	882.3	744.7	795.5	861.9	906.0	950.6	867.3	830.4
Algeria	-	-	8.0	20.0	24.0	16.0	25.7	27.3	30.0	29.9
Republic Of South Africa	47.2	53.1	65.5	63.5	64.6	76.0	79.1	75.4	81.4	80.9
Republic Of Zaire	63.6	67.7	68.7	65.6	60.9	51.1	43.5	43.7	43.8	58.0
Zambia	55.7	52.9	57.9	46.9	37.0	40.1	42.4	38.2	32.7	33.0
Total Africa	166.5	173.7	200.1	196.0	186.5	183.2	190.7	184.6	187.9	201.8
Australia	295.0	299.4	276.8	193.3	246.5	256.3	294.2	309.6	305.9	301.3
U.S.S.R.*	649.4	680.2	979.6	1,029.8	1,031.8	1,019.8	1,054.8	1,084.8	1.060.0	1,059.0
Bulgaria*	79 8	80.0	80.0	80.0	89.8	90.0	91.0	89.0	91.0	90.7
Germany, D.R.*	15 4	15.4	15.4	15.0	18.0	15.5	16.0	17.0	16.0	15.9
Hungary	-	-	-	-	-	0.6	0.7	0.7	0.8	0.8
Poland*	228 3	223.9	232.9	243.0	240.0	228.1	222.0	209.0	215.2	167.8
Rumania*	59.9	65.3	70.0	70.0	72.0	51.9	49.8	46.5	45.0	44.4
China*	119 7	119.7	130.0	130.0	132.0	155.0	160.0	160.0	155.0	155.1

	197,	1973	1974	1975	1976	1977	1978	1979	1980	1981
North Korea*	119.7	129.7	129.7	140.0	138.0	135.0	130.0	120.0	105.0	105.2
Vietnam	-	-	-	-	-	10.0	10.0	10.0	10.0	10.0
Total	1,272.2	1,314.2	1,637.6	1,707.8	1,721.6	1,705.9	1,734.3	1,737.0	1,698.0	1,648.9
World Total	5,457.4	5,592.8	5,976.4	5,422.1	5,832.6	5,522.7	6,033.6	6,140.4	6,152.7	6,139.8

Source : American Bureau of Metal Statistics Inc., U.S. Bureau of Mines, Metallgesellschaft AG, World Bureau of Metal Statistics and various other sources.

(a) Includes production from reclaimed scrap.

* Conjectural.

Table IV-2-3 World Consumption of Slab Zinc

Metric Tons

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
United States	1,286.4	1,363.0	1,167.9	839.2	1,022.3	999.3	1,050.4	1,000.4	810.9	834.5
Canada	124.9	134.7	134.4	149.2	133.5	134.0	147.0	156.3	132.5	131.8
Mexico	48.8	61.0	59.8	62.7	71.9	63.7	78.9	83.3	88.9	99.8
Argentina	38.4	36.6	38.9	42.0	44.2	31.4	32.7	35.5	26.7	21.9
Bolivia	-	-	-	-	-	1.5	0.7	1.4	2.2	1.8
Brazil	47.2	80.0	93.4	83.0	96.0	105.5	123.5	123.7	137.7	108.8
Chile	-	-	-	-	-	3.1	6.1	5.2	5.9	2.7
Colombia	-	-	-	-	-	12.2	12.1	12.4	10.3	12.0
Honduras	-	-	-	-	-	1.0	1.2	0.8	0.7	0.9
Nicaragua	-	-	-	-	-	-	0.4	0.4	1.0	0.9
Peru	6.0	27.3	30.0	25.0	36.0	9.6	16.0	28.9	23.2	23.6
Venezuela	-	-	-	-	-	20.3	16.3	17.1	24.4	20.9
Other America	-	-	-	-	-	7.2	14.3	21.9	18.5	18.1
Total America	1,551.7	1,703.6	1,524.4	1,201.1	1,403.9	1,388.8	1,499.6	1,487.3	1,282.9	1,277.7
Austria	19.6	21.4	25.2	24.4	21.0	24.4	26.5	25.4	26.9	26.0
Belgium	139.1	180.0	194.8	103.3	120.4	140.4	139.8	138.7	154.7	138.8
Denmark	12.9	12.8	13.0	11.9	6.0	13.0	14.4	15.8	16.1	12.0
Finland	11.0	16.0	19.0	16.0	19.9	17.0	19.2	22.0	24.6	21.3
France	264.0	290.3	306.0	222.5	265.0	257.7	281.6	286.6	330.0	272.0
Germany, F.R.	435.5	438.1	388.3	296.8	334.4	333.9	390.9	417.0	405.6	373.7

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Greece	8.3	14.7	15.6	11.7	16.7	13.4	17.2	20.9	18.8	18.1
Ireland	-	-	-	-	-	2.0	1.9	2.5	2.3	3.6
Italy	193.6	219.9	202.0	149.9	205.5	197.0	220.9	224.9	235.9	215.0
Netherlands	20.0	32.3	32.7	28.6	31.6	52.3	55.5	50.6	45.2	49.0
Norway	26.0	26.0	28.5	30.0	20.0	21.0	21.2	24.4	22.5	18.1
Portugal	11.0	10.0	11.5	8.0	12.0	15.2	17.0	14.0	17.0	12.0
Spain	100.9	111.6	119.5	92.1	127.7	105.8	104.6	97.8	91.1	104.5
Sweden	38 9	43.3	35.6	43.5	39.8	31.5	38.9	36.4	38.0	34.0
Switzerland	32 7	28.0	24.5	16.2	17.8	26.6	25.6	21.0	25.2	22.0
United Kingdom	277 2	305.4	268.4	207.1	240.4	244.7	247.5	238.7	181.2	289.6
Yugoslavia	51.7	62.5	67.1	64.9	65.8	69.3	65.0	66.0	72.1	72.6
Other Europe	-	-	-	-	-	0.1	0.1	2.5	0.1	-
Total Europe	1,642.4	1,812.3	1,751.7	1,326.9	1,544.0	1,565.3	1,687.8	1,705.2	1,707.3	1,582.3
Burma	-	-	-	-	-	1.0	0.2	0.2	0.8	0.8
Hong Kong	-	-	-	-	-	14.6	19.3	24.3	22.6	23.6
India	102 8	77.9	77.5	55.0	91.5	97.0	107.9	115.0	108.7	90.7
Indonesia	-	-	-	-	-	36.6	44.6	44.7	52.3	54.4
Iran	-	-	-	-	-	8.0	10.8	7.0	4.2	3.6
Japan	670.2	772.4	666.9	547.0	698.5	716.6	732.3	778.5	756.1	699.3
Republic of Korea	-	-	-	-	-	46.3	58.0	72.6	63.9	68.0
Malaysia	-	-	-	-	-	9.0	11.6	13.5	12.8	12.8
Philippines	-	-	-	-	-	18.8	27.3	26.6	16.8	18.1

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Singapore	-	-	-	-	-	6.1	11.2	17.4	11.8	11.8
Taiwan	-	-	-	-	-	27.9	50.9	37.3	38.4	45.4
Thailand	-	-	-	-	-	29.3	33.4	35.0	36.8	36.3
Turkey	-	-	-	-	-	27.2	26.0	20.0	12.3	17.0
Other Asia	-	-	-	-	-	16.9	15.3	22.8	13.9	16.4
Total Asia	773.0	850.3	744.4	602.0	790.0	1,055.3	1,148.8	1,214.9	1,151.4	1,098.2
Algeria	-	-	-	-	-	4.0	5.0	6.0	5.0	5.4
Egypt	-	-	-	-	-	10.0	10.0	12.0	12.0	11.8
Morrocco	-	-	-	-	-	2.3	2.5	2.9	2.4	3.6
Nigeria	-	-	-	-	-	5.3	8.2	5.5	12.7	13.6
Republic of South Africa	-	-	-	-	-	56.7	71.7	78.2	84.1	83.4
Tunisia	-	-	-	-	-	2.0	0.9	0.9	1.2	1.0
Zaire	-	-	-	-	-	2.0	1.0	0.9	0.3	0.3
Zambia	-	-	-	-	-	2.0	0.6	3.7	0.7	0.9
Other Africa	-	-	-	-	-	25.4	24.5	23.6	24.5	23.6
Africa	88.9	87.1	98.7	81.4	93.0	-	-	-	-	-
Total Africa	88.9	87.1	98.7	81.4	93.0	109.7	124.4	133.7	142.9	143.6
Australia and New Zealand	84.8	91.2	141.5	94.9	105.1	-	-	-	-	-
Australia	-	-	-	-	-	80.5	92.2	102.5	102.2	104.8
New Zealand	-	-	-	-	-	22.4	20.0	20.0	22.6	23.6
Other Australasia		-	-	-	-	-	0.1	0.1	0.1	-

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Total Australasia	84.8	91.2	141.5	94.9	105.1	102.9	112.3	122.6	124.9	128.4
World Total	4,140.8	4,544.5	4,260.7	3,306.3	3,936.0	4,222.0	4,572.9	4,663.7	4,409.4	4,230.2

Table IV-2-4 LME Zinc Price

U.S. Cents Per Pound

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
January	17.206	17.527	60.183	36.181	31.341	31.320	23.469	32.641	35.034	35.217
February	17.660	19.110	68.609	35.978	31.267	31.861	21.620	35.921	39.388	33.105
March	17.990	21.502	73.759	36.394	32.925	32.556	23.005	36.004	33.637	34.328
April	17.903	23.253	78.813	35.462	35.776	29.658	25.115	35.739	32.042	37.312
May	17.509	24.879	80.607	33.838	35.028	27.716	25.432	35.275	31.309	38.560
June	16.770	29.711	63.794	34.005	33.928	24.546	26.169	34.133	30.710	38.062
July	16.494	38.062	49.647	32.041	35.121	24.529	26.448	32.687	32.323	39.210
August	16.480	41.424	48.243	33.385	33.529	23.543	28.007	30.124	34.833	43.276
September	16.691	44.174	41.267	32.786	32.263	23.435	28.727	32.794	36.065	42.567
October	16.481	52.655	37.361	31.983	28.935	23.200	32.262	31.998	36.486	40.414
November	17.160	73.246	35.965	31.949	27.335	23.792	31.149	31.764	36.329	39.744
December	16.996	73.269	34.966	31.083	29.073	24.353	31.136	33.977	35.501	38.314
Year	17.117	38.314	55.973	33.792	32.304	26.733	26.870	33.588	34.482	38.932

Source : Metal Bulletin

3. Zinc Extracting Process

Broadly speaking, zinc extracting processes can be classified in two types, namely, the hydrometallurgical process, where the ore is roasted, lixiviated and electrolytic zinc produced by electro-winning, and the pyrometallurgical process where prime western grade zinc is obtained by roasting, sintering, reduction and volatilization of the ore. In the latter case special high grade zinc is obtained by distillation refining of prime western grade zinc.

An outline of the extracting processes is illustrated in Figure IV-3.

Sulfide ore is the principal raw material used for production of zinc. Approximately 80% of zinc produced in the world is turned out by means of the hydrometallurgical process, in view of factors such as the high grade of the metal obtained, easy measures for coping with environmental protection requirements, etc. The hydrometallurgical process consists of the following steps;

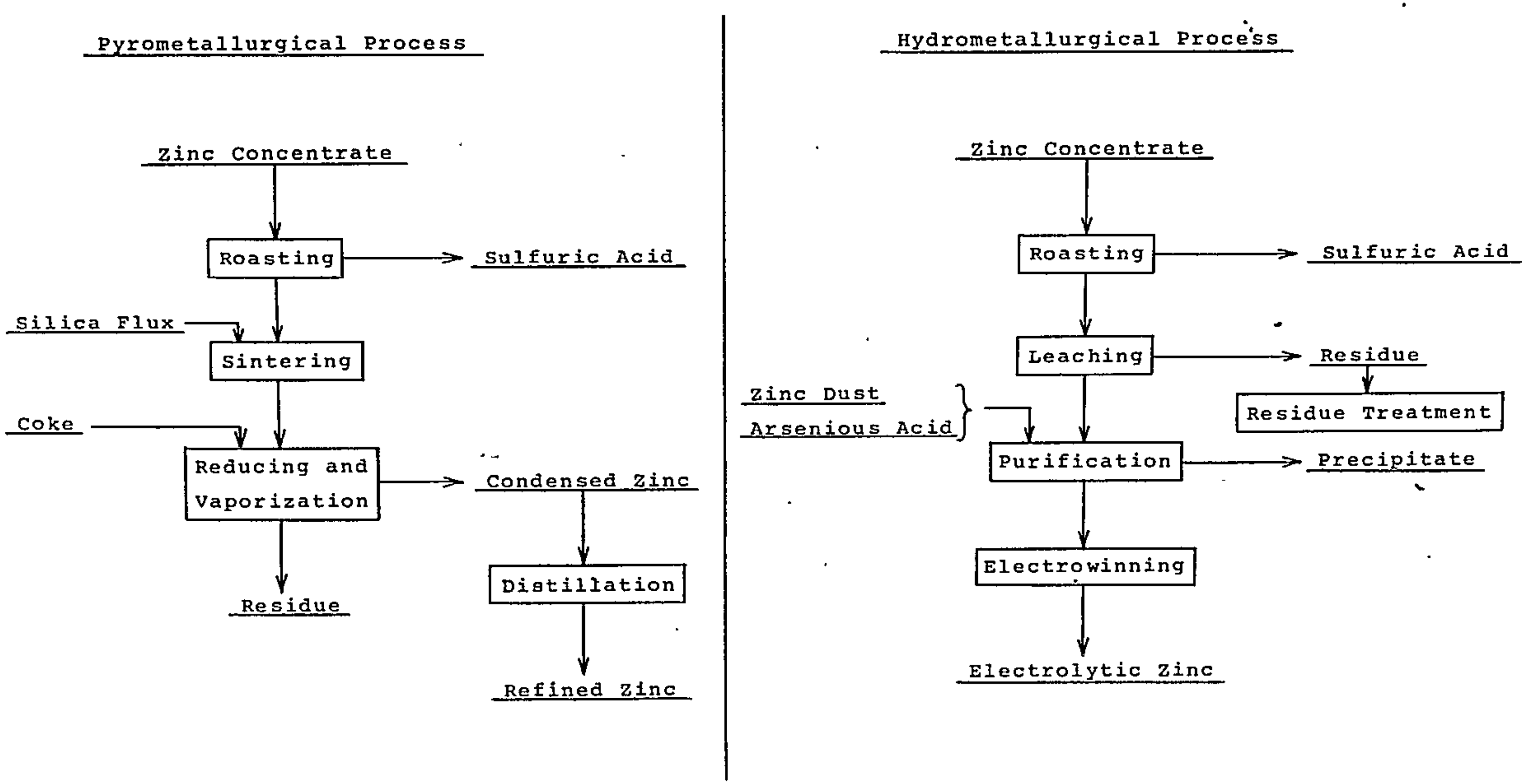
- Roasting: The sulfide ore, composed basically of ZnS, is roasted and the ore is oxided in the form of ZnO.

- Leaching: The roasted ore is leached with H_2SO_4 solution (electrolyte residue) and is converted to $ZnSO_4$ solution. Impurities like Cu, Cd, Co, etc., are eliminated from this solution.

- Electrolytic zinc (purity of more than 99.997%) is obtained by electro-winning, through the precipitation of Zn from the purified solution on an Al cathode plate using a Pb-Ag(Ag 1%) anode.

The Zn is recovered from the leaching residue by submitting it to separate processing because it contains Zn in the form of $ZnO \cdot Fe_2O_3$ (zinc ferrite). Impurities such as Cu, Cd, etc., separated at the purification process, are subjected to a separate recovery process. In the roasting process S contained in the ore becomes a gas in the form of SO_2 and is recovered an sulfuric acid in the sulfuric acid plant.

Figure IV-3 Zinc Extracting Process



4. Zinc Ore and Byproducts

4-1 Zinc Ore

Zinc ores normally used for production of this metal normally consist of zinc blend (ZnS). This is often found in nature together with galena. The grade of crude ore is of the order of 3% and this is refined by converting the ore into zinc concentrate containing more than 50% Zn by means of flotation. Therefore, zinc ore is negotiated in the market as concentrate.

Currently, world deposits of zinc are estimated to be of the order of 240 million tons.

The principal countries blessed with natural resources of zinc are Canada with $62x10^6$T (25.8%), the U.S. with $48x10^6$T (20.0%), Australia with $24x10^6$T (10.0%), Peru and Mexico. It is estimated that the communist block has some $24x10^6$T (10.0%) of zinc deposits.

A temporary worldwide shortage of zinc ore has occurred for some time in spite of concentrate sufficient deposits, due to the absence of development motivation for new resources caused by recent stagnation of zinc prices. The balance between supply and demand is expected to even out on a long term basis, however.

4-2 Byproducts

Zinc concentrate contains many metals which can be separated out as byproducts during refining.

4-2-1 Sulfuric Acid (H_2SO_4)

Sulfur (S) contained in the zinc is separated out in the form of SO_2 gas. This gas is fixed and recovered concentrate as H_2SO_4, $CuSO_4 \cdot 2H_2O$, liquid SO_2, etc. The recovered byproduct can be sold if there is a demand.

4-2-2 Lixiviation Residue

Lixiviation residues are materials which do not dissolve in the H_2SO_4 lixiviation solution. They consist principally of zinc ferrite ($ZnO \cdot Fe_2O_3$). Precious metals like Ag are contained in this lixiviation residue. There are various treatment methods to recover Zn and Ag from the lixiviation residue.

4-2-3 Precipitates of Various Types

The solution purification process consists of various steps, each one of these generating a precipitates consisting mainly of Cu, mainly of Cd, etc. These precipitates are sent to processes for recovery of the various kinds of metals contained therein.

5. Expected Zinc Extracting Project for Paraguay

5-1 Status quo of Zinc Market in South America

A portion of the statistical data of Section 2 referring to South America in 1981 is presented in Table IV-5-1.

Table IV-5-1 Zinc Market in South America (1981) $x10^3T$

	Mine Production	Slab Zinc Production	Consumption
Argentina	34.0	26.9	21.9
Bolivia	48.0	-	1.8
Brazil	67.1	91.9	108.8
Chile	1.0	-	2.7
Peru	496.9	129.0	23.6

Ore is exported by Peru and Bolivia, while metal is exported by Peru only. In the South American region there is insufficient zinc refining capacity, as in the case of copper. On the other hand, demand is growing in Brazil and in Argentina and further increases in quantity are expected to develop in future.

For the South American region as a whole, it is obviously necessary to meet the increasing demand for zinc metal. On the other hand, with regard to ore exported from this region, it is thought best to increase the added value by converting it at least into metal and, if possible, processing it further into finished products.

5-2 Form of Zinc Extracting Industry to be Introduced in Paraguay

In the custom smelters and refineries of Japan and Europe which use integrated extracting processes from raw material to electrolytic zinc, the transportation of ore is rationalized by using large-sized ore carrying vessels. In view of the geographical peculiarities of the country, it is expected that Paraguay will face disadvantages from the point of view of transportation. However, discussion of the form of the zinc extracting industry to be introduced in Paraguay can be set forth paying attention to the following points, should there be advantageous conditions regarding factors related to the other items composing the smelting and refining cost such as electricity cost, etc., compared with other zinc smelters and refineries.

(1) The study of a zinc refining plant for Paraguay should take into consideration the pursuit of an integrated system consisting of the production of ore -- refining -- consumption and export of the metal within South America.

(2) The raw materials should be obtained as economically as possible with minimum transportation cost.

(3) Electricity should be used as effectively as possible for production of metallic zonc.

Such being the case, transportation of raw materials produced in the South American region as efficiently as possible to produce electrolytic zinc by means of the hydrometallurgical zinc refining process is recommended in view of the large consumption of electricity an export of the product to consumption markets is recommended. In this case, it is necessary to reduce the refining cost by cutting the electricity cost as much as possible in order to compete with other refineries.

5-3 Plant Site

This study is set forth assuming construction of a plant in the vicinity of Asuncion, capital city of Paraguay in view of the availability of electricity and labour and the advantages of the fluvial route of the La Plata River for transportation of raw materials and products.

5-4 Sources for Supply of Raw Materials and Markets for Products

Peru and Bolivia can be considered as possible sources of the raw materials required for operation of the plant. The source which will actually supply the concentrate is not concretely know yet but it is presumed that transportation can be carried out in principal by sea. It will be necessary to study the most efficient method of transportation. Land transportation is possible, but is not necessarily adequate for handling zinc concentrate, which is a very bulky material. Possible markets for the products obtained are Brazil in South America and North America.

5-5 Production Scale

The scale of the hydrometallurgical zinc refineries which currently exist around the world vary from 5,000 T/Y to 300,000 T/Y. The refineries in South America are La Oroya, Peru, with 70,000 T/Y capacity, Cajamarquilla with 100,000 T/Y and some other plants in Brazil and Argentina. In the case of custom refineries, the larger the production scale the more advantageous from the point of view of economy. A production scale of the order of 100,000 T/Y seems best. In the case of Paraguay, however, the study is set forth assuming an annual production capacity of 72,000 T, which is the minimum economical scale.

6. General Description of the Model Plant Process

6-1 Production Process

Roasting:	Fluid solid bed roasting process
Lixiviation:	Composite continuous lixiviation process
Purification:	Continuous purification process
Electrolysis:	Electro-winning
Lixiviation residue treatment:	E.G., sulfation roasting process (only construction costs are calculated)

6-2 General Description of Processes

The process flow sheet is given in Figure IV-6-2.

Zinc concentrate, the raw material, is charged in the fluid bed roaster in the form of a slurry where it is oxidized and roasted. The roasted concentrate is lixiviated with electrolyte and the residue is separated from the solution. After removal of impurities the solution is sent to the electro-winning process as electrolyte. In the electro-winning process, Zn is precipitated on the Al cathode using a Pb anode. Pure metallic Zn precipitated on the cathode is stripped off at intervals of 36 to 48 hours. The Zn obtained is melted and cast to become the finished product.

Gas generated in the fluid bed roaster is sent to a sulfuric acid plant where it is converted into sulfuric acid.

Byproducts such as copper and cadmium are obtained in the form of precipitates in the purification process of the lixiviation solution. The lixiviation residue contains Zn so it is necessary to submit it to separate treatment like lixiviation after roasting with sulfation. When the raw material contains Ag, it is recovered in the residue treatment process. The final residue is disposed of.

The residue treatment process to be adopted in the model plant should be determined based on the results of analysis of the raw material. The process actually to be adopted in this plant has not been selected yet therefore. (The sulfation roasting process is indicated as an example in the process flow sheet).

6-3 Plant Layout

Plant layout is given in Figure IV-6-3.

Figure IV-6-2 Process Flow Sheet

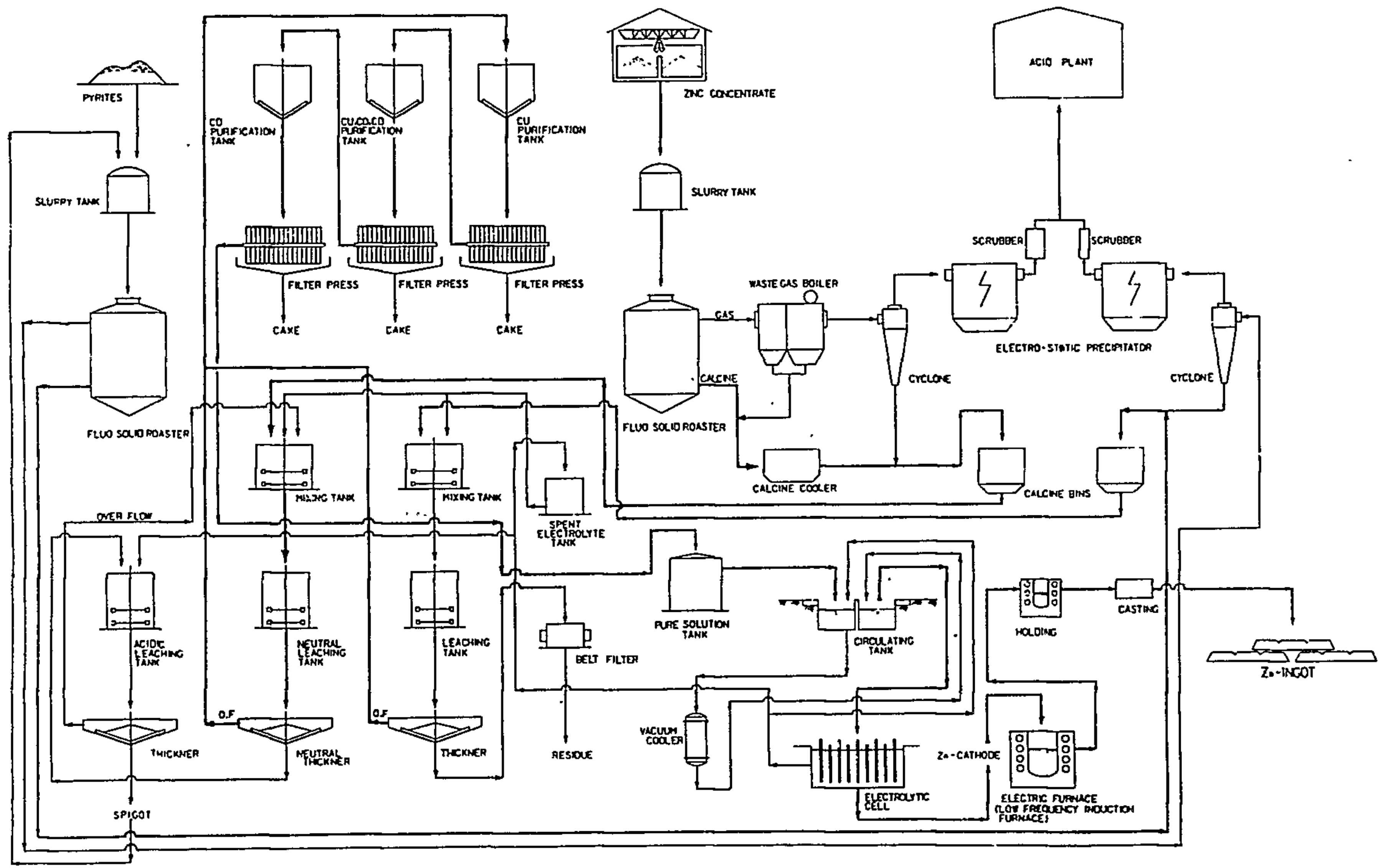
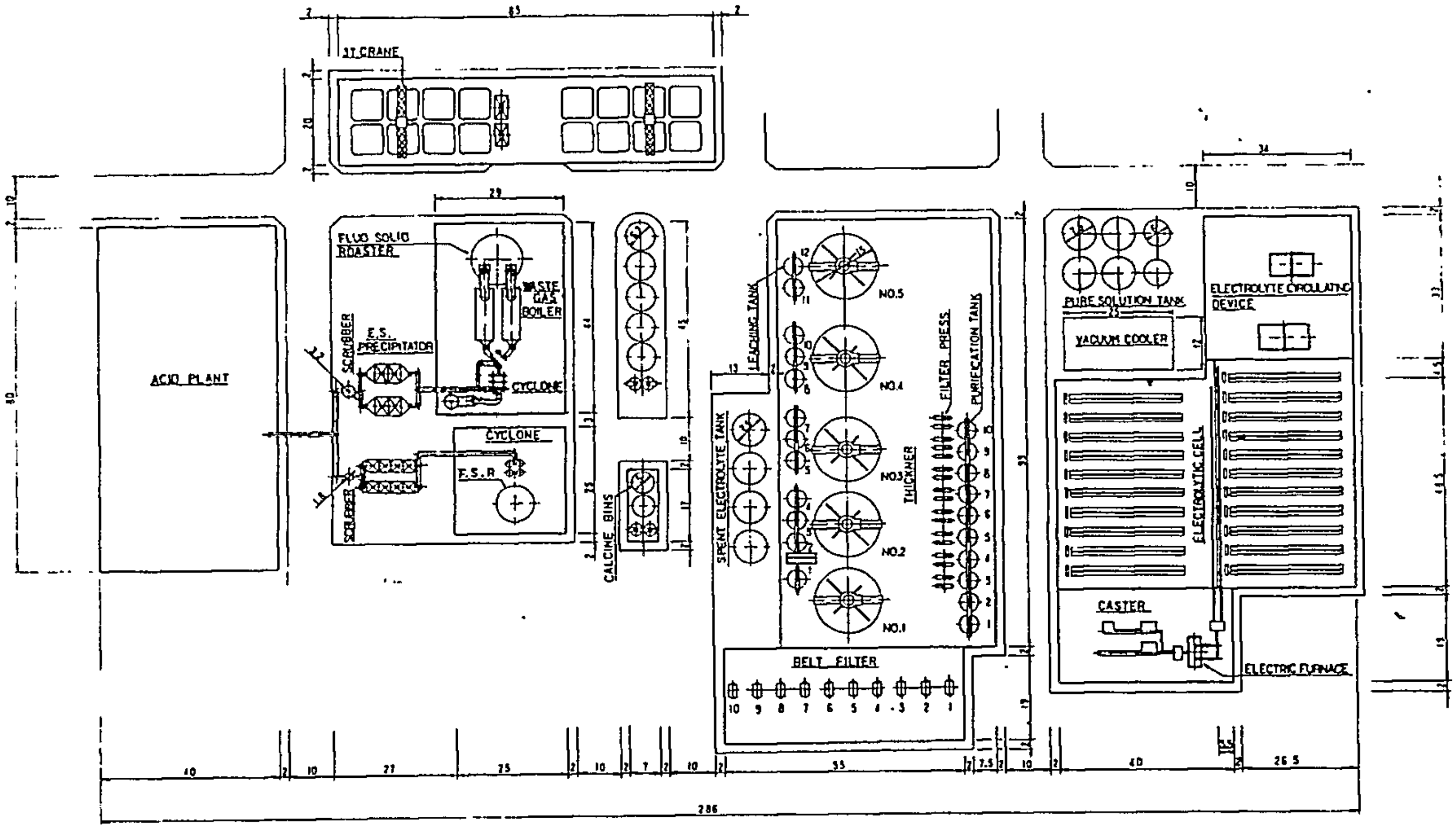


Figure IV-6-3 Plant Layout



7. Estimation of Model Plant Construction Cost

The construction cost of the model plant assumed in this study is estimated on the following premises:

(1) Construction cost is estimated by referring to prices quoted in the Japanese market as of August, 1982 plus 25%.
(The accuracy of prices quoted for the Japanese market is assumed to be ±30%).

(2) Installation cost is included in the estimation.

(3) Land and land preparation costs are not included in the estimation.

(4) Cost of facilities such as maintenance workshops, management office buildings, warehouses, etc. are not included in the estimation.

The construction costs of the various plants are estimated as follows:

Plant	Estimated Construction Cost (10^3 US$)
Ore storage plant	4,000
Roasting plant	17,900
Lixiviation and purification plant	7,700
Electrolysis plant	13,600
Casting plant	2,800
Sulfuric acid plant	23,500
Total	69,500

8. Operation Conditions Expected for Model Plant

8-1 Amounts of Materials to be Handled (Raw Materials, Intermediate Products, Finished Product)

The grades and amounts of the principal materials to be handled in the model plant are as follows:

Name	Grade (%)		Amount (T/Y)
Zinc concentrate	Zn	50	152,000
Lixiviation residue	Zn	20	46,000
Electrolytic zinc	Zn	99.997<	72,000
Sulfuric acid	H_2SO_4	98<	128,000
Copper precipitate	Cu	50	2,000
Fe residue	Fe	50	25,000

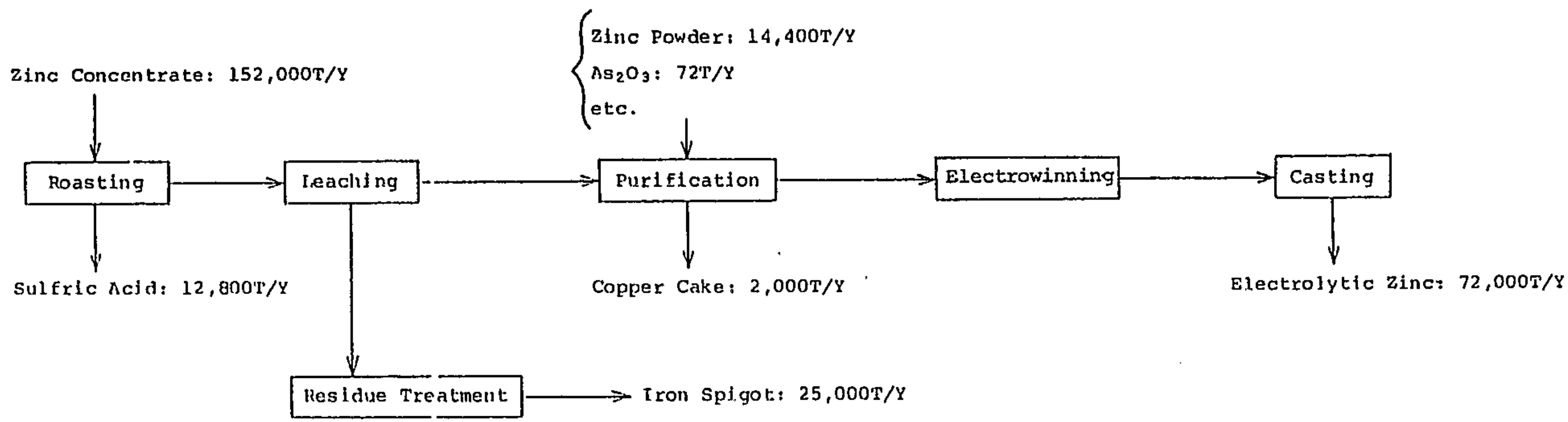
8-2 Principal Operation Materials

The base units and annual consumption of the principal materials required in addition to spare parts are as follows:

Zinc dust	20 kg/T	14,400 T/Y (in house production)
Arsenious acid	1 kg/T	72 T/Y
Slaked lime	125 kg/T	9,000 T/Y
Precipitant	0.25 kg/T	18 T/Y

Material flow of the items in sections 8-1 and 8-2 is given in Figure IV-8-1.

Fig. IV-8-1 Material Flow



8-3 Utilities Requirements

The base units and annual consumption of the various utilities required for operation of the model plant assumed in this study are as follows:

Electricity	4,100 KW/T	295,200 MWH/T
Steam	1 T/T	72,000 T/Y (recovered from the roasting plant)
Industrial water	100 T/T	$7.2x10^5$ T/Y

8-4 Personnel Required

The personnel required for operation of the model plant assumed in this study are as follows (Only plant operation personnel):

Manager 1

	Engineers	Foremen	Operators
Roasting plant	1	1	15
Lixiviation & Purification plant	1	1	30
Electrolysis plant	1	1	48
Smelting plant		1	9
Sulfuric acid plant	1	1	9
Total	4	5	111

9. Estimation of Production Costs in the Model Plant

9-1 Profitability in the Case of Custom Refining

9-1-1 Determination of Terms of Ore Purchase

Zinc refineries are classified into two types, namely domestic refinery and custom refinery, as in the case of copper refining. Broadly speaking, ore purchase terms (CIF basis) are as follows:

Zinc concentrate price (US$/T)
= K x (x-b) x 2204.6 - c (9.1.1)

Where:

K:	Metal cost (¢/Lb)
x:	Zinc grade (%)
b:	Unit reduction
2204.6:	2204.6 Lb = 1T
c:	Treatment Charge (T/C) (US$/T)

c: T/C is corresponds to the treatment charge for obtaining electrolytic zinc from zinc concentrate, b: Unit reduction corresponds to recovery.

When the zinc concentrate contains Ag in excess of a fixed percentage, the content of the precious metal is evaluated by deducting a fixed amount from the content in question and multiplying the difference with the quoted price.

Zinc ore contains a variety of metals but S, Cu, Cd, etc., are recovered as byproducts. On the other hand, in the case of impurities like Fe and others, these are considered noxious component and a penalty is applied when they exceed a fixed proportion. The penalty is applied in the form of reduction of an amount corresponding to the impurities from the ore price.

Expenses such as domestic transportation cost, commission paid to the trading company participating in negotiations and other miscellaneous costs are added to the zinc concentrate price given by expression (9.1.1) when the concentrate is actually delivered to the refinery. The actual purchasing prices are not clearly known, at present, as in the case of copper. This study is carried out by estimating the CIF prices of zinc concentrates with those prevailing at custom refineries in Asia and Europe, estimating the domestic transportation cost, commission paid to the trading companies involved in the transaction, other miscellaneous costs, inventory interest, etc., and by setting a target of the order of 10 to 11¢/Lb for the refining cost.

In a more advanced study, it is indispensable to determine the target value based on ore purchasing conditions proposed by an existing ore supply source.

In particular, it is indispensable to materialize transportation conditions equivalent or close to those of custom refineries in Asia and Europe because otherwise it will be necessary to further cut the refining cost target value. Therefore, a concrete study of the methods and routes of transportation is important for determining ore purchasing conditions.

9-1-2 Profitability of Custom Refinery

The mechanism for determination of the profitability of a zinc refinery is the same as in the case of a copper refinery.

Materials considered as byproducts are sulfuric acid, copper precipitate, etc., but Cd and other materials can also be included if there is a market for them. As for the Zn contained in the lixiviation residue, it seems appropriate to include it in the recovery difference.

If the lixiviation residue is disposed of as is, the process itself becomes simpler but from the point of view of profitability it is better to recover the Zn from this residue. Residue treatment technique is new, however, and so there are a number of processes. Accordingly, the best process should be selected in accordance with results of analysis of the lixiviation residue to be treated.

This study assumes that the lixiviation residue is submitted to Zn recovery treatment but the treatment process itself has not been selected. The recovered Zn is evaluated at approximately 30% of the metal price, taking into consideration treatment costs.

In this study the profitability of the refinery is discussed by estimating the refining cost, including earnings resulting from sale of the byproducts, and by comparing the estimated refining cost with the target value.

9-2 Estimation of Refining Cost

Refining cost estimation for the model plant and elucidation of each element of the cost are carried out on the following premises:

(1) Depreciation cost (Refer to section 7 of this report for details)

A depreciation period of 13 years is applied, assuming a residual book value of 10%, 10 years for depreciation of the refining facilities, 20 years for depreciation of the sheds and a proportion of 70:30 for construction costs of the refining facilities and sheds, respectively.

(2) Interest

It is assumed that all funds required for construction of model plant are covered by loans with an annual interest rate of 10%.

(3) Real estate tax and insurance

Real estate tax and insurance are not taken into consideration in the calculations.

(4) Personnel expenditures (Refer to section 8-4 of this report for details on personnel required for operation of the model plant)

Personnel expenditures are calculated only for personnel required for operation of the model plant, assuming the following wages per function (personnel expenditures for auxiliary management sections are included in the overhead costs):

Manager	US$48,000/Y
Engineer	US$24,000/Y
Foreman	US$19,200/Y
Operator	US$14,400/Y

(5) Maintenance cost

2%/year of installation cost.

(6) Material costs (Refer to section 8-2 of this report for details on principal materials required for operation of the model plant)

(7) Utility costs (Refer to section 8-2 of this report for details on utilities requirement for operation of the model plant)

It is assumed that the electricity cost is US¢3/KWH.

(8) Transportation costs

Only the costs of transportation of materials inside the plant are taken into consideration in this study.

(9) Overhead cost, etc.

50% of personnel expenditures

(10) Earnings resulting from sale of byproducts

Sulfuric acid	US$30/T
Copper precipitate	Evaluated at US$1,000/T.Cu (Evaluated as an intermediate product)
Zinc recovered from lixiviation residue	Evaluated at US$250/T.Zn (This portion of zinc corresponds to the part in excess of the recovery

stipulated in the ore purchasing terms. The treatment process is not chosen, but is evaluated by deducting an amount corresponding to the treatment cost).

Ag is not taken into consideration in this calculation	(Recovery is assumed to be the same as that stipulated in the ore purchasing terms).

(11) Direct marketing cost, etc.

10% of the prime cost

(12) Exchange rate

¥250/US$

The refining cost estimate based on the exchange rate above is given in the Table IV-9-2.

Table IV-9-2 Estimated Electrolytic Zinc Refining Cost

Item	Total amount (x10⁶US$/Y)	Amount per ton of electrolytic copper (US¢/Lb)	Share (%)
(Fixed Cost)			
Depreciation	4.812	3.03	27.1
Interest	0.535	0.34	3.0
Real estate tax, insurance, etc.	-	-	-
(1) Sub-total	5.347	3.37	30.1
(Variable Cost)			
Personnel expenditures	1.838	1.16	10.3
Maintenance costs	1.390	0.88	7.8
Material costs	2.294	1.44	12.8
Utility costs			
Electricity cost	9.216	5.80	51.6
Others	0.072	0.55	0.4
Transportation costs	0.288	0.18	1.6
Overhead cost, etc.	0.919	0.58	5.1
(2) Sub-total	16.017	10.09	89.6
(1)+(2) Total prime cost	21.364	13.46	119.6
Earnings of by-products	5.640	3.55	31.6
Direct marketing cost, etc.	2.136	1.34	12.0
Total Prime Cost	17.860	11.25	100.0

9-3 Influence of Various Factors on Estimated Cost

9-3-1 Scale Merit

The influence of the production scale on the cost when using the same system starting from 72,000 T/Y is indicated in the Table IV-9-3-1.

Table IV-9-3-1 Influence of Production Scale on Cost

Production Scale (T/Y)	Estimated Refining Cost (US¢/Lb)	Share
72,000	11.26	1.00
144,000	9.94	0.88
216,000	9.13	0.81
288,000	8.76	0.78

Data indicated in the table above reveals that when using 72,000 T/Y as a reference, the cost is cut by 10% when the production scale is doubled and by 20% when the production scale is quadrupled.

9-3-2 Influence of Electricity Cost

The electricity cost has a considerable influence on the refining cost because it represents more than 50% of the total production cost. The influence of the electricity cost on the estimated refining cost in the case of a 72,000 T/Y model plant is shown in Table IV-9-3-2.

Table IV-9-3-2 Influence of Electricity Cost on Zinc Cost

Electricity Cost (US¢/KWH)	Estimated Refining Cost (US¢/Lb)	Share
1	7.00	0.62
2	8.99	0.80
3	11.25	1.00
4	13.38	1.19

Data indicated in the table above shows that with an electricity cost of 3 US¢/KWH as a reference, the refining cost is cut by 20% in the case of 2 US¢/KWH and by 40% in the case of 10 US¢/KWH.

10. International Competitiveness of Estimated Cost

The estimated refining cost calculated in section 9-2 is rather expensive compared with the target amount set in section 9-1-1. The estimated refining cost has the following characteristics:

(1) The fixed cost represents approximately 30%.

(2) The electricity cost represents approximately 50% when the electricity charge is 3 US¢/KWH.

(3) The share of earnings brought about by sale of the byproducts is approximately -30%.

With regard to fixed costs, it is necessary to discuss the construction cost and means for raising funds under advantageous conditions and advantageous depreciation methods, as in the case of copper.

On the other hand, the share of the electricity cost is large, unlike in the case of copper, and, therefore, the total cost may be cheaper even when other disadvantageous factors exist, if the electricity charge is low compared with other countries.

As for the byproducts, the following conditions should be fulfilled to obtain earnings from them.

(a) A firm market is required for approximately 120,000 T/Y of sulfuric acid.

(b) The appropriate zinc residue treatment process should be selected.

As for sulfuric acid, production should be based on a reliable demand study in the domestic market of Paraguay and in the South American region, closely related with the chemical industry and fertilizer industry.

For residue processing, it is possible to recover zinc in excess of the recovery stipulated in the purchasing terms, depending on the treatment process.

It will be necessary to check one by one the aforementioned refining cost component elements. On the other hand, as mentioned in the case of copper refining, examination of the purchasing terms (conditional refining cost and conditional recovery) and transportation cost is the most important point in this study.

Regarding the importance of the introduction of a zinc refining industry in Paraguay for the South American region, it is necessary to understand conditions in the countries related to the matter in order to obtain the most advantageous terms for purchase of concentrate, transportation and marketing of the finished product.

Materialization of the zinc refining industry in Paraguay might be proven possible by studying carefully ore purchasing terms and other relevant factors described in the foregoing.

11. Problematic Points of This Study

In this study the refining cost is estimated based on various conditions, with reference to a model plant adopting the very usual process. It is necessary to improve the accuracy of the study by determining further concrete conditions. The following lists are various conditions which should be confirmed in a future study:

(1) Market Survey

Timing is a very important factor in investment planning, therefore, correct judgement should be inplemented based on an accurate market forecast of world supply and demand.

(2) Raw Materials

The purchase terms depend on each individual case. They should be examined with regard to concrete cases, based on the treatment charges (T/C), conditional recovery, etc. (In particular, it is recommendable to seek the most advantageous terms within the South American region).

(3) Products and Byproducts

It is necessary to conduct studies about concrete marketing conditions such as price, specifications, etc., of the selling destinations (In particular, a very careful study is required for sulfuric acid).

(4) Materials

It is necessary to study aspects such as availability, alternate materials, price, quality and other purchasing conditions for the principal materials.

(5) Transportation

Study of rational transportation means and routes and cost evaluation for the raw materials, products, secondary raw materials, consumption materials, etc. to be used. (In particular, a very careful study is required for the zinc concentrate).

(6) Processes

Process design making the best use of local conditions and based on results of analysis and properties of the raw materials to be actually used. (In particular, the lixiviation residue treatment process should be chosen from among the various processes available based on results of analysis of the raw materials).

(7) Construction

Estimation of the construction cost taking into consideration local conditions such as procurement of materials, import conditions, labour conditions, etc. (The purchase of equipment from South American countries should also be taken into consideration).

(8) Utility

Study of utility supply plan and evaluation of costs, based on the process design actually implemented. (The cost of electricity should be evaluated with particular care, in view of its importance in cost make up).

(9) Fund Raising Plan

Study of cash flow plan advantageous fund rising and the economy of Paraguay.

SECTION IV

FERROALLOY INDUSTRY

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The Ferroalloy Industry

I. Introduction

1. General Description of Ferroalloys

Ferroalloys are ingredients indispensable in the steelmaking industry and, as represented by ferro-manganese, ferro-silicon, ferro-chromium, etc., they are alloys composed mainly of iron. Nowadays there are many types of ferroalloy, as shown in Table I-7, as results of the progress occurred in steelmaking technology and the development of many kinds of steel. The volume of production and the price of these ferroalloys presents considerable variation, depending on the types. From the point of view of use, ferroalloys can be classified into those used as deoxidants, desulfurants, etc., which have the function of eliminating impurities like oxygen, sulfur, etc. Which got contained in the steel in the steelmaking process, and those used as additives with the function of improving steel properties. Ferroalloys used as deoxidants and desulfurants are represented by ferrosilicon and ferromanganese. They are characterized by massive production and low price. On the other hand, ferroalloys used as additives, represented by ferrochromium and ferronickel used in the production of stainless steel. They are characterized by relative small volumes of production and high prices.

The ferroalloy industry is a kind of refining industry which uses mineral ores as raw materials. The ferroalloy production process is composed principally of the reduction in the aforesaid impurities by melting them.

Accordingly, it is an installation-intensive industry of the energy-intensive type and at the same time a capital-intensive industry.

The submerged arc type electric furnance is currently used for production of most ferroalloys because they have a high melting point. Accordingly, it is a typical example of electricity-intensive industry within the class of energy-intensive industry.

The cost of ferroalloys is determined by three predominant factors:

- Price of the raw materials (ores)
- Installation costs, mainly for the electric furnace
- Electricity cost

The ideal location of a ferroalloy plant is conditioned on three factors.

- Proximity to the source of raw materials
- Availability of cheap and abundant electricity
- Cheap transportation cost for the products to consumption centers

So far the ferroalloy industry has developed mainly in the major iron and steel producing countries because it is the source of an important ingredient for the iron and steel industry. Since the oil shock of 1974, the major iron and steel producing countries have been faced with difficulty in increasing production in their due to increases in the cost of electricity, and as a consequence imports from ferroalloy producing countries with cheaper electricity cost has shown a tendency to increase. This tendency is especially pronounced in the case of products like ferrosilicon, ferromanganese, silicon-manganese, etc., for which the electricity cost in the production cost represents a major share.

On the other hand, as for types of ferroalloys, for which a high percentage of the cost of production cost is raw material cost, together with the electricity cost, the location of the plant for their production has tended to shift from the iron and steel consumer countries to countries where both raw materials and electricity are available at low prices. Currently, world production of iron and steel is decreasing due to the worldwide recession and, therefore, production of the ferroalloy industry is at a low level. However, on a long-term basis it is evident that the world production of iron and steel will increase and in such a case, the aforementioned change in the ferroalloy industry distribution pattern in various countries of the world is expected to become more pronounced. In other words, it is expected that the production of ferroalloy in countries where cheap electricity is available low in raw material producing countries will become more active, with expansion of production and the implantation of new industries. From the point of view of production technology the ferroalloy industry is quite mature. The transfer of technology is relatively easy because it is an installation-intensive industry and at the same time most of the technology is concentrated in the installation itself. A very high degree of operating skill and installation maintenance technique is required, however, because the ferroalloy industry is a heavy industry which handles very large quantities of raw materials and products at high temperature. Accordingly, production control in this industry requires a small number of high grade engineers and workers with a very high degree of skill.

2. Selection of the Ferroalloy Products which can be Produced in Paraguay

When discussing the location of the ferroalloy industry in Paraguay it is necessary to always bear in mind that the consumption of ferroalloys in the domestic market is negligible, therefore, discussion should be set forth on the premise that the products to be exported world markets. Accordingly, the key point in determining feasibility of the project is production of ferroalloys at sufficiently low cost to ensure competitiveness on the world market.

Frankly speaking, it is premature to conclude that a ferroalloy industry can be located in Paraguay, an inland country with an economy based mainly on agriculture, merely because cheap and abundant electricity will be generated in Itaipu. On the other hand, it is also not correct to conclude that a ferroalloy industry in Paraguay is impossible simply because the country is not rich in mineral and other natural resources. It is thought that the Paraguayan ferroalloy industry may acquire competitiveness in the international market, with possibility of exporting its products, should the necessary conditions be gradually improved on a long-term basis of the order of 10 to 20 years. Improvement of the aforesaid conditions is also necessary in the case of other electricity-intensive industries. These necessary conditions are as follows:

1. Overcoming of the disadvantages inherent to an inland country
2. Training of industrial engineers and workers
3. Formation of fund-raising capacity

The long-term effort of the government through appropriate policies and the cooperation of the people are indispensable for materialization of these goals. However, it is not correct to conclude that the location of industries in Paraguay will be impossible since the aforementioned conditions are not fulfilled. It is possible to progress by setting out towards industrialization with products able to maintain cost competitiveness under current conditions, in parallel with the improvement of those conditions.

In order to develop the ferroalloy industry in Paraguay as an export industry, it will be necessary to select products which can be turned out under the conditions currently prevailing and expected to develop in the near future and to discuss the possibility of production related to each individual product. As mentioned above, there are many ferroalloy types with different cost compositions, production techniques, market and other peculiarities. Selection of the type of ferroalloy best suited for production in Paraguay is the first step for examination of the possibility of its location in the country.

The following conditions should be taken into consideration in selecting the type of ferroalloy to be produced in Paraguay.

(1) The raw materials should be available from domestic sources or from neighbouring countries or they should be available more easily and more economically than on the international market.

(2) The transfer of technology should be easy. In other words, the production process should not be technically sophisticated.

(3) The electricity cost should represent a large proportion of the production cost.

(4) The products should be exportable to the world market in future.

When implanting an export oriented ferroalloy industry, it seems that ferrosilicon, ferromanganese and silicon-manganese are the most appropriate type in view of the aforementioned conditions, the strong possibility of raw materials deposits in the country and the large proportion of the electricity cost in the production cost. Next is ferrochromium, in view of the availability of imported raw materials and the future potential of the export market.

This report discusses the current world market situation, raw materials and other ingredients related to the 4 types of ferroalloys mentioned above and described the contents of the optimum scale and expected production cost of the plant assumed for Paraguay.

The reader is asked to bear in mind that this report has been written under a number of unfavourable conditions, mentioned below and the production costs calculated based on many suppositions.

(1) In view of the worldwise recession, the international iron and steel industry is experiencing extremely unfavourable conditions. Accordingly, the international ferroalloy market is in a very confused state and prospect for the future is gloomy.

(2) The cost of electricity to be generated at Itaipu, Paraguay, is not clearly known at present.

(3) The transportation infrastructure of Paraguay has major deficiencies and currently transportation costs are very expensive.

(4) Engineers and workers are not available in sufficient quantity or quality.

Table I-1 Preminary Evaluation of the Ferroalloy Project

Type	Chemical Composition	Raw Material	Electricity	International Price	World Production	Tecnology
	%		Kwh / MT	US$ / MT	10^3 MT	
Ferro-manganese	Mn: 60.0~85.0 C : 0.7~ 8.0 Si: 0.5~ 2.0	Manganese Ore Silico-manganese Cokes	1,700~2,600	350 ~ 610	4,430	Moderate H-C Ferro-manganese Rather Complicated M-C Ferro-manganesa L-C Ferro-manganese
Silico-manganese	Mn: 60.0~70.0 Si: 14.0~25.0 C : 2.5 Max	Manganese Ore H-C Fe-Mn Slag Cokes, Coal	4,200~4,600	400 ~ 450		Moderate
Ferro-silicon	Si: 15~90.0	Quartzite Cokes, Coal	5,000 ~11,000	350 ~ 600	2,530	Rather Complicated
Ferro-chrome	Cr: 50.0~70.0 C : 0.1~ 9.0 Si: 0.5~ 8.0	Chrome Ore Silico-chrome Cokes	2,500 ~ 5,500	560 ~ 1,150	1,910	Moderate H-C Ferro-chrome Rather Complicated M-C Ferro-chrome L-C Ferro-chrome
Silico-chrome	Cr: 30.0 Min Si: 40.0 Min C : 0.1 Max	HC Ferrochrome Cokes, Coal Quartzite	5,200 ~ 5,800	650 ~ 700		Moderate
Ferro-nickel	Ni: 18.0~23.0 C : 0.01~3.00	Nickel Ore Cokes, Coal	19,000 ~23,000	1,300 ~ 1,620	460	Moderate
Calcium-silicon	Ca: 25.0~35.0 Si: 55.0~65.0	Quiekline Quartzite Cokes, Coal	12,000 ~13,000	1,200 ~ 1,300	50	Complicated
Ferro-molybdenum	Mo: 55.0~70.0 C : 0.1	Molybdenum Ore Aluminum		9,630 ~12,250	36	Rather Complicated
Ferro-vanadium	V : 45.0~85.0 C : 0.2 max	Vanadium Ore Aluminum		6,750 ~12,750	27	Rather Complicated
Ferro-niobium	Nb + Ta : 60.0 C : 0.2 max	Niobium Ore Aluminum		7,380 ~ 8,610	10	Rather Complicated
Ferro-tungsten	W : 75.0~85.0 C : 0.2 max	Tungsten Ore		12,000~13,000	5	Rather Complicated

II. Ferromanganese

1. General Description of Ferromanganese

Ferromanganese is an alloy of iron and manganese. It generally contains 73% to 85% manganese, 1.0% to 7.3% carbon, 0.5% to 2.0% silicon and the remainder iron. Ferromanganese can be divided into 3 groups, namely, high carbon, medium carbon and low carbon, according to the carbon content. Each of these groups has several specifications. The most popularly used ferromanganese is the high carbon type, which has the largest production. High carbon ferromanganese is the object of discussion in this report. Hereinafter in this report the term "ferromanganese" shall be used to mean "high carbon ferromanganese". Ferromanganese is used in every type of steel as a deoxidant and desulfurant. It is also used as an additive in the steelmaking process. For alloy steels such as high manganese steel.

Ferromanganese is the ferroalloy used most popularly in the steelmaking industry. In Japan, which is the largest consumer of this product in the world, it is consumed at rates of 3.5 to 4.0 kg per ton of steel. Ferromanganese represents 21% of the total consumption of ferroalloys.

2. Market and Prices Trends for Ferromanganese

World production of ferroalloys reached its peak in 1974 but since then it has stagnated at levels of the order of 3.4 to 3.5 million tons per year in view of the poor showing of steel production. In terms of production per country, the Soviet Union, a country with abundant deposits of manganese ore and iron and steel production of top level in the world on par with the U.S. and Japan, has the highest production, representing approximately 25% of the total quantity turned out in the world.

The Soviet Union has sufficient export capacity and is one of the most important exporters to its satellite countries and to Europe.

The U.S., Japan, France and West Germany, countries with massive production of iron and steel, are also important producers of ferromanganese following Russia. These countries rely, however, on imports for supply of most of the required raw material ores. Furthermore, production costs have risen considerably due to the rise in electrical energy costs after the oil shock. Currently the production of ferroalloys in these countries is stagnant or in decline due to recession in the iron and steel industry in addition to the unfavourable circumstance mentioned above.

In countries like South Africa, Brasil, Australia, etc., where manganese ore is abundant and development of electric power is being promoted, the production of ferroalloys is increasing thanks to the favourable evolution of exports, in spite of the recession in the world iron and steel industry. In Europe, Norway is maintaining its production of ferroalloys at satisfactory levels, based chiefly on exports to the European market, thanks to the availability of cheap electricity from hydroelectric power stations.

The rise in the cost of electricity brought about as a consequence of the rise in the price of crude oil after the oil shock of 1974 resulted in an important change in the structure of the world ferroalloy industry. Ferromanganese is not an exception.

The production cost in the ferromanganese industry of the major iron and steel producing countries such as the U.S., Japan and European countries is suffering a pronounced increase due to the increases in the raw material transportation cost, electricity cost and environmental protection cost. As a consequence, the ferroalloy industry in these countries is declining as a consequence of the pressure exerted by imports from countries with cheap production costs like Norway, the Soviet Union, etc., and from newcomers like Brazil, South Africa, etc.

It is evident that from now on the major consumers of ferromanganese like the U.S., Japan and European countries will gradually increase their reliance on imports from ferroalloy producing countries where electricity is available at cheaply.

Currently the price of ferromanganese in the world market is not unified because it depends on circumstances such as the supply demand balance at the time of a transaction, the commercial relations between the producer and consumer, etc. Therefore it is quite difficult to grasp precisely the current market situation. The most recent price trend inferred from the transaction prices in Japan and the U.S. which are the two largest consumers of ferroalloy in the world, is presented in the table below.

Table II-2 Evolution of Ferromanganese Import Price in Japan and the U.S. (Unit: US$)

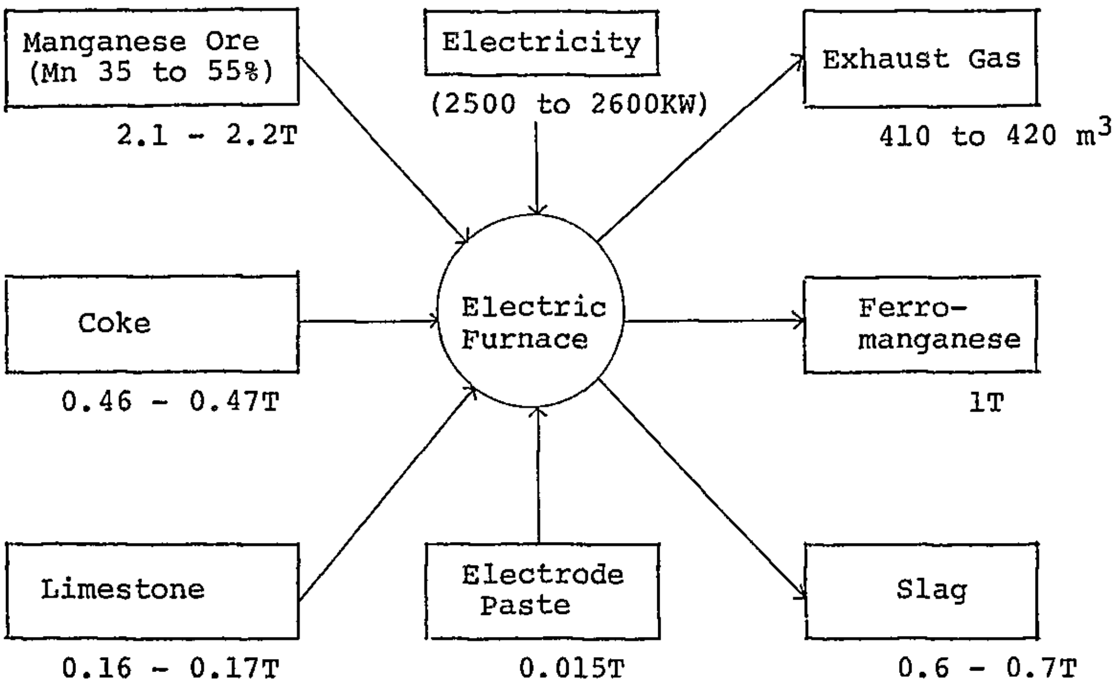
	1972	1973	1974	1975	1976	1977	1978	1979	1980
Japan	228	236	256	370	412	480	480	480	580
U.S.A.	125	126	197	307	287	291	261	313	350

Note: USA -- CIF
Japan -- Plant CIF

In spite of the stagnant consumption of ferromanganese in the iron and steel industry after 1973, the price has risen substantially due to the increase in petroleum energy costs. It goes without saying that this is a consequence of the substantial rise in the electricity cost resulting from the reliance of Japan and US on oil fired thermoelectric plants. Other important factors which should be taken into consideration are rises in the cost of raw material ores and the rise in transportation costs. In spite of the substantial rise in the prices of ferroalloy in the world market, ferromanganese producers of the U.S., Japan, West Germany, France, etc., are suffering substantial impoverishment in profitability because the rises in production cost caused by the rise in electricity cost surpass increases in the price of the product. Therefore, these traditional ferroalloy producers are losing ground to the Soviet Union, Norway, South Africa, Brazil and other exporters in the world market.

3. Method of Ferromanganese Production

Ferromanganese is produced in electric furnaces using manganese ore with 35% to 55% Mn as the principal raw material and coke, limestone or dolomite and electrode paste as secondary material.



The approximate quantities of electricity and raw materials required to turn out 1 ton of ferromanganese are indicated in the figure above. Exhaust gas composed principally of carbon monoxide and carbon dioxide and slag containing approximately 30% manganese are turned out together with ferromanganese.

4. Raw Materials for Ferromanganese Production

4.1 Manganese Ore

Manganese ore is distributed quite unevenly in the various countries of the world. The largest deposits are located in South Africa, the Soviet Union, Australia, Gabon and Brazil.

Currently, manganese deposits throughout the world are estimated to be of the order of 2.5 to 2.6 billion tons, and the largest deposits in Latin America are located in Brazil and in Mexico.

In view of the geological characteristics of Paraguay and the state of distribution of manganese ore in Brazil, it is presumed that there is considerable chance of manganese deposits being found in Paraguay. The manganese ores used as raw material for production of ferromanganese are those containing manganese dioxide, like pirolusite, manganite, blowsite, etc. Normally, ores containing 25 to 55% manganese are used in the ferroalloy industry.

The most important producers of manganese ore are South Africa, which has abundant deposits of this material, followed by Australia, the Soviet Union, Gabon and Brazil. These countries consume part of their own production in ferroalloy industries and export the remainder. (Refer to Table II-4).

There are considerable differences in the price of manganese ore in the world market according to the content of metallic Mn. The evolution of import contract prices of Japan, one of the principal importers of this

Table II-4 Export of Manganese-Ore

(1,000 MT)

No	Year / Nation	1972	1973	1974	1975	1976	1977	1978
1	South Africa	2,450	3,677	4,221	4,500	3,472	2,587	2,500
2	Australia	652	978	1,120	1,132	1,380	811	1,301
3	U.S.S.R	1,278	1,298	1,482	1,411	1,342	1,397	1,186
4	Gabon	2,162	776	2,104	2,205	2,100	1,450	1,142
5	Brazil	1,175	789	1,493	1,557	1,073	560	894
6	Ghana	475	290	281	373	355	281	229
	Others	591	574	1,589	1,221	753	480	363
	TOTAL	8,783	8,382	12,290	12,393	10,575	7,468	7,615

ore, indicates that a substantial increase occurred after the oil shock of 1974. The prices shifted from US$25 to US$31 in 1972 to US$67 to US$88 in 1981.

4-2 Coke

Steelmaking coke with a grading of 5 to 30 mm, fixed carbon of the order of 85% and low impurity content phosphorus and sulfur is used for production of ferroalloys.

The world production of coke is of the order of 350 to 400 million tons and the quantity used for production of ferroalloys is of the order of 10 million tons. Accordingly, it is easy to import the required quantity of coke.

4-3 Limestone

Limestone required for production of ferroalloys is found everywhere in the world and all producers use limestone obtained from domestic sources. As for the quality of limestone required, it should contain 95% of more calcium carbonate, and products with low silicon oxide impurities are best.

4-4 Electrode Paste

Electrodes of the self-baking type are used in electric furnaces for production of ferroalloys. Accordingly, the parts of the electrode consumed in the ferroalloy production process should be supplied in the form of paste. The principal suppliers of self-baking electrode paste are Japan, Norway, the U.S., Brazil, etc., and this product is easily available on the wrold market.

5. Excepted Ferromanganese Production Project in Paraguay

5-1 Plant Site

Currently, it is impossible to carry out analysis of the feasibility of production of ferroalloys in Paraguay because some important cost conditions such as electricity cost, transportation cost, etc., are not clearly known.

However, we believe discussion of the economical feasibility of the project assuming some premises is by no means absurd. Such being the case, we carried out two model calculations regarding the ferromanganese project.

The selection of the plant site is conditioned on two factors

(1) The plant should be located at a site offering the cheapest transportation costs for the raw materials and the finished products.

(2) The plant should be located at a site making possible the stable supply of cheap electricity.

There is possibility that manganese deposits in Paraguay exist but for the time being discussion is carried forward on the assumption raw material ore is imported. Such being the case, the outskirts of Asuncion, the capital city, seem to offer the most favourable conditions for siting the plant in view of the conveniences for fluvial transportation and availability of electricity.

5-2 Supply Sources and Prices of Raw Materials

The following factors should be taken into consideration in selecting the manganese ore supply source.

- Transportation distance from the production site to the plant site.
- Purity, configuration and quality of the ore.

In the case of Paraguay, it seems best to import ore principally from Brazil and South Africa. The addition of ore of Australian origin is expected to contribute to stabilization of the operation of the ferroalloy plant.

As for the coke, it is thought best to import from Brazil and Argentine, taking into consideration transportation costs. Import from the U.S. is another possible alternative from the point of view of the stable supply. Limestone is available from domestic Paraguayan sources. As for electrode paste, import from Brazilian producers seems best in view of the geographical proximity.

The expected CIF prices of the raw materials at the plant are as follows:

Table II-5-2 CIF Prices for Ferromanganese Raw Materials at the Plant

Unit: US$

	Source	Exporting Country FOB	Ocean Freight	Fluvial Freight	Other Expenses	Total Plant Site CIF
Manganese Ore	Brazil	(C & F) 87.50		35.00	7.70	130.20
	South Africa (HG)	67.50	20.00	"	"	130.20
	South Africa (LG)	47.00	"	"	"	109.60
	Australia (HG)	67.30	25.00	"	"	135.00
	Australia (MG)	40.60	"	"	"	108.20
Coke	U.S.	76.00	28.00	35.00	8.90	147.90
Electrode Paste	Brazil	450.00	30.00	35.00	19.00	534.00
Limestone	Domestic					14.00

5-3 Production Scale of the Plant

The production scale of ferromanganese is determined by the capacity of the electric furnace, the principal production facility. Theoretically, the larger the scale of the furnace, the better the economic performance, e.g., investgment efficiency, thermal efficiency, etc. The largest furnaces in the world have production capacities of the order of 100,000 tons per year, in view of restrictive conditions such as difficulty of operation, strength of the refractories and firebrick, etc. As a matter of fact, furnace with annual capacities of the 300,000 ton class are considered the most advantageous from the economical point of view. In the case of producing ferroalloys in Paraguay, it is recommendable to start out with furnaces with an annual production capacity of the order of 10,000 tons, the minimum scale from the economical point of view, and at the same time best suited for learning of operation techniques. This is termed Case A. A plant with an annual production capacity of 30,000 tons, considered the average economical scale in the world, is termed Case B. The construction of the model plant is discussed for these two cases.

6. Estimation of the Model Plant Construction Cost

The costs for construction of the plants for Case A and Case B are estimated on the following premises:

(1) The land for construction of the plant is obtained free of charge

(2) The equipment and materials for construction of the plant are imported

(3) All imports required are exempted from duty

(4) Welfare facilities such as dwellings, hospitals, etc., for the workers are already available in the vicinity of the plant site

(5) Labour for construction of the plant is hired in Paraguay

The estimated prices of the principal installations of the plant are as follows.

Table II-6 Construction Costs of the Principal Facilities

(Unit: US$1,000)

	CASE A	CASE B
Total Construction Cost of the Plant	14,400	31,200
Raw material facilities	1,220	2,650
Electric furnaces	4,510	9,760
Finished product handling facilities	480	1,030
Substation facilities	840	1,810
Utility facilities	1,740	3,780
Sheds	4,460	9,670
Others	1,150	2,500

7. Expected Operation Conditions for the Model Plant

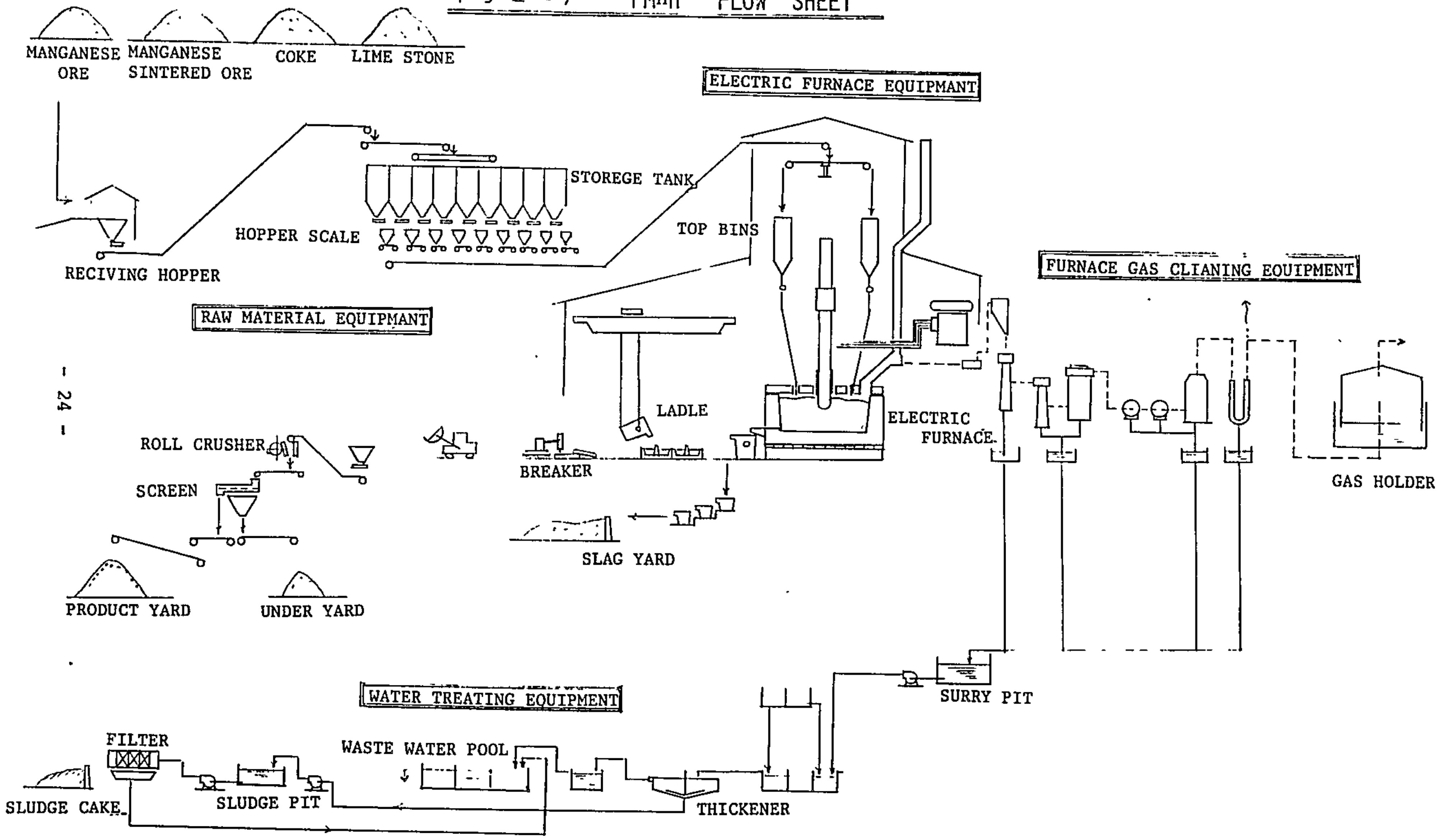
The operation conditions for the plant scales assumed in Case A and Case B, based on conditions related to the raw materials expected in this project and taking into consideration the empirical values for similar cases accumulated so far, as estimated as follows: (Refer to Table II-7).

The flow sheet of the plant is shown in Figure II-7.

Table II-7 Operation Conditions of High Carbon Ferro-manganese Plant

	Unit	Case A	Case B
Transformer Capacity	KVA	5,500	16,000
Transformer Power Factor	%	85	75
Average Load	KW	3,500	11,000
Energy Consumption	MWH	27,720	87,120
Basic Power Unit	KWH/T	2,600	2,560
Production of Ferromanganese	T/Y	10,600	34,300
Product Yield	%	90	90
Product Quantity	T/Y	9,500	31,000
Land for Construction of the Plant	m^2	55,000	95,000
Quantity of Cooling Water	T/H	50	410
Personnel Requirement for Operation	Persons	(62)	(84)
Management staff	"	1	1
Engineers	"	1	1
Technicians	"	6	6
Workers	"	54	76
Basic Raw Material Unit	Kg	2,755	2,721
Manganese Ore	"	2,112	2,246
Limestone	"	159	-
Coke	"	469	461
Electrode Paste	"	15	15
Number of Days of Operation	Day	330	330

Fig II - 7 FMnH FLOW SHEET



III. Silicomanganese

1. General Description of Silicomanganese

Silicomanganese is an alloy consisting mainly of a compound of silicon and manganese and ferromanganese carbide $(MnFe)_3C$. Generally it contains 60 to 70% manganese, 14 to 25% silicon, less than 2.5% carbon and the remainder iron.

Silicomanganese is used as a deoxidant and desulfurant in the steelmaking process for products such as high carbon ferromanganese. It is used mostly in the production of alloy steels and special steels because it has a lower carbon content and stronger deoxidizing capacity than high carbon ferromanganese.

Data on production is not as readily available as in the case of ferromanganese but in Japan consumption is of the order of 80% of ferromanganese. Silicomanganese is often replaced by a combination of ferromanganese and ferrosilicon for economical reasons.

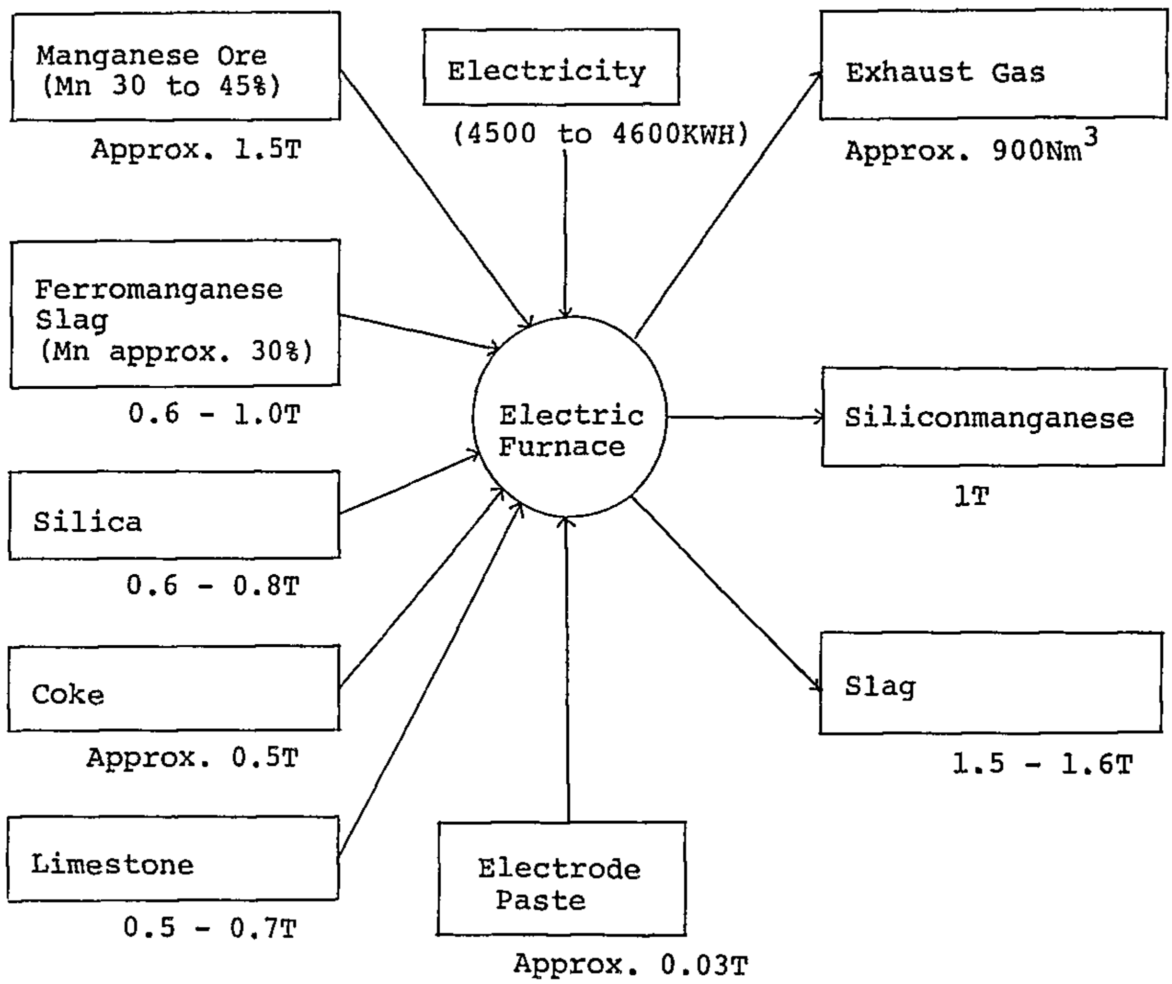
2. Market and Price Trends for Silicomanganese

Inferring from the consumption in Japan, it is presumed that the market for silicomanganese is of the order of 2.7 to 2.8 million tons per year.

Discussion of the producing countries, consuming countries and energy situation for silicomanganese are omitted here because they are similar to those for high carbon ferromanganese discussed in the previous sections of this report.

3. Method of Silicomanganese Production

The silicomanganese production process uses manganese ore with 30 to 45% Mn as the principal raw material in addition to slag generated in the ferromanganese production process which is recycled as a source of Mn and SiO_2. Silicomanganese is produced in electric furnaces using silica, coke, limestone and electrode paste as additional materials.



An example of the quantities of electricity and raw materials needed to turn out 1 ton of silicomanganese is shown in the figure above.

4. Raw Materials for Silicomanganese Production

As for raw materials, the following differences occur in the case of silicomanganese as compared with ferromanganese.

- Ferromanganese slag is used in addition to manganese ore as Mn source with the goal of using natural resources more effectively.
- In addition to silica, ores with high SiO_2 content are selected to ensure supply of the required quantity of Si.

Such being the case, the same discussions related to the raw materials of high carbon ferromanganese are applicable to this case.

5. Silicomanganese Production Project in Paraguay

5-1 Plant Site

Plants for production of silicomanganese are often constructed in conjunction with high carbon ferromanganese plants. One of the reasons for this arrangement is the use of ferromanganese slag for production of silicomanganese, as described in the section on raw materials, in order to reduce costs.

It is recommendable to construct the silico-manganese plant within the high carbon ferromanganese plant in this project.

5-2 Sources and Prices of Raw Materials

Compared with ferromanganese, ferrosilicon requires two more raw materials, namely, ferromanganese slag and silica. In this study it is assumed that silica is available from domestic sources at US$26/ton and the price of ferromanganese slag is calculated at US$44.8/ton, in terms of content of Mn.

5-3 Production Scale of the Plant

As for the production scale of silicomanganese, the larger the capacity of the electric furnace, the better the investment efficiency and thermal efficiency, resulting therefore in greater economy, as in the case of ferromanganese. On the other hand, large sized furnaces are technically more complicated and require more sophisticated operating techniques. As there are also other restrictive conditions, the maximum world production scale is currently of the order of 70,000 tons/year. This project assumes production scales able to maintain a balance with consumption of slag generated as a byproduct of the ferromanganese plant. Discussion is therefore set forth assuming production scales of 8,000 tons/year and 25,000 tons/year, termed Case A and Case B, respectively.

6. Estimation of Model Plant Construction Cost

The cost for construction of the silicomanganese plant is estimated on the same premises as for the ferro-manganese project.

Table III-6 Investment for Construction of Principal Installations

(Unit: US$1,000)

	CASE A	CASE B
Total Construction Cost of the Plant	16,000	34,000
Raw material facilities	1,360	2,890
Electric furnaces	5,000	10,640
Finished product handling facilities	530	1,120
Substation facilities	930	1,970
Utility facilities	1,940	4,110
Sheds	4,960	10,540
Others	1,280	2,730

7. Operation Conditions Expected for Model Plant

The operation conditions for the plant scales assumed in Case A and Case B, based on the conditions related to the raw materials expected to prevail in this project and taking into consideration the empirical values for similar cases accumulated so far, are estimated to be those indicated in Table III-7.

The flow sheet of this plant is shown in Figure III-7. Figure III-7-2 shows a sample layout with the ferromanganese plant and silicomanganese plant sited together.

Table III-7 Operation Conditions of the Silicomanganese Plant

	Unit	Case A	Case B
Transformer Capacity	KVA	6,300	22,000
Transformer Power Factor	%	85	75
Average Load	KW	5,000	15,700
Energy Consumption	MWH/Y	39,302	124,396
Basic Electric Energy Unit	KWH/T	4,570	4,540
Production of Silicomanganese	T/Y	8,600	27,400
Product Yield	%	90	90
Product Quantity	T/Y	7,800	24,600
Land for Construction of the Plant	m2	FMnH+SiMn 90,000	150,000
Quantity of Cooling Water	T/H	60	350
Personnel Requirements for Operation	Persons	(59)	(66)
Management staff	"	1*	1*
Engineers	"	1	1
Technicians	"	4	5
Workers	"	54	60
Basic Raw Material Unit	Kg	3,954	4,066
Manganese ore	"	1,445	1,456
High carbon ferro-manganese slag	"	730	714
Silica	"	744	685
Limestone	"	507	669
Coke	"	498	512
Electrode paste	"	30	30
Number of Days of Operation	Day	330	330

Fig III - 7 SiMn FLOW SHEET

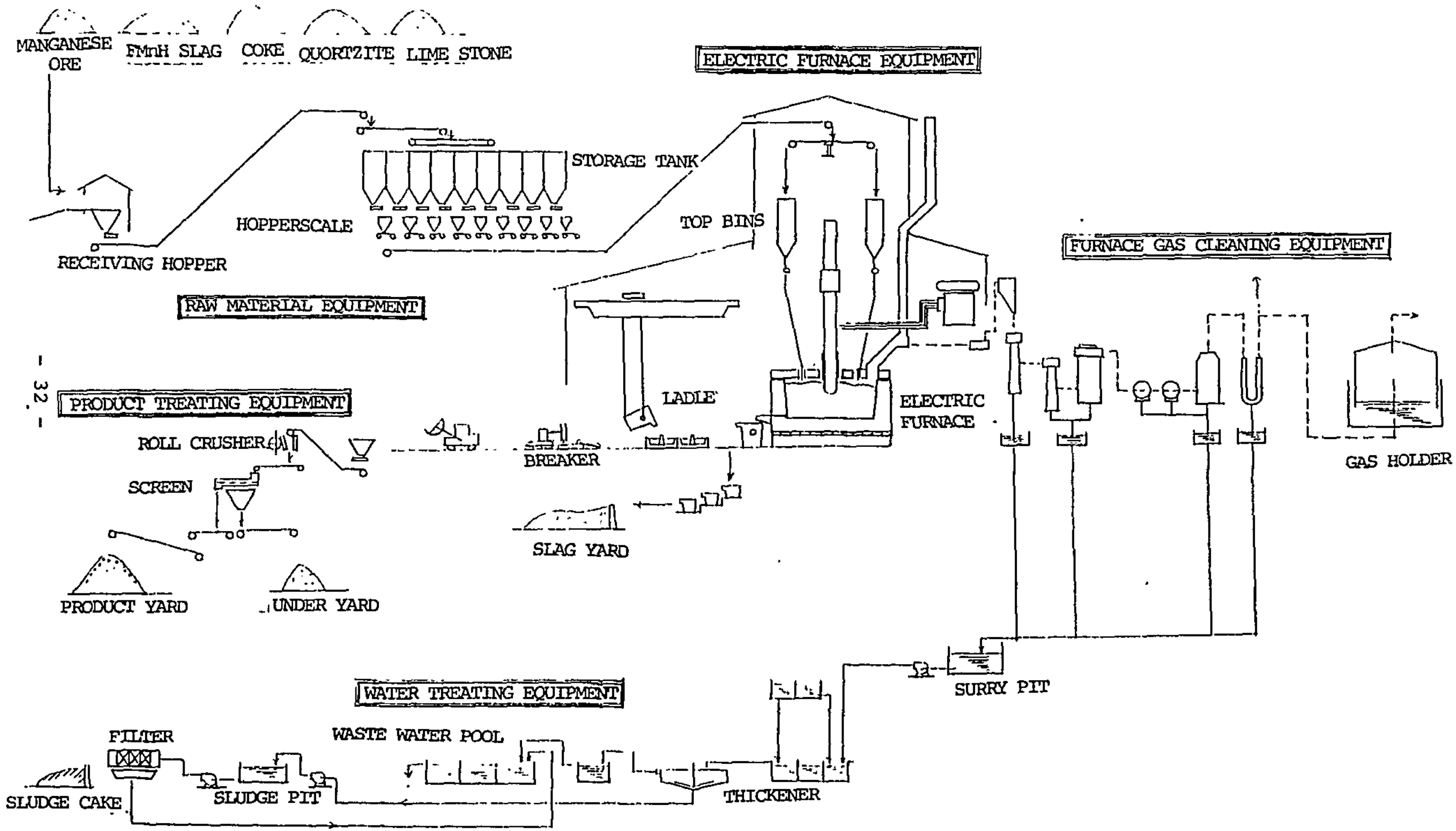
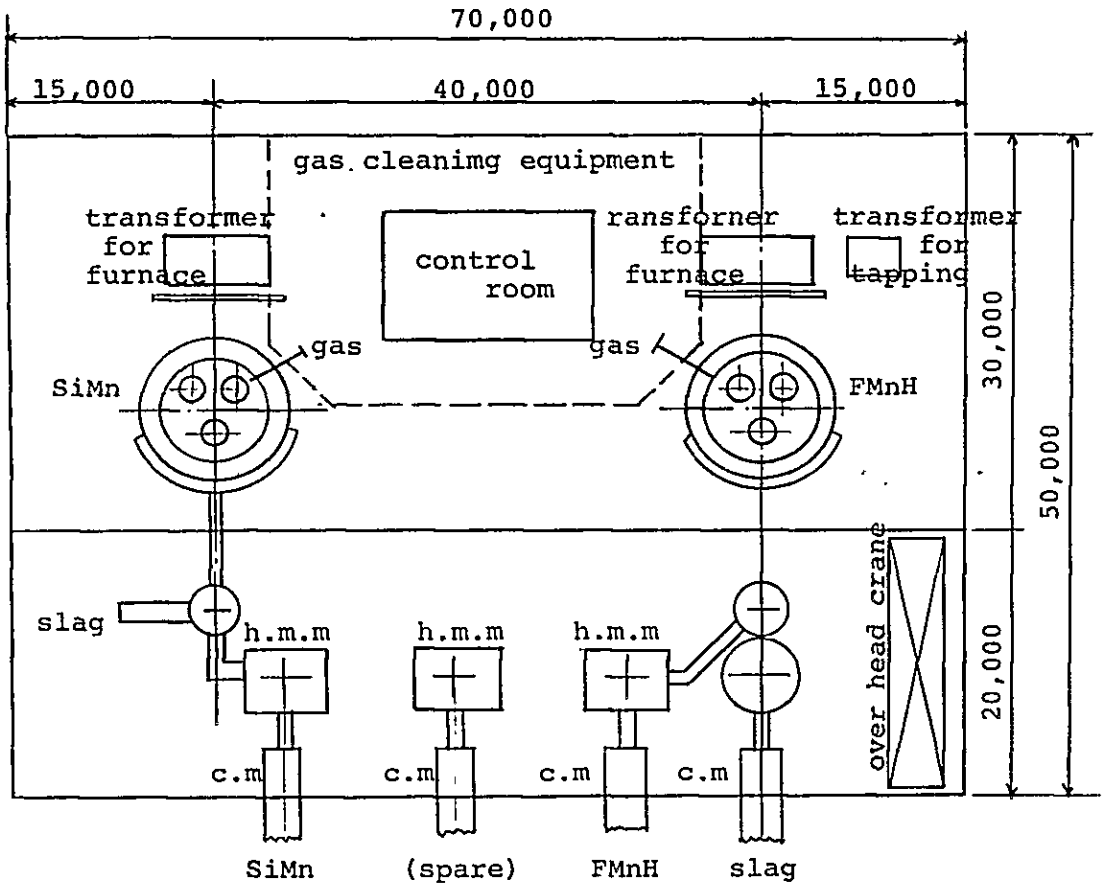


Fig Ⅲ - 7 - 2 LECTRIC FURNACE LAY OUT



h.m.m = hot metal mixing

c.m = casting machine

(memo)

1. It is used the over head crane in time of repair , usually not used.

2. Control room is prepared for two furnace.

3. Gas cleaning equipment is prepared every furnace in the building, in case of small building, is prepared in the open air.

IV. Ferrosilicon

1. General Description of Ferrosilicon

Ferrosilicon is an alloy of iron and silicon. It generally consists of 15 to 80% silicon, 1 to 2% aluminum and the remainder of iron. Ferrosilicon has one weak point, i.e., it may disintegrate depending on aluminum and phosphorus content of the product. Nowadays, however, this problem is avoidable through careful study after the raw materials and casting method used.

Ferrosilicon is used as a deoxidant, additive for addition of Si, heat insulator to maintain the temperature of the molten metal, innoculation agent, reducing agent for thermite, etc. Low aluminum ferrosilicon is used for production of silicon steel.

As mentioned above, alloys of the silicon family produced in the form of ferrosilicon cover practically every content of silicon, but this discussion is set forth based on 75% ferrosilicon, which is produced in the largest quantities and is the most popular type.

2. Market and Price Trends for Ferrosilicon

Like for other ferroalloys, production of ferrosilicon reached its peak in 1974 and after dropped to levels of the order of 2.6 million to 2.8 million due to stagnation of iron and steel manufacture in the world.

In terms of production per country, the U.S. has the largest output among the principal iron and steel producing countries of the world with approximately 28% of the world total followed by the Soviet Union, Japan and Norway, the latter country favored with cheap cost of electricity.

However, the production of ferrosilicon consumes large quantities of electrical energy and the percentage of electricity cost in the production cost is particularly high, therefore, the rise in the price of petroleum after the oil shock has had a pronounced effect on this industry, particularly in Japan, which relies on thermal power plants for generation of most of its electrical energy. The ferrosilicon industry in Japan has no margin of profit and currently production has declined to half that of the 1974 level.

The same tendency for a decline in production is taking place in the U.S. and the Europe.

On the other hand, countries favoured with cheap electricity thanks to use of hydroelectric power plants, e.g., Norway, Brazil, Canada, etc., are expanding production of ferrosilicon based on exports.

Countries favoured with low cost electricity are planning further reinforcement of production facilities and therefore the tendency of change in the structure of the international market for ferrosilicon is expected to become further pronounced.

The prices for ferrosilicon negotiated in the world market are extremely variable, due to factors such as supply and demand situation variations in exchange rates, etc., and therefore there is no unified price. The marketing prices in Japan and the U.S., the largest importers of ferrosilicon in the world, are presented in the table below for reference and to give an idea of recent price trends.

Table IV-2 Evolution of ferrosilicon import prices in Japan and the U.S.

(Unit: US$/ton)

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Japan	216	251	474	586	454	492	501	632	753
U.S.	235	233	532	595	426	407	392	528	471

NOTE: Products with 70 to 80% silicon content in the U.S. and products with more than 40% silicon content in Japan.

Also in the case of ferrosilicon, a sharp rise in market prices took place after the oil shock of 1974 but in the principal iron and steel producing countries of Japan, the U.S. and Europe, which rely on thermoelectric power stations for generation of electricity, it was not sufficient to absorb the rise in production costs due to increased petroleum prices. Profitability of ferrosilicon makers of these countries is poor, therefore, and they have been forced to either cut down the volume of production or to stop operation altogether.

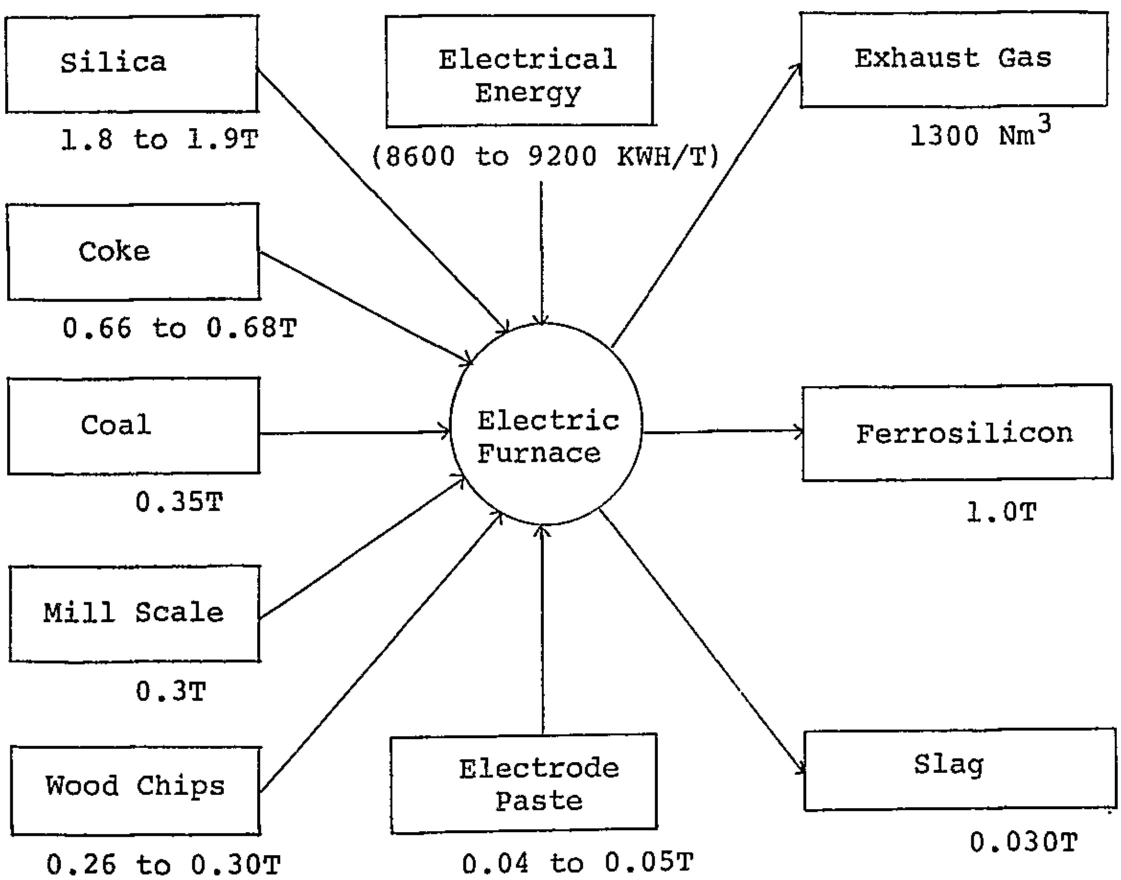
On the other hand, countries favored with cheap electricity are planning increases in production so the price of this product is expected to remain stable for the time being.

3. Method of Ferrosilicon Production

The principal raw material in ferrosilicon is silica, and this alloy is produced in electric furnaces using ingredients such as coal, coke, wood chips, mill scale or iron ore as the Fe source and electrode paste.

An important peculiarity of the process for production of ferrosilicon is the fact that it generates practically no slag, unlike in the case of other ferroalloys.

The approximate quantities of raw materials, electrode and electrical energy required to turn out one ton of ferrosilicon are indicated below.



4. Raw Materials for Production of Ferrosilicon

4-1 Silica

Silica, the principal raw material for production of ferrosilicon, is the mineral most commonly found in the crust of the earth. It is found everywhere in the world, and except in the case of applications requiring material of very special quality, silica of domestic origin is used throughout the world.

As for composition, it is best to use silica with few impurities and containing 98% or more SiO_2. The presence of impurities is not desirable from the point of view of the silicon reduction mechanism because it lowers the melting point of the silica itself.

Further, silica used as the raw material for production of ferrosilicon must be strong to heat shock in order to prevent decomposition into particles in the furnace. It is appropriate to use silica sized at 20 to 40 mm.

4-2 Coal

Coal is a raw material indispensable for smooth ferrosilicon refining.

In this case coal is must have a high coking capacity. The recommended size is of the order of 5 to 25 mm.

Coal is produced abundantly throughout the world, and is readily available. In this project it is assumed that coal is domestically available in Paraguay.

4-3 Coke

It is recommended that coke with approximately 85% of fixed carbon and sulfur content not exceeding 0.5% because sizes of 10 to 25 mm are approximate in this case.

4-4 Iron Source

(1) Mill scale is generally used as the iron source for production of ferrosilicon but can be replaced by iron ore.

4-5 Wood Chips

Wood chips are a low grade material used as a reducer but indispensable for controlling the bulk density of the raw materials. Sizes of 20 to 50 mm are appropriate for this application.

4-6 Electrode Paste

Generally speaking, electrodes of electric furnaces are the self-baking type (Soderberg electrode) and, therefore, the consumed portion of the electrode should be replenished by adding paste. The principal suppliers of self-baking type electrode paste are Japan, Norway, the U.S., Brazil, etc., and it can easily be imported at the international market price.

5. Ferrosilicon Production Project in Paraguay

5-1 Plant Site

The criteria for selection of the site for construction of the ferrosilicon plant are the same as those for the ferromanganese project. In the ferrosilicon project it is assumed that silica is available from domestic sources but in view of convenience for export of the product, availability of consolidated infrastructure, etc., it seems best to locate the plant in the outskirts of Assuncion for the time being.

5-2 Sources and Prices of Raw Materials

In the case of ferrosilicon it is assumed that silica will be supplied from domestic sources. It should be available at a plant CIF (including mining and transportation costs) not exceeding approximately US$26/MT, which is the plant CIF price of ferrosilicon makers of other countries. As for coke, it is recommended that this be imported from the USA in order to ensure stable supply. As for coal, this study assumes the use of products supplied from domestic sources.

For the electrode paste, import from Brazil, the nearest source, is recommended.

The expected plant site CIF prices of the raw materials for production of ferrosilicon are as follows:

Table IV-5 Plant Site CIF Prices of Raw Materials for Production of Ferrosilicon

(Unit: US$/ton)

	Source	Exporting Country FOB	Ocean Freight	Fluvial Freight	Other Expenses	Total Plant Site CIF
Silica	Domestic					26.00
Coke	U.S.	76.00	28.00	35.00	8.90	147.90
Coal	Domestic					100.00
Scale	Domestic					40.00
Wood Chips	Domestic					20.00
Electrode Paste	Brazil	450.00	30.00	35.00	19.00	534.00

5-3 Production Scale of the Plant

As for the ferrosilicon production scale, furnaces with the largest annual production capacity in the world are of the order of 40,000 tons in view of the same restrictive conditions applicable to ferromanganese. Furnaces with annual production capacities of the 20,000 ton class seem to offer the best balance between ease of operation and economy.

On the other hand, in the case of ferrosilicon production in Paraguay, it is recommended that the project start with an annual capacity of the 6,000 ton class, which is adequate to learn operation technique and is at the same the minimum scale from the economical point of view. This is termed Case A. A furnace with an annual production capacity of 20,000 tons, the average economical scale, is studied as Case B. The study is set forth assuming the two model plants with the capacities mentioned above.

6. Estimation of Model Plant Construction Cost

The cost of construction of the model plant is estimated on the same premises as in the case of the ferromanganese project.

The estimated costs for construction of the principal facilities of the ferrosilicon plant are indicated in Table IV-6.

7. Expected Operation Conditions of the Model Plant

The operating conditions for the plant scales assumed in Case A and Case B are estimated taking into consideration empirical data related to operation accumulated so far, are indicated in the Table IV-7.

The flow sheet of the ferrosilicon plant is shown in Figure IV-7.

Table IV-6 Costs for Construction of the Principal Facilities of the Ferrosilicon Plant

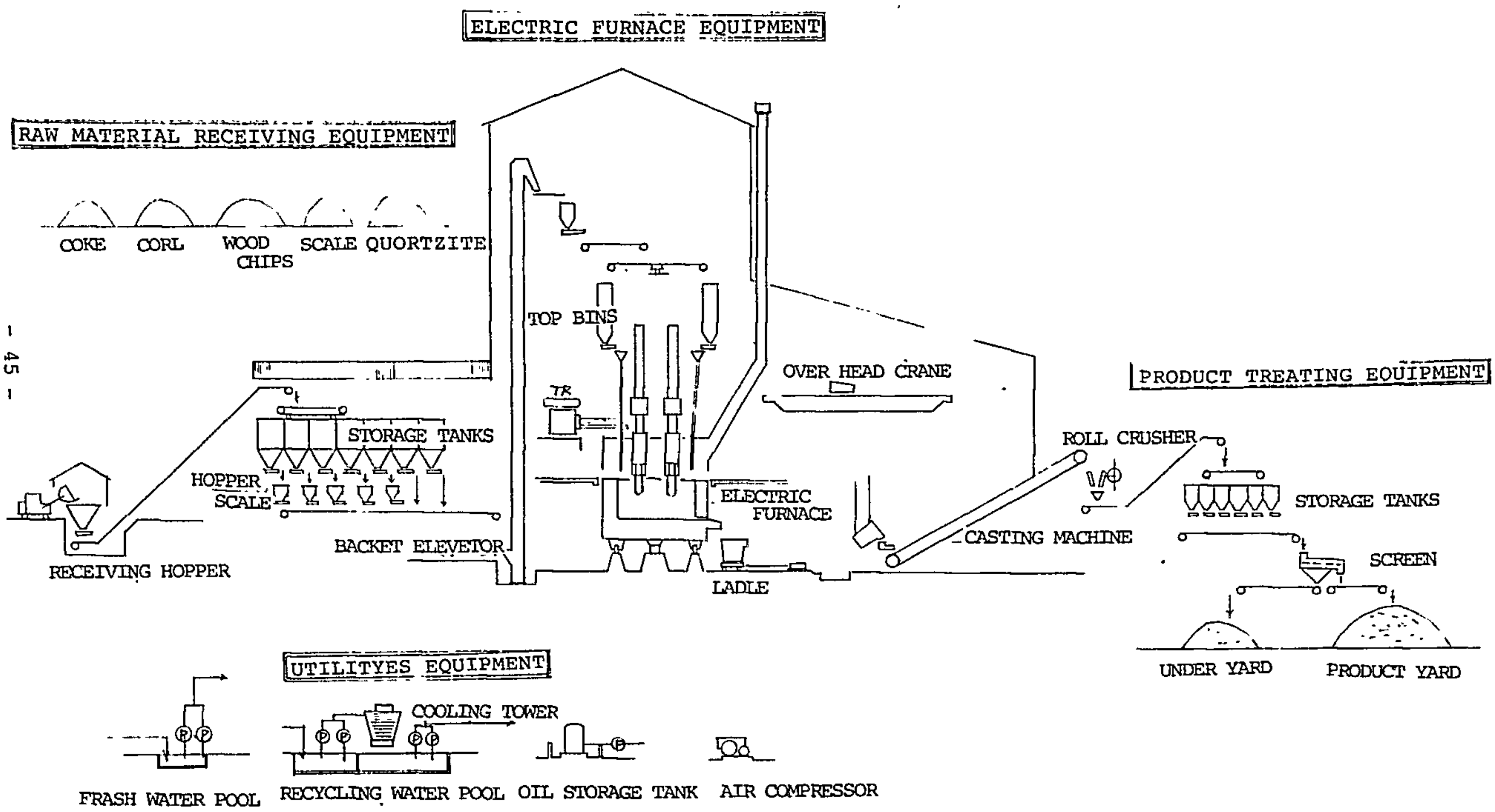
(Unit: US$1,000)

	CASE A	CASE B
Total Construction Cost of the Plant	20,000	36,000
Raw material facilities	1,700	3,060
Electric furnaces	6,260	11,300
Finished product handling facilities	660	1,200
Substation facilities	1,160	2,000
Utility facilities	2,420	4,360
Sheds	6,200	11,200
Others	1,600	2,880

Table IV-7 Operation Conditions of the Ferrosilicon Plant

	Unit	Case A	Case B
Transformer Capacity	KVA	9,000	32,000
Transformer Power Factor	%	82	72
Average Load	KW	7,000	23,000
Electrical Energy Consumption	MWH/Y	58,800	184,800
Basic Electrical Energy Unit	KWH/T	9,000	8,700
Production of Ferrosilicon	T/Y	6,500	21,200
Product Yield	%	93	93
Product Quantity	T/Y	6,000	19,700
Land for Construction of the Plant	m^2	55,000	95,000
Cooling Water Quantity	T/H	150	600
Personnel Requirement for Operation	Persons	(38)	(49)
Management staff	"	1	1
Engineers	"	1	1
Technicians	"	5	6
Workers	"	31	41
Basic Raw Material Unit	KG/T	3,467	3,567
Silica	"	1,846	1,910
Scale	"	300	300
Coke	"	663	678
Coal	"	353	359
Wood Chips	"	260	270
Electrode Paste	"	45	45
Number of Days of Operation	Day/ Year	350	350

Fig IV - 7 FeSi FLOW SHEET



V. Ferrochromium

1. General Description of Ferrochromium

Ferrochromium is an alloy of chromium and iron and is classified as high carbon, medium carbon or low carbon according to the carbon content. The component materials are variable within the range of chromium 55 to 70%, carbon 0.1 to 9.0%, silicon 1.0 to 8.0% and the remainder iron. High carbon ferrochromium is the most popularly used type.

High carbon ferrochromium is the object of discussion in this report, and therefore, the term "ferrochromium" shall be used to refer hereinafter to high carbon ferrochromium. Ferrochromium is a typical additive for special steel, particularly stainless steel, and is the most popularly used of this class of products. Japan has the largest production of stainless steel in the free world. Accordingly, the consumption of ferrochromium in Japan is the largest.

The quantity of ferrochromium used to produce one ton of special steel, including stainless steel, is of the order of 29 to 34 kg.

2. Market and Price Trends for Ferrochromium

The world production of ferrochromium reached its peak in 1974 but after become stagnant at levels of the order of 1.8 million to 1.9 million ton due to recession in the iron and steel industry as in the case of other ferroalloys like ferromanganese, ferrosilicon, etc.

In terms of production per country, South Africa is the largest producer. Favoured with abundant chromium ore deposits and cheap electricity, this country is expanding its exports to the principal iron and steel producing countries, and nowadays it generates approximately 26% of the world production of ferrochromium. Next ranked are Japan, the Soviet Union, the U.S. and Sweden.

Production of ferrochromium in Japan, the U.S. and Europ, which are the principal producers of iron and steel and used to be the principal producers of ferrochromium, is declining gradually, however, because they rely on imports of chromium ore, and are confronted by exports from countries favoured by chromium ore resources and cheap electricity, in addition to the worsening profitability of ferrochromium business due to the rise in prices of electricity after the oil shock.

On the other hand, countries which have both chromium ore and cheap electricity like South Africa and Brazil and countries favoured by cheap electricity like Norway, etc., are expanding production based on increased exports. As a result, the rise in prices of electricity generated in thermoelectric power plants caused by the rise in the price of petroleum after the oil shock of 1974 and the rise in the chromium ore price influenced by the former are bringing about a substantial change in the distribution of producers of ferrochromium in the world. It is expected that from now on this tendency will become further pronounced and Japan, the U.S. and the principal iron and steel producing countries of Europe will be forced to increase their imports of ferrochromium from countries favored with chromium ore and cheap electricity.

The ferrochromium transaction price on the world market is subject to considerable fluctuation depending on factors such as demand and supply, fluctuations in exchange rates, etc. The evolution of the ferrochromium import price in the U.S., which is one of the most important importers of this product, is indicated in the table below.

Table V-2 Evolution of Ferrochromium Import Price in the U.S.

(Unit: ¢/LB of Cr)

	1972	1973	1974	1975	1976	1977	1978	1979	1980
U.S.	20	20	50	56	42	35	38	46	46

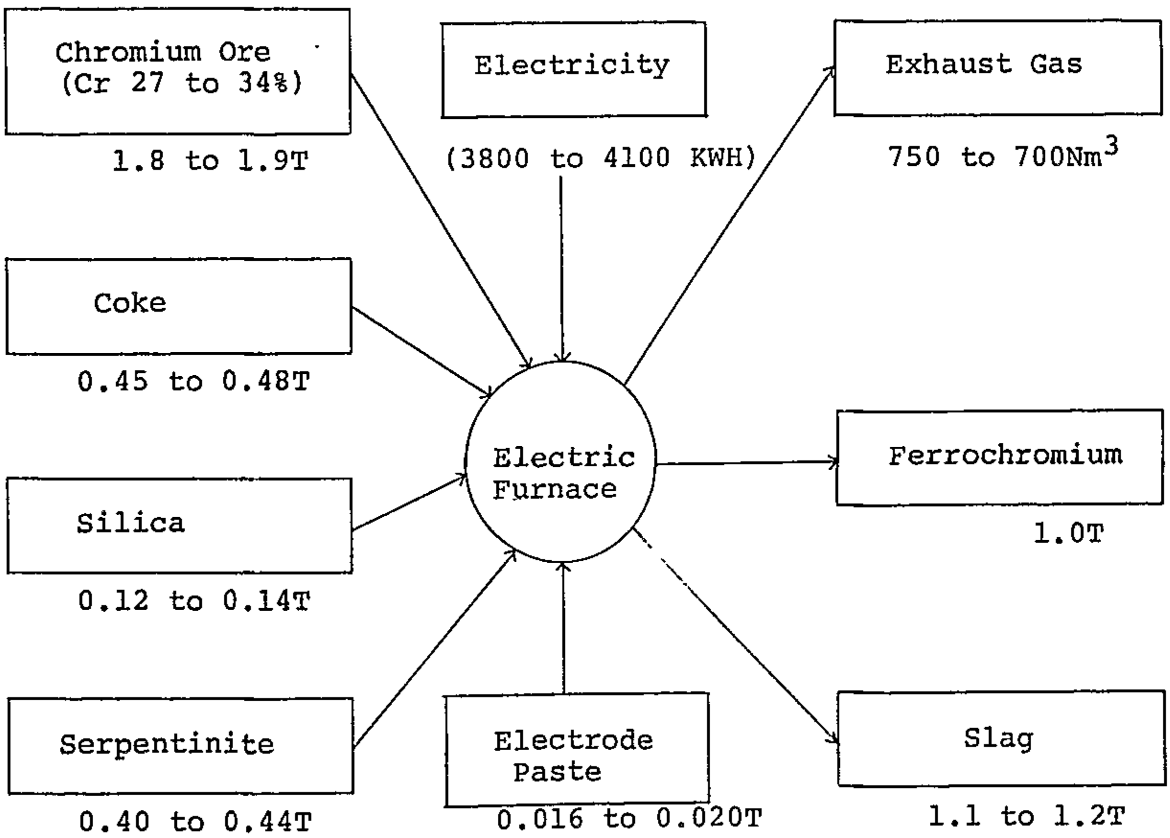
The international market price of ferrochromium was approximately 20¢/LB of Cr until 1973. After the oil shock of 1974 it soared temporarily, reaching levels of the order of 70 to 80¢/Lb of Cr after which it declined, dropping to approximately 30¢/Lb of Cr in 1977 and in the U.S. and European countries reaching the point of where imports were restricted to protect domestic ferrochromium makers.

After this, the market price recovered to a level of 44 to 48¢/Lb of Cr. Currently the price seems to have stabilized.

Even at this price level, however, it is impossible for the U.S., Japan and European countries to absorb rises in electricity and chromium ore prices which occurred after the oil chock. They are faced with imports of cheap products turned out by newcomers in the industry and the business is running with no profit margin. It is expected that production of ferrochromium in South Africa, Brazil, Sweden, etc. will increase further and, therefore, it is probable that the price of this ferroalloy will remain stagnant on the international market for the time being.

3. Method of Production of Ferrochromium

Ferrochromium is produced in electric furnaces with Cr ore with 27 to 34% Cr as the principal raw material. Secondary materials include coke, silica, serpentinite (peridotite) and electrode paste.



The approximate quantities of raw materials and electrical energy required to turn out one ton of ferrochromium are indicated above. Slag generated in this process is either discarded or crushed and used as paving aggregate.

4. Raw Materials for Production of Ferrochromium

4-1 Chromium Ore

Confirmed deposits of chromium ore total 1.8 billion tons, and total deposits, including estimated sources, are of the order of 4.7 billion ton.

Chromium ore is distributed very unevenly around the world, as in the case of manganese ore, and South Africa, Zimbabwe and the Soviet Union have 97% of total world deposits.

In terms of production of chromium ore, South Africa and the Soviet Union represent the absolute majority, followed by Albania, Turkey and Zimbabwe. Most of the chromium ores produced contain 26 to 34% of Cr and the Cr/Fe ratio is of the order of 1.1 to 3.4.

The prices of chromium ore on the world market rose considerably after the oil shock of 1974, as in the case of other ores for production of ferroalloys. The evolution of the import price (FOB) in Japan, is one of the major importers of chromium ore, shows that until 1973, immediately before the oil shock, it was of the order of 16 to 20 dollars but after 1974 rose considerably. Today it is of the order of 45 to 50 dollars.