Table 4 - 5 - (c) Iron Ore Imports by EC 7 Countries & U.S.A.

(Unit: 1,000 wet M.T.)

		1973			1974			1975			1976			1977			1978		
EC 7 Total	Brazil	21,174	(2)	15.2	25,848	(2)	17.0	23,555	(1)	19.3	26,594	(1)	20.5	23,064	(1)	20.2	27,007	(1)	22.8
	Sweden	27,971	(1)	20.1	27,949	(1)	18.4	16,227	(2)	13.3	16,408	(2)	12.6	14,591	(2)	12.8	14,984	(2)	12.7
	Liberia	18,638	(3)	13.4	19,894	(3)	13.1	13,524	(5)	11.1	14,184	(6)	10.9	14,216	(3)	12.4	14,597	(3)	12.3
	Australia	8,649	(6)	6.2	11,647	(6)	7.7	13,994	(4)	11.5	15,360	(3)	11.8	12,736	(4)	11.1	12,599	(4)	10.6
	France	17,715	(4)	12.7	18,263	(4)	12.0	15,698	(3)	12.9	15,349	(4)	11.8	12,095	(5)	10.6	10,715	(5)	9.1
	Canada	12,070	(5)	8.7	11,908	(5)	7.8	10,694	(6)	8.8	14,602	(5)	11.2	11,910	(6)	10.4	10,000	(6)	8.5
	Mauritania	7,468	(7)	5.4	8,320	(7)	5.5	6,981	(7)	5.7	6,924	(7)	5.3	6,869	(7)	6.0	5,323	(7)	4.5
	Other countries	25,673		18.3	28,047		18.5	20,839		17.4	20,560		15.9	18,951		16.5	23,082		19.5
	Total	139,358		100	151,876		100	121,812		100	129,981		100	114,432		100	118,307		100
U. S. A.	Canada	21,975	(1)	49.9	20,018	(1)	41.0	19,418	(1)	40.9	25,362	(1)	56.2	25,689	(1)	66.7	19,545	(1)	57.2
	Venezuela	13,323	(2)	30.3	15,625	(2)	32.0	13,347	(2)	28.1	9,146	(2)	20.3	6,278	(2)	16.3	6,180	(2)	18.1
	Brazil	3,234	(3)	7.3	6,678	(3)	13.7	7,647	(3)	16.1	5,475	(3)	12.1	2,230	(3)	5.8	4,043	(3)	11.8
	Liberia	2,778	(4)	6.3	2,773	(4)	5.7	2,536	(4)	5.3	2,187	(4)	4.9	1,820	(4)	4.7	2,205	(4)	6.5
	Peru	1,525	(5)	3.5	1,839	(5)	3.8	1,576	(5)	3.3	727	(5)	1.6	1,037	(5)	2.7	831	(5)	2.4
	Chile	208	(8)	0.5	301	(8)	0.6	946	(6)	2.0	617	(7)	1.4	575	(6)	1.5	397	(6)	1.2
	Norway	-			-			54	(10)	0.1	153	(10)	0.3	-			307	(7)	0.9
	Australia *	472	(6)	1.1	697	(6)	1.4	815	(7)	1.7	627	(6)	1.4	310	(7)	0.8	268	(8)	0.8
	Sweden	278	(7)	0.6	340	(7)	0.7	185	(8)	0.4	449	(8)	1.0	156	(9)	0.4	260	(9)	0.8
	S. Africa	-			1	(9)	-	131	(9)	0.3	164	(9)	0.4	254	(8)	0.7	95	(10)	0.3
	Other countries	234		0.5	528		1.1	835		1.8	194		0.4	164		0.4	25		-
	Total	44,027		100	48,800		100	47,490		100	45,101		100	38,513		100	34,156		100

* '73 - '75 including N.Z.

Source: World Trade Statistics

Table 4 - 5 - (d) Iron Ore Imports by Japan

(Unit: 1,000 wet M.T.)

		1973			1974			1975			1976			1977			1978		
Japan	Australia *	66,227	(1)	49.2	70,290	(1)	49.6	65,756	(1)	49.9	64,094	(1)	47.9	63,096	(1)	47.6	52,626	(1)	45.9
	Brazil	12,821	(3)	9.5	19,523	(2)	14.0	23,460	(2)	17.8	25,380	(2)	19.0	23,743	(2)	17.9	20,815	(2)	18.1
	India	19,083	(2)	14.2	17,333	(3)	12.2	16,790	(3)	12.8	17,593	(3)	13.2	17,878	(3)	13.5	14,355	(3)	12.5
	Chile	8,493	(4)	6.3	8,571	(4)	6.0	8,057	(4)	6.1	7,604	(4)	5.7	6,718	(4)	5.1	6,106	(4)	5.3
	S. Africa	3,080	(6)	2.3	2,214	(6)	1.5	1,632	(7)	1.2	2,414	(6)	1.8	5,556	(5)	4.2	5,831	(5)	5.1
	Philippine	2,312	(8)	1.7	1,636	(9)	1.2	1,513	(8)	1.2	885	(10)	0.7	2,042	(8)	1.5	3,620	(6)	3.2
	New Zealand	-			-			-			2,336	(7)	1.7	2,546	(7)	1.9	3,332	(7)	2.9
	Peru	6,133	(5)	4.6	5,960	(5)	4.1	2,732	(5)	2.1	2,477	(5)	1.8	2,976	(6)	2.2	2,610	(8)	2.3
	Swaziland	1,671	(9)	1.2	1,925	(8)	1.3	1,725	(6)	1.3	1,518	(8)	1.1	1,039	(10)	0.8	779	(9)	0.7
	Mauritania	1,332	(10)	1.0	2,187	(7)	1.5	975	(9)	0.7	1,342	(9)	1.0	1,108	(9)	0.8	519	(10)	0.5
	Liberia	2,456	(7)	1.8	1,315	(10)	0.9	528	(10)	0.4	746	(11)	0.6	382	(11)	0.3	113	(11)	0.1
	Other countries	11,068		8.2	10,862		7.7	8,489		6.5	7,338		5.5	5,487		4.2	3,939		3.4
	Total	134,676		100	141,816		100	131,657		100	133,727		100	132,571		100	114,645		100

* '73 - '75 including N.Z.

Source: World Trade Statistics

Table 4 - 5 - (e) Iron Ore Imports by COMECON

(Unit: 1,000 wet M.T.)

		1973			1974			1975			1976			1977			1978
Poland	U.S.S.R.	11,096	(1)	81.2	11,379	(1)	72.9	11,106	(1)	72.0	11,831	(1)	74.7	11,761	(1)	69.4	N.A.
	Sweden	1,427	(2)	10.4	2,528	(2)	16.2	2,250	(2)	14.6	2,305	(2)	14.6	2,890	(2)	17.1	
	Brazil	462	(3)	3.4	712	(3)	4.6	810	(3)	5.3	1,110	(3)	7.0	1,525	(3)	9.0	
	Norway	302	(5)	2.2	307	(5)	2.0	490	(5)	3.2	245	(5)	1.5	307	(4)	1.9	
	India	380	(4)	2.8	395	(4)	2.5	578	(4)	3.7	311	(4)	2.0	286	(5)	1.7	
	Venezuela	-			-			-			26	(6)		164	(6)		
	Other countries	-			288			189			27			174			
	Total	13,667		100	15,609		100	15,423		100	15,829		100	16,943		100	
Czechoslovakia	U.S.S.R.	11,557	(1)	87.5	11,825	(1)	85.1	12,222	(1)	82.6	12,734	(1)	82.7	13,329	(1)	83.5	N.A.
	Brazil	404	(3)	3.1	474	(4)	3.4	659	(2)	4.4	1,039	(2)	6.7	896	(2)	5.6	
	Sweden	401	(4)	3.0	547	(3)	3.9	419	(5)	2.8	408	(4)	2.6	521	(3)	3.3	
	India	691	(2)	5.2	624	(2)	4.5	477	(4)	3.2	430	(3)	2.8	446	(4)	2.8	
	Algeria	121	(5)	0.9	244	(5)	1.8	248	(6)	1.7	99	(6)	0.6	88	(5)	0.6	
	Liberia	-			142	(6)	1.0	496	(3)	3.4	194	(5)	1.3	N.A.			
	Other countries	37			39			281			506			N.A.			
	Total	13,211		100	13,895		100	14,802		100	15,410		100	15,970		100	
Rumania	U.S.S.R.	(*5,801)	(1)	(61.6)	(*5,699)	(1)	(57.0)	(*6,288)	(1)	(57.8)	(*5,135)	(1)	(43.7)	(*4,599)	(1)	(37.1)	N.A.
	India	N.A.			N.A.			N.A.			N.A.			N.A.			
	Algeria	N.A.			N.A.			N.A.			N.A.			N.A.			
	Brazil	N.A			N.A.			N.A.			N.A.			N.A.			
	Peru	N.A.			N.A.			N.A.			N.A.			N.A.			
	Liberia	N.A.			N.A.			N.A.			N.A.			N.A.			
	Other countries	N.A.			N.A.			N.A.			N.A.			N.A.			
	Total	9,501		100	10,002		100	10,879		100	11,740		100	12,402		100	

Table 4 - 5 - (f) Iron Ore Imports by COMECON

(Unit: 1,000 wet M.T.)

		1973		1974		1975		1976		1977		1978
Hungary	U.S.S.R.	3,623		3,910		4,011		4,126		4,112		
	Other countries	89		195		250		108		169		N.A.
	Total	3,712	100	4,105	100	4,261	100	4,234	100	4,281	100	
East Germany	U.S.S.R.	(*1,775)		(*1,802)	(100)	(*2,118)	100	(*1,926)	(93.8)	(*2,012)	(88.8)	
	India	-		-		-		(*127)		(*255)		
	Other countries	-		-		-		-		-		N.A.
	Total	1,775	100	1,802	(100)	2,118	100	2,053	100	2,267	100	
Bulgaria	U.S.S.R.	(*1,602)	(95.8)	(*1,962)	(100)	(*1,679)	(87.5)	(*1,638)	(68.4)	(*1,682)	(89.2)	
	Other countries											N.A.
	Total	1,672	100	1,638	100	1,918		2,396		1,886		
Yugoslavia	India	(*390)	100	(*430)	(100)	(*598)	(100)	(*482)	(100)	(*516)	(100)	
	Other countries	-		-		-		-		-		
	Total	390	100	430	100	598	100	482	100	516	100	

Source: World Trade Statistics

CHAPTER 5

RAW MATERIALS, OPERATION, AND PRODUCTION PLANS

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5.1 Mine and Iron Ore

5.1.1 Outline

For sinter production, it is desirable for the plant to have a stable supply of uniform quality of iron ore over a long period of time. The iron ore should not only be of a suitable quality for sinter production but also be mined and beneficiated in a technically and economically acceptable manner.

5.1.2 *Location and History*

The Marcona mine owned by Hierro-Peru is located in Marcona, Nazca, Ica, Peru at latitude 15°30'S and longitude 75°W, and is 400 km south-southest of the capital city of Lima. A beneficiation plant, pelletizing plants, and a loading port are located in a coastal city, San Nicolas, about 15 km west-southwest of the mine.

The Marcona iron ore deposit was discovered in the early twentieth century. Santa Corporation, established by the Peruvian Government, obtained the mining rights in 1943 and began prospecting in the area.

In 1952, Santa Corporation concluded an exploration agreement with Utah Construction Co., and Utah Construction Co. organized Marcona Mining Company jointly with Cypress Mining Corp. The first iron ore shipment was made in 1953. Thereafter, a beneficiation plant was constructed at San Nicolas, and in 1963 and 1966, pelletizing plants were built. In July 1975, Hierro-Peru took over the mine.

5.1.3 Ore Deposits and Iron Ore

The iron ore exists in contact matasomatic deposits which are concordant with the strata of two sedimentary rock formations: the Marcona formation, which is thought to be Lower Carboniferous, and the Middle Jurassic Cerritos formation. The iron ore deposits are scattered within an area approximately 10 km x 15 km. (Fig. 5-1)

The ore deposits are classified into three zones from the surface of the ground downward according to the degree of weathering. (Fig. 5-2)

The upper zone is called the oxidized zone and consists of secondary hematite and small portions of magnetite and geothite.

Below the oxidized zone is the transition zone, which is a mixture of magnetite and hematite ores. Pyrite existing in the lower part of the oxidized zone is transformed to jarosite and botryogen in the upper part.

The primary zone lies at the bottom, and the primary ore in this zone accounts for the major part of the total ore reserves. Thus, the main iron ore material for sintering will be a processed primary ore.

In the primary ore, ore minerals consist mostly of magnetite. Gangue minerals consist mostly of pyrite and actinolite with small contents of quartz, plagioclase, chlorite, chalcopyrite, pyrrhotite, etc.

A considerable portion of pyrrhotite, though scarce in other ore bodies, is included in a part of the Mine-5 ore body. The primary ore with a high pyrrhotite content is called refractory ore.

The sulphur content of iron ore derives mainly from the pyrite, pyrrhotite, and chalcopyrite content. The pyrite and chalcopyrite can be removed relatively easily by magnetic separation if the pyrite and chalcopyrite are liberated, but it is difficult to remove pyrrhotite by magnetic separation. Instead the pyrrhotite must be removed by flotation.

The CaO and MgO contents derive from calcium amphiboles such as actinolite. The Cu content of the ore derives mainly from chalcopyrite. The greater part of these impurities can be removed from the ore by magnetic separation and flotation.

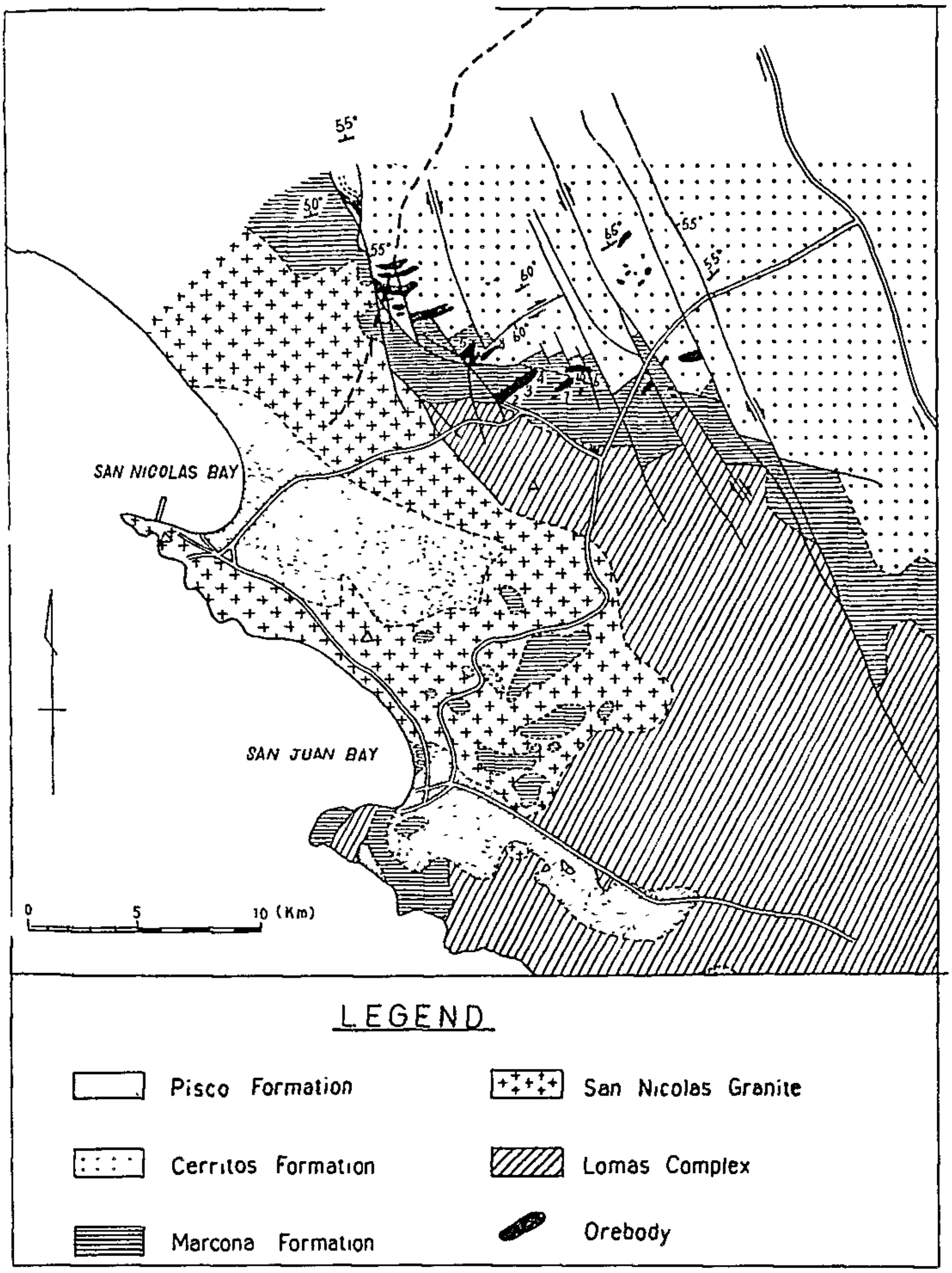


Fig. 5 - 1 Geology of Marcona Mine and Distribution of Orebody

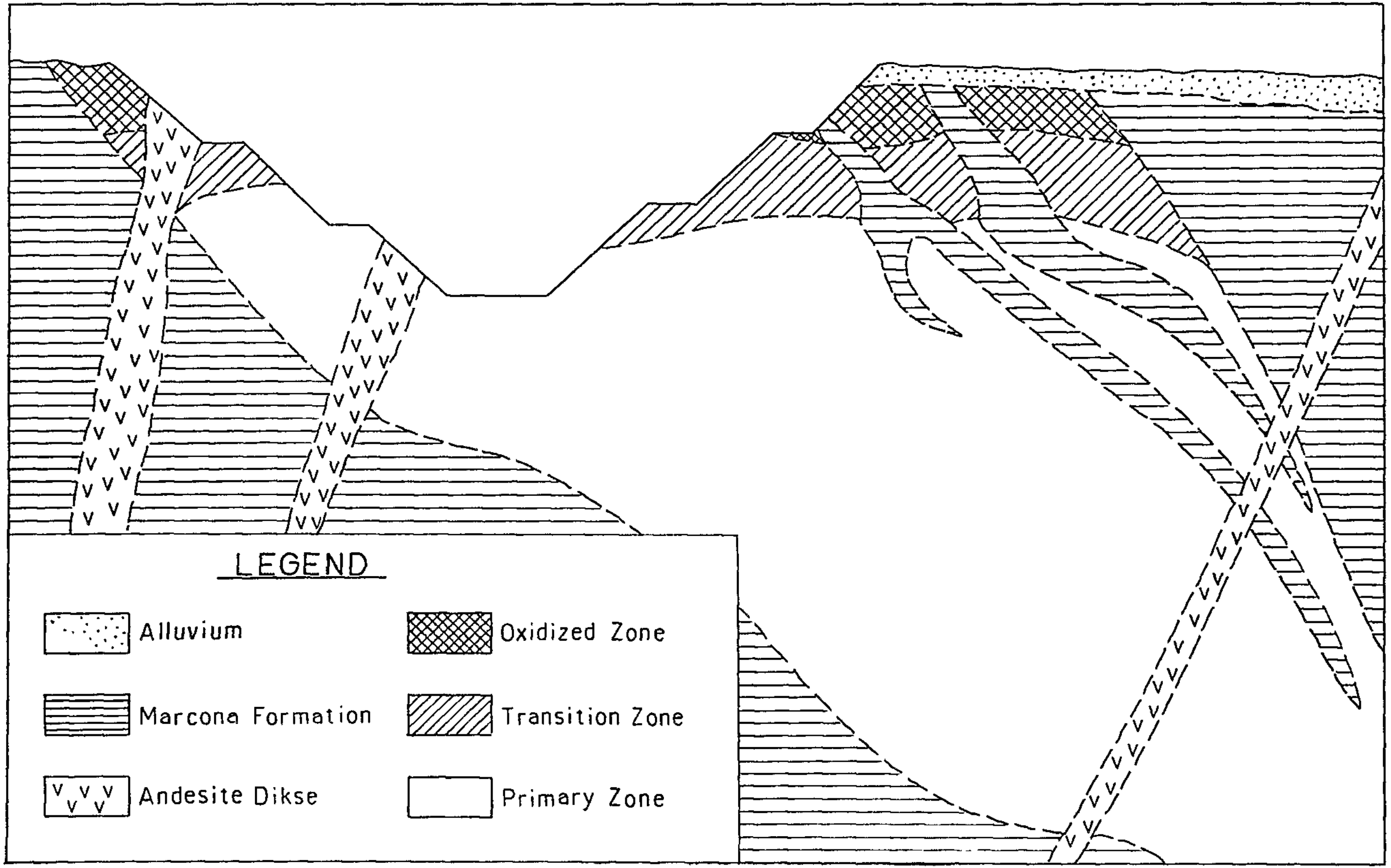


Fig. 5 - 2 Schematic Geological Section

5.1.4 Ore Reserves and Ore Grade

According to data prepared by Hierro-Peru, the ore reserves and ore grades of the Marcona ores are as shown in Tables 5.1 and 5.2.

Table 5.1 Geological reserves (as of December 31, 1978)

($\times 10^3$ t)

	Proven			Probable		
Formation	Oxidized	Transition	Primary	Oxidized	Transition	Primary
Marcona	24,939	61,339	379,111	900	3,930	516,139
Cerritos	60,391	57,883	24,639	29,357	142,702	209,520
Total	85,330	119,222	403,750	30,257	146,632	725,659

(Source. Hierro-Peru)

Table 5.2 Chemical Composition of Proven Reserves

(%)

	Oxidized			Transition			Primary		
Formation	Fe	S	Cu	Fe	S	Cu	Fe	S	Cu
Marcona	54.7	0.31	0.20	53.1	1.76	0.09	57.8	2.93	0.11
Cerritos	49.4	0.41	0.08	44.9	2.14	0.07	46.6	2.42	0.12
Average	50.9	0.38	0.11	49.1	1.94	0.08	57.1	2.90	0.11

(Source. Hierro-Peru)

Table 5-1 shows that a major portion of the ore in the Marcona formation is primary ore.

Table 5-2 shows that the Fe grade of the ore in the Marcona formation is considerably higher than that of the ore in the Cerritos formation.

5.1.5 Mining and Transportation

Among the many ore bodies which exist at Marcona, those being mined at present are Mine 4 and Mine 5. Both transition ore and primary ore are mined at Mine 4, but only primary ores (some including a considerable portion of pyrrhotite) are mined at Mine 5. In 1978, 5,260,000 tons of primary ore and 1,800,000 tons of transition ore were produced, while 15,780,000 tons of waste was removed.

The mines are of the conventional open pit bench cut method with 12 m high benches. The iron ore is drilled with holes 230 ~ 305 mm in diameter and then blasted. By analyzing cuttings from the drilling, the quality of the ore to be mined is controlled. After blasting, the ore is loaded onto 65 ~ 120 ton trucks with 4.6 ~ 11.5 m^3 shovels and transported to the crushing plant at the mine. The ore is then crushed to 100 mm or less and transported to the stockyard.

The curshed ore is transported from the stockyard at the mines to the San Nicolas plant on the coast by a 15 km belt conveyor. The width of the belt is 900 mm, the speed of the belt is 180 m/min., and the transportation capacity is 2,000 t/hr. The largest amount of ore ever handled in a single year was the 13,370,000 tons transported in 1974.

5.1.6 Beneficiation

The crushed iron ore transported from the mine is separated by ore type (transition, primary, etc.) and stockpiled at the crude ore yard. Iron ore reclaimed from the crude ore yard is then crushed to 19 mm or less at the two fine crushing plants and fed into separate beneficiation plant feed bins by ore type. There are eight feed bins, six of which are for primary ore and two for transition ore.

The beneficiation plant has eight processing lines which perform various beneficiation operations depending on the properties of the feed ore and the Fe grade and size of ore product required. The processing capacity of the plant depends on the Fe grade and type of the feed ore and the product type but totals approximately 9 ~ 10 million tons for both sinter feed and pellet feed. The ratio of sinter feed and pellet feed in the product can easily be adjusted. (Figs. 5-3 and 5-4).

Sinter feed is processed in three of the eight beneficiation plant lines· two lines are for primary ore and one for transition ore. To produce sinter feed, the ore is ground in a rod mill and processed using magnetic separation. In the case of primary ore flotation desulphurizing is necessary, and the water is removed from the concentrate by a classifier and a screen. Primary ore concentrate and transition ore concentrate are then blended at the plant to produce a single kind of sinter feed. The record shipment of sinter feed is 6,246,000 tons in 1970. The moisture content of the sinter feed at the sinter feed yard is 8% or less.

Some of the pellet feed is processed at pelletizing plants at San Nicolas. The record production of pellets in one year was 3,893,000 tons in 1974. The pellet feed not processed into pellets is for sale as filter cake or as slurry.

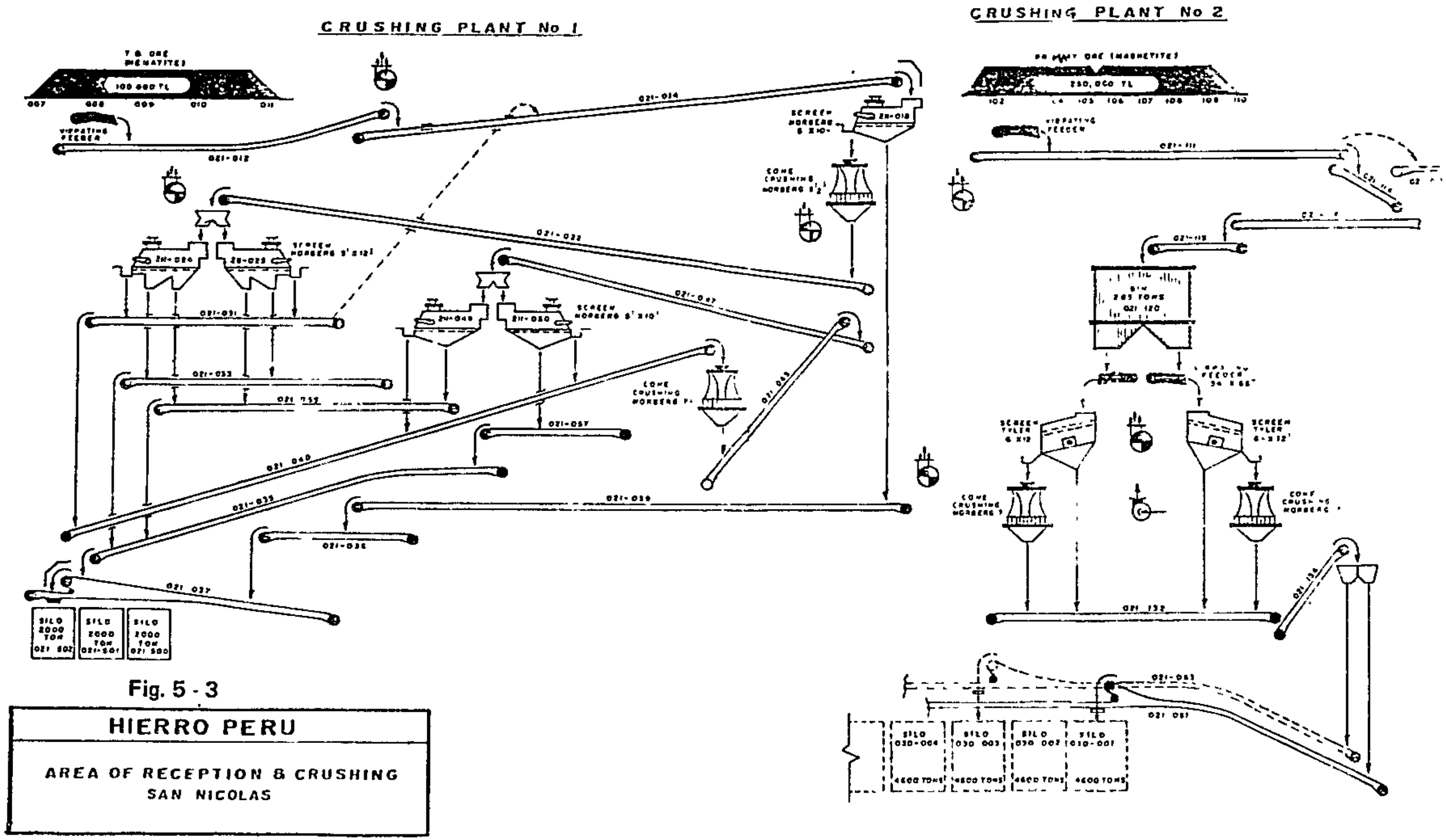


Fig. 5 - 3

HIERRO PERU

AREA OF RECEPTION & CRUSHING
SAN NICOLAS

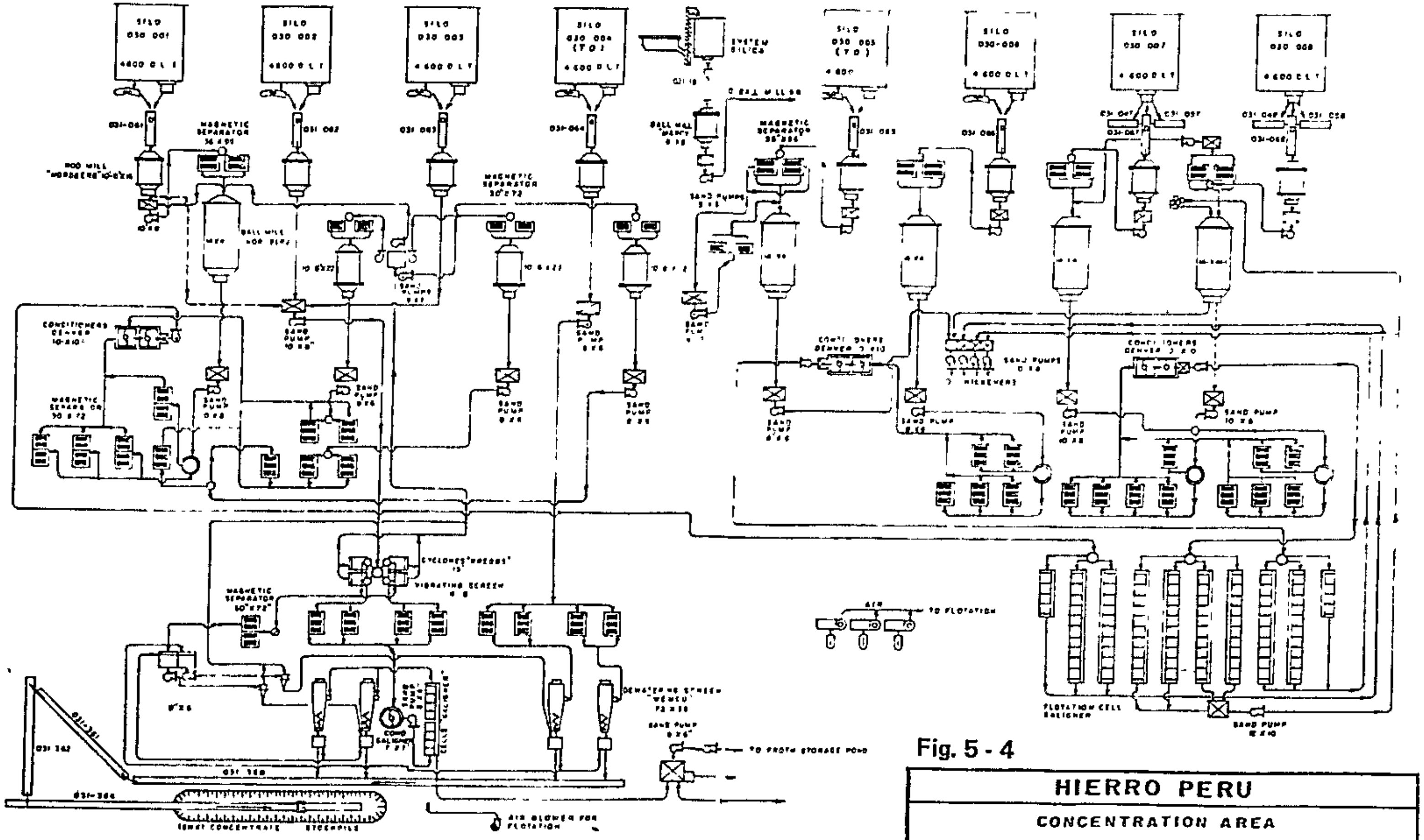


Fig. 5 - 4

HIERRO PERU

CONCENTRATION AREA

MAGNETIC AND FLOTATION FACILITIES

SAN NICOLAS

5.2 Sub-raw Materials

5.2.1 Limestone

(1) Limestone Sources

Limestone is required as a raw material for self-fluxing sinter production. Several sources of CaO, such as deposits of limestone and coquina (clastic calcareous sediments consisting mainly of shells and calcareous algae) exist near the Marcona mine (Fig. 5-5), the coquina deposits, however, are too small to provide a stable supply of CaO. Of the several limestone deposits, the one which has been most throughly investigated is the one adjoining iron ore deposit N-14 on the east.

This study, therefore, is made based on the assumption that the limestone will be supplied from this deposit, but Hierro-Peru will continue to study other limestone deposits.

(2) Limestone Deposit N-14

(a) Location and Ore Deposit

Limestone deposit N-14 is located about 8 km north-northwest of the mine office, about 10 km distant by road.

Limestone exists in a layer of which strike in N 60°E and the dip is 15° ~ 20°N. The length of the deposit along the strike is about 1,700 m, as far as has been determined. The thickness of the deposit is 10 ~ 20 m. To the east the layer splits into two parts, and to the west at a distance of about 20 m, another limestone layer appears. The footwall is calcareous sandstone, and the hanging wall is calcareous sandstone 0 ~ 30 m thick and andesite.

(b) Limestone Reserves and Grade

According to the data prepared by Hierro-Peru, reserves and grades of the limestone are as follows:

Table 5-3 Geological Reserve Limestone N-14 Deposit

Bed	Reserve	Grade (%)						
	(x10³ t)	CaO	MgO	SiO_2	Al_2O_3	Na_2O	K_2O	LOI
South	3,907	44.94	1.22	11.82	2.69	0.285	0.532	36.18
North	377	28.53	3.04	28.13	5.69	0.349	1.127	27.51
Total	4,284	43.50	1.38	13.26	2.95	0.291	0.584	35.42

(Source: Hierro-Peru)

Proven minable reserves at present are limited to 1,010,000 tons (requiring the stripping of 1,901,000 tons of waste), while almost 400,000 tons of limestone will be required annually. Consequently, further exploration of the remaining portion of limestone deposit N-14 and other limestone deposits is urgently required.

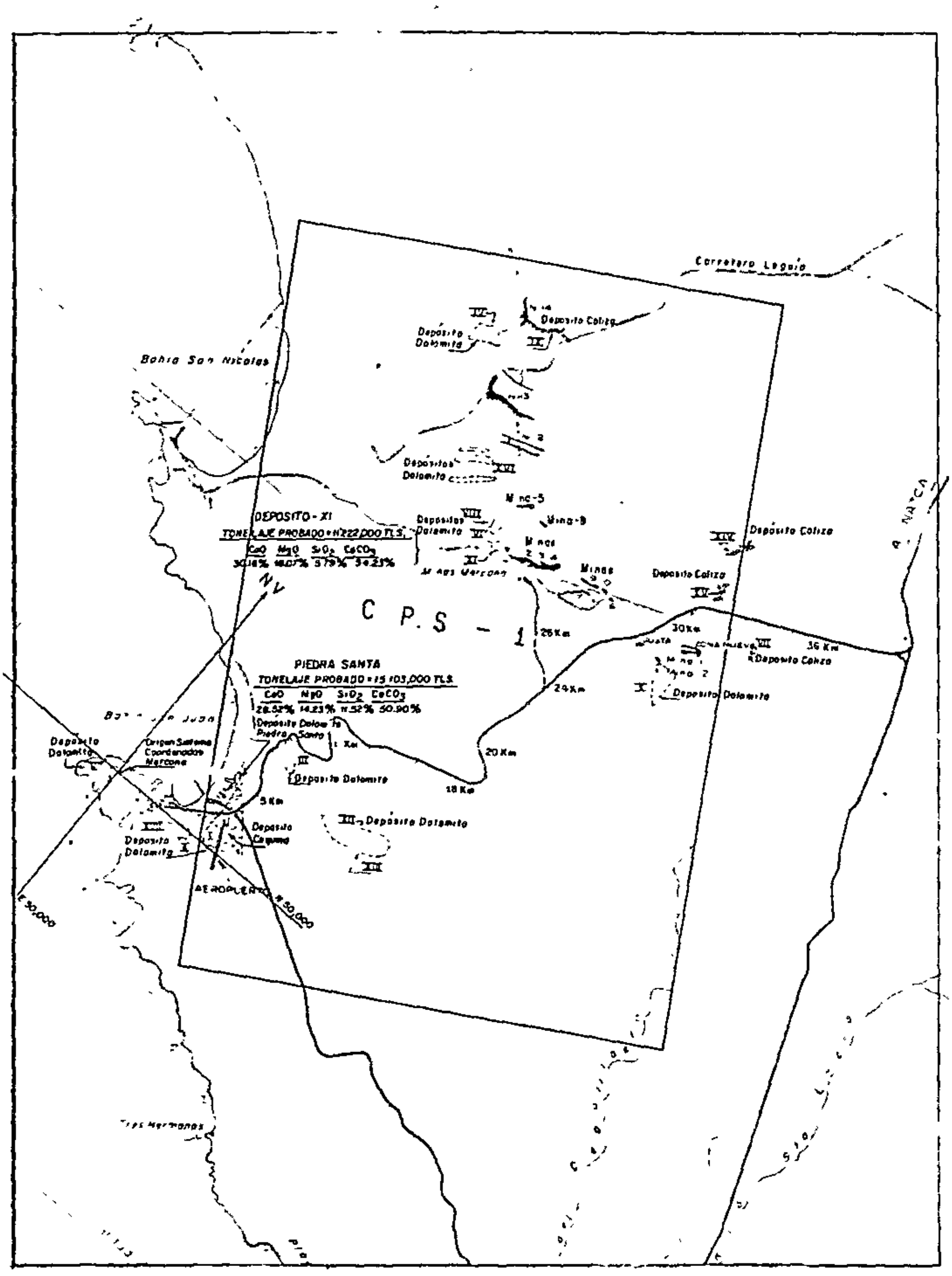


Fig. 5 - 5 LOCATION OF LIMESTONE SOURCES

5.2.2 Silicastone

Silicastone may be required for the adjustment of the SiO_2 content of the sinter feed.

Mine 7, which supplies silicastone for the pelletizing plants, may also be utilized as an SiO_2 source for the sinter plant. The minable reserves of Mine 7 are 2 million tons, and the chemical composition of the silicastone is 74.30% SiO_2, 0.367% Na_2O, and 0.313% K_2O. Mine 7 is 2.3 km from the crushing plant at the mine.

The other SiO_2 source, the Sur Mancha deposit, has 4 million tons of minable reserves, and the chemical composition of the silicastone is 81.42% SiO_2, 0.343% Na_2O, and 0.242% K_2O.

The project will require 50,000 ~ 60,000 tons of silicastone per year, and consequently, the existing deposits can easily fill this requirement, although the SiO_2 content of the deposits is relatively low.

5.2.3 Carbon Material

(1) Coke Breeze

Coke breeze is utilized as carbon material in this study as is normally the case.

Annual consumption of coke breeze is estimated at 125 thousand tons. As coke breeze is the undersize of coke and a by-product, difficulty may arise in securing a stable supply of coke breeze in sufficient amounts.

Our survey, however, proved that it is possible to import coke breeze from neighboring countries. Table 5-4 hereunder shows the supply capacity and specifications of coke breeze from Mexico, Argentina, and Chile.

Table 5-4 Supply Capacity and Grade of Coke Breeze from Mexico, Argentina, and Chile

	Mexico	Argentina	Chile
Producer	SICARTSA	SOMISA	CAP
Supply Capacity	70,000 MT/year	90,000 MT/year	40,000 ~ 60,000 MT/year
Coke Grade			
Ash (dry)	13 ~ 16%	Max. 17%	15%
V.M. (dry)	1 ~ 3	Max. 4	5
F.C. (dry)	86 ~ 81	Min. 81	80
S (dry)	0.56 ~ 1.00	1	1
T.M.	10	18 ~ 20	18
P		0.02	0.013
Size	- 20mm100 ~ 90%	- 20mm 100%	- 6mm 85%
Cal		6,500 Kcal/kg	6,500 ~ 7,000 Kcal/kg

It is also possible for Hierro-Peru to import coke breeze from the U.S.A., Colombia, and other countries if the C.I.F. price, including freight cost, is acceptable.

Sider-Peru being the only domestic supply source of coke breeze with production limited to approximately 15,000 tons per year, it may be difficult to secure a stable supply domestically.

(2) Anthracite

Anthracite, of which deposits are known to exist abundantly in Peru, can substitute for coke breeze as a carbon material. According to the data prepared by Hierro-Peru (GT-80-021 of January 23, 1980), however, commercial production of anthracite will take time and therefore it is difficult to utilize anthracite for the time being.

(a) Suitable anthracite for sinter production has a minimum of 80% fixed carbon, low ash content, low volatile matter, and low moisture.
It has been confirmed that there are many coal areas of these desirable qualities.

(b) These coal areas are unexplored or produce limited tonnages and require development before Hierro-Peru can utilize them.

(c) Obstacles in developments

(i) Coal areas are located in a mountainous area and 135-160 km from the nearest city. Availability of roads for transportation is unknown.

(ii) Coal areas are distant from ports and its capacity is unknown.

(iii) Other consumers for joint development of the coal areas are required as anthracite demand of Hierro-Peru is too small.

(iv) Reserves of the coal areas are relatively small and mining conditions are not favourable as underground mining is required.

(d) A huge amount of investment is necessary for coal development and the above-mentioned difficulties must be overcome. It appears, therefore, more time will be needed before anthracite coal areas are developed for utilization by Hierro-Peru.

5.3 Test Sample

The iron ore sample utilized in the Pot Tests is a blend of R.O. and T.O. on a 60/40 basis. Chemical components and size distribution for R.O. and T.O. are as shown in Tables 5-5 and 5-6.

Table 5-5 Chemical Composition of Sinter Feed Sample

	R.O.	T.O.
	%	%
T.Fe	66.23	64.65
FeO	23.92	11.48
SiO_2	3.13	3.76
Al_2O_3	0.62	0.48
CaO	0.63	0.66
MgO	1.34	1.30
S	1.61	0.559
Cu	0.040	0.050
P	0.022	0.046
Na_2O	0.165	0.312
K_2O	0.091	0.096
LOI	- 0.73	1.87

(Source: Hierro-Peru)

Table 5-6 Size Distrubution of Sinter Feed Sample

Tyler	R.O.	T.O.
	%	%
+10 mesh	0.4	4.8
10 ~ 20	7.8	24.8
20 ~ 65	47.8	43.3
65 ~ 100	12.0	7.5
-100 mesh	32.0	19.6
Total	100.0	100.0

(Source: Hierro-Peru)

Limestone sample utilized in the Pot Tests was mined from the N-14 ore deposit and has the following chemical compositions.

Table 5-7 Chemical Compositions of Limestone Sample

	(%)
LOI	41.36
CaO	51.49
MgO	0.80
SiO_2	4.00
Al_2O_3	1.15
Na_2O	0.166
K_2O	0.264
Fe	0.500
S	0.054
Cu	0.007
FeO	0.10
P_2O_5	0.062
$CaCO_3$	91.96

(Source: Hierro-Peru)

In Planning raw matrerial blending and raw material balance, the chemical compositions in Tables 5-5, 5-6, and 5-7 are adopted for iron ore and limestone.

5.4 Pot Tests of Hierro-Peru Sinter Feed

5.4.1 General

Sinter Pot tests of Hierro-Peru iron ore were carried out at the research laboratories of Kawasaki Steel Corporation as part of the feasibility study for the Hierro-Peru Sintering Plant.

Two kinds of iron ore, refractory ore (R.O.) and transition ore (T.O.), were selected for the pot tests as materials to be supplied for sintering on the most stable basis.

Before the pot tests were begun, the chemical compositions and the properties of the ores were examined. Then the pot tests were carried out using a basic blend of R.O. to T.O. of 60/40 in various possible blends of the available raw materials, and the sintering productivity and the properties of the sintered ore were determined.

The results of the Hierro-Peru ore tests were also compared with those of sinter pot tests using the iron ores being used by the Philippine Sinter Corporation (PSC).

5.4.2 Properties of Hierro-Peru Sinter Feeds

The chemical compositions of R.O. and T.O., as determined by Kawasaki Steel, are shown in Table 5-8. The total volume of iron oxide (hematite and magnetite) is 91.11% for R.O. and 90.31% for T.O. In the case of R.O., 82.7% of the total iron oxide is made up of magnetite, and in the case of T.O., 41.4% in magnetite. Both kinds of ore are very high in sulphur.

The size distribution of Hierro-Peru ores is shown in Tables 5-9 and 5-10 and in Fig. 5-6. In comparison with the Mt. Newman and Rio Doce iron ores being utilized as raw materials by PSC, the size distribution range of the Hierro-Peru ores is small, and there is little coarse or very fine ore. In general, R.O. is finer than T.O..

The chemical compositions of each size group are also shown in Tables 5-9 and 5-10. For both R.O. and T.O., the finer the ore is, the higher the iron content and the magnetite level. The SiO_2 content decreases as particle size grows smaller. In the case of R.O., however, the percentage of SiO_2 in the gangue shows almost no change. R.O. with particle size of 1 to 2 mm was crushed to below 417μ, and the crushed R.O. was processed at 15,000 gauss in a Davis tube magnetic separator. The non-magnetic elements collected through the separation process were identified by the X-ray powder method. The magnetic elements constituted 83.8% of the ore, and the non-magnetic elements collected constituted 8.8%.

The results of X-ray analysis are shown in Fig. 5-7. Silicates, such as tremolite, quartz, chlorite, plagioclase, etc., were found in the gangue, as was a large quantity of pyrite.

5.4.3. Test Methods

(1) Preparation of Materials

Samples of R.O., T.O., and Peruvian limestone were delivered to the laboratory on January 4, 1980. At the time of delivery, the quantity and moisture content were as follows.

	Quantity delivered	Moisture content
R.O.	3.5 tons (6 drums)	8.5 ~ 8.8%
T.O.	2.5 tons (4 drums)	7.0 ~ 8.0%
Limestone	1.2 tons (4 drums)	trace

Both ores and limestone are dumped on the floor from each drum, first to be mixed thoroughly within each of the three groups. Each of the three groups thus obtained was sampled out at a fixed ratio; namely, 2.2 tons in total for R.O., 1.1 tons for T.O., and 0.3 ton for limestone. For chemical analysis and size distribution analysis, the above groups were further blended, and then spread out on the floor in the shape of a square and divided into twenty equal sections. Using a small shovel designed for incremental sampling, one shovelful was taken from each of the twenty sections, and these samples were processed in a riffle divider to produce the required test samples. The R.O. and T.O. samples were dried at 80° ~ 90°C for about eight hours. Since some of the ore tended to form aggregates during drying, particles larger than 1 mm in diameter were processed for 30 seconds in a small ball mill (300 mmϕ x 300 mm). To prevent segregation during handling, the R.O. and T.O. were processed in a screening apparatus (Gyro-sifter) and divided into the following size ranges: +2 mm, -2 mm to +1 mm, -1 mm to +0.589 mm, -0.589 mm to +0.295 mm, 0.295 mm below.
When the sinter materials were blended, the R.O. and T.O. were recombined in proportion to the weight of the size groupings in the original sample. The limestone was used without separation into size groupings.

Samples of the raw materials used at PSC (Mt. Newman, Rio Doce and Carol Lake ores, coke breeze, anthracite, and silicastone were obtained from the stockpiles at the Kawasaki Steel ore yard in Chiba Works. The chemical composition and size distribution of each of the materials used in the tests are given in Table 5-11. Return fine, for respective test runs, was taken and crushed into minus 6 mm from the sintered ore, which was prepared, using the same materials as the proportion of the sinter blends at the main test.

(2) Sinter Pot Tests and Sinter Test Methods

The apparatus for the sinter pot tests is shown in Fig. 5-8. The sintering pot measured 300 mmϕ at the top, 280 mmϕ at the bottom, and 300 mm in height, and was capable of receiving about 35 kg of sinter mix.

The sinter mix were blended for three minutes in a V-type blender capable of holding 80 liters, then granulated by watering through rotation for five minutes in a small mixer at 24 r.p.m.The mixed materials were then fed into the pot as uniform manner as possible, avoiding segregation. 2 kg hearth-layer of sintered ore was prepared from 8 ~ 15 mm size sintered ore, in each tests.

Charcoal fines of 200 g were spread over the sinter mix in the pot and ignited by lighting the ignition furnace burner for 30 seconds using coke oven gas. The suction pressure during sintering was kept at - 1,200 mm H_2O. Three minutes after the exhaust gas temparature had reached a maximum, the blower was shut off. The sintered ore was then immediately removed and allowed to cool.

The items measured during each test were the weight of the materials used, volume of sucked air, exhaust gas temperature, product yield, shatter strength, productivity, unit consumption of coke breeze, etc. . The concentration of SO_2 in the exhaust gas was also measured, using an infrared gas analyzer. In addition, the reduction disintegration index (RDI), the reducibility index (RI), and the chemical composition (total Fe, FeO, SiO_2, CaO, Al_2O_3, MgO, S,

Na_2O and K_2O) were determined and microscopic observation carried out using samples of the sintered ore produced (15-20 mm in size). The procedures and methods of calculation used for determining product yield, shatter index, productivity, coke breeze consumption, RDI, and RI are given in Table 5-12.

(3) Test Conditions

The basic blending ratio of Hierro-Peru sinter feeds was set up at R.O./T.O.=60/40. The SiO_2 content of sintered ore was set at 5.5% and adjusted to that level by the addition of silicastone. Basicity (CaO/SiO_2) was 1.50. Return fines were added in the ratio of 35: 100, as the total weight of the iron ore, limestone, and silicastone being 100.

The blend of PSC raw materials prepared for comparison with Hierro-Peru sinter feed was made up of 50% Mt. Newman ore, 40% Rio Doce ore, and 10% Carol Lake ore. The SiO_2 content, basicity (CaO/SiO_2), and the proportion of return fines were the same as those for Hierro-Peru sinter feeds.

First of all, the effects of the moisture content of the Hierro-Peru sinter feed, blended as above, were ascertained, and the optimum moisture content determined. The effect of the addition of coke breeze on both Hierro-Peru and PSC sinter feeds was tested, and the optimum coke content determined.

Secondly, the effects of variations in basicity (CaO/SiO_2 1.2 ~ 1.8), SiO_2 content (SiO_2: 4.5 ~ 6.0%), and the amount of return fines (30 ~ 40%) were examined.

Thirdly, various blending ratios of Hierro-Peru ore (R.O./T.O.) 100/0, 40/60, and 0/100), and the blend of coarse sized ore were also examined. The change of size distribution for the various blending ratios is shown in Fig. 5-9. In addition, to test the effects of using anthracite, the fuel which was made up of 50% anthracite and 50% coke breeze was added in the proportions of 3.5% and 4%.

Finally, the changes in alkali content were measured (a) when seawater was, added for granulation and (b) when 0.5% of $CaCl_2$ was added. The test conditions and blending ratios for the tests are listed in Table 5-13.

5.4.4 Test Results

A summary of the test results is given in Tables 5-14 and 5-15.

(1) Effects of Moisture Content

The effects of variations in the moisture content are shown in Fig. 5-10. As the amount of water added for granulation is increased, the shatter index and product yield decrease almost linearly. When the moisture content was 5%, sintering time was the shortest, and productivity was the highest. Therefore, the moisture was set at 5% for all following tests.

(2) Effects of Coke Content on Hierro-Peru and PSC ores

The effect of variations in coke content on Hierro-Peru and PSC sinter feeds are shown in Fig. 5-11. In the case of Hierro-Peru sinter feeds, the shatter index was the highest at 3 ~ 4% coke breeze, and product yield was the highest at 3% coke breeze. For PSC sinter feeds, the maximum for shatter index and product yield were obtained with 4.5% coke breeze. Neither of the two sinter feeds showed any great variation in productivity between 3% and 4.5% coke breeze.

In actual sinter operations, it is desirable to achieve at least a certain level of shatter strength and simultaneously to attain maximum productivity.

Accordingly, in this test, productivity at a fixed shatter index was calculated for each level of coke breeze added using a certain coefficient. This coefficient was obtained from actual experience at the Kawasaki Steel sinter plant in the Chiba Works and equals a 0.05 t/hm^2 drop in productivity for each 1% increase in the shatter index.

The results of these calculations are given in Fig. 5-12. At each level of coke breeze content, assuming the achievement of a shatter index of 77.4%, the productivity reaches a maximum at 3 ~ 4% coke breeze for Hierro-Peru sinter feed and at 4.5% for PSC sinter feed. Therefore, the subsequent tests were carried out using 4% coke breeze.

As shown in Fig. 5-11 and 5-12, with low coke breeze content, Hierro-Peru sinter feeds show better sintering characteristics than PSC sinter feeds. With high coke breeze content, the sintering characteristics of sinter feed is higher than that of Hierro-Peru sinter feed. This shows that although the most appropriate level of coke breeze content differs for the two ores, there is little difference in their sintering characteristics, if the most appropriate level of coke is added for each ore. In other words, it can be expected that the Hierro-Peru ore will attain the same quality and productivity as PSC ore with a smaller addition of coke breeze.

As shown in Fig. 5-11, when the coke breeze content increases, the FeO content of Hierro-Peru sintered ore goes up and its RDI improves, but its RI decreases slightly. The RDI of Hierro-Peru sintered ore is superior to that of PSC sintered ore.

As shown in Photo 5-1, examination of the microstructure of Hierro-Peru sintered ore reveals that when the coke content increases, the calcium ferrite decreases, and the structure changes into bonding of silicate slag, containing scattered magnetite particles. There are no outstanding differences in the microstructures of Hierro-Peru and PSC sintered ores with 4% coke breeze.

(3) Effects of Basicity

The effects of increased basicity (CaO/SiO_2) are shown in Fig. 5-13. As the basicity increases, the shatter index decreases, but also sintering time decreases, and productivity improves. Also, the FeO content of Hierro-Peru sintered ore decreases as the basicity increases. This is because when the basicity increases, the Fe content decreases, and also the degree of oxidation rises. RI and RDI improves as the basicity increases. As shown in Photo 5-2, the calcium ferrite content rises along with the increase in basicity.

(4) Effects of SiO_2

The effects of increases in the SiO_2 content are shown in Fig. 5-14. Sintering characteristics differs depending on the level of coke breeze content. With 3% coke breeze content, the shatter strength and product yield improve along with an increase in SiO_2. Productivity remains unchanged. With 4% coke breeze, when the SiO_2 content is increased, the shatter strength drops, but product yield and productivity reach maximum at 5% SiO_2. FeO content decreases with an increase in SiO_2. In the microstructure, calcium ferrite increases along with an increase in SiO_2 (refer to Photo 5-2).

(5) Effects of Return Fine

The effects of return fine are shown in Fig. 5-15. As the proportion of return fine increases, the shatter index rises, sintering time decreases, and productivity improves.

(6) Changes due to Variation of the Blending Ratio

As shown in Fig. 5-9, as the proportion of T.O. increases, the particle size coarsens.

The blend, with an R.O./T.O. ratio of 60/40 and with eliminating finer particles, produces the coarsest particle size.

Fig. 5-16 shows the variations in sintering characteristics, RDI, and RI. As the proportion of T.O. increases, product yield and productivity improve, and sintering time drops. The shatter index is extremely low with 100% R.O. In the case of the coarsest particle size with 60/40 sinter feed blend, and with eliminating finer particles, the sintering time was relatively decreased, and productivity was high, but the shatter index and product yield were low. As the proportion of T.O. increases, FeO content drops, RDI worsens, and RI improves.

The change in the SO_2 concentration and temperature of the waste gas are shown in Fig. 5-17. The SO_2 concentration begins to rise soon after sintering is begun and starts falling just before the flame front reaches the grate.

Fig. 5-18 shows the relationship between the amount of sulphur charged with the sinter feed and the maximum figures for the concentration of SO_2 in the waste gas. The SO_2 concentration is proportionate to the amount of sulphur charged and decreases along with a decrease in the proportion.

However, the SO_2 concentration is, in any case, extremely high.

(7) Effects of Anthracite

The effects of anthracite are shown in Fig. 5-19. By using anthracite, the shatter index and product yield are somewhat improved. Productivity also tends to increase. That means sintering characteristics is not adversely affected by anthracite. RDI is slightly lowered by the use of anthracite.

(8) Tests for Decreasing Alkali Content

The alkali balance before and after sintering is shown Fig. 5-20. By adding $CaCl_2$, the decrease in a alkali content is magnified, probably because the sodium and potassium content is vaporized as NaCl and KCl. When seawater is used instead of fresh water for granulation, the NaCl in the seawater is vaporized during sintering but does not contribute to a reduction in alkali content. The addition of $CaCl_2$ does not decrease sintering characteristics but when seawater is used, shatter strength and product yield decrease.

5.4.5 Discussion

Judging from the results of the sinter pot tests, it can be expected that the same sintering characteristics can be obtained from Hierro-Peru ore as from PSC ore with the addition of a smaller amount of coke breeze.

Hierro-Peru ore is characterized by the following:

(1) Hierro-Peru ore contains much magnetite and has a high FeO content.

(2) The range of size distribution is narrow.

(3) The sulphur content is high.

The above affects the sintering characteristics of the ore and the dispositions of the sinter product.

In both pot tests and actual sinter operations, peaks at a certain level of coke breeze content. Below this level, as the coke breeze content increases, the melting process gets more complete, and the shatter strength increases. However, above this level, the melting process goes too far, causing the sinter to become porous, and th shatter strength decreases with the increase of coke breeze content.

In these pot tests, the product yield for Hierro-Peru sinter feeds tended to decrease at coke breeze levels above 3%, which suggests that at these levels, melting proceeds too far. In order to confirm this, the relationship between the air flow rates and waste gas temperatures during sintering were shown in Fig. 5-21.

After the flame front has reached the grate and the waste gas temperature starts to rise, there appears a sharp increase in the rate of air flow, and the higher the coke breeze content is, the higher the rate of air flow.

It appears that the tendencies shown in Fig. 5-21 indicate that the permeability of the sintered zone increases with the rise in coke content. The porosity of the sintered zone calculated from the apparent density of the sintered ore is 43.7% with 3% coke breeze, 47.3% with 3.5% coke breeze, 48.2% with 4.0% coke breeze and 50.0% with 4.5% coke breeze. These figures indicate that as more coke breeze is added, the porosity increases (Table 5-16).

The reason why the product yield and the shatter strength of Hierro-Peru sintered ore reach maximum at a lower level of coke breeze content than in the case of PSC sintered ore is presumably that Hierro-Peru ore melts more easily than PSC ore, even though the quantity of heat supplied by the coke breeze is the same for both sintered ores.

One of the reason why Hierro-Peru ore melts more easily may be the heat from the oxidation of the magnetite and from the combustion of the sulphur into SO_2. The FeO content of the Hierro-Peru sintered ore decreases by 1 ~ 4% as a result of oxidation during sintering, compared with that of sinter mix. Also, the greater part of the sulphur content in the sinter feed turns into SOx gas, as shown in Fig. 5-18.

When the caloric value of sinter feed with a R.O./T.O. ratio of 60/40 and 4% coke breeze content is calculated before and after sintering from the FeO and sulphur contents, the heat of oxidization of FeO to Fe_2O_3 amounts to 447 Kcal, and, the heat of conbustion of S to SO_2 amounts to 399 Kcal. The total caloric value is equal to the addition of about 0.3% coke breeze.

The FeO content of the PSC sinter feeds increases by 1 ~ 5% after sintering. The sulphur content of the PSC sinter feed is low. Consequently, Hierro-Peru sinter feeds are supplied with extra heat equal to an addition of about 0.4% coke breeze in comparison with PSC sinter feeds.

Another reason that Hierro-Peru sinter feeds melt easily is the large amount of FeO they contain. Fig. 5-22 shows the melting zones of $CaO\text{-}SiO_2\text{-}FeO$ ($P_{O_2} = 10^{-2}$ atm.) and $CaO\text{-}SiO_2\text{-}Fe_2O_3$ ($P_{O_2} = 1$ atm.) systems at

1,300°C and above. If coke breeze content is high or FeO content is high, Fe^{++} ions increase in the melt, and the melting zones approach that of CaO-SiO_2-FeO system, as shown in Fig. 5-22. The resulting structure is magnetite and silicate slag. The FeO content of HierroPeru sintered ore is 10 ~ 15%. At coke breeze content level of 4% and over, magnetite and silicate slag structures proliferate. That means the melting area expands and the sinter feeds become more easily melted. The FeO content in PSC sintered ore is 8% or less.

As shown in Fig. 5-14, the variation of shatter index and product yield with changes in SiO_2 content differs depending on the level of coke breeze content. In the case of 4% coke breeze, the caloric value supplied is high, making the feed melt more easily. It is assumed that as a result, the melted quantity increases further with SiO_2 content, producing a porous sintered ore with reduced shatter strength. It is also assumed that with 3% coke breeze, the feed does not melt excessively and that with the larger amount of gangue in the sintered ore, the bonding is strengthened. As stated above, the permeability of the sintered zone increases with the SiO_2 content at the level of 4% coke breeze and decreases with 3% coke breeze. As a result, it can be assumed that the melting ability of Hierro-Peru sinte sinter feeds had a great influence on the results of the pot tests. In general, the permeability of sinter feeds also has a great effect on sintering characteristics. Packing density and size distribution affect the permeability, too. Shatter strength increases as density increases. As particle size becomes larger, sintering time decreases, and productivity increases. For example, there often is a linear relationship between the percentage of particles below 500μ in size.

Fig. 5-23 shows the effects of density on the permeability before ignition and shatter index, and Fig. 5-24 shows the effects of the percentage of fine (-589μ) particles in sinter mix on the permeability before ignition and productivity.

The permeability before ignition is figured using the following formula:

$$\Phi = P/Q^n$$

where,

P = Suction pressure (mmH_2O)

Q = Sucked air flow ($m^3/min.$)

n = 1 variable index which takes into account the type of flow

$n = 1$ in case of laminar flow

$n = 2$ in case of turbulent flow

Index was set at $n = 1.4$ through measurement during actual operation.

Φ = permeability Index ($mmH_2O/m^3/min.$)

With the increase in density, the permeability decreases, but the shatter index decreases in opposition to its usual increase. The permeability, before ignition increases when particle size becomes coarser but the relationship with productivity is unclear. The reason why the permeability has an influence on sintering characteristics, contrary to previous experience, is probably that melting ability has a great effect on the test results, in case of the present test.

Fig. 5-25 and Fig. 5-26 show the relation of FeO with RDI and with RI. With the increase of FeO content, reducibility decreases, and the reduction disintegration index (RDI) drops. When FeO is increased, the magnetite content increases, and the hematite content decreases. Hematite causes reduction disintegration, and the reducibility of hematite is superior to that of magnetite. Therefore, a decrease in the hematite content lowers the reduction rate and the level of reduction disintegration. Since a dense structure, composed of magnetite and silicate slag, is produced by an increase in FeO, reduction gas does not diffuse into the internal structure. Thus, reactions take place only at the boundary between gas and solid, and the area of the reaction decreases with the increase in FeO.

Based on the examination in the pot tests of the effects of several operating factors, such as coke breeze content, blend components, sinter feed blends, etc., optimum levels for operating factor are considered below.

In terms of the levels of coke breeze and SiO_2, in order to gain maximum productivity with a set degree of shatter strength, an addition of 4% coke breeze is appropriate at SiO_2 level of 4%, and 3% coke breeze is appropriate with 6% SiO_2. Thus, it would be advantageous to increase coke breeze content, in the case of low levels of SiO_2 and decrease coke breeze content when the SiO_2 level is high.

Concerning basicity (CaO/SiO_2), nothing can be stated exactly. but with 4% coke breeze, a higher basicity is required from the viewpoint of productivity.

As for the sinter feed blend, it would be advantageous for the proportion of T.O. to be high. However, care must be taken not to lower the RDI as a result of decreasing the FeO content.

5.4.6 Conclusion

The results of the sinter pot tests of Hierro-Peru sinter feeds can be summarized as follows:

(1) The FeO content is high (23.4% in R.O. and 11.6% in T.O.). The range of size distribution is narrow, and the sulphur content is high (1.6% in R.O. and 0.6% in T.O.).

(2) It is expected that Hierro-Peru sintered ore will be able to attain the quality and productivity of PSC sintered ore with the addition of less coke breeze than in the case of PSC sintered ore.

(3) The effects of the SiO_2 content vary in accordance with the coke breeze content. In terms of productivity, it would be advantageous to blend in more coke breeze when the level of SiO_2 is low and less coke breeze when the SiO_2 level is high.

(4) The higher the proportion of T.O. sinter feed, the better the product yield and the higher the productivity will be.

(5) Hierro-Peru sinter feeds melt easily during sintering because of the high FeO content, and melting ability has a much greater effect on the results of the pot tests than permeability.

(6) The consentration of SO_2 in the waste gas rises as high as 10,000 ppm, which is very high.

(7) The K_2O and Na_2O levels in the sintered ore can be reduced by about 80% and 60% respectively, through the addition of $CaCl_2$.

(8) Sintering characteristic remains unchanged, even if the coke breeze as fuel is partially replaced with anthracite.

Table 5 - 8 Chemical composition of Hierro-Peru ores

	Refractory Ore (R.O.) (%)	Transition Ore (T.O.) (%)
Fe Total	65.54	64.06
S	1.62	0.566
Cu	0.042	0.039
FeO	23.39	11.61
SiO_2	3.47	3.89
Al_2O_3	0.68	0.54
CaO	0.80	0.77
MgO	1.15	1.07
TiO_2	0.07	0.06
P	0.030	0.059
Na_2O	0.22	0.29
K_2O	0.12	0.09
Mn	0.04	0.03
Zn	0.003	0.007
Pb	0.002	0.004
V	0.012	0.005
As	0.001	0.001
Sn	0.003	0.001
Ni	0.002	0.001
Cr	0.001	0.002
C.W.	0.44	1.15

Table 5 - 9 Size distribution and chemical composition of each size of Hierro-Peru refractory ore (R.O.)

	Size (micron)					
	+2000	2000 ∿1000	1000 ∿589	589 ∿295	295 ∿147	-147
Size distribution (%)	0.6	6.6	17.1	24.0	23.5	28.2
Chemical Composition (%)						
T. Fe	59.84	60.64	62.24	65.18	67.13	69.16
Cu	0.058	0.057	0.048	0.040	0.032	0.025
FeO	19.31	19.44	20.49	22.16	23.74	25.36
SiO_2	6.59	6.66	5.73	3.81	2.57	1.50
Al_2O_3	1.06	1.01	0.89	0.66	0.49	0.33
CaO	1.53	1.55	1.33	0.89	0.59	0.33
MgO	2.32	2.26	1.94	1.32	0.93	0.56
TiO_2	0.08	0.08	0.07	0.06	0.06	0.06
P	0.051	0.051	0.041	0.034	0.028	0.020

Table 5 - 10 Size distribution and chemical composition of each size of Hierro-Peru transition ore (T.O.)

	Size (micron)					
	+2000	2000 ∿1000	1000 ∿589	589 ∿295	295 ∿147	-147
Size distribution (%)	3.7	21.4	22.1	18.2	15.7	18.9
Chemical composition (%)						
T. Fe	61.13	62.11	62.80	63.92	65.67	66.99
Cu	0.060	0.045	0.041	0.036	0.030	0.030
FeO	10.25	10.89	11.17	11.83	13.05	13.08
SiO_2	5.85	5.21	4.61	3.89	2.92	2.18
Al_2O_3	0.57	0.50	0.49	0.48	0.42	0.37
CaO	1.24	1.01	0.91	0.74	0.48	0.31
MgO	1.61	1.47	1.28	1.08	0.77	0.62
TiO_2	0.05	0.05	0.06	0.06	0.06	0.06
P	0.072	0.063	0.062	0.055	0.042	0.033

Table 5 - 11 Properties of raw material for sinter pot tests

	Chemical composition (%)							Size distribution (%)						
	T.Fe	FeO	SiO_2	Cao	Al_2O_3	MgO	S	+3000$^{\mu}$	3000 μ ∿2000	2000 μ ∿1000	1000 μ ∿589	589 μ ∿295	295 μ ∿147	-147$^{\mu}$
R.O.	65.54	23.39	3.47	0.80	0.68	1.15	1.62		0.6	6.6	17.1	24.0	23.5	28.2
T.O.	64.04	11.61	3.89	0.77	0.54	1.07	0.566		3.7	21.4	22.1	18.2	15.7	18.9
Return fine								34.1	34.6	18.8	6.2	3.5	1.6	1.2
Mt. Newman	61.8	0.18	6.55	0.03	2.78	0.04	0.007		16.0	15.5	14.4	9.0	10.2	34.9
Rio Doce	64.4	0.11	5.35	0.03	1.44	0.04	0.006		18.2	10.7	9.3	5.3	7.6	48.9
Carol Lake	66.0	8.24	3.72	0.36	0.19	0.29	0.003			0.9	3.6	18.0	46.7	30.7
Peruvian limestone		Fe_2O_3 0.65	4.12	50.00	0.94	0.90	0.076			19.1	32.1	16.7	12.8	19.3
Silicastone			91.38	0.2						11.6	38.4	18.8	13.6	17.6
	Fixed Carbon	Volatile Matter	Ash	S										
Coke breeze	86.0	1.2	12.8	0.55					12.8	43.6	18.5	13.3	8.7	3.1
Anthracite	79.5	6.8	13.7	0.22					5.9	26.6	16.7	14.8	14.8	21.2

Table 5 - 12 Test methods for sinter product

	Method	Calculation
Product Yield	Apparatus : Shatter box (2m high x 0.4 x 0.45m) Height of drop : 2 m Number of drops : 1	$\frac{\text{(Weight of +10mm product after 1 time drop (kg))}}{\text{(Original weight (kg))}} \times 100$ (%)
Shatter strength test (Shatter Index, S.I.)	Apparatus : Shatter box (2m high x 0.4 x 0.45m) Height of drop : 2 m Number of drops : 4	$\frac{\text{(Weight of +10mm product after 4 times drops (kg))}}{\text{(Weight of +10mm product after 1 time drop (kg))}} \times 100$ (%)
Productivity		$\frac{\text{(Weight of +10mm product after 1 time drop (kg))}}{\text{(Sintering time (min))}}$ x 0.909 x 100 ($t/h.m^2$) 0.909 : Coefficient converting $kg/min.cm^2$ → $ton/hr.m^2$
Coke consumption		$\frac{\text{(Coke content in Sinter mix (kg))} \times 1000}{\text{(Weight of +10mm product after 1 time drop (kg))}}$ (kg/ton-sinter)
Reducibility test (RI) (JIS M8713)	Apparatus : Electrically heated furnace Reduction tube : 75 mmø Sample weight : 500 g Sample size : 15 - 20 mm Reduction temp. : 900 °C Reduction time : 3 hrs Reduction gas : 30 % CO, 70 % Reduction gas flow rate : 15 Nl/min	$\frac{\text{(mass loss after 3 hr of reduction (g))}}{\text{(total input of oxygen combined with iron (g))}}$ x 100 (%)
Reduction disintegration test (RDI)	Reduction tube, mass of sample, size of sample, reduction gas and flow rate : Same as for reducibility test. Reduction temp. : 550 °C Reduction time 30 min Tumbling drum : 130mmø x 200mm with two lifters Drum revolution : 30 r.p.m x 30 min Sieving : Rotap testing sieve shaker 1 min	$\frac{\text{(Weight of -2.83mm product after tumbling (kg))}}{\text{(Sample weight after reduction (kg))}} \times 100$ (%)

Table 5 - 13 Test conditions and blending ratio of sinter mix

		Test conditions						Blending ratio (%)					
	Test	Ore	Return fine to new mix (%)	$\frac{CaO}{SiO_2}$	SiO_2 (%)	Moisture (%)	Coke (%)	R.O.	T.O.	Lime stone	Silica -stone	Return fine	
1	Effect of moisture	R.O./T.O. = 60/40	35	1.5	5.5	4,5,6,7	4.0	37.4	25.0	10.5	1.2	25.9	
2	Effect of coke on Hierro-Peru ore	R.O./T.O. = 60/40	"	"	"	5	2.5,3.0 3.5,4.0 4.5	"	"	"	"	"	
	PSC ore	MN50,RD40, CL10	"	"	"	"	2.5,3.0 3.5,4.0 4.5	0	0	10.5	0.2	"	MN31.7 RD25.4 CL 6.3
3	Standard test	R/T=60/40	"	"	"	"	4.0	37.4	25.0	10.5	1.2	"	
4	Effect of CaO/SiO_2	R.O./T.O. = 60/40	"	1.2	"	"	"	38.7	25.8	8.3	1.3	"	
			"	1.8	"	"	"	36.2	24.1	12.6	1.2	"	
5	Effect of SiO_2	"	"	1.5	4.5	"	3.0,4.0	39.9	26.6	7.5	0.1	"	
					5.0	"	" "	38.3	25.4	9.5	0.9	"	
					6.0	"	" "	36.6	24.4	11.5	1.6	"	
6	Effect of return fine	"	30	"	5.5	"	4.0	38.9	25.9	10.8	1.3	23.1	
			40	"	"	"	"	36.1	24.0	10.1	1.2	28.6	
7	Effect of R/T ratio	R.O./T.O. =100/0	35	"	"	"	"	62.2	0	10.5	1.4	25.9	
		40/60	"	"	"	"	"	25.1	37.4	10.4	1.2	"	
		0/100	"	"	"	"	"	–	62.5	10.5	1.1	"	
8	Effect of coarse size ore	cf.Fig.4	"	"	"	"	"	37.8	25.2	10.3	0.7	26.0	
9	Effect of Anthracite	R.O./T.O. = 60/40	"	"	"	"	coke 1.75 anth 1.75	37.4	25.0	10.5	1.2	"	
			"	"	"	"	coke 2.0 anth 2.0	"	"	"	"	"	
10	Decrease of alkali by sea water	"	"	"	"	"	4.0	"	"	"	"	"	
	Decrease of alkali by $CaCl_2$	"	"	"	"	"	"	"	"	"	"	"	$CaCl_2$ 0.5%

Table 5 - 14 Results of sinter pot tests

Test			Charged mix (wet)			Product yield			Shatter index			Sintering time			Productivity		
			kg		X̄	%		X̄	%		X̄	min		X̄	t/h-m²		X̄
1	Moisture	4%	34 40	34.40	34 40	77 2	79.2	78.2	76.9	75.8	76.4	15.2	14 5	14 9	1 48	1 59	1.54
		5	33 77	33 77	33.77	77 6	76.1	76.9	74 2	73 5	73 9	13 8	13 0	13 4	1.59	1.67	1 64
		6	33 88	34 36	34 12	71 4	75 2	73.5	70 9	70.3	70 6	14.0	13.5	13 8	1 52	1.54	1.53
		7	34.76	34.76	34 76	72.8	74 1	73 5	70 3	69.5	69.9	13.5	14 0	13 8	1 54	1.52	1.53
2	Coke (Hierro-Peru)	2 5%	35 32	35 32	35.32	72 9	75 9	74 4	71.8	73 3	72.6	13.5	13 3	13.4	1 62	1.72	1.68
		3.0	34 68	35 00	34.84	81 1	77 2	79 2	77 4	75 7	76.6	16.7	15 3	16.0	1 42	1.45	1.44
		3 5	33 90	33.91	33 90	76 4	77 1	76.8	74 8	75.9	75 3	15.5	15 0	15.3	1 41	1.47	1.44
		4 0	33.88	33.88	33.88	74 8	75 8	75 3	77.9	76.8	77 4	14.3	14 3	14.3	1 48	1.49	1.49
		4.5	33 47	33 56	33 51	72 7	70 6	71.7	66 5	65 5	66 0	14.0	13.5	13.8	1 45	1 46	1.46
	Coke (PSC)	2 5%	35 51	35 51	35 51	37 3	39.7	38 5	42 0	44 8	43 4	16.7	14 8	15 8	0 68	0 82	0 75
		3 0	35 58	35.65	35 62	73.2	73.2	73 2	62 7	67 5	65.1	13.5	14 0	13 8	1 63	1.52	1.58
		3 5	34 92	34.92	34 92	73 4	74 0	73 7	73 7	75.2	74.5	13.7	14.7	14.2	1.57	1 47	1 52
		4 0	34 65	34.53	34 61	79 5	76.6	77 8	73.3	73 5	73 1	14.5	14 0	14 5	1 53	1.63	1 55
			34 65			77 3			72 4			15 0			1.50		
		4 5	33.94	33 94	33.94	83.6	79.6	81 6	77.1	77 3	77 2	14.2	15 4	14 8	1.65	1.45	1 55
3	Standard		33 78	33.78	33.78	74.7	76.3	75 7	72 7	74.9	73 7	14.3	14.0	14.1	1.48	1.54	1.52
			33.78			76.1			73 4			14 0			1.53		
4	CaO/SiO_2	1 2	34.07	34.07	34.07	76 0	77 3	76.7	74.2	74.0	74.1	15.2	15.0	15 1	1 44	1.47	1.46
		1.8	33.36	33.48	33 42	78 3	78 7	78.5	71.9	73.0	72.5	13 4	13 0	13.2	1 63	1 69	1.66
5	SiO_2 with 3% coke	4.0%	35.03	35.03	35 03	72.9	76 1	74.5	73 5	71.3	72 4	14.8	15.0	14.9	1.48	1 52	1.50
		5.0	34 16	34 16	34.16	78 9	79 5	79 2	75 3	76.0	75.7	15.0	16 0	15.5	1 52	1 43	1.48
		6.0	33.67	33.67	33.67	82 0	80.0	81.0	78 2	76.3	77 3	15.0	15.5	15 3	1.56	1.46	1.51
	with 4% coke	4.0%	34.60	34.52	34 56	74.5	74 5	74.5	77.2	76.4	76 8	15.0	15 0	15.0	1.45	1.45	1 45
		5 0	34.22	34.22	34.22	77.8	75.9	76.9	74.9	74 8	74.9	14.5	13.7	14 1	1 54	1.59	1.57
		6 0	33 70	33.83	33.77	73 8	76 1	75.0	72 6	72 4	72.5	14 2	14.0	14 1	1.51	1.53	1 52
6	Return fine	30%	33 95	33.95	33.95	76.2	76.6	76.4	73.1	71 4	72.3	14 5	14.5	14 5	1.50	1.49	1.50
		40	33.97	34.04	34.01	78.6	76.2	77 4	74.6	75 0	74.8	14.0	13.7	13 9	1 60	1.60	1.60
7	R.O./T.O. ratio	100/0	33 94	34.12	34.03	74.6	74.8	74 7	68.9	67.0	68 0	14 5	14.0	14.3	1 47	1.54	1.51
		40/60	34.16	34.16	34.16	76.6	76.7	76 7	76.6	73.6	75 1	14 1	14.0	14.1	1 55	1.56	1.55
		0/100	33.13	33.65	33.39	76.3	78.3	77 3	74.2	74.0	74.1	12 5	12.7	12.6	1.69	1 73	1 71
8	Coarse size ore		34.42	34.42	34.42	72.9	74.6	73 8	71.8	71.0	71.4	13.5	12.5	13 0	1.55	1.70	1 63
9	Anthracite																
	coke 1.75 anth 1.75		35.90	35 90	35.90	76 0	77 4	76.7	78.8	78.8	78.8	15.8	15 0	15 4	1 45	15.0	1.48
	coke 2.0 anth 2.0		35.62	35 62	35.62	77.7	76 7	77.2	75 8	76.9	75.4	15 0	14.9	15 0	1.54	1.53	1 54
10	Alkali																
	Sea water		34 43	34.43	34 43	75 5	73 5	74 5	71.0	70.2	70.6	14.0	14.2	14.1	1 55	1.48	1.52
	$CaCl_2$		34 42	34.42	34 42	75.2	76.9	76 1	76.3	72.4	74.4	13.8	13.6	13.7	1.57	1.63	1.60

Table 5 - 15 Properties of sinter product

Test			Chemical composition (%)									RDI (%)		RI
			T.Fe	FeO	SiO_2	CaO	Al_2O_3	MgO	S	Na_2O	K_2O	-2.83mm	-1mm	%
2	Coke	3.0%	58.54	9.89	5.94	8.74	0.91	1.22	0.014	0.15	0.06	23.2	9.9	74.8
	(Hierro-	3.5	58.98	12.01	5.88	8.93	0.96	1.11	0.015	0.15	0.06	17.1	7.3	67.5
	Peru)	4.0	58.71	13.19	5.94	9.03	0.94	1.14	0.013	0.16	0.06	12.8	4.1	64.0
		4.5	58.73	14.74	5.99	9.03	0.99	1.11	0.011	0.16	0.06	13.2	4.0	66.1
	Coke (PSC)	2.5%	58.30	2.56	6.25	8.16	2.12	0.24	0.015	0.04	0.06			
		3.0	58.13	2.73	6.46	8.28	2.16	0.21	0.008	0.04	0.06			
		3.5	58.25	4.22	6.34	8.12	2.19	0.24	0.007	0.04	0.06			
		4.0	58.54	5.92	6.41	8.05	2.17	0.23	0.005	0.04	0.06	23.7, 22.2	10.1 9.5	68.6
		4.5	58.64	7.79	6.38	8.04	2.24	0.20	0.005	0.03	0.06			
3	Standard		59.15	13.19	5.79	8.90	0.99	1.07	0.012	0.16	0.06	14.7, 14.6	5.8 5.7	65.4
4	CaO/SiO_2	1.2	60.49	14.34	5.80	7.00	0.93	1.15	0.008	0.15	0.05	20.3	8.1	62.3
		1.8	57.50	12.53	5.93	10.44	0.96	1.11	0.018	0.16	0.06	14.8	6.1	68.6
5	SiO_2 with	4.0%	61.55	10.35	4.50	6.51	0.84	1.15	0.010	0.15	0.06			
	3% coke	5.0	60.07	10.07	5.28	7.80	0.92	1.09	0.011	0.15	0.07			
		6.0	58.21	9.63	6.13	9.47	0.98	1.13	0.019	0.16	0.08			
	with	4.0%	61.94	14.93	4.41	6.46	0.82	1.15	0.006	0.16	0.04	13.9	5.7	60.1
	4% coke	5.0	60.19	13.80	5.34	7.98	0.90	1.11	0.016	0.15	0.05	15.1	6.1	61.7
		6.0	57.92	13.13	6.46	9.50	1.00	1.13	0.015	0.16	0.07	13.5	5.2	66.6
7	R.O./T.O.	100/0	59.13	14.94	5.73	8.69	1.00	1.10	0.014	0.13	0.05	13.1	5.1	64.0
	ratio	40/60	58.91	12.67	6.07	8.79	0.93	1.13	0.014	0.17	0.06	16.6	6.5	65.2
		0/100	58.56	10.81	6.09	8.93	0.89	1.07	0.014	0.20	0.06	23.2	9.1	75.1
9	Anthracite													
	coke 1.75 anth 1.75		58.88	10.52	5.91	8.96	0.91	1.08	0.018	0.16	0.06	29.7	13.0	
	coke 2.0 anth 2.0		58.76	12.27	5.89	8.86	0.95	1.11	0.014	0.16	0.06	17.1	7.6	
10	Alkali													
		Sea water	58.56	13.65	5.99	8.87	0.98	1.15	0.010	0.16	0.04			
		$CaCl_2$	58.51	13.62	5.98	9.05	0.94	1.17	0.007	0.07	0.02			

Table 5 - 16 Density of sinter particles (15 - 20 mm) and porosity of sintered bed for Hierro-Peru ore (R.O./T.O. = 60/40)

Coke breeze content (%)	Density (g/cm^3)	Porosity (%)
3.0	3.70	43.7
3.5	3.81	47.3
4.0	3.83	48.2
4.5	3.91	50.0

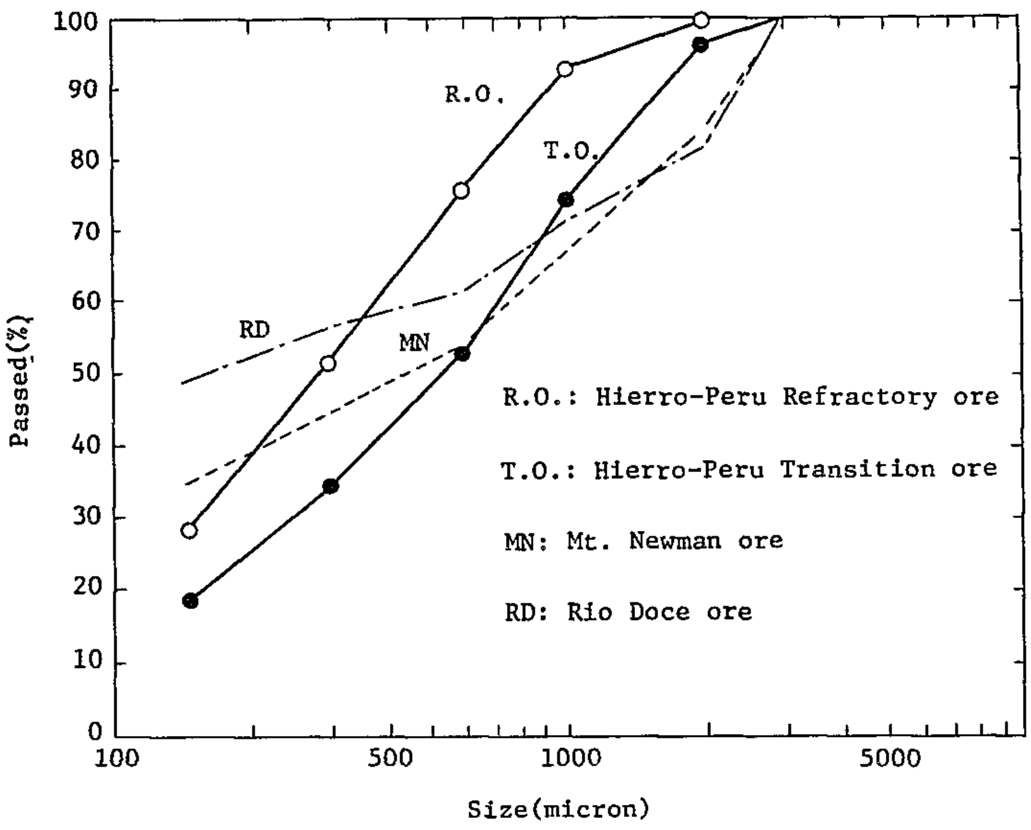


Fig. 5 - 6 Size distribution of Hierro-Peru ores and PSC ores

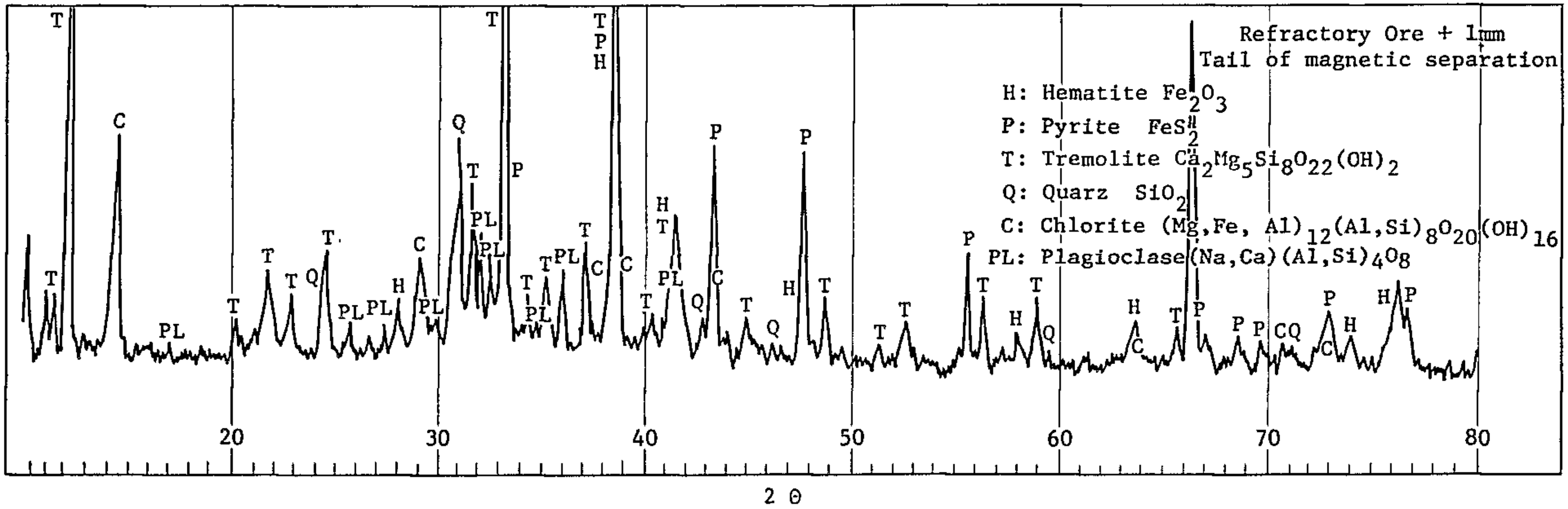


Fig. 5 - 7 X ray diffraction pattern of Hierro-Peru ore

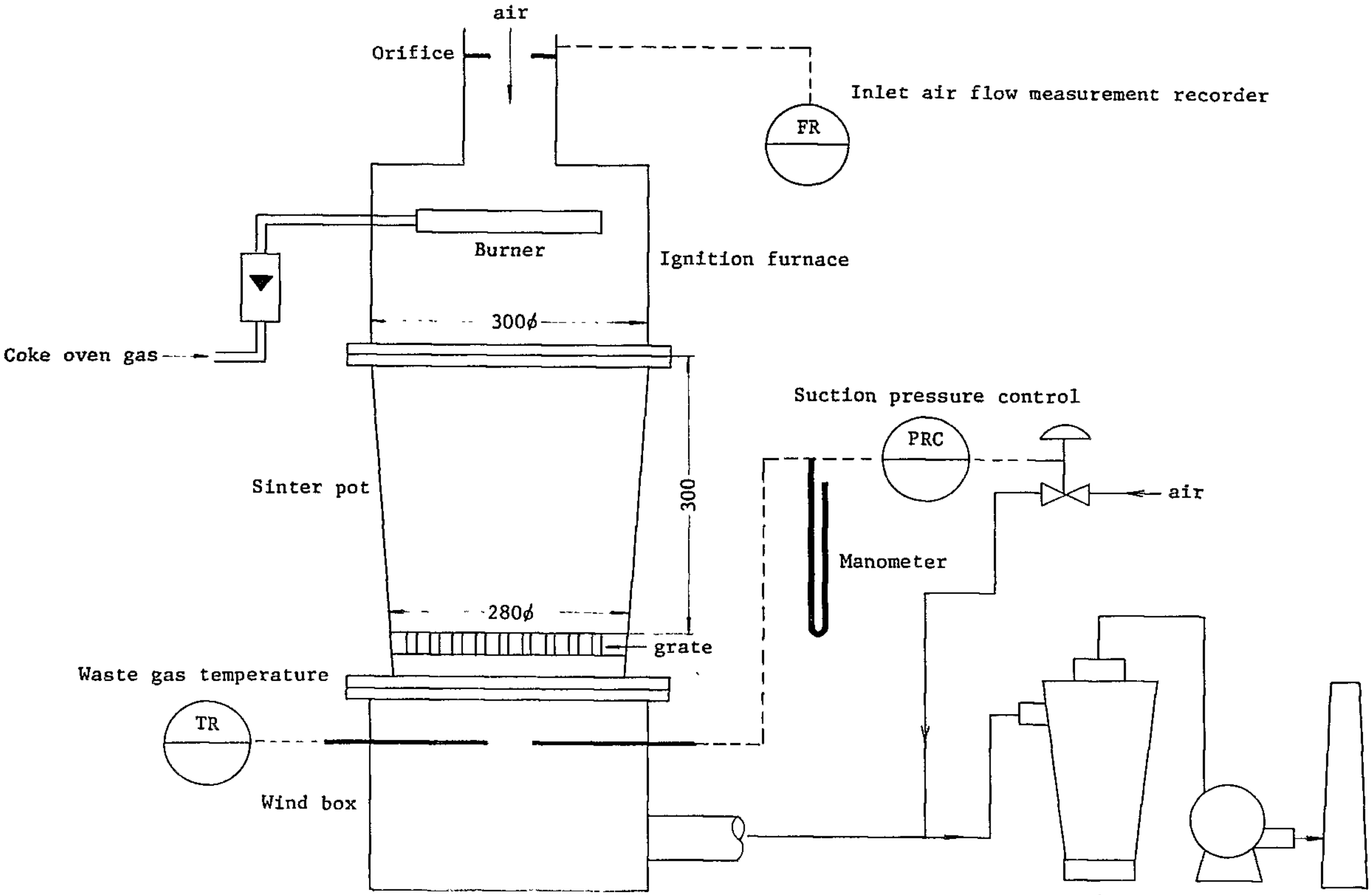


Fig. 5 - 8 Apparatus for sintering test

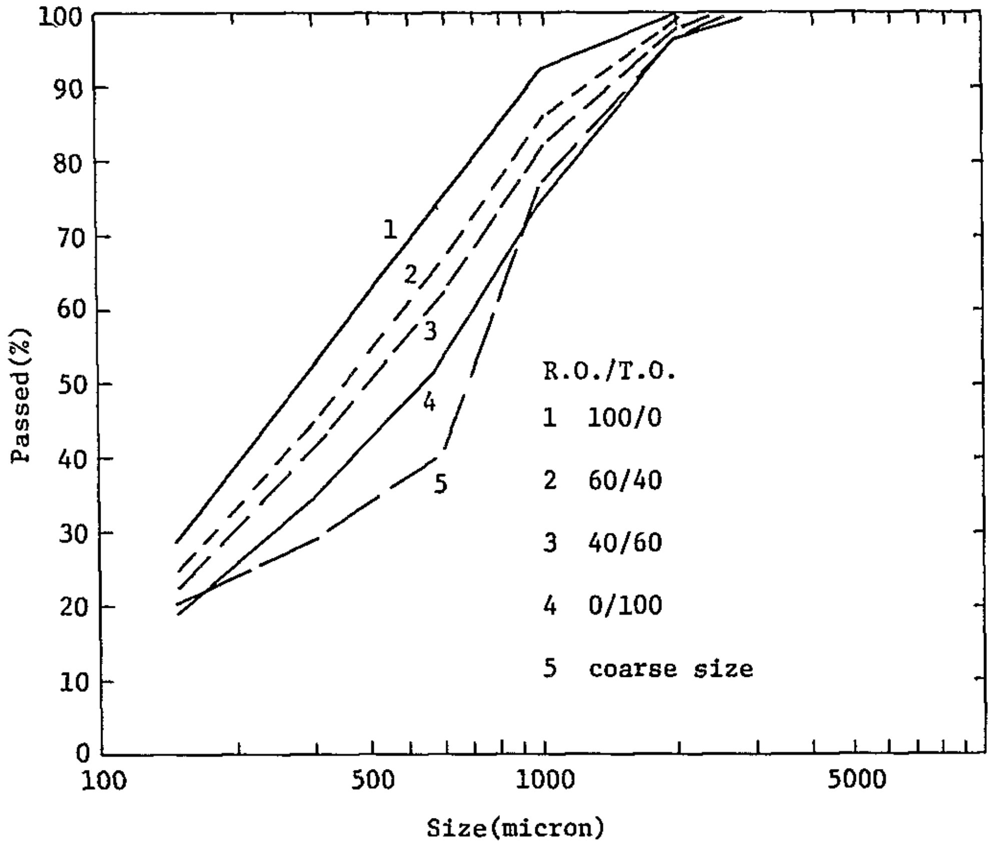


Fig. 5 - 9 Change of size distribution for the blending ratio of Hierro-Peru ores

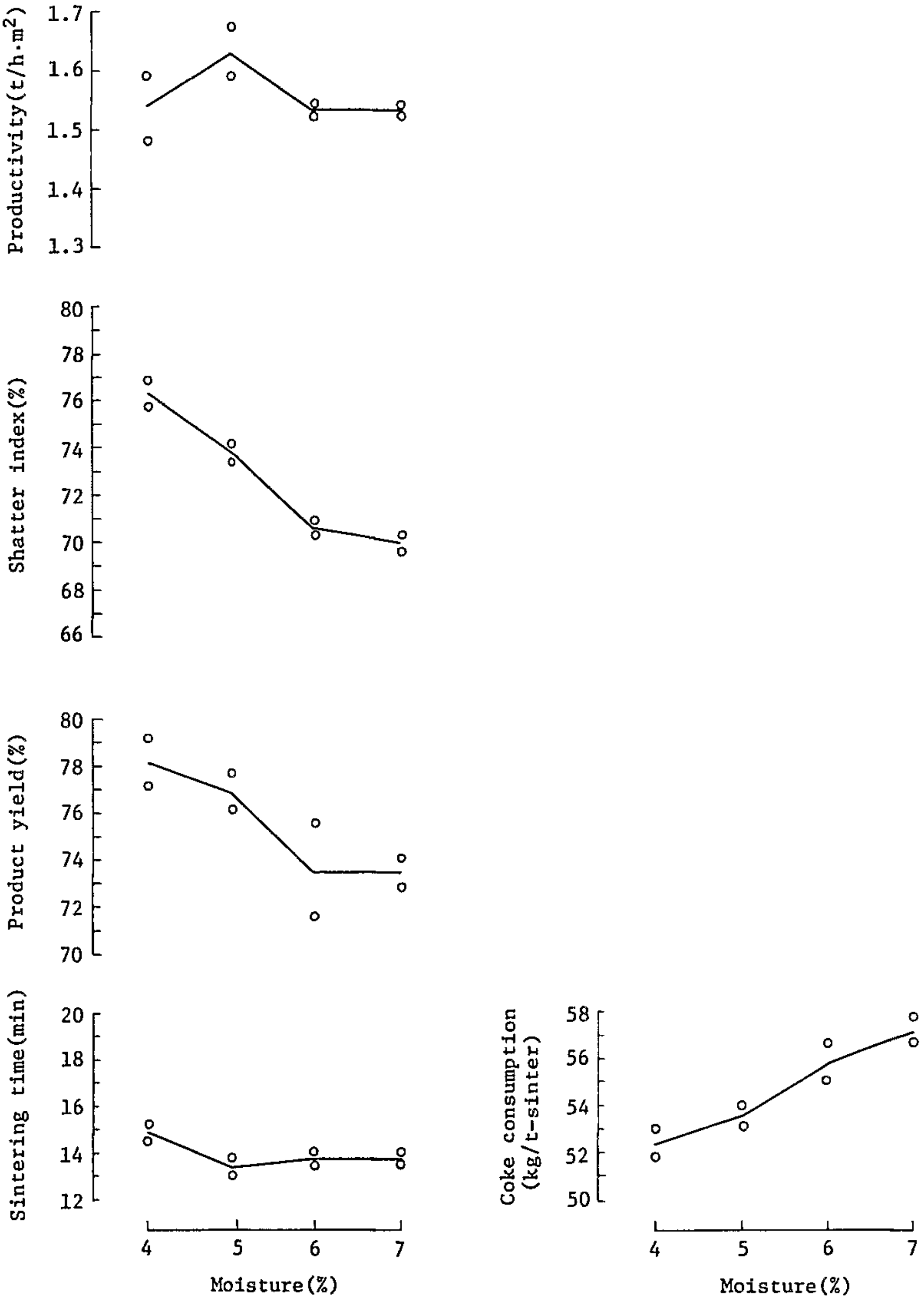


Fig. 5 - 10 Effects of moisture content (R.O./T.O. = 60/40, 4% Coke breeze)

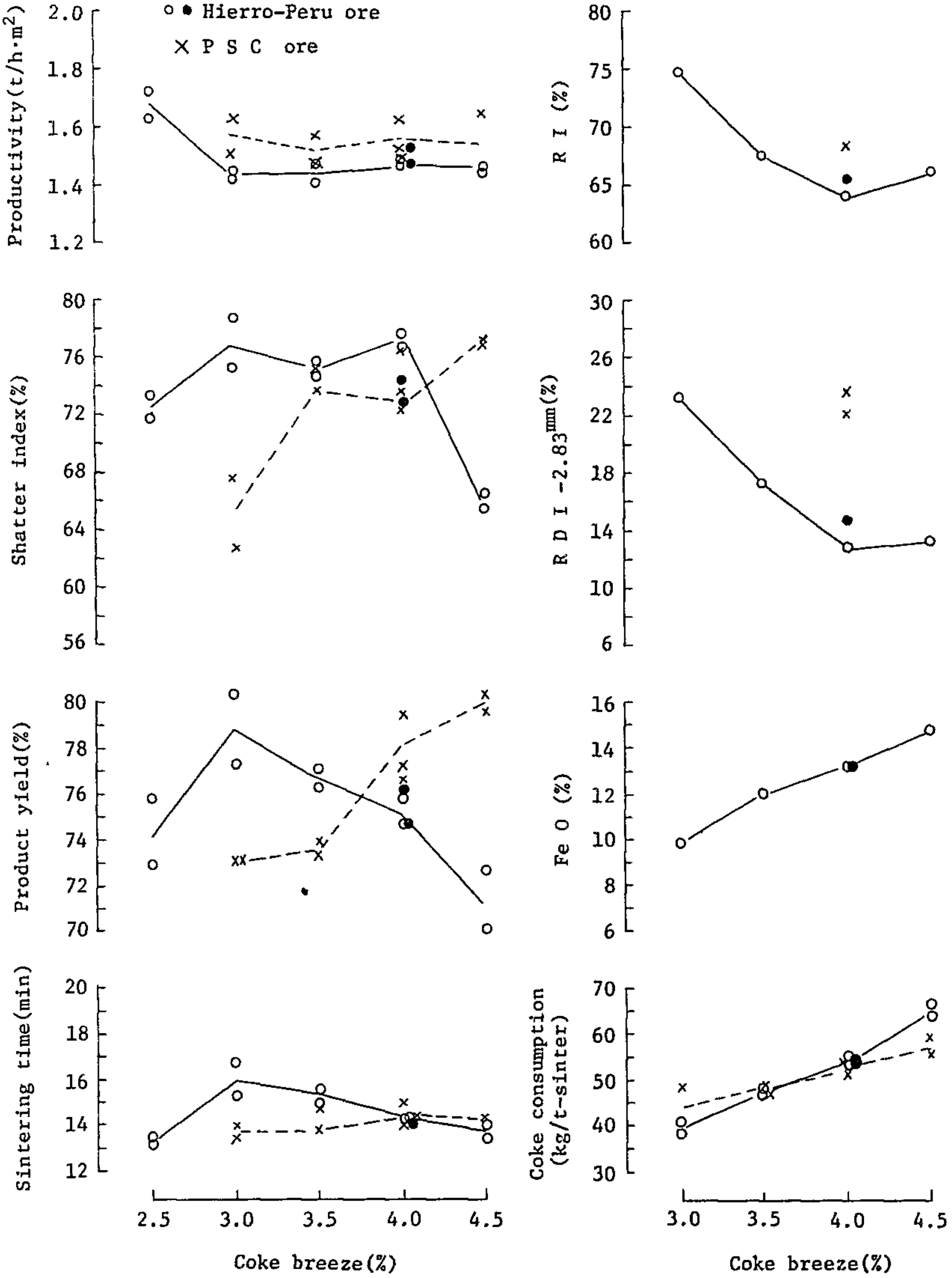


Fig. 5 - 11 Effects of coke content on Hierro-Peru and PSC ores

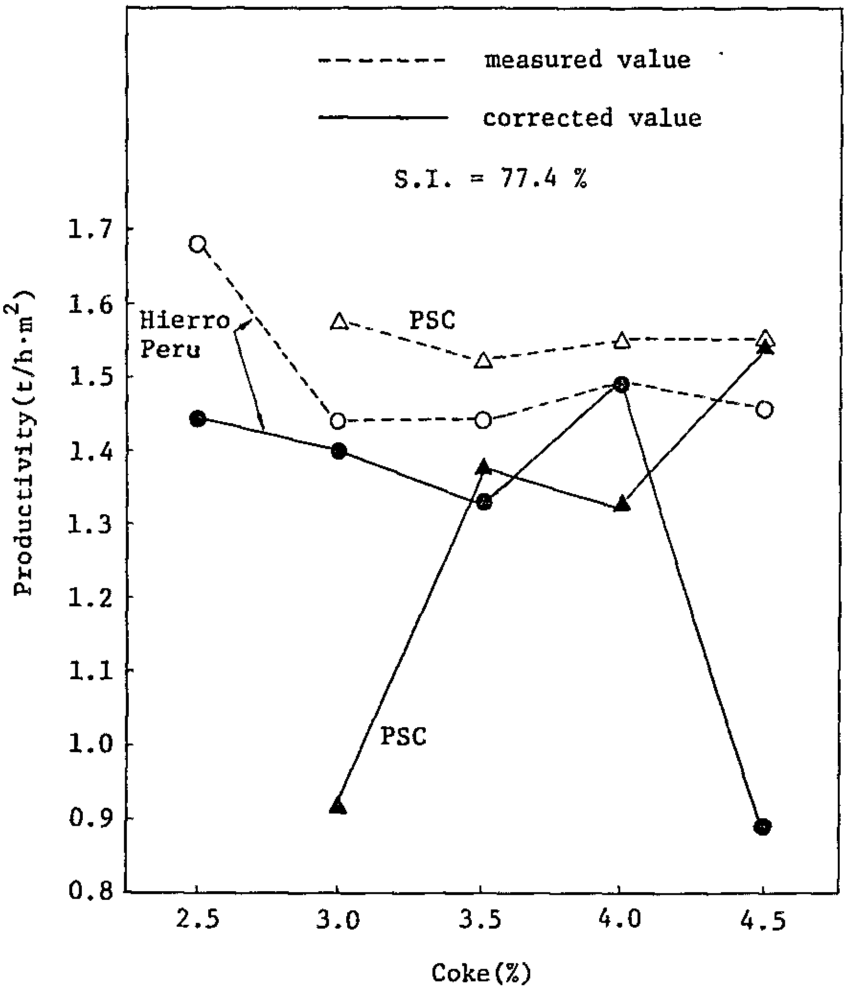


Fig. 5 - 12 Productivity corrected under the constant shatter index (S.I.) (correction factor - 0.05 t/h.m2/% S.I.)

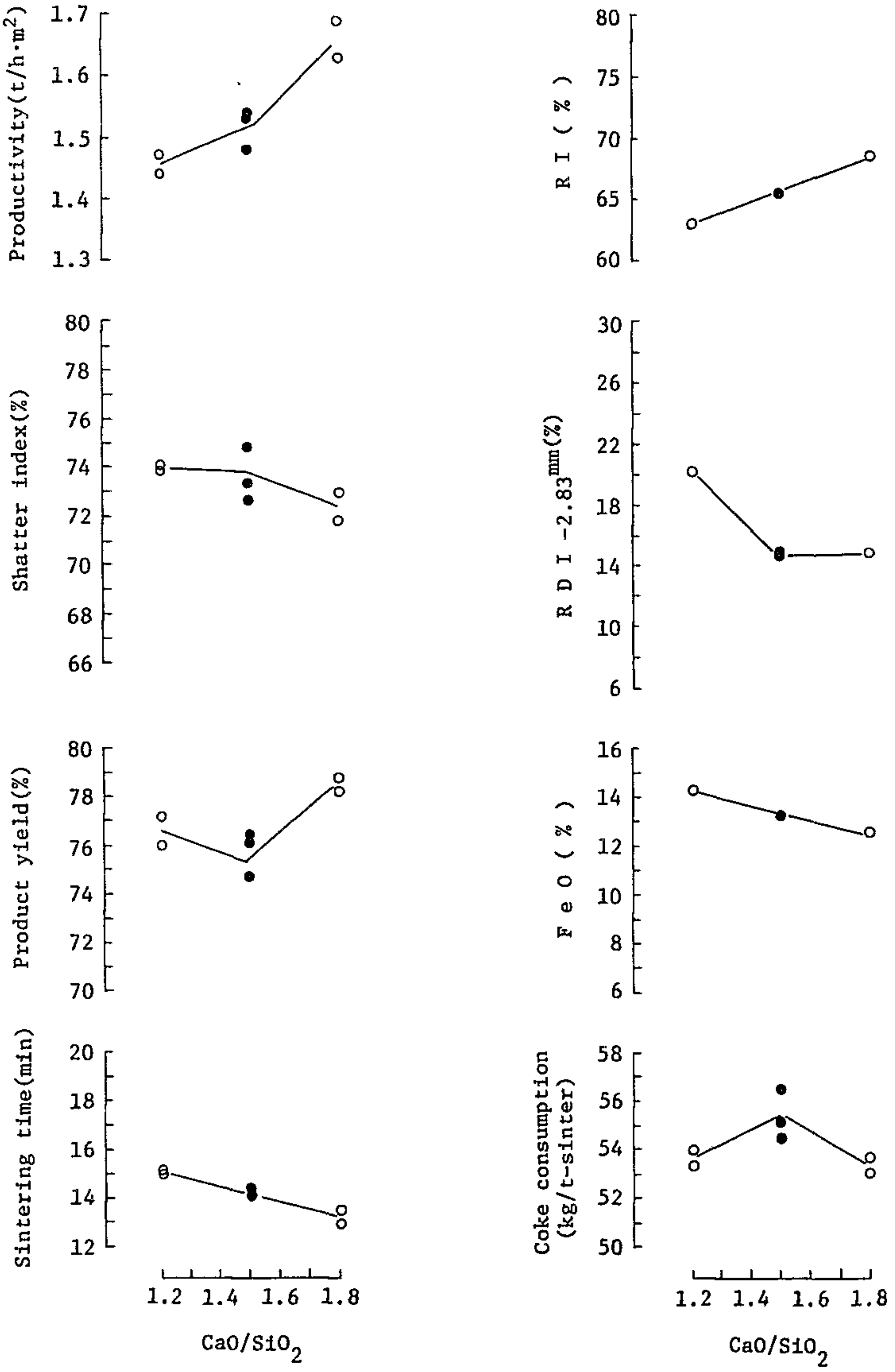


Fig. 5 - 13 Effects of basicity (CaO/SiO$_2$)
(R.O./T.O. = 60/40, 4% Coke breeze)

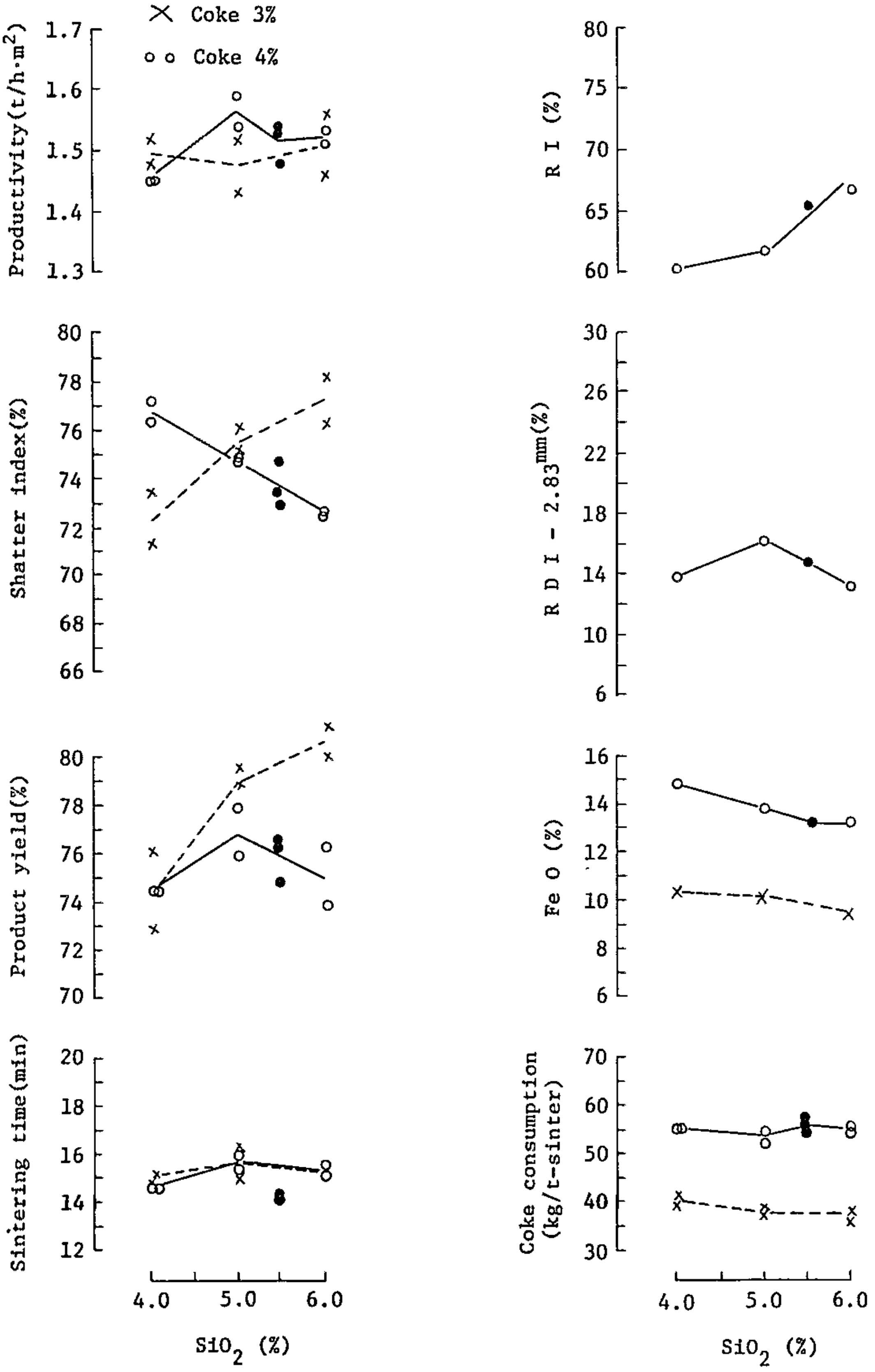


Fig. 5 - 14 Effects of SiO_2 (R.O./T.O. = 60/40)

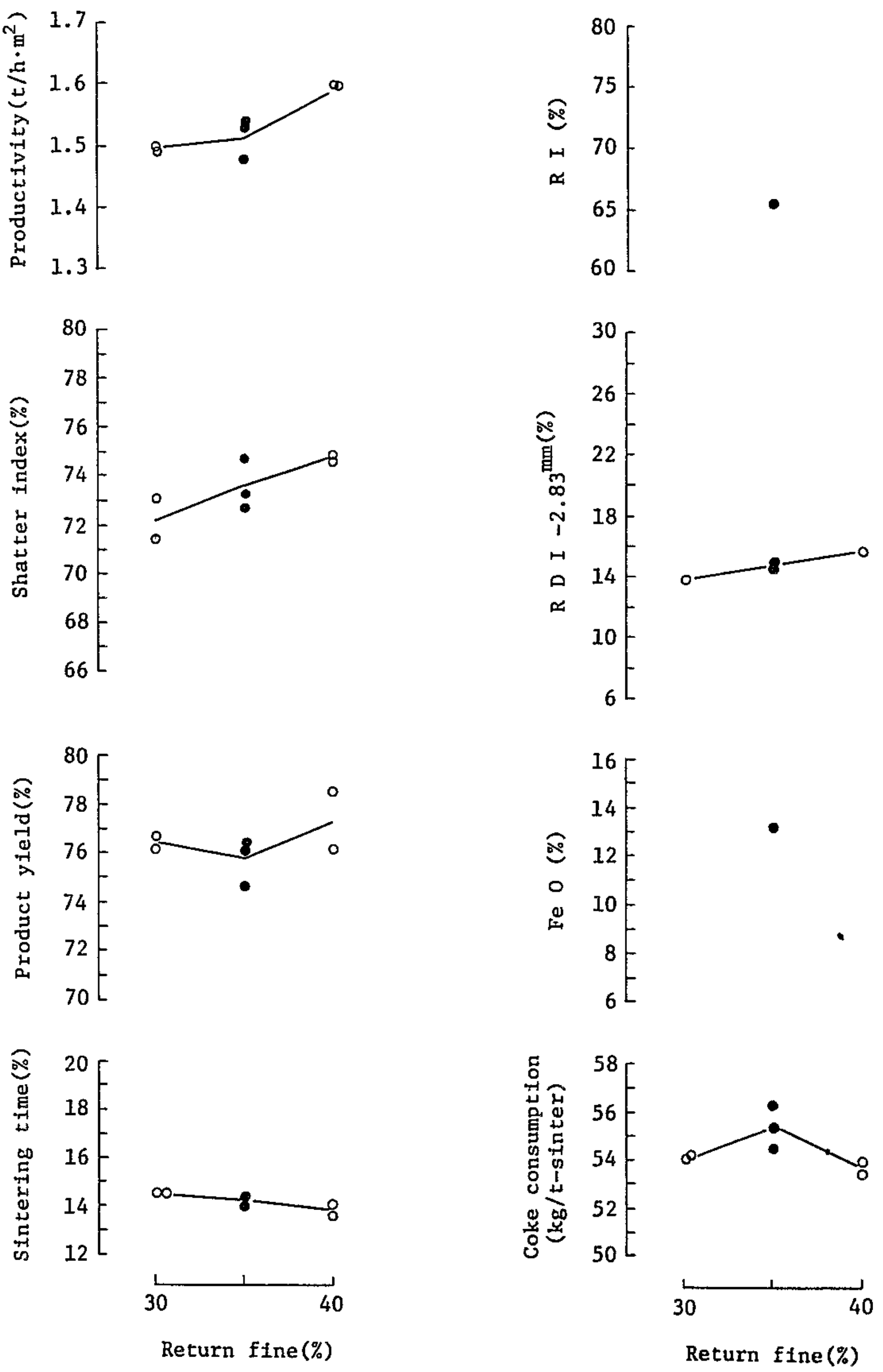


Fig. 5 - 15 **Effects of return fine**
(R.O./T.O. = 60/40, 4% Coke breeze)

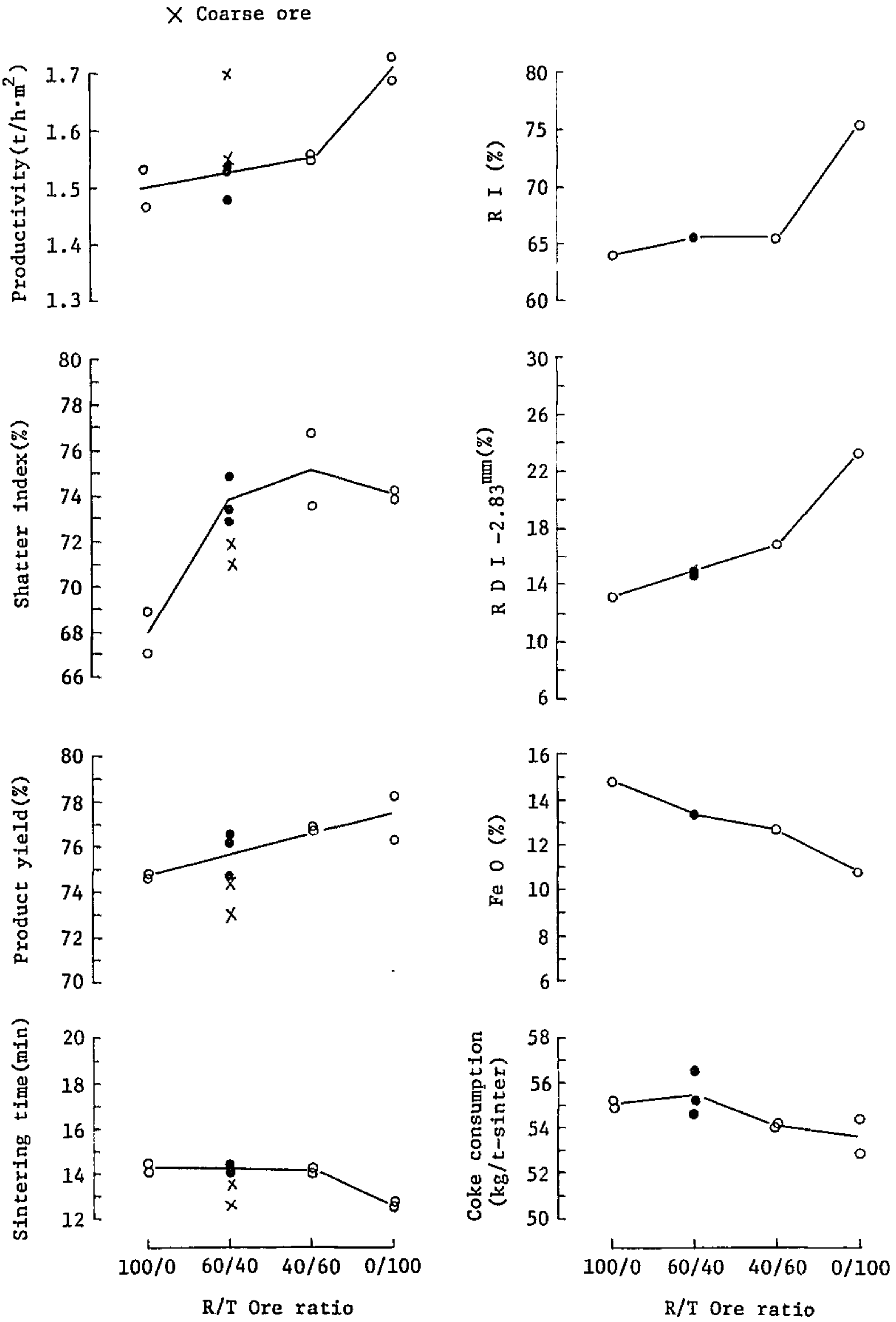


Fig. 5 - 16 Effects of blending ratio of refractory and transition ores (4% Coke breeze)

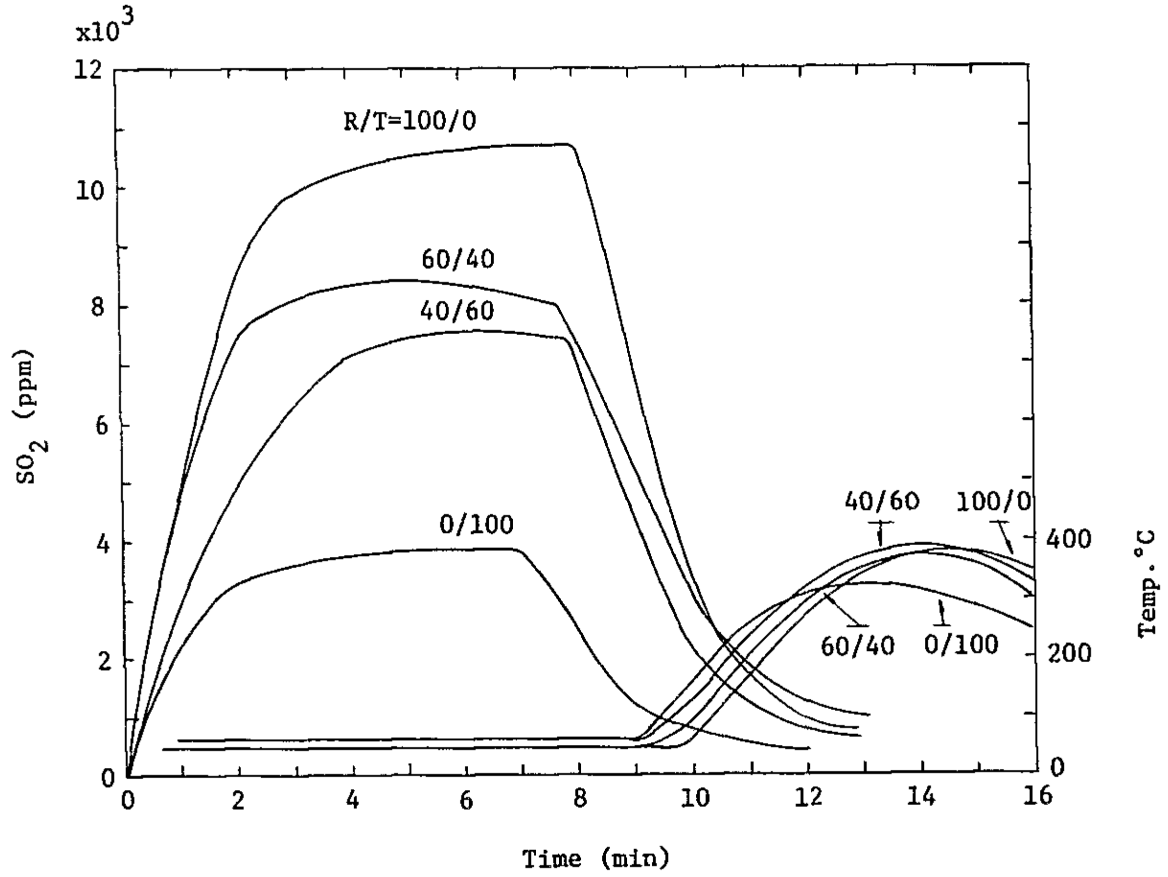


Fig. 5 - 17 Change of SO_2 in waste gas during sintering

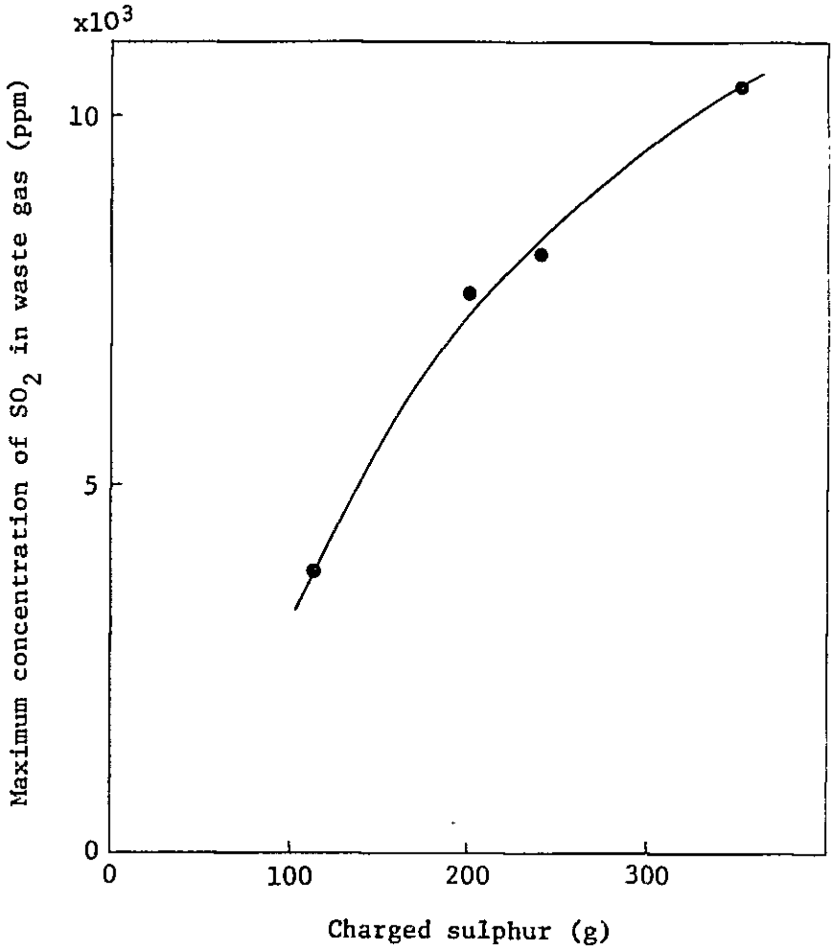


Fig. 5 - 18 Relationship between charged sulphur and concentration of SO_2 in waste gas during sintering

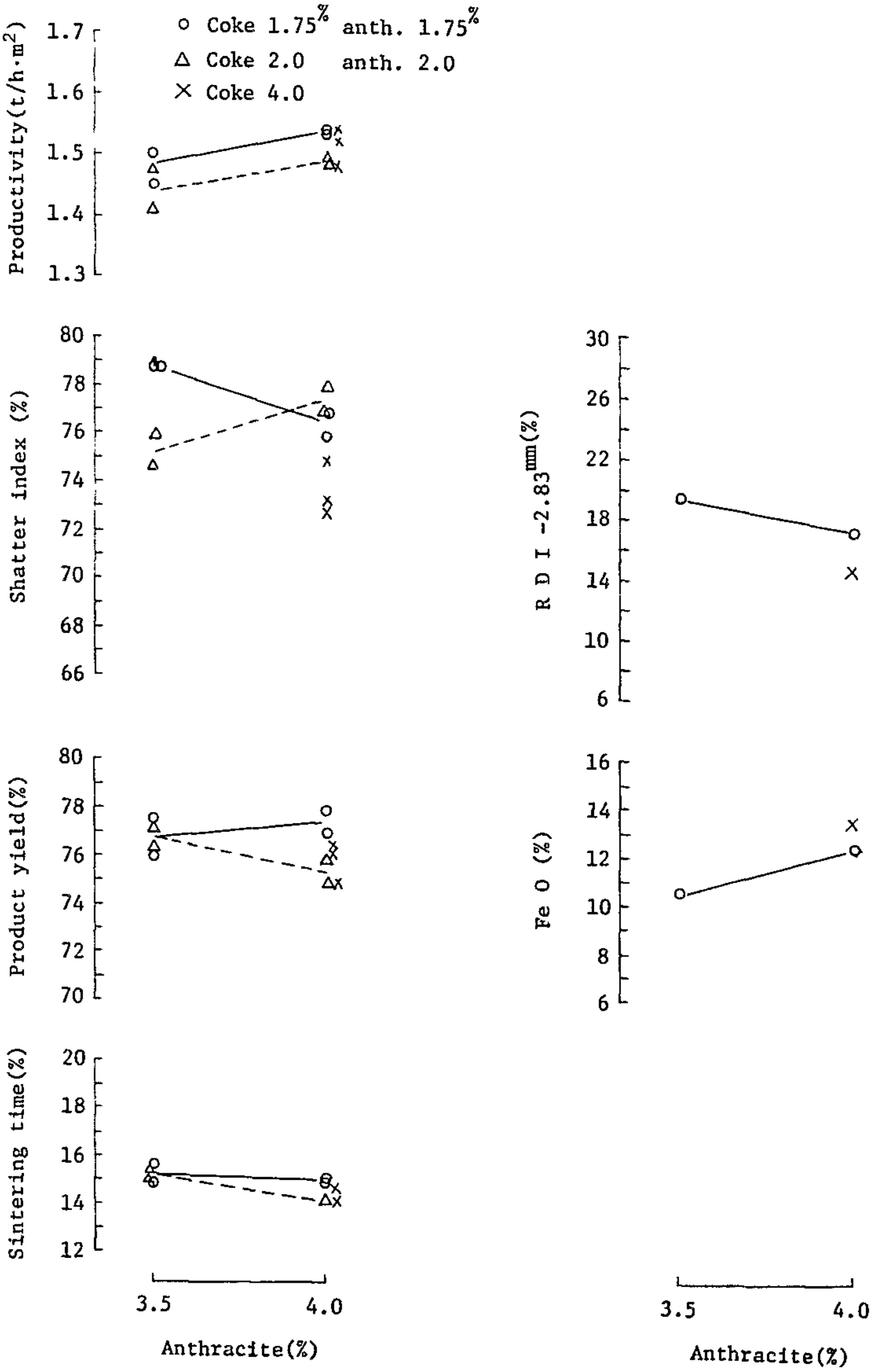


Fig. 5 - 19 Effects of Anthracite
(R.O./T.O. = 60/40).

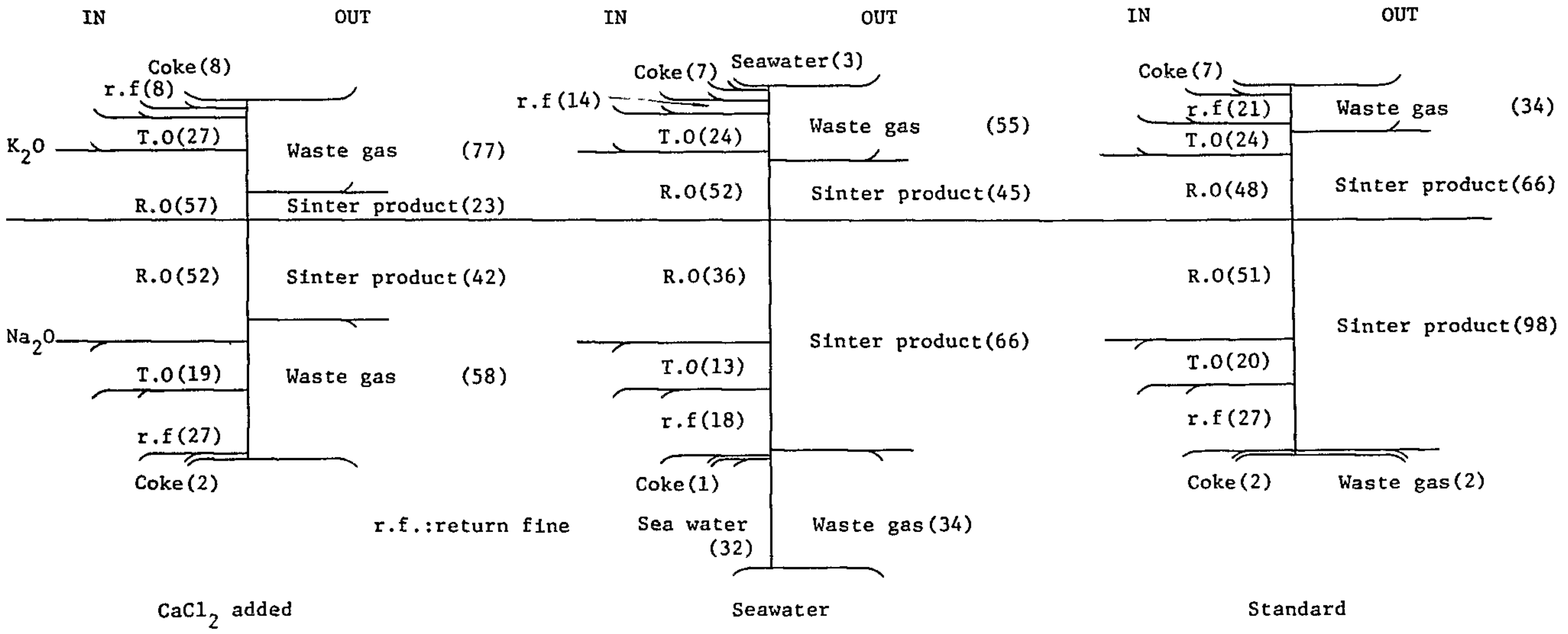


Fig. 5 - 20 Alakali balance in before and after sintering

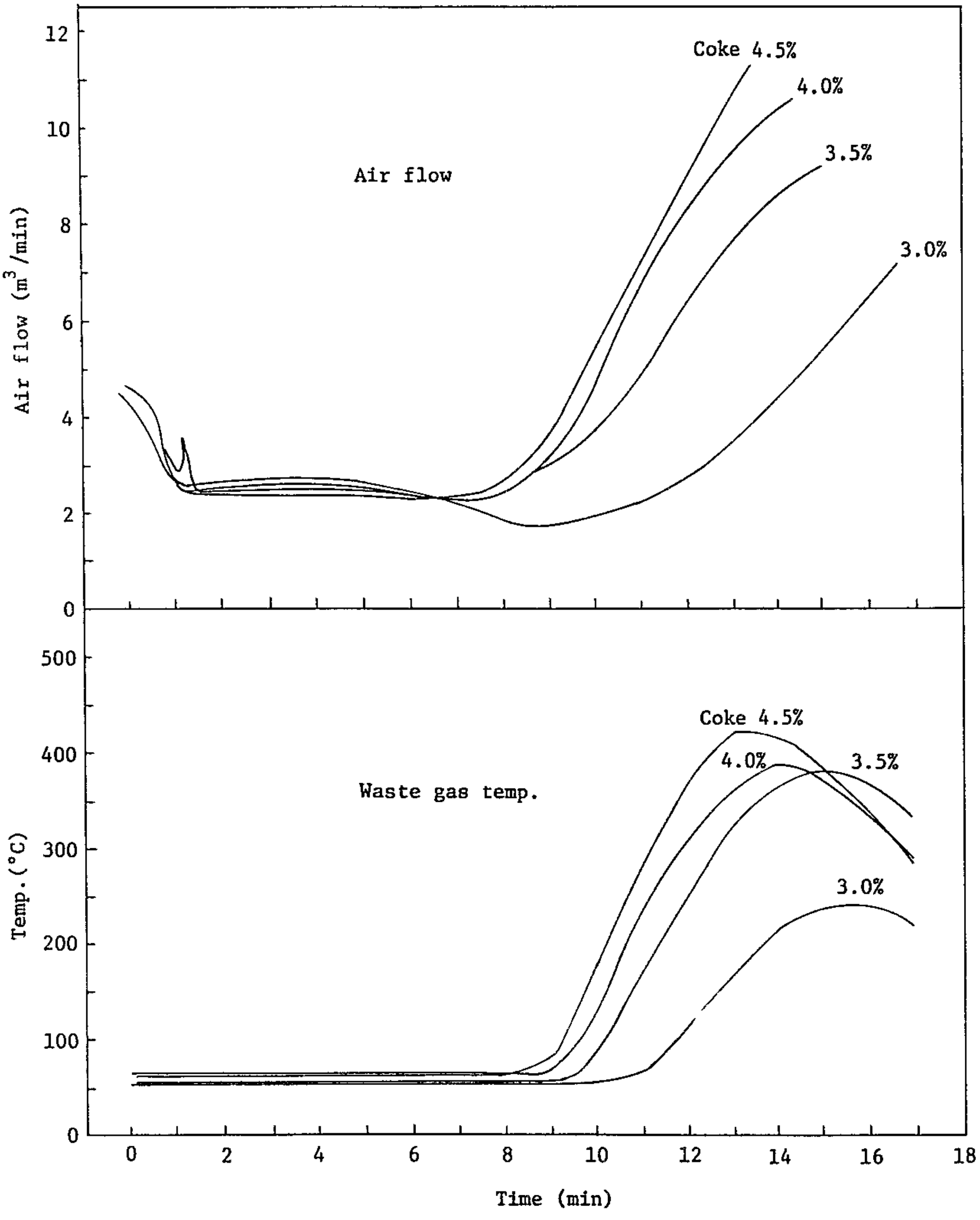


Fig. 5 - 21 Change of air flow and waste gas temperature during sintering

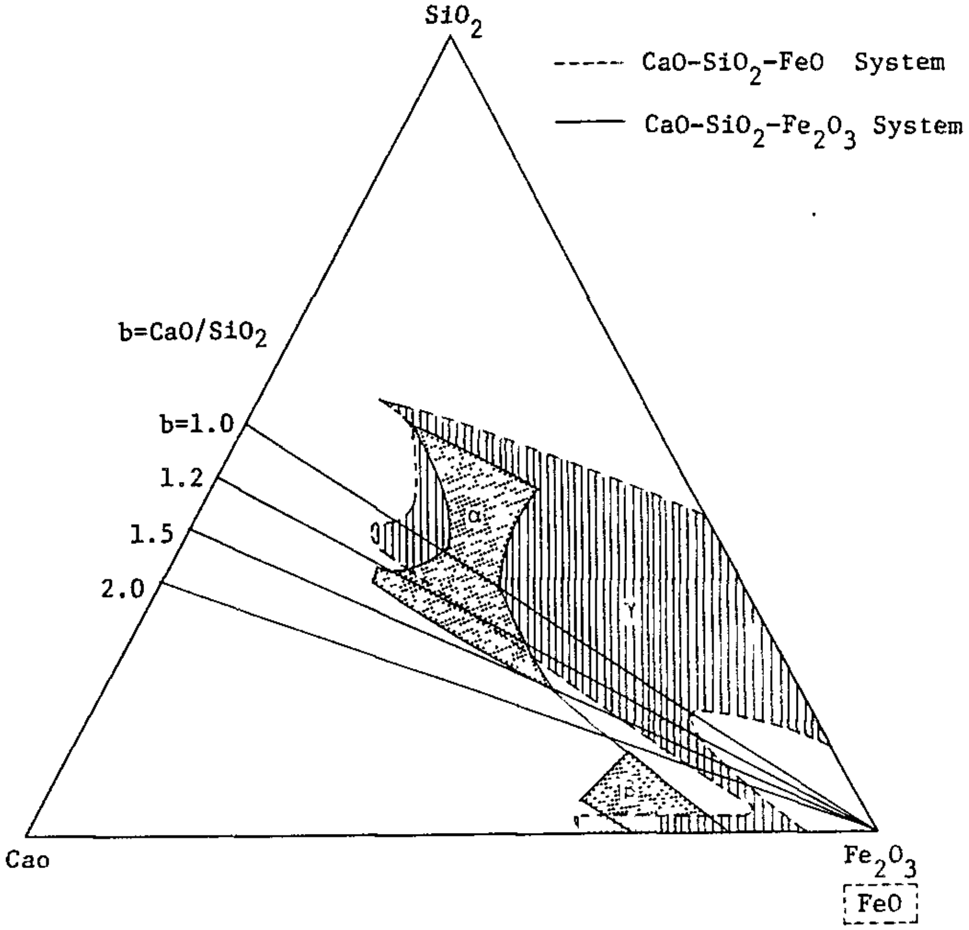


Fig. 5 - 22 Melting zones for CaO-SiO$_2$-iron oxide (FeO, Fe$_2$O$_3$) systems at 1300°C and above

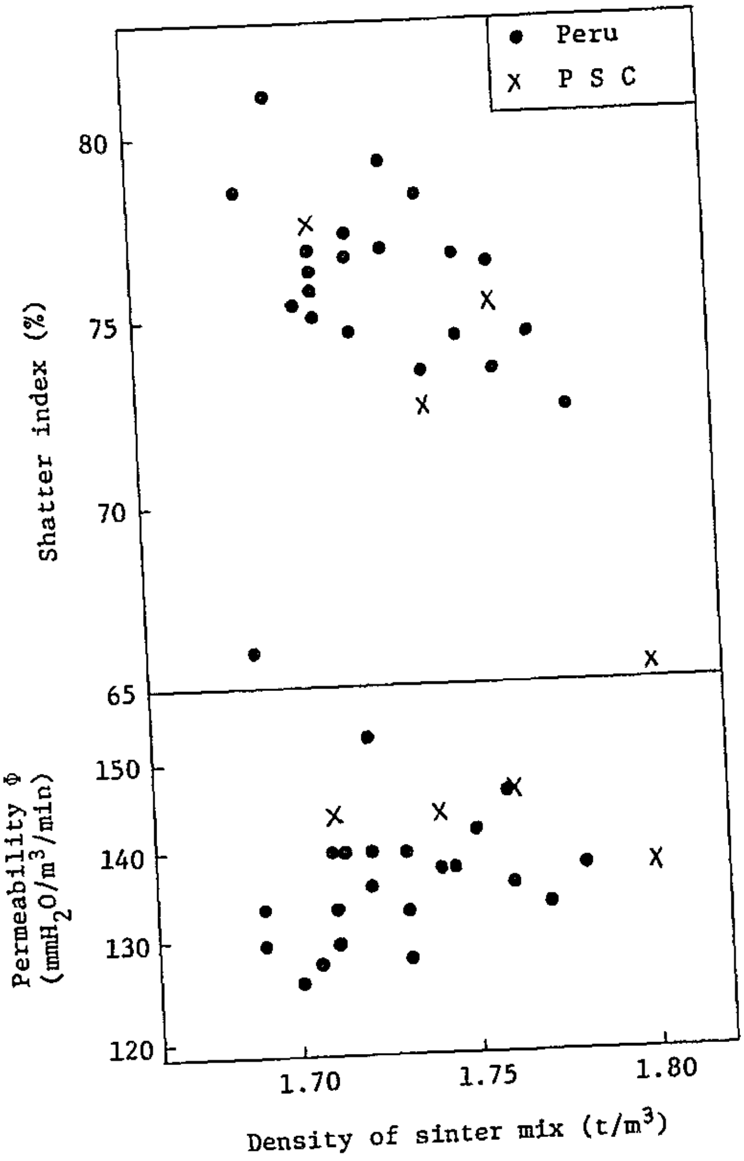


Fig. 5 - 23 Effects of density of sinter mix on permeability before ignition, and shatter index

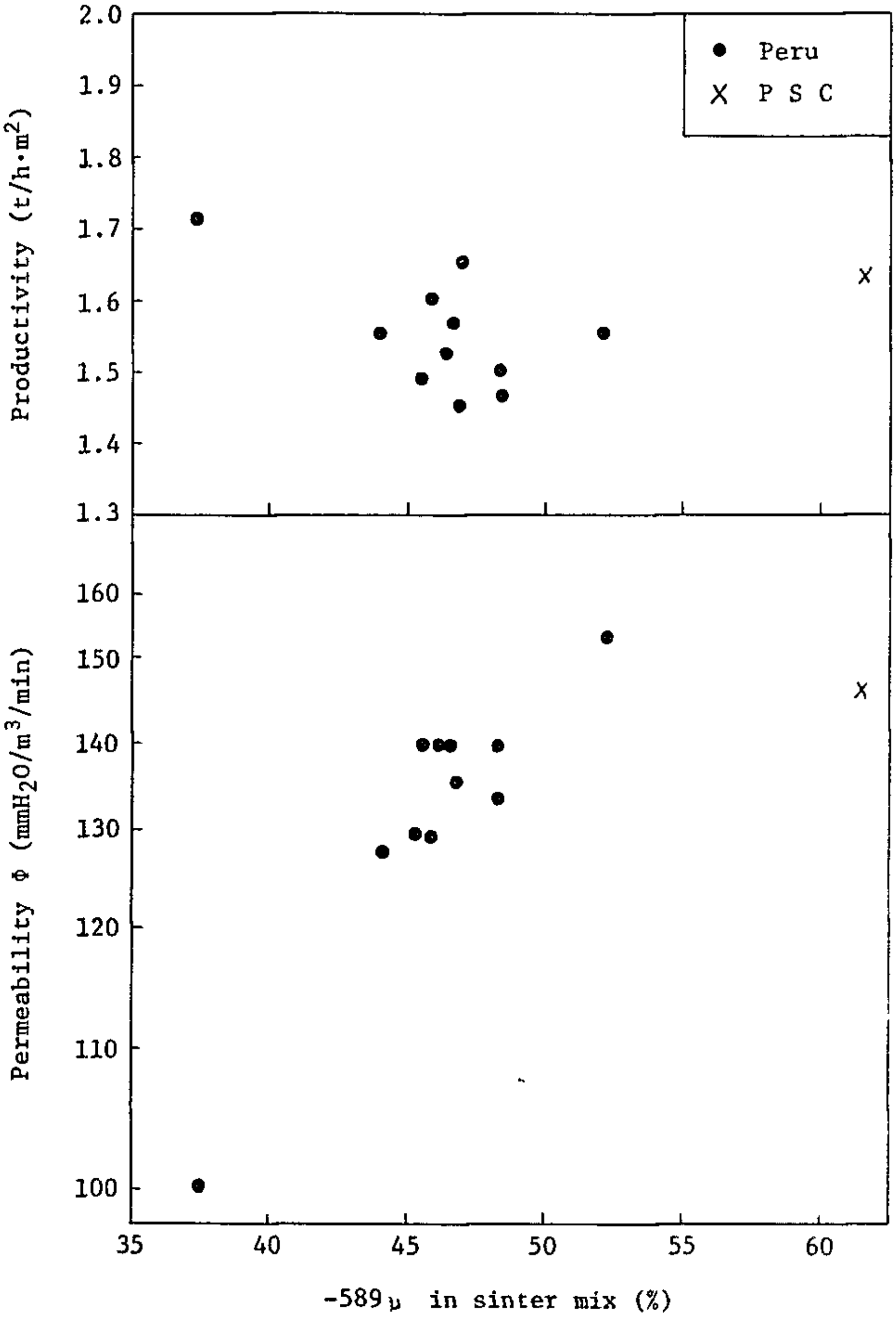


Fig. 5 - 24 Effects of fine particles in sinter mix on permeability before ignition, and productivity

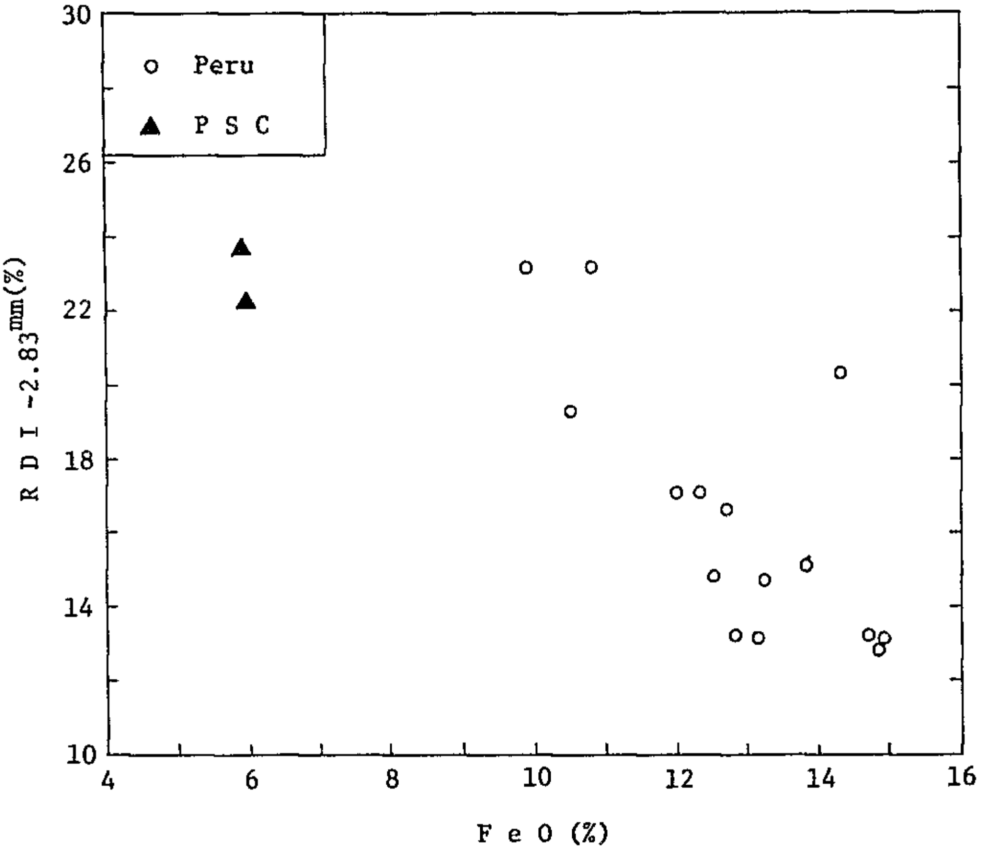


Fig. 5 - 25 Relationship between FeO in sinter product and R D I

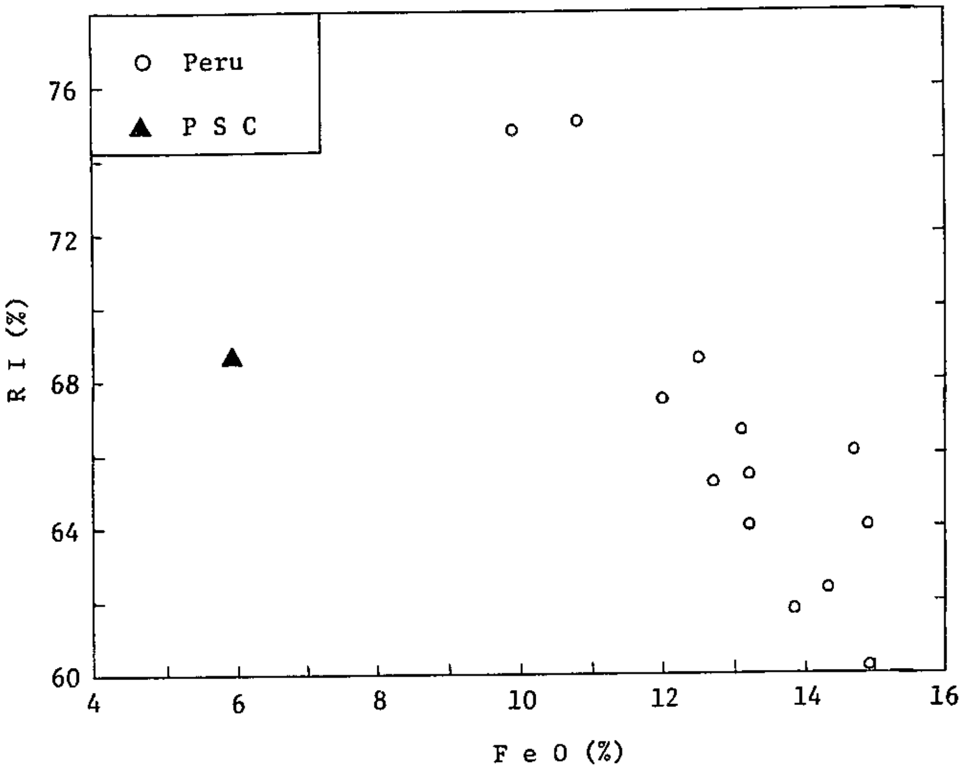
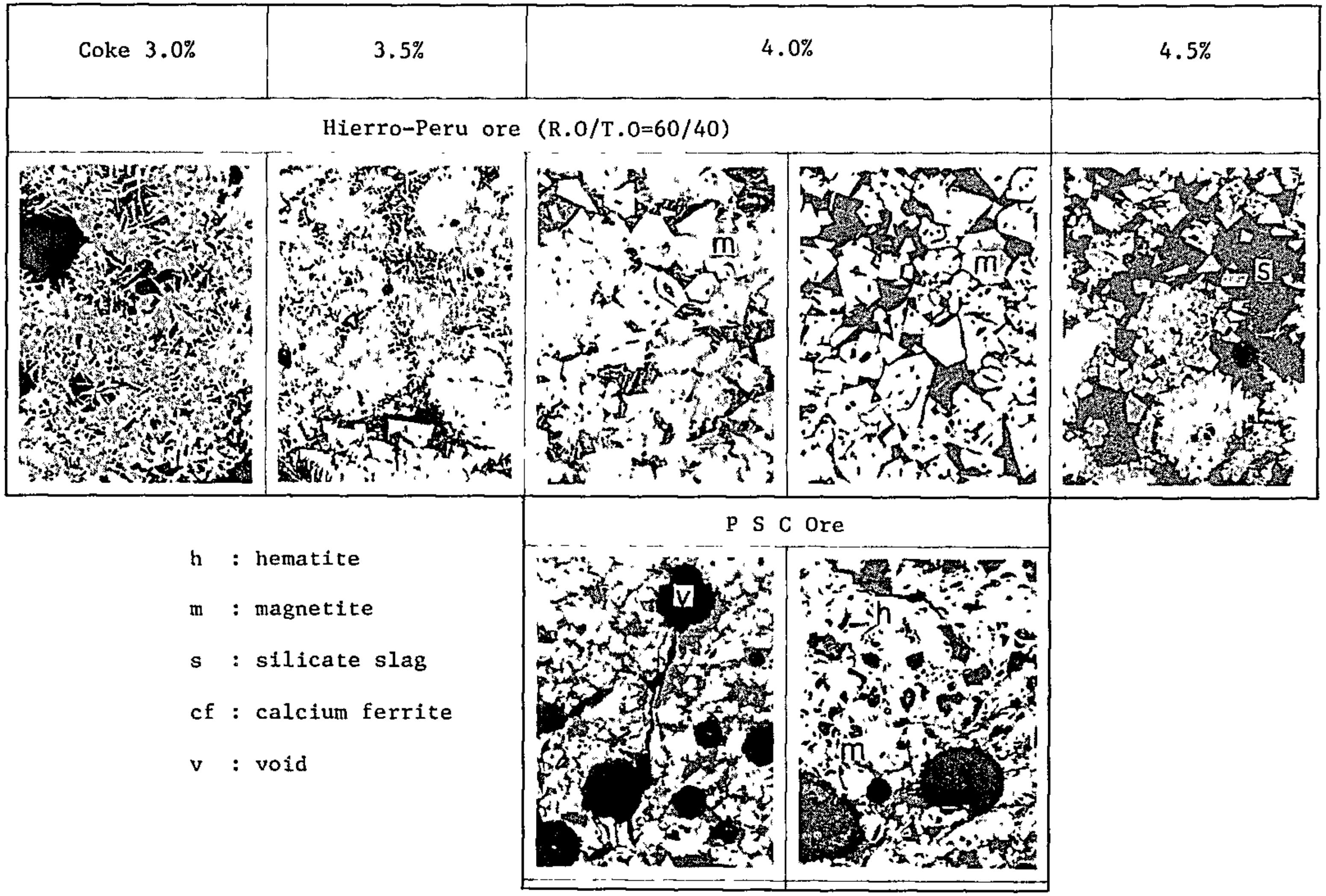


Fig. 5 - 26 Relationship between FeO in sinter product and R I

Photo 5 - 1 Microstructure of Hierro-Peru ore sinter in relation to coke breeze content (x100)



h : hematite

m : magnetite

s : silicate slag

cf : calcium ferrite

v : void

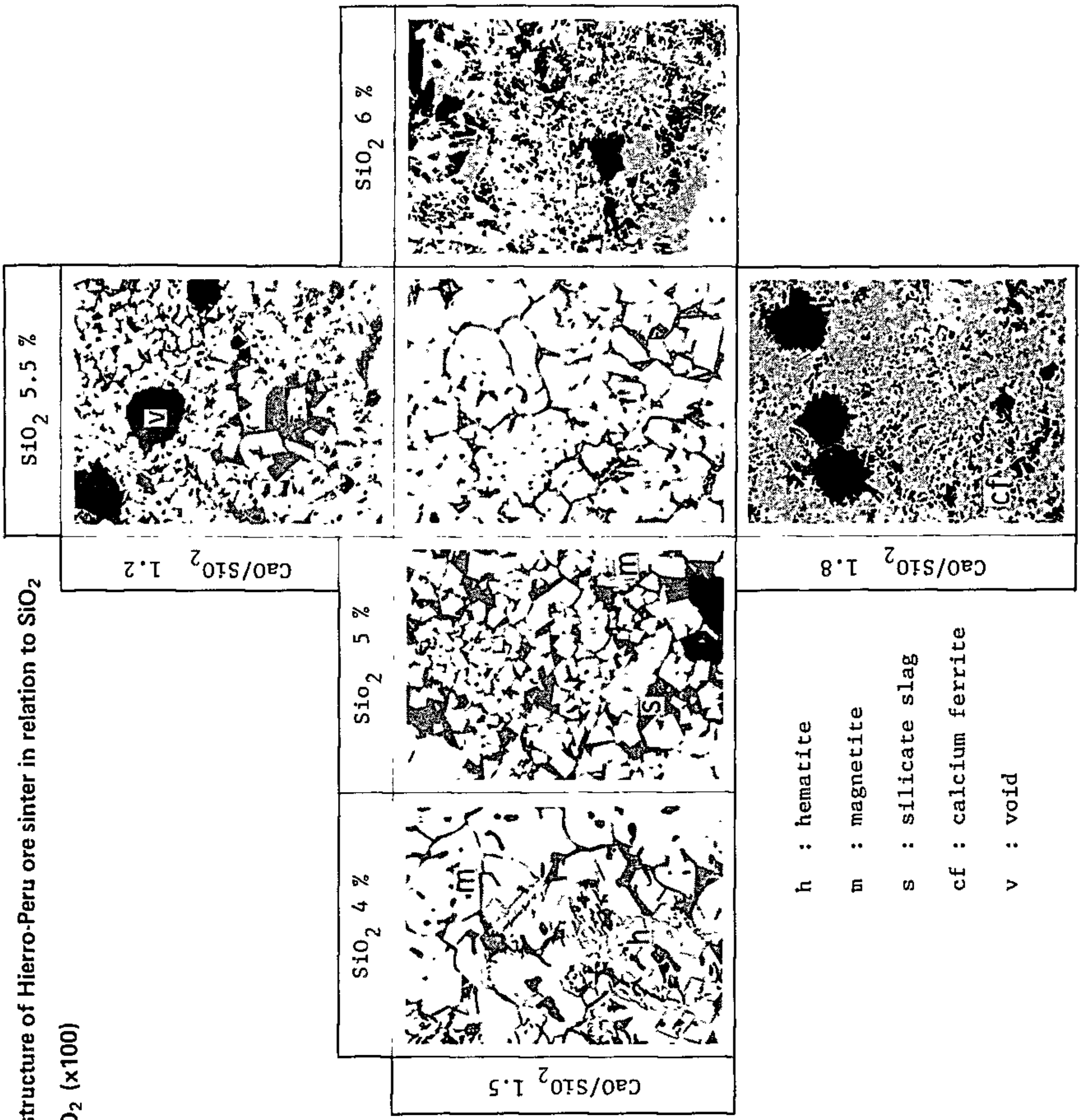


Photo 5-2 Microstructure of Hierro-Peru ore sinter in relation to SiO$_2$ content and CaO/SiO$_2$ (x100)

5.5 Study of Raw Materials and Production Conditions

5.5.1 Outline

Hierro-Peru iron ore has a large variation in its chemical compositions and contains a high percentage of sulphur and alkali. Taking into consideration the effects the properties of the iron ore have upon sintering operations, blast furnace operations and the environment countermeasures for several problems were studied.

The chemical and physical properties of the ore and the unit consumption of various items necessary for producing sintered ore were studied using the results of the pot tests and various other examinations.

A pot test is a simulated sintering operation. Because of some problems as to its accuracy, the study was carried out with a comparison of the results of pot tests using PSC sinter feed and with the properties of PSC sintered ore.

Before the implementation of the Hierro-Peru sintering project, it is desirable to carry out a test using actual sintering facilities and Hierro-Peru ore. This test will enable the confirmation of the unit consumptions of the raw materials and add to the understanding of operating conditions, such as the method of material charging and data which were not obtainable from the pot test.

5.5.2 Variation of Chemical Composition and Countermeasures

(1) Need to Reduce Variation of Chemical Composition

The results of the study of variation in the chemical composition of Hierro-Peru iron ore carried out by Hierro-Peru in December 1979, the chemical assays made in 1979 and in the past five years are shown in Tables 5 - 17, 5 - 18, and 5 - 19.

The results show that the standard variation of SiO_2 was $\sigma = 0.490\%$. For sinter produced with this ore, the SiO_2 content varies 2% or more, basicity (CaO/SiO_2) varies 0.4, and the shatter index and reduction disintegration index vary 2 ~ 6% and 6 ~ 10% respectively. When blast furnace burden contains 20% of Hierro-Peru sinter, the variation of basicity of the slag in the blast furnace is 0.09.

As sintered ore with such a large variation in quality may cause variations in the conditions of the blast furnace, it is necessary to take proper measures in advance. For example, the range of standard variation of $\sigma = 0.16\%$ for Kawasaki Steel Corporation's sintering material which is equivalent to 1/3 of the amount of the ore in question.

To raise the commercial value of Hierro-Peru sintered ore, it is essential to decrease the variation in the SiO_2 content. It is considered that the causes for the variation of SiO_2 in Hierro-Peru iron ore are differences of ore deposits, the degree of beneficiation, particle size (since chemical assay differs according to size: Tables 5 - 9, and 5 - 10), and in the blending proportion of R.O. to T.O., etc. Since it is difficult to eliminate these factors, it will be effective to obtain homogeneity by ore bedding.

Table 5 - 17 n, max, min, mean and standard deviation of Concentrate type KN by Shift (December, 1979)

	Concentrate KN from T.O.							Concentrate KN from P.O.							Concentrate Total KN						
	-100 mesh	Fe	S	CaO	MgO	SiO_2	Al_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO_2	AL_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO_2	Al_2O_3
n	73	87	87	87	87	87	47	73	87	87	87	87	87	47	72	87	87	87	87	87	47
max.	30.7	66.8	0.960	1.33	1.89	4.36	0.53	43.9	67.4	1.270	1.50	1.84	4.81	1.14	39.1	67.0	1.080	1.33	1.66	4.82	0.86
min.	14.5	64.0	0.470	0.50	0.71	2.45	0.16	28.8	63.7	0.532	0.53	1.01	2.50	0.40	22.0	64.0	0.664	0.52	0.95	2.59	0.32
mean	21.44	65.26	0.6251	0.803	1.329	3.422	0.349	94.65	65.71	0.9903	0.878	1.371	3.604	0.659	31.28	65.53	0.8953	0.840	1.353	3.542	0.566
$\hat{\sigma}_{n-1}$	2.90	0.64	0.0988	0.170	0.135	0.421	0.069	2.84	0.81	0.1166	0.198	0.168	0.542	0.160	2.69	0.59	0.0920	0.159	0.134	0.490	0.120

Table 5 - 17 - a Variation of Chemical Components on Concentrate, Type KN, December 1979

Date	Shift	Concentrate KN from T.O.							Concentrate KN from P.O.							Concentrate Total KN						
		-100 mesh	Fe	S	CaO	MgO	SiO_2	AL_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO_2	Al_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO_2	Al_2O_3
1979 Dec.																						
1	1	23.2	66.8	0.576	0.64	1.29	2.77	0.25	34.4	67.2	0.998	0.76	1.25	2.80	0.41	30.5	67.0	0.904	0.74	1.28	2.73	0.32
	2	22.3	66.4	.733	73	1.26	3.15	.34	35.5	67.0	1.014	.84	1.36	2.90	.46	30.5	66.7	.882	.70	1.23	2.95	.41
	3	-	66.6	529	.64	1.16	2.70	.24	-	67.4	1.097	.73	1.23	2.85	.40	-	65.9	1.080	.95	1.36	3.10	.54
2	1	21.2	65.7	0.480	0.81	1.53	3.55	0.27	34.7	67.0	0.927	0.78	1.20	2.65	0.46	29.8	66.6	0.862	0.76	1.29	3.30	0.46
	2	23.8	66.1	.621	.74	1.13	2.70	.26	32.3	66.7	.995	.70	1.16	2.61	.53	32.0	66.5	.975	.64	1.06	2.59	.50
	3	21.5	66.0	.470	.76	1.16	2.72	18	30.2	65.9	1.035	.78	1.18	3.34	.70	29.1	66.8	.848	.70	1.06	3.10	.55
3	1	24.1	66.0	0.527	0.76	1.33	2.45	0.16	31.5	65.9	1.036	0.90	1.39	3.15	0.67	29.4	66.3	0.900	0.70	1.33	2.85	0.54
	2	16.3	65.8	.520	.62	1.26	3.00	27	30.3	66.7	1.200	.77	1.25	2.95	45	28.1	66.3	1.040	.74	1.26	2.82	.43
	3	18.8	66.0	.524	.63	1.29	2.84	.29	31.4	66.4	0.980	.83	1.33	2.85	.53	31.4	66.2	0.880	.77	1.33	3.05	.50
4	1	17.5	65.7	0.620	0.62	1.34	3.30	0.32	28.8	67.0	0.984	0.70	1.25	3.12	0.51	27.4	66.3	0.232	0.67	1.29	3.21	0.45
	2	15.5	65.8	496	.53	1.20	3.00	.33	31.7	66.8	.980	.53	1.15	2.50	.46	31.0	66.1	840	.62	1.28	3.08	.44
	3	19.9	64.8	.580	67	1.29	3.10	.33	30.3	66.2	.881	.60	1.16	2.62	.42	32.7	65.6	.960	.64	1.25	3.07	.47
5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	19.6	65.6	0.610	0.68	1.36	3.77	0.35	28.9	66.7	1.084	0.75	1.23	3.29	0.54	28.7	66.3	0.909	0.72	1.30	2.60	0.44
	3	23.7	64.7	.665	.92	1.26	3.15	.36	33.7	65.6	1.164	.70	1.23	3.20	.63	39.1	65.1	.942	.67	1.39	3.10	.56
6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	14.5	65.2	0.626	0.67	1.34	3.54	0.38	34.7	66.2	1.101	0.73	1.33	3.32	0.70	31.1	65.8	1.018	0.70	1.34	3.44	0.60
	3	21.0	65.6	700	.77	1.26	3.00	.42	37.2	66.1	1.130	.78	1.34	3.37	.96	34.9	65.8	1.000	.76	1.33	3.24	.86
7	1	23.2	65.8	0.580	0.53	0.71	2.85	0.33	86.0	66.2	1.160	0.83	1.29	3.25	0.84	31.4	66.0	0.920	0.78	1.00	2.90	0.63
	2	21.0	64.8	.592	.90	1.38	3.16	.42	39.6	66.0	1.270	.77	1.33	3.36	1.07	33.3	65.4	.919	.80	1.36	3.25	.84
	3	20.1	64.8	.548	.69	1.26	3.07	.40	35.6	66.2	0.865	0.84	1.39	3.20	0.88	34.8	65.4	.768	.80	1.34	3.19	.76
8	1	24.8	66.7	0.480	0.78	1.28	2.85	0.33	35.2	65.6	0.930	0.84	1.36	3.60	1.14	29.6	65.8	0.820	0.92	1.53	3.45	0.86
	2	21.4	66.2	.505	.70	1.11	3.54	.53	34.6	65.1	.970	1.10	1.61	3.08	0.78	28.1	65.7	.869	1.02	1.29	2.75	.79
	3	21.4	65.0	.600	90	1.48	3.50	10	43.9	66.5	.925	1.13	1.43	3.20	.56	36.0	65.8	.845	0.97	1.36	3.28	.48
9	1	-	65.8	0.494	0.84	1.28	3.87	0.10	-	65.5	0.898	0.91	1.29	3.36	0.70	-	65.6	0.710	0.84	1.28	3.44	0.50
	2	-	65.3	559	1.06	1.58	2.67	42	-	66.2	0.780	.98	1.34	3.94	.65	-	65.7	.740	.99	1.39	3.50	.54
	3		[illegible]	.549	1.01	1.67	3.51	.28	-	66.0	0.792	.83	1.34	4.13	.56	-	65.6	664	85	1.39	3.74	.45

Table 5 - 17 - b

Date	Shift	Concentrate KN from T.O.							Concentrate KN from P.O.							Concentrate Total KN						
		-100 mesh	Fe	S	CaO	Mgo	SiO2	AL_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO2	Al_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO2	Al_2O_3
10	1	-	65.7	0.550	0.97	1.54	3.40	0.32	-	65.2	0.980	0.90	1.33	3.79	0.73	-	65.5	0.800	0.92	1.43	3.55	0.60
	2	-	65.0	.660	1.01	1.54	3.54	.35	-	64.7	1.000	.90	1.36	3.18	.75	-	65.1	.750	.96	1.41	3.56	.61
	3	-	65.3	.644	0.70	1.28	3.01	.35	-	65.1	0.972	.84	1.47	3.98	.82	-	65.4	.844	.74	1.23	3.08	.57
11	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	65.0	0.589	0.85	1.34	3.42	0.35	-	65.1	0.904	1.12	1.54	3.60	0.68	-	65.0	0.783	1.01	1.41	3.45	0.55
	3	-	66.3	.626	1.12	1.29	3.60	.38	-	64.8	.922	1.02	1.31	4.15	.70	-	65.2	.798	1.07	1.31	3.65	.58
12	1	-	64.7	0.632	1.05	1.34	3.92	0.41	-	65.0	.964	1.27	1.61	4.05	0.71	-	65.5	0.796	1.06	1.43	3.97	0.51
	2	-	64.8	.565	0.94	1.18	3.55	.31	-	65.8	1.151	0.99	1.10	3.52	.59	-	64.9	0.919	0.96	1.13	3.52	.46
	3	-	65.2	.629	0.57	1.31	3.56	.38	-	63.7	1.041	0.71	1.36	3.45	.62	-	65.9	.944	0.56	1.25	3.25	.48
13	1	-	64.9	0.661	0.95	1.46	3.88	0.36	-	65.9	0.891	0.62	1.28	3.34	0.50	-	65.4	0.965	1.23	1.44	3.80	0.40
	2	-	65.5	.577	.52	1.23	3.40	.38	-	65.8	1.070	0.62	1.38	3.70	.67	-	65.6	1.049	0.53	1.33	3.60	.57
	3	16.2	64.7	.608	.78	1.89	3.43	.41	32.4	65.6	0.891	1.40	1.28	3.45	.68	25.2	64.8	0.702	1.11	1.29	3.91	.67
14	1	23.5	64.5	0.640	0.95	1.67	4.12	0.40	34.3	64.9	1.101	1.06	1.64	4.09	0.76	29.9	64.5	1.041	0.94	1.63	3.94	0.69
	2	26.2	65.2	.588	.78	1.53	3.55	.32	36.4	66.0	0.866	0.77	1.25	3.23	.59	30.5	65.4	0.886	.92	1.41	3.71	.57
	3	21.1	65.3	.754	.76	1.25	3.70	.38	35.0	66.6	0.970	0.67	1.08	3.08	.57	28.7	66.4	0.943	.74	1.26	3.32	.52
15	1	25.2	65.1	0.726	0.71	1.11	3.60	0.39	37.0	66.1	0.941	0.74	1.25	3.70	0.65	32.2	65.5	0.859	0.78	1.31	3.39	0.55
	2	14.5	64.1	.665	.91	1.44	4.00	.38	39.6	66.6	.826	1.05	1.26	3.17	.59	29.8	65.5	.772	.77	1.26	3.45	.56
	3	16.9	64.7	.672	.98	0.83	4.02	.40	32.1	64.9	.881	0.77	1.39	3.89	.73	26.1	64.8	.797	.87	1.26	4.23	.65
16	1	30.7	65.4	0.710	0.90	1.58	4.36	0.44	30.7	65.0	0.938	0.88	1.86	3.75	0.70	32.4	64.9	0.964	0.85	1.38	4.05	0.66
	2	20.7	64.2	.744	.94	1.66	4.13	.41	35.2	65.6	.926	.78	1.18	3.58	.67	31.2	64.7	.904	.88	1.49	4.21	.65
	3	25.5	65.4	.732	1.13	1.66	4.09	.39	35.2	65.0	.936	1.16	1.44	4.51	.82	34.4	65.2	.785	.69	1.49	3.33	.57
17	1	21.4	64.0	0.882	1.13	1.59	4.18	0.44	30.2	65.1	1.129	1.12	1.33	3.87	0.74	28.3	64.9	1.070	0.84	1.39	3.76	0.62
	2	25.2	64.9	.703	1.06	1.51	3.90	.41	35.0	65.9	0.877	1.16	1.20	3.40	.68	32.8	65.5	0.808	1.08	1.38	3.78	.61
	3	21.2	66.4	.573	0.66	1.23	3.31	-	33.0	64.7	0.870	0.71	1.36	4.09	-	28.9	65.6	0.830	0.66	1.29	3.88	-
18	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	23.5	65.1	0.754	0.81	1.38	3.68	-	39.5	65.4	1.086	0.90	1.41	3.72	-	33.7	65.3	0.887	0.85	1.36	3.64	-
	3	19.1	65.4	.537	.88	1.23	3.80	-	34.9	64.3	1.053	1.27	1.64	3.42	-	32.2	65.2	.998	1.04	1.41	4.00	-

Table 5 - 17 - c

Date	Shift	Concentrate KN from T.O.							Concentrate KN from P.O.							Concentrate Total KN						
		-100 mesh	Fe	S	CaO	MgO	SiO_2	AL_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO_2	Al_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO_2	Al_2O_3
19	1	25.3	64.4	0.617	0.74	1.34	3.16	-	36.7	64.8	0.882	0.95	1.51	4.20	-	-	65.0	0.838	0.90	1.41	3.77	-
	2	24.6	65.1	.511	.71	1.34	3.50	-	35.9	64.1	1.051	.94	1.64	4.20	-	31.0	64.8	.935	.87	1.48	3.75	-
	3	22.8	65.1	.603	.80	1.43	3.60	-	33.6	64.3	1.096	.94	1.74	4.40	-	28.9	64.8	1.008	.91	1.69	4.25	-
20	1	20.6	65.2	0.701	0.53	1.28	3.60	-	37.7	65.3	0.986	0.59	1.43	3.90	-	31.2	65.1	0.877	0.67	1.41	3.74	-
	2	21.8	66.0	.608	.50	1.26	3.29	-	34.8	65.6	0.964	.62	1.41	3.62	-	31.1	65.6	.877	.52	1.39	3.53	-
	3	20.7	65.2	.734	.87	1.33	3.65	-	37.6	65.3	1.122	.90	1.48	4.13	-	29.7	65.3	.996	.63	.95	4.05	-
21	1	22.7	65.8	0.797	0.84	1.23	2.80	-	38.3	66.3	0.996	0.67	1.21	3.34	-	31.6	65.9	0.870	0.67	1.31	3.23	-
	2	21.7	65.9	.682	.70	1.39	2.56	-	37.8	65.9	.870	.81	1.10	3.41	-	32.0	65.9	.860	.70	1.33	3.44	-
	3	21.4	65.7	.650	.94	1.23	3.17	-	31.1	64.5	1.110	1.33	1.51	4.70	-	29.2	65.0	1.001	1.33	1.49	4.07	-
22	1	25.0	64.9	0.715	1.33	1.44	4.03	-	32.5	64.9	1.082	1.30	1.61	4.55	-	32.2	64.4	1.062	1.13	1.53	4.82	-
	2	21.5	64.1	.723	1.11	1.16	2.98	-	36.1	64.8	1.042	1.50	1.68	4.23	-	35.3	64.5	1.012	1.15	1.51	4.14	-
	3	25.4	64.3	.916	0.62	1.15	3.31	-	35.3	64.1	1.020	0.81	1.43	3.91	-	33.6	64.0	1.002	0.73	1.33	3.86	-
23	1	21.8	65.0	0.960	0.59	1.10	3.35	-	33.4	66.3	0.931	0.76	1.46	3.67	-	31.9	65.7	0.848	0.70	1.33	3.37	-
	2	16.6	65.4	.627	.56	1.18	3.38	-	30.0	66.0	.801	.78	1.41	3.83	-	31.1	65.8	.815	.77	1.43	4.04	-
	3	22.5	65.2	.742	.56	1.13	3.02	-	40.0	65.5	.911	.87	1.49	4.04	-	37.6	65.2	.834	.80	1.46	3.76	-
24	1	21.1	64.7	0.792	0.74	1.25	3.58	-	35.0	64.7	0.970	0.94	1.48	4.52	-	31.1	64.7	0.940	0.92	1.44	4.38	-
	2	21.3	64.5	.511	.81	1.31	3.92	-	36.6	65.1	.909	.96	1.49	4.25	-	31.7	64.7	.945	.92	1.31	4.43	-
	3	20.1	65.0	.613	.92	1.48	3.72	-	34.0	65.8	.942	.84	1.38	3.35	-	29.5	65.5	.836	.87	1.29	3.45	-
25	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	21.1	65.1	0.535	0.98	1.31	3.41	-	33.8	65.5	1.024	1.25	1.79	3.91	-	34.1	65.2	0.951	1.08	1.56	3.72	-
	3	23.8	66.4	.502	.85	1.29	3.20	-	33.6	64.8	1.086	0.95	1.53	4.50	-	31.1	65.3	.951	0.92	1.43	4.23	-
26	1	20.3	66.2	0.621	0.87	1.34	3.50	-	32.2	64.3	1.119	1.02	1.53	4.41	-	30.2	65.3	0.998	0.99	1.49	3.84	-
	2	17.6	64.5	.515	1.01	1.48	3.87	-	34.1	66.0	1.021	0.90	1.38	4.24	-	31.3	65.5	0.919	0.99	1.41	4.01	-
	3	20.9	65.2	.617	0.90	1.38	3.26	-	36.0	66.1	0.936	0.85	1.31	3.62	-	36.4	65.6	0.872	.85	1.38	3.52	-
27	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	22.5	65.2	0.555	0.99	1.79	3.22	-	37.6	63.7	1.131	0.87	1.58	4.81	-	31.9	64.4	0.850	0.90	1.61	4.20	-
	3	22.8	64.8	.608	.75	1.16	3.26	-	34.9	65.5	0.936	1.09	1.71	4.00	-	31.9	65.3	.831	1.04	1.66	3.65	-

Table 5 - 17 - d

Date	Shift	Concentrate KN from T.O.							Concentrate KN from P.O.							Concentrate Total KN						
		-100 mesh	Fe	S	CaO	MgO	SiO_2	AL_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO_2	Al_2O_3	-100 mesh	Fe	S	CaO	MgO	SiO_2	Al_2O_3
28	1	22.6	65.0	0.717	0.91	1.46	3.60	-	31.1	64.7	1.194	1.11	1.84	4.60	-	22.0	65.0	1.053	0.95	1.59	3.81	
	2	21.4	65.3	.554	.85	1.25	3.03	-	38.3	66.6	1.006	0.91	1.31	2.85	-	33.0	66.5	0.875	.88	1.26	2.90	
	3	22.1	65.1	.680	.67	1.23	3.30	-	35.3	66.3	1.100	0.84	1.18	2.70	-	30.6	66.1	0.950	.76	1.25	2.85	
29	1	18.7	65.9	0.509	0.88	1.38	3.85	-	36.4	66.5	0.944	0.73	1.26	3.70	-	30.2	66.3	0.794	0.66	1.23	3.80	
	2	18.1	65.0	.538	.56	1.10	3.20	-	36.5	67.0	0.532	.74	1.33	2.85	-	35.0	66.0	0.839	.66	1.16	2.74	
	3	24.1	65.3	.490	.73	1.29	3.32	-	32.5	66.4	0.776	.64	1.21	3.81	-	32.8	65.9	0.651	.88	1.23	2.52	
30	1	23.0	65.8	0.744	0.76	1.25	3.60	-	34.2	66.5	1.056	0.67	1.25	3.18	-	32.3	66.0	0.980	0.67	1.23	3.35	
	2	24.4	65.5	.543	.88	1.63	3.31	-	35.4	65.1	1.086	0.59	1.01	4.06	-	29.0	65.6	.960	.83	1.46	3.84	
	3	20.6	64.3	.674	.62	1.08	3.93	-	36.1	66.1	0.903	0.92	1.59	3.43	-	31.4	65.6	.886	.95	1.59	3.85	
31	1	18.0	64.3	0.654	0.76	1.29	4.04	-	33.5	65.9	1.052	0.81	1.36	3.63	-	31.2	65.7	0.906	0.84	1.25	3.43	
	2	22.1	64.1	.634	.74	1.36	4.12	-	37.2	66.3	0.953	.69	1.18	3.21	-	33.2	65.6	.831	.77	1.28	3.65	
	3	19.2	65.4	.599	.63	1.23	3.15	-	33.6	67.0	1.237	.71	1.21	3.41	-	30.8	66.0	1.012	.74	1.25	3.42	

Table 5 - 18 Sinter Feed from Transition Ore

		Chemical Compositions (%)												Size (%)
		Fe	S	Cu	FeO	SiO2	Al_2O_3	CaO	MgO	Mn	P	Na_2O	K_2O	-100 mesh
1978	December	65.1	0.446	0.070	13.3	3.32	0.41	0.70	1.16	0.028	0.040	0.230	0.078	23.0
1979	January	65.2	0.539	0.048	15.9	3.68	0.48	1.27	1.48	0.021	0.034	0.238	0.065	23.1
	February	64.1	0.583	0.072	13.7	3.96	0.46	0.78	1.46	0.023	0.040	0.244	0.097	26.7
	March	64.3	0.761	0.059	14.1	3.80	0.48	1.18	1.41	0.030	0.029	0.263	0.096	22.1
	April	63.0	0.717	0.069	13.8	4.02	0.43	1.23	1.46	0.029	0.032	0.301	0.095	22.3
	May	64.5	0.654	0.056	16.6	3.76	0.49	0.92	1.41	0.019	0.034	0.255	0.085	24.6
	June	64.5	0.623	0.051	13.9	3.72	0.39	1.02	1.31	0.025	0.032	0.258	0.073	15.8
	July	64.4	0.516	0.065	13.7	3.30	0.38	0.85	1.29	0.016	0.041	0.279	0.059	18.5
	August	64.5	0.637	0.048	11.1	3.55	0.55	0.57	1.08	0.024	0.037	0.282	0.156	19.7
	September	65.0	0.545	0.042	9.9	3.67	0.42	0.70	1.05	0.022	0.031	0.310	0.071	20.7
	October	65.2	0.634	0.032	14.6	3.47	0.43	0.63	1.18	0.021	0.030	0.255	0.109	23.3
n=11	max.	65.2	0.761	0.072	16.6	4.02	0.55	1.27	1.48	0.030	0.041	0.310	0.156	26.7
	min.	63.0	0.446	0.032	9.9	3.30	0.38	0.57	1.05	0.016	0.029	0.230	0.059	15.8
	$\bar{x}$	64.53	0.605	0.056	13.7	3.659	0.45	0.90	1.30	0.023	0.035	0.265	0.089	21.8
	σ	0.64	0.091	0.013	1.9	0.234	0.05	0.25	0.16	0.004	0.004	0.025	0.027	3.0

Table 5 - 19 HIGH GRADE SINTER FEED

YEAR	VARIATION	CHEMICAL Compositions												%	SCREEN ANALYSIS					
		Fe	S	Cu	FeO	SiO2	AL_2O_3	CaO	MgO	Na_2O	K_2O	P	Mn	H_2O	+ 1/4"	+ 10M	+ 20M	+ 65M	+ 100M	- 100M
1975	MAX.	65.9	1.518	.039	26.6	5.04	.83	1.45	2.23	N.A.	N.A.	.035	N.A.	8.3	1.5	12.5	14.5	45.2	17.6	31.2
	MIN.	64.3	.878	.030	22.3	3.89	.61	.77	1.39	N.A.	N.A.	.027	N.A.	5.2	0.0	2.4	7.1	36.7	8.5	24.3
1976	MAX.	67.2	1.170	.041	26.2	4.28	.70	1.27	1.74	.153	.143	.028	N.A.	6.6	0.7	10.1	17.3	46.1	16.1	32.9
	MIN.	65.5	.834	.031	23.4	3.05	.48	.85	1.30	.109	.127	.019	N.A.	2.5	0.0	0.8	5.6	39.1	8.8	22.6
1977	MAX.	66.1	.962	.051	25.1	4.14	.67	1.20	1.77	.295	.140	.037	N.A.	6.6	0.8	7.0	17.5	46.6	11.2	32.9
	MIN.	65.1	.820	.039	19.1	3.12	.47	.73	1.27	.154	.102	.023	N.A.	4.6	0.0	3.3	11.9	39.3	8.6	23.7
1978	MAX.	65.9	.872	.052	20.8	3.86	.56	1.13	1.50	.214	.136	.032	N.A.	4.9	0.0	7.2	16.8	43.2	10.7	29.8
	MIN.	65.2	.805	.043	20.0	3.37	.48	.73	1.06	.131	.088	.025	N.A.	3.3	0.0	4.3	14.9	38.1	8.6	26.6
1979	MAX.	65.8	.874	.047	25.1	4.00	.63	1.59	1.59	.094	.126	.041	.026	6.0	0.1	6.3	19.4	47.2	11.2	29.7
	MIN.	65.0	.768	.037	19.1	3.52	.49	.72	1.35	.147	.208	.025	.019	3.3	0.0	3.7	11.8	41.1	9.1	23.4

(2) Effects of Ore Bedding

The variation of SiO_2 in the material was ascertained using the results of investigations on the variation of the chemical composition carried out by Hierro-Peru and the results of the research done by Kawasaki Steel Corporation on the composition of the sinter feed.

For analysis, the variations of SiO_2 were classified as either short-term variation (variation within a bed) or long-term variation (variation between beds), with eight days as one unit. (Refer to Tables 5 - 20 and 5 - 21).

Table 5 - 22 SiO_2 Variation

	Short-term Variation (within a bed) σ_E	Long-term Variation (between beds) σ_A	Total Variation	SiO_2 Average
Hierro-Peru Iron Ore	0.343%	0.350%	0.490%	3.54%
Kawasaki Steel Corp. Sintering Materials	0.148%	0.064% *	0.161%	5.64%

Note: Since short-term SiO_2 variation in the Kawasaki Steel raw materials was not available, the above figures for SiO_2 variation of sintered ore are estimates.

The SiO_2 content of Hierro-Peru iron ore varies greatly not only on a short-term basis but also on a long-term basis. For this reason, it is necessary to estimate the average SiO_2 in the bed, to adjust the SiO_2 level to a constant level using silicastone, and to decrease the short-term variation by ore bedding

(a) Reduction of variation within a bed

Bedding conditions were examined in order to determine what bedding conditions would produce the same SiO_2 variation within a bed for Hierro Peru as for the ore used by Kawasaki Steel.

Table 5-20 Surveyed Data of SiO_2 Variation of Hierro-Peru Iron Ore

Division	A_1(12/1 ~ 12/8)			A_2(12/9 ~ 12/16)			A_3(12/17 ~ 12/24)			A_4(12/25 ~ 12/31)		
SiO_2 (%)	2.73	2.95	3.10	3.44	3.50	3.74	3.76	3.78	3.88		3.72	4.16
	3.30	2.59	3.10	3.55	3.56	3.08		3.64	4.00	3.84	4.01	3.52
	2.85	2.82	3.05		3.45	3.65	3.77	3.75	4.25		4.20	3.65
	3.21	3.08	3.07	3.97	3.52	3.25	3.74	3.53	4.05	3.81	2.70	2.85
		2.60	3.10	3.80	3.60	3.91	3.23	3.44	4.07	3.80	2.74	3.52
		3.44	3.24	3.94	3.71	5.32	4.82	4.14	3.86	3.35	3.84	3.85
	2.90	3.25	3.17	3.39	3.45	4.23	3.37	4.04	3.96	3.43	3.65	3.42
	3.45	2.75	3.25	4.05	4.21	3.33	4.38	4.43	3.45			

Table 5-21 Surveyed Data of SiO_2 Variation of Kawasaki Steel Sintering Materials

No. of bed	B_1 (4B – 303)			B_2 (4B – 304)			B_3 (4B – 305)		
SiO_2 (%)	5.51	5.63	5.02	5.47	5.71	5.67	5.50	6.05	5.43
	5.52	5.58	5.40	5.73	5.90	5.45	5.57	5.81	5.63
	5.50	5.51	5.46	5.57	5.72	5.82	5.73	5.70	5.85
	5.66	5.79	5.57	5.57	5.58	5.62	5.67	5.51	5.46
	5.58	5.56	5.50	5.82	5.75	5.88	5.76	5.59	5.49
	5.90	5.64	5.64	5.57	5.84	5.29	5.60	5.70	5.72
	5.82	5.85	5.62	5.68	5.58	5.75	5.45	5.53	
	5.40								

Since Kawasaki places a sub-raw material containing SiO_2 in the beds, the SiO_2 content in the beds is high.

The variation of SiO_2 within a bed will decrease by increasing the number of bedding layers. The relation is shown in the following formula:

$$\sigma_E = \frac{\sigma_{EO}}{\sqrt{n}}$$

σ_{EO} : Variation of SiO_2 within a bed

n : Number of bedding layers

σ_E : Variation of SiO_2 within a bed after ore bedding

When the SiO_2 level in the bed corresponds to 3.54% and if the variation within the bed is $0.148\% \times \frac{3.54\%}{5.64\%} = 0.093\%$ (σ_E), the required number of bedding layers will exceed 14 with $\sigma_{EO} = 0.343\%$.

(b) Reduction of variation between beds

The SiO_2 in a bed is estimated by sampling and analyzing stacked ore. The difference between the estimated content and the target content of SiO_2 is adjusted by the addition of silicastone. In this case, the variation between beds is considered to be caused by errors in the estimation of the SiO_2 content in the beds and errors in the amount of silicastone added.

To maintain the variation between beds at the same level as that of Kawasaki Steel, it is necessary to keep the difference of the estimated SiO_2 in the bed less than 0.064%. If the difference in the estimation is shown as $\frac{0.490}{\sqrt{m}}$ (m = number of samples), the required number of samples will be 59 per bed. This implies that one sample should be taken for every 1,000 tons of stacking.

The above study was carried out with ideal conditions for stacking and reclaiming. However, in practice, the variation of SiO_2 will be larger than the theoretical figure. In actuality, the number of bedding layers is between 300 and 700 which is considered adequate to obtain a sufficient homogeneity.

5.5.3 Effects of Alkali

Hierro-Peru iron ore contains a high level of alkali. The effects which the alkaline content of the ore has on sintering operation and blast furnace operation were considered together with the steps which could be taken to relieve the problem.

(1) Effects on Sintering Operations

The problems which came to light in Japan when Peruvian ore was used in the past were clogging of the grate in the sintering equipment, corrosion, and low efficiency of the electrostatic precipitators. The alkaline compound evaporates in the sintering process and condenses on the surface of the grate, producing condensed material with a low melting point which combines with the sintering material as a binder and causes the clogging. This alkaline compound also causes abnormal corrosion of the grate bar by molten salt at temperatures of 800 - 900 °C.

In order to deal with these problems, it is necessary to install a pallet cleaner, to increase the thickness of the hearth layer, to study the structure of the pallet grate bar, and to study the material of which the grate bar is made.

(2) Effects on Blast Furnace Operation

Alkali contained in ore and coke, circulates and accumulates in the blast furnace and is the cause of scab in the furnace, a decrease of coke strength, etc., which destabilizes blast furnace operations. At steel mills, the alkali balance is controlled by reducing the alkali charging volume and adjusting the alkali given off by adjusting the basicity of the slag.

The amount of alkali charged into the blast furnace is 0.7~1.0 kg/ton of pig iron from coke breeze and 1.0~1.6 kg/ton of pig iron from iron ore, totaling approximately 1.7~2.6 kg/ton of pig iron.

If 10% of the sintered ore is Hierro-Peru sinter, the quantity of alkali charged into the blast furnace increases by 0.2 kg/ton of pig iron. At steel mills which have a sufficient quantity of alkaline material to be charged, it is probable that the use of Hierro-Peru sintered ore would be limited.

To decrease the alkaline content of Hierro-Peru sintered ore, it is effective to add $CaCl_2$ as in the pot tests.

5.5.4 Study of Chemical Composition of Sintered Ore

(1) SiO_2

The SiO_2 in the sintered ore was examined, taking into account the quality of the sintered ore, sintering costs and methods of adjusting the SiO_2 level. As for quality, the shatter index (SI) and the reducibility index (RI) are the determining factors. With respect to the shatter index, the same properties as those of PSC sintered ore may be obtained by blending a quantity of coke breeze appropriate to the SiO_2 level (Fig. 5 - 11).

The desired reducibility index is 65% or over, but when the SiO_2 contained is less then 5.5%, this cannot be maintained (Fig. 5 - 14). The reason for this is the increase in magnetite which results from the decrease in calcium ferrite and the increase in the level of coke breeze which is used to maintain the shatter index.

The sintering cost is indicated by a change in the value of the sinter in accordance with the cost of the raw materials and changes in the chemical composition of the sintered ore.

Two cases with a different SiO_2 level (5.5% and 6.5%), are shown in Table 5 - 23.

Table 5-23 SiO_2 Content in Hierro-Peru Sintered Ore and Change in Unit Cost

SiO_2		5.5		6.5		
Basicity	CaO/SiO_2	1.5		1.5		
	Unit Price	Unit Consumption	Unit Cost (C)	Unit Consumption	Unit Cost (D)	Difference Between Unit Cost (D) – (C)
Iron ore	0.81¢/kg	893kg/t	723¢/t	865kg/t	701¢/t	22¢/t
Limestone	0.32	149	48	180	58	10
Silicastone	0.36	17	6	28	10	4
Coke breeze	7.38	50	369	42	310	–59
Total (A)			1146		1079	–67
Total Fe (B)	65¢/Fe unit*	58.6%	3809	56.7%	3686	–123
Balance (A) (B)			–2663		–2607	56

Note: * Fe unit cost is assumed to be 65 ¢.

The unit cost of the 5.5% SiO_2 blend is 56¢ per ton lower than the 6.5% SiO_2 blend.

To adjust the SiO_2 in the sinter mix, it is necessary to make the target SiO_2 content more than the total of the maximum SiO_2 content of the bed and the minimum feed volume of silicastone.

The maximum SiO_2 content in a bed is estimated to be 3.7% + 0.35% x 3 = 4.8% (in the past 3.7% SiO_2 has been the average value). On the other hand, the minimum feed volume of silicastone is 2 ton/hr., which corresponds to 0.6% SiO_2. Therefore, the target SiO_2 content will be more than 4.8% + 0.6% = 5.4%. As a result of these studies the target SiO_2 level was fixed at 5.5%.

(2) Basicity

With the basicity of sintered ore set below 1.5, an appropriate reducibility index cannot be maintained (Fig. 5 - 13). This is due to the increase in magnetite which accompanies the decrease in calcium ferrite (CF).

The relation between basicity and the change in the cost of the sintered ore was obtained with reference to SiO_2 (Table 5 - 24).

Table 5-24 Basicity of Hierro-Peru Sintered Ore and Change of Unit Cost

Basicity CaO/SiO_2		1.5		1.6		
SiO_2		5.5		5.5		
	Unit Price	Unit Consumption	Unit Cost (C)	Unit Consumption	Unit Cost (D)	Difference Between Costs (D)-(C)
Iron ore	0.81¢ /kg	893kg/t	723¢/t	887kg/t	718¢/t	-5
Limestone	0.32	149	48	160	51	3
Silicastone	0.36	17	6	17	6	0
Coke breeze	7.38	50	369	50	369	0
Total (A)			1146		1144	-2
Total Fe	65¢/Fe unit*	58.6%	3809	58.2%	3783	-26
(A) - (B) balance			-2663		-2639	24

Note: * Fe unit cost is assumed to be 65 ¢.

Sinter with a bacisity of 1.5 is 24¢ lower than that with a basicity of 1.6.

In blast furnace operation with 100% sinter, the basicity of the sinter will be between 1.4 and 1.5 because of adjustments to the slag component. It is necessary to fix the basicity of Hierro-Peru sinter at 1.4 or above.

As a result of these studies, the target basicity (CaO/SiO_2) was set at 1 5.

5.5.5 Sinter Quality Control

(1) Quality Control Targets

The targets for quality control of Hierro-Peru sintered ore were set based on those for PSC sinter.

The reason for this was that PSC sinter is excellent as blast furnace burden and has low degradation which is important.

The value of PSC sinter as blast furnace burden is demonstrated by the fact that PSC sinter, making up 40 ~ 50% of the blast furnace burden, has been used in Kawasaki Steel's large 4,500 m^3 blast furnace, and stable furnace operation and a low rate of fuel consumption (annual average 436 kg/t) have been achieved. To maintain a low rate of degradation by improving shatter strength of the sinter at the ambient temperature, operations are carried out at a low level of production and thus, the shatter index is kept at 90% or over. In this study, the same level of productivity (1.3 $t/hr.m^2$) as PSC was adopted, fixing the effective area of the sintering facilities at 249 m^2.

$249\ m^2 \times 1.3\ t/hr.m^2 \times 24\ hr \times 365\ days \times 0.9 = 2,500,000\ t/y$

Table 5 - 25 shows the quality control targets for the Hierro-Peru sinter plant.

Table 5 - 25 Quality Control Targets for Sintered Ore

Item		Target of Quality Control
(1) Chemical Composition	Total Fe	58%
	SiO_2	5.5%
	CaO/SiO_2	1.5
(2) Physical Properties	S.I.	90% min.
	Fine Generation (-5mm)	3% max.
	R.D.I. (-3mm)	38% max.
	R.I.	65% min.

In order to maintain the operational objectives and minimize variation in the chemical composition of the sinter product, the mine, the beneficiation plant, and the sinter plant must cooperate with one another.

(2) Unit Consumption of Coke Breeze

Because Hierro-Peru ore melts well and has high sulphur and FeO content, the unit consumption of coke breeze will be lower than that for PSC. In the pot tests, the unit consumption of coke breeze was 6 ~ 13 kg/t lower than that for PSC ore (Fig. 5 - 11).

This is a result of the heat from the oxidation of S and FeO and the easy formation of molten $CaO-SiO_2-FeO$ and $CaO-SiO_2-Fe_2O_3$ systems from gangue minerals at a low temperature. (Refer to 5.4.5. Sinter Pot Test Discussion, and Fig. 5 - 22.)

Judging from the unit consumption of coke breeze for PSC sintered ore, which is 60 kg/t, the unit consumption of coke breeze for Hierro-Peru sintered ore will be approximately 50 kg/t.

The pot test showed that the use of anthracite as a substitute fuel for coke breeze had practically no effect on the sinter product.

(3) Characteristics of Hierro-Peru Iron Ore

The standard material mixing ratio of R.O. and T.O. at the Hierro-Peru sinter plant is 6:4.

Since the characteristics of Hierro-Peru ore vary with changes in the ratio of R.O. to T.O., the size distribution, the beneficiating conditions, ore deposits, and so on, material control and operation control appropriate to the conditions are important.

Hierro-Peru sinter feed cannot form a dense layer because of the lack of fine and coarse particles, and it tends to produce porous sintered ore. Therefore, it is necessary to add raw material which will increase the density.

Regarding the moisture content, since R.O. and T.O. contain about 8% water, the moisture content in the sinter mix will be approximately 5.4% without the addition of water. The installation of dryers is considered unnecessary because a considerable reduction in the moisture content is expected while the ore is stacked in the ore beds.

5.5.6 SO_2 Emission and the Environment

The sulphur content of Hierro-Peru iron ore (1.62% for R.O. and 0.57% for T.O.) is high, and consequently, the concentration of SO_2 in the waste gas of the projected sinter plant is expected to be high. For this reason, the effect on the environment of SO_2 emission in the San Nicolas area was examined.

The winds at San Nicolas are mostly southerly to south-southeasterly, as shown in Fig. 5 - 27, with velocities of 6 - 8 m/sec. on the average (19 m/sec. maximum and 2 m/sec. minimum). Average monthly temperatures range from 18°C to 25°C.

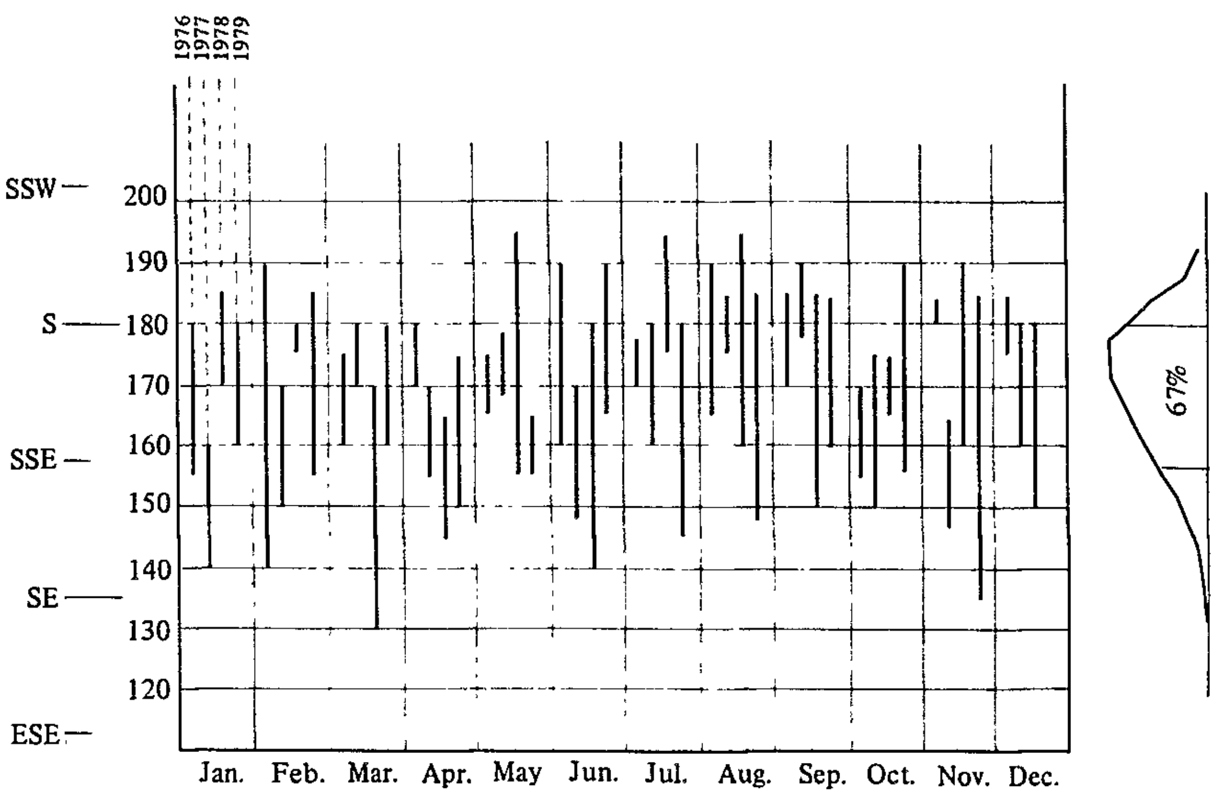


Fig. 5 - 27 Wind Directions at San Nicolas by Month (1976 - 79)

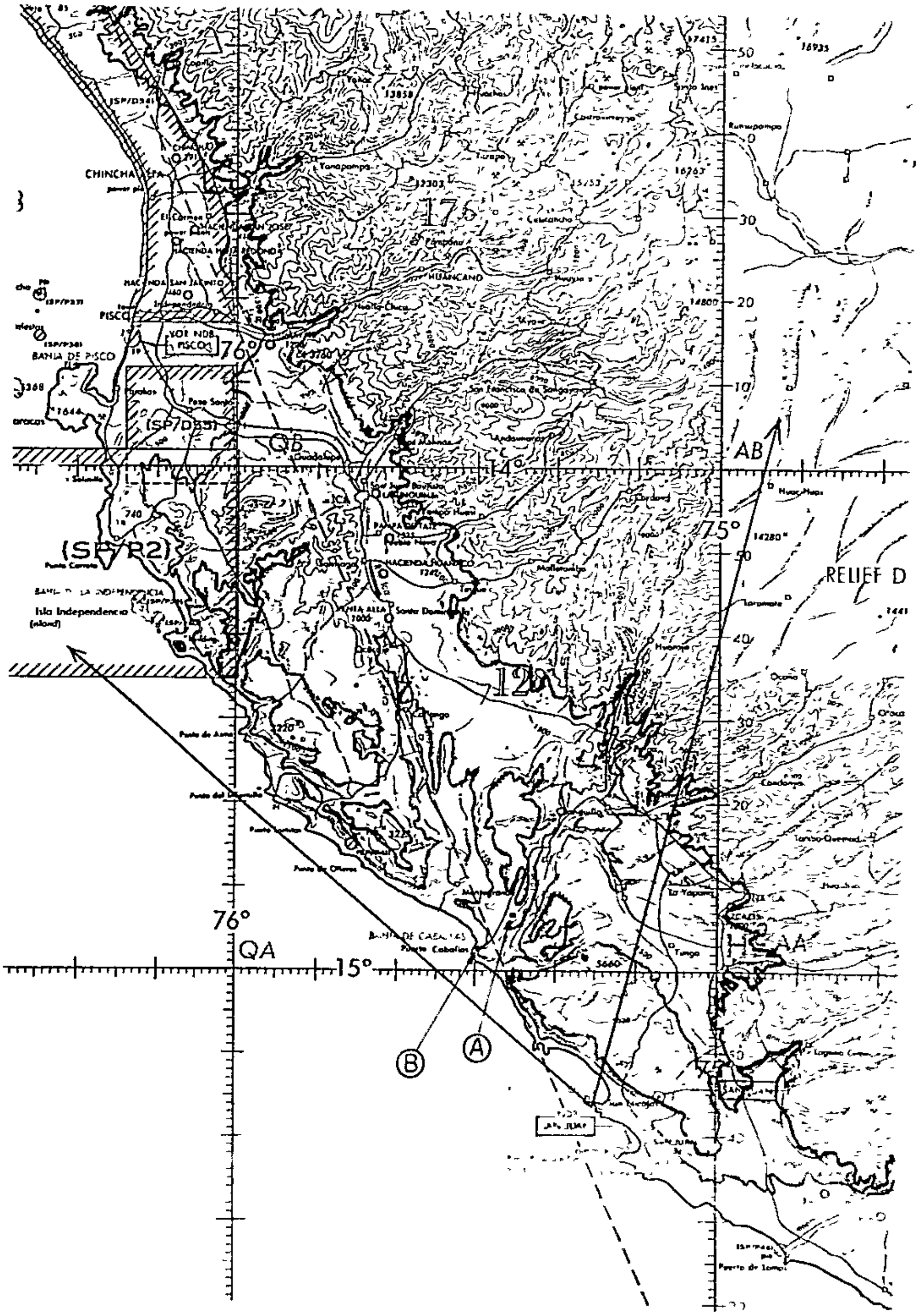


Fig. 5 - 28 Geographical feature of circumference of San Nicolas

The topography of San Nicolas and surrounding areas is shown in Fig. 5-28. A plateau rising to altitudes of over 900 m lies downwind of the plant between 150° and 190° from due south. The plant site is surrounded by uninhabited desert, and the only residential or agricultural areas downwind of the plant site are located at a distance of 40 km to the northwest along the Rio Grande river valley and 60 km to the northwest along the Rio Ica river valley.

In Peru, the permissible level of SO_2 for residential and agricultural areas is set at an average of 0.06 ppm for any 24 hour period.

The diffusion of SO_2 can be calculated using the following formula.

$$C_N = \frac{Q}{2\pi.\sigma_y.\sigma_z.U} \times \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \times \left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right] \times 10^6$$

C_N : SO_2 concentration (ppm)

Q : SO_2 emission (0.62 Nm^3/sec.)

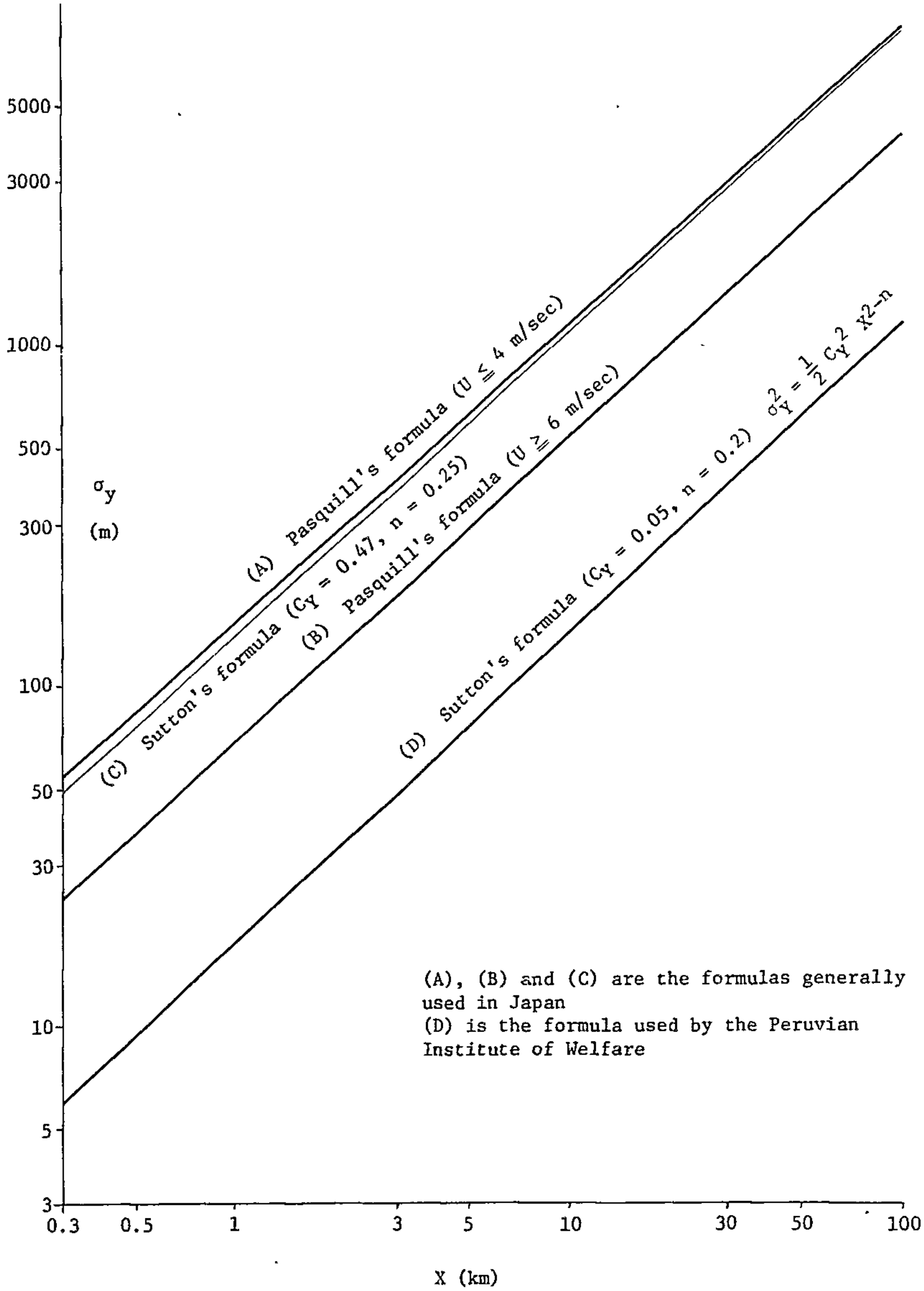
H : effective height of stack (181 m)

U : wind velocity (m/sec.)

y, z : horizontal and vertical distances of the emission zone (m)

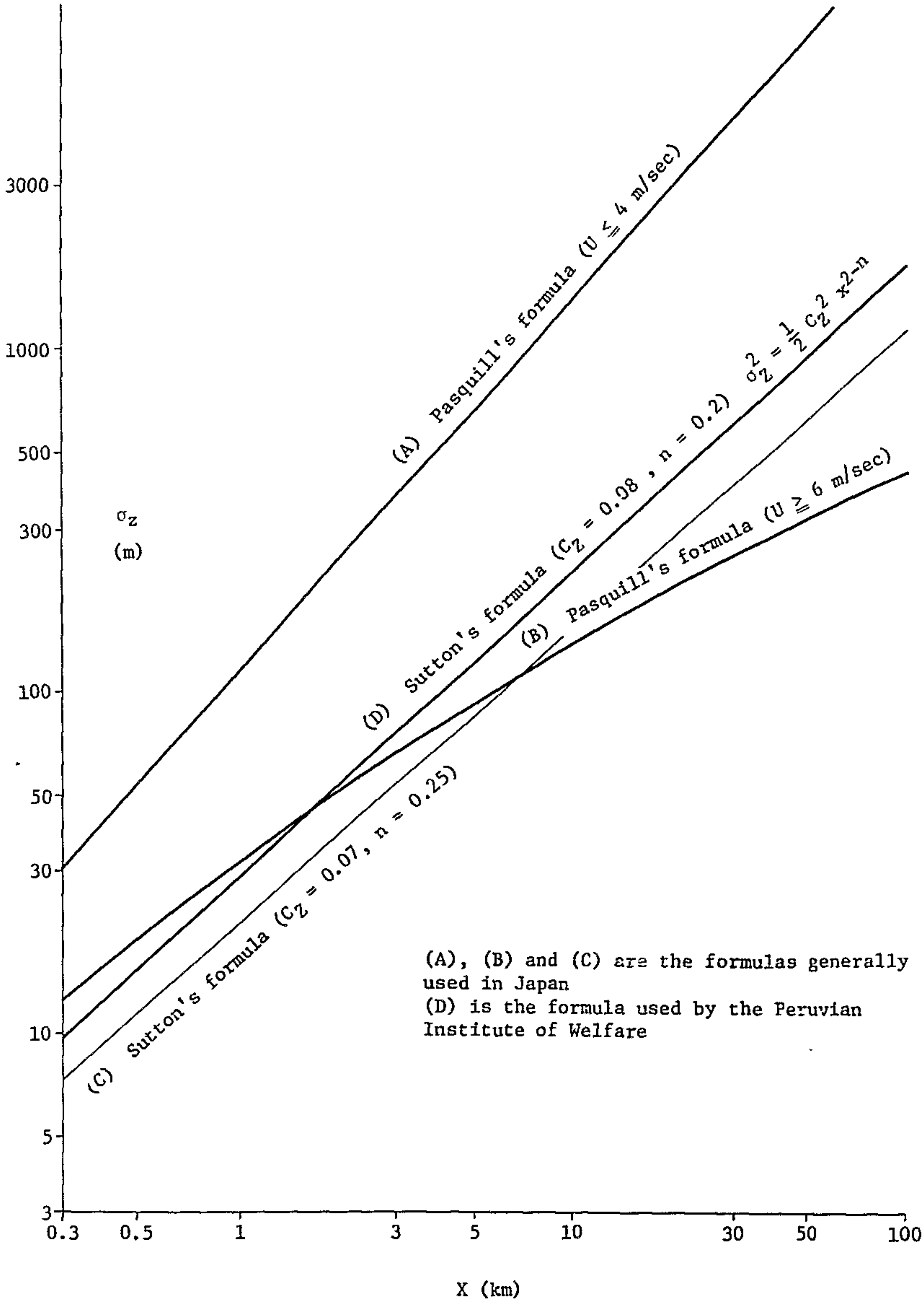
σ_y, σ_z : standard deviations for horizontal and vertical distances of the emission zone (m)

The standard deviations for horizontal and vertical distances of the emission zone σ_y or σ_z, can be calculated as shown in Figs. 5-29 and 5-30, using the Sutton and the Pasquill formula, which were developed based on experimental data of SO_2 emission. In this report the Sutton formula is used for calculations. Table 5-26 shows the SO_2 concetration on the ground at a distance of 40km from the stack in the wind direction as calculated from Figs. 5-29 and 5-30. At a distance of 40 km from the stack in the wind direction the area with an SO_2 concentration of 0.06 ppm and above has a width of 600 m.



(A), (B) and (C) are the formulas generally used in Japan
(D) is the formula used by the Peruvian Institute of Welfare

Fig. 5 - 29 Horizontal Diffusion of Exhaust Gas



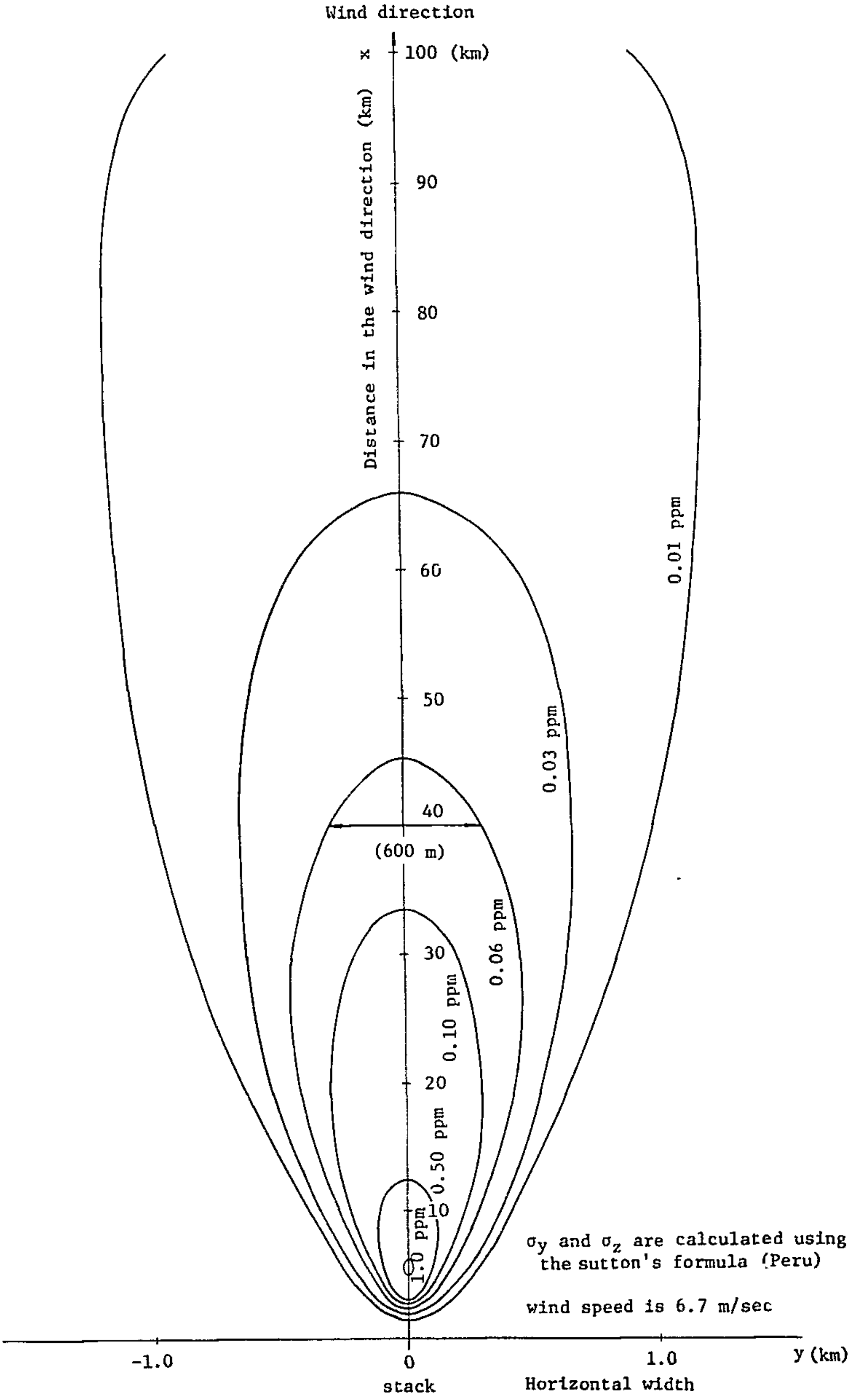
(A), (B) and (C) are the formulas generally used in Japan
(D) is the formula used by the Peruvian Institute of Welfare

Fig. 5 - 30 Vertical Diffusion of Exhaust Gas

Table 5-26 SO_2 Concentration on the Ground at 40km in the Wind Direction

Height (m)	Wind Velocity (m/sec.)	σ_y (m)	σ_z (m)	Concentration on the Ground (ppm)	Formula Used
0	6.7	490	784	0.075	Sutton (Peru)
0	6.7	1080	290	0.077	Pasquill (Japan)
0	6.7	3600	525	0.015	Sutton (Japan)
0	2.1	490	784	0.238	Sutton (Peru)
0	2.1	3800	6500	0.004	Pasquill (Japan)
0	2.1	3600	525	0.047	Sutton (Japan)
0	15.4	490	784	0.032	Sutton (Peru)
0	15.4	1080	290	0.034	Pasquill (Japan)
0	15.4	3600	525	0.006	Sutton (Japan)

Note: Values for σ_y and σ_z are obtained from Figs. 5-29 and 5-30.



σ_y and σ_z are calculated using the sutton's formula (Peru)

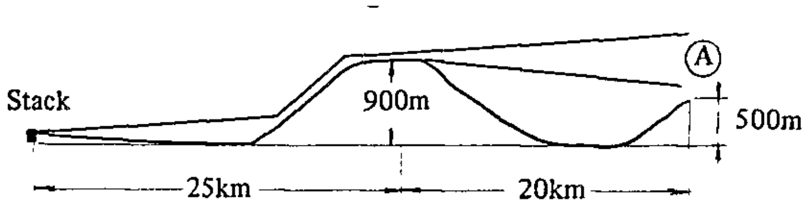
wind speed is 6.7 m/sec

Fig. 5 - 31 Distribution of SO_2 Concentrations on the Ground

The daily fluctuation of wind direction at San Nicolas is shown in Fig. 5-32. When the direction of the wind shifts by 1°, the point at a distance of 40 km in the wind direction shifts horizontally 700 m and therefore completely moves out of the original area receiving an SO_2 concentration of 0.06 ppm and over.

Momentary concentrations of SO_2 on the ground at a distance of 40 km may exceed the 0.06 ppm level, but as a result of changes in the wind direction, the daily average will remain below 0.06 ppm.

The SO_2 concentration may be affected by the topography of an area. When a plateau 900 m in height lies downwind of the stack, the vertical width of the emission zone narrows as the waste gas flows over the plateau and then widens again on the lee side of the plateau. The SO_2 concentration at point A in the Rio Grande river valley is calculated using the following equation:

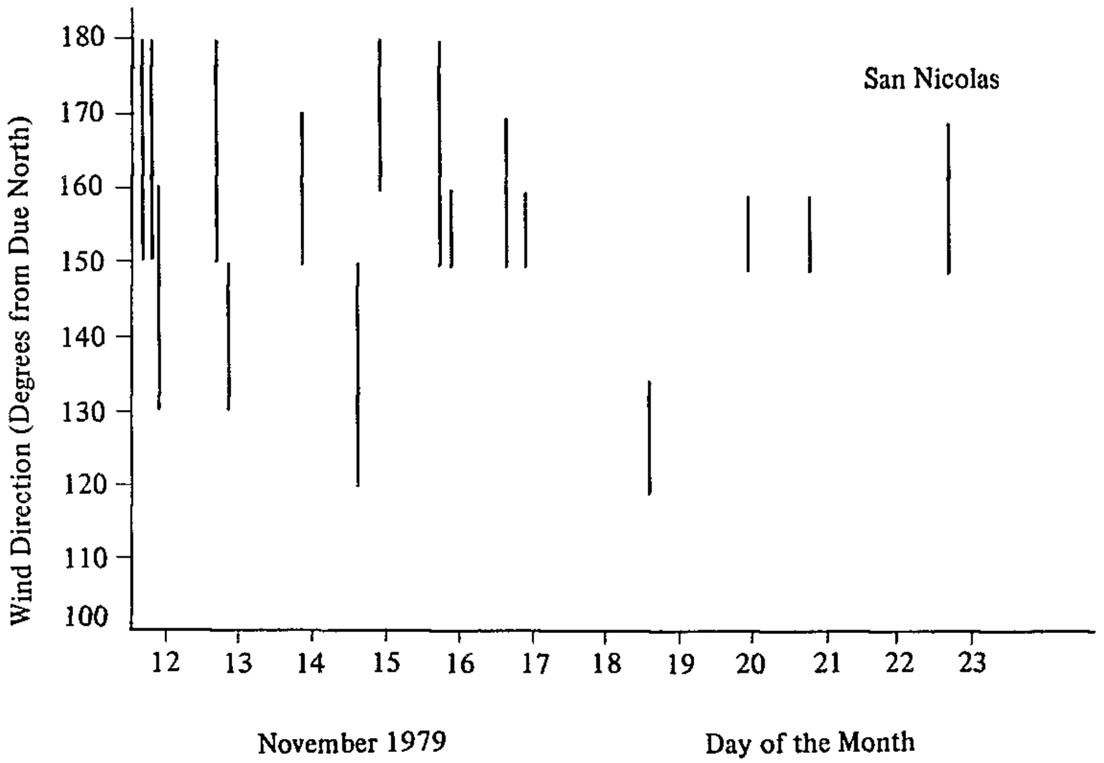


$\sigma_y = 490\text{m}$ $\sigma_z = 430\text{m}$ $n = 0.2$ $U = 6.7\text{m/sec}$

$$C = \frac{0.62}{2\pi \times 490 \times 430 \times 6.7} \times \left\{ e^{-\frac{(900-500)^2}{2 \times 430^2}} + e^{-\frac{(900+500)^2}{2 \times 430^2}} \right\} \times 10^6 = 0.046 \text{ ppm}$$

(σ_y and σ_z are calculated using the Sutton formula in Peru. However, σ_z was calculated with $x = 20$ km.)

When the waste gas passes over a plateau, the SO_2 concentrations on the ground are lower than if there are no obstacles.



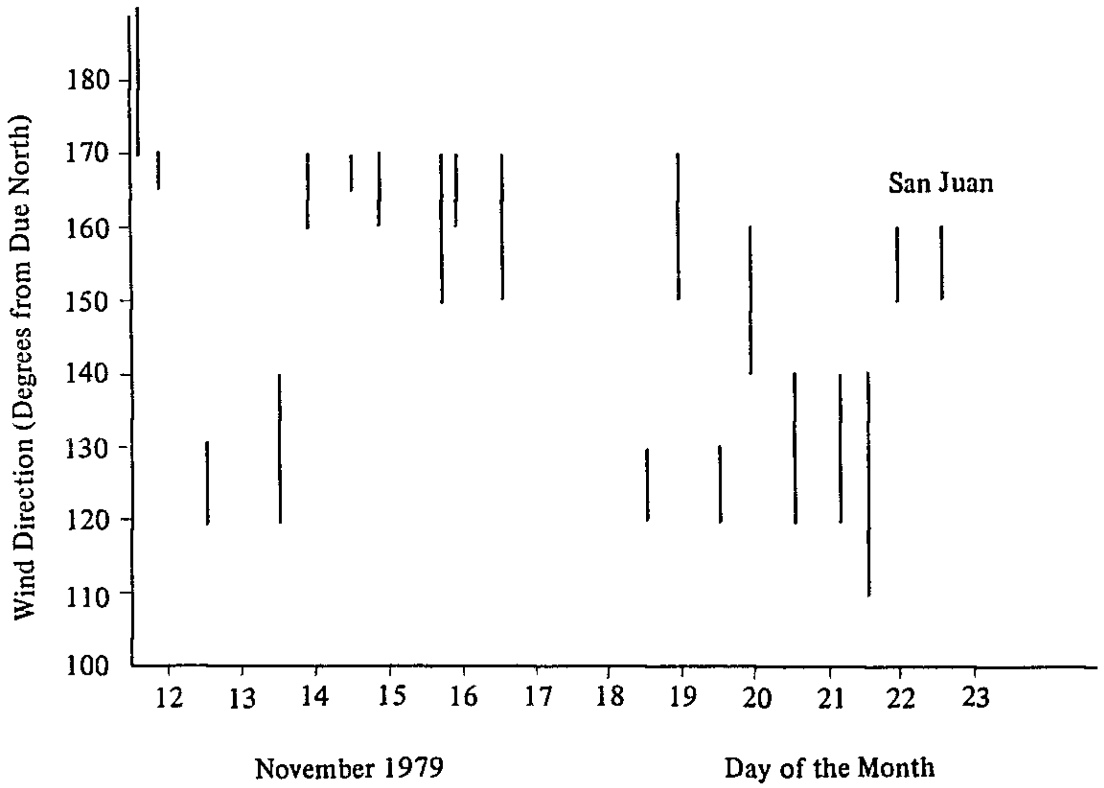


Fig. 5 - 32 Fluctuation in Wind Direction

With a southeast wind, the waste gas blows along the surface of the plateau, and the SO_2 is reflected back. Consequently, the SO_2 concentration on the windward slopes of the plateau is doubled. At a distance of 40 km and over, the waste gas again begins to diffuse. However, southeast winds are very rare and thus will not pose a significant problem.

It may be concluded that the average concentration of SO_2 over a 24 hour period in residential and agricultural areas will not exceed the 0.06 ppm level in spite of a certain lack of precision in the calculation methods.

For the purpose of pullution control, however, measurement of wind direction and velocity, SO_2 emission and concentration on the ground, and other environmental observations may be required before and after the projected sinter plant commences operation.

5.6 Production Plan and Unit Consumption

Low production and somewhat high unit consumptions are foreseen in the first stage of production while initial problems with the equipment are being worked out and the engineers and workers are gaining technical knowledge and experience. Smooth operation will be achieved within a few months through proper maintenance, etc. The level of technical expertise of the engineers and workers will improve, and stability in quality, scale of production, and unit consumption can be expected. It is expected that normal operation will be attained within a year. However, since sales activities may not match the output potential of the sinter plant, production for the first year will be fixed at 1.65 million tons per year, the second year 2.0 million tons per year, and from the third year on 2.5 million tons per year. Production, consumption of raw materials, and inventory plans are shown in **Tables 5-27** to **5-30**.

Table 5 - 27 Unit Consumption Rate during the Normal Operation

Kg/ton Sinter

	Iron Ore R.O.	Iron Ore T.O.	Iron Ore Total	Limestone	Silica-stone	Coke Breeze
Unit Consumption	536 kg/t	357 kg/t	893 kg/t	149 kg/t	21 kg/t	50 kg/t
	Electric Power	Fuel Oil	Fresh Water	Sea Water	Steam	LPG
Unit Consumption	35 kWH/t	2 ℓ/t	0.05 m^3/t	2.0 m^3/t	3.2 kg/t	0.01 kg/t

Table 5 - 28 Change in Unit Consumption of Major Items

kg/ton Sinter

Year	Consumption Rate								Remarks
	Iron Ore R.O.	Iron Ore T.O.	Iron Ore Total	Limestone	Silica-stone	Coke Breeze	Electric Power	Fuel Oil	
1	539 kg/t	360 kg/t	899 kg/t	151 kg/t	22 kg/t	56 kg/t	39 kWH/t	2.6 ℓ/t	
2	536	357	893	149	21	50	35	2	
3	536	357	893	149	21	50	35	2	
4	536	357	893	149	21	50	35	2	
5	536	357	893	149	21	50	35	2	

Table 5 - 29 Production & Raw Materials Plan

ton/year

Year	Production	Required Raw Materials				
		Iron Ore R.O.	Iron Ore T.O.	Limestone	Silica-stone	Coke Breeze
1	1,650,000t	889,350t	594,000t	249,150t	36,300t	92,400t
2	2,000,000	1,072,000	714,000	298,000	42,000	100,000
3	2,500,000	1,340,000	892,500	372,500	52,500	125,000
4	2,500,000	1,340,000	892,500	372,500	52,500	125,000
5	2,500,000	1,340,000	892,500	372,500	52,500	125,000

Table 5 - 30 Inventory Plan

Unit: metric tons

	Inventory	
	Normal	Maximum
Iron Ore (yard)	30,000	58,000
Iron Ore (ore bed)	57,000	57,000
Limestone	2,000	4,000
Silicastone	500	1,200
Coke Breeze	15,000	30,000
Sinter	150,000	260,000

CHAPTER 6

OUTLINE OF THE SINTER PLANT

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6.1 Design Basis

6.1.1 Plant Site

The San Nicolas Works of Hierro-Peru is located at a place about 400 km south of Lima, which faces the Pacific Ocean. The Pacific side of the Andes of Peru is mostly a desert with no exception and so, the surrounding area of the works is also totally an uninhabited desert.

The nearest city is San Juan 14 km southeastward. Most of 22,000 inhabitants are the Works' employees. Other neighbouring towns are Nazca about 60 km in the northeast and Ica about 140 km in the north, but the area between these towns is mostly desert, while a major city in the south part of Peru, Arequipa, is situated about 420 km southeast of the Works. (Ref. Fig. 6-1)

The Marcona Mine where the iron ore is mined is located about 15 km east-northeast of the Works. The Mine and the Works are connected by cross-country conveyors and thereby the iron ore is transported to the Works. Practically, the Works is situated on a small peninsula forming the south end of the San Nicolas Bay, of which coastal part is a cliff and forms a plateau. Under such circumstances, the most facilities of the Works are located more than 40 m above the sea level. Existing here at present are the crude ore yard, crushing plant, beneficiation plant, pellet plant, slurry pond, pellet yard, fine ore yard, electric power generation plant, pier for the iron ore shipment, and other facilities. The substation of Electro-Peru also is located at a corner of this area and supplying the electric power to the Works.

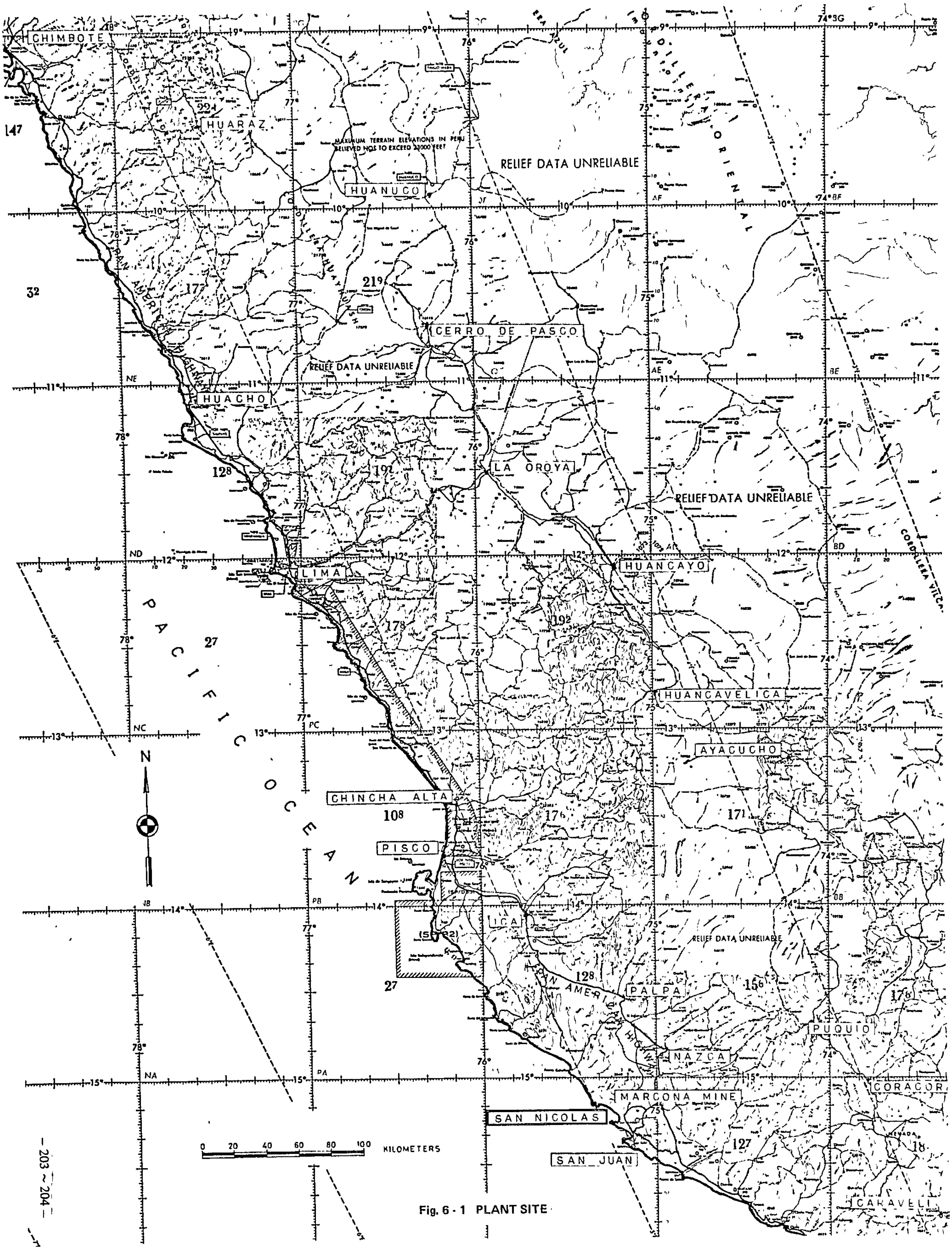


Fig. 6 - 1 PLANT SITE

6.1.2 Climatic and Marine Meteorological Conditions

The meteorological observation data in San Nicolas are shown in Appendix-D.

(1) Atmospheric temperature and relative humidity

The mean monthly temperature and relative humidity at San Nicolas in 1976 through 1978 are indicated in Figs. 6-2 and 6-3 respectively.

(2) Rainfall

According to the statistics, the rainfall at San Nicolas in 1976 thru. 1979 is trace or zero. The rainfalls at San Juan in 1962 thru. 1971 are shown as reference in Table 6-1.

Table 6-1 Rainfall at San Juan (mm)

Year	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Mean
Rain Fall	5.0	2.1	Trace	15.8	7.4	0.3	0.1	5.6	7.9	14.0	5.8

(3) Wind

According to the statistics from 1976 thru. 1979 at San Nicolas, the wind direction is 130° ~ 195° (SE ~ SSW) and the Wind speed is 8 ~ 38 knots (4 ~ 19 m/sec).

The wind rose of the maximum daily wind speeds observed at San Juan is shown in Fig. 6-4.

The "Reglamento Nacional De Construcciones" of Peru is applied to the design of the structures to the wind pressure.

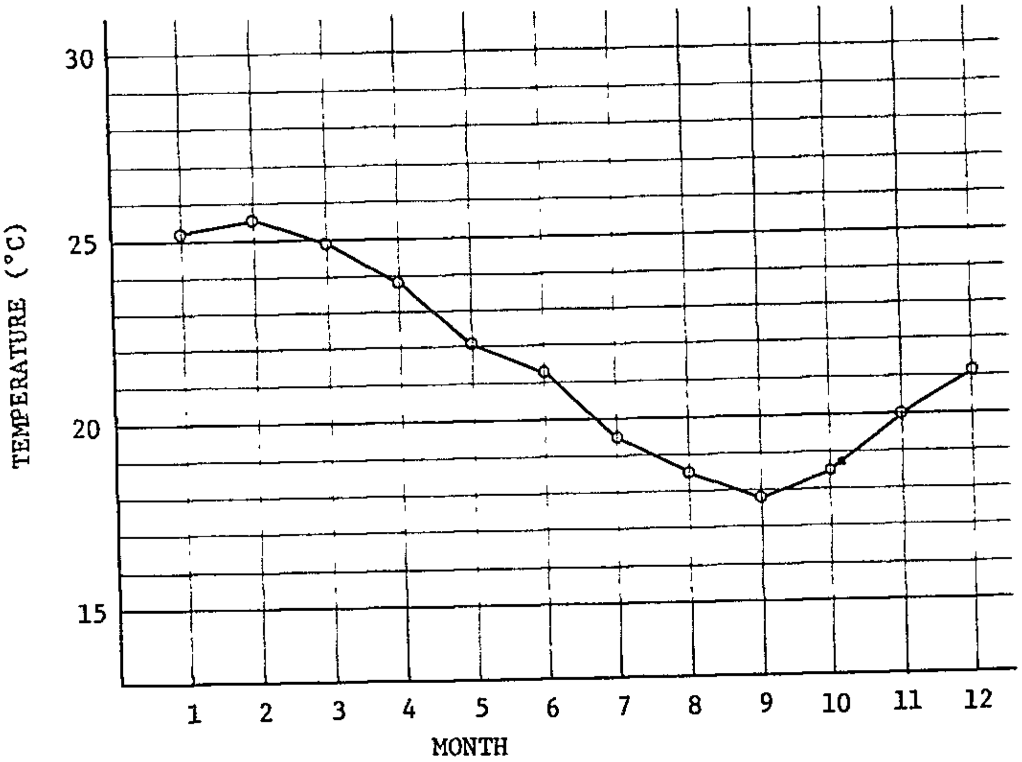


Fig. 6 - 2 Mean Monthly Temperature at San Nicolas (Hierro-Peru, 1976-1978)

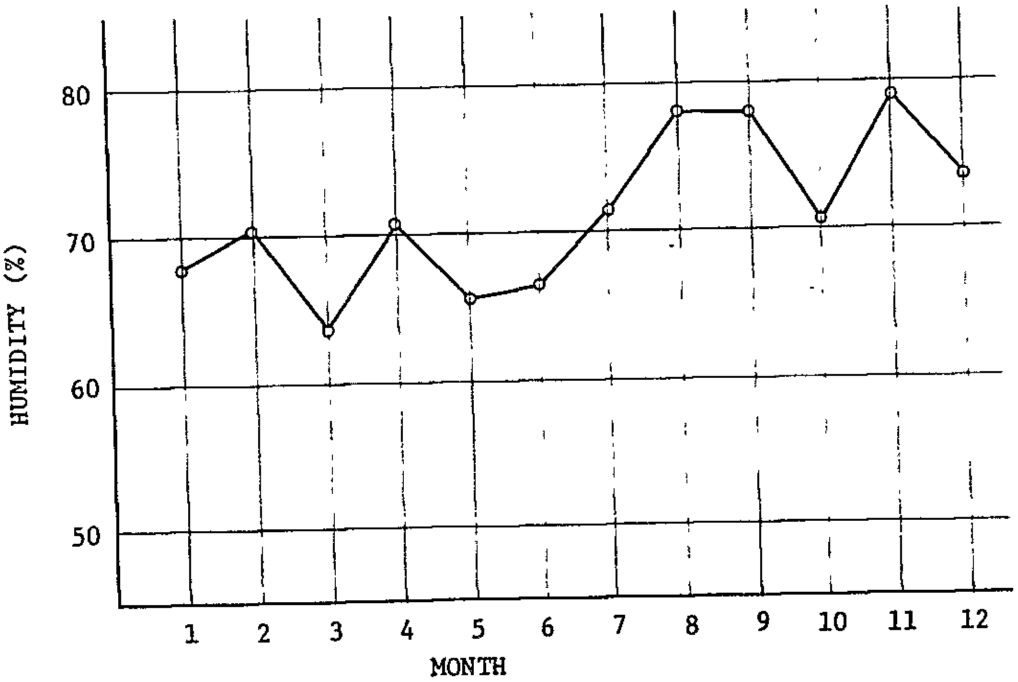
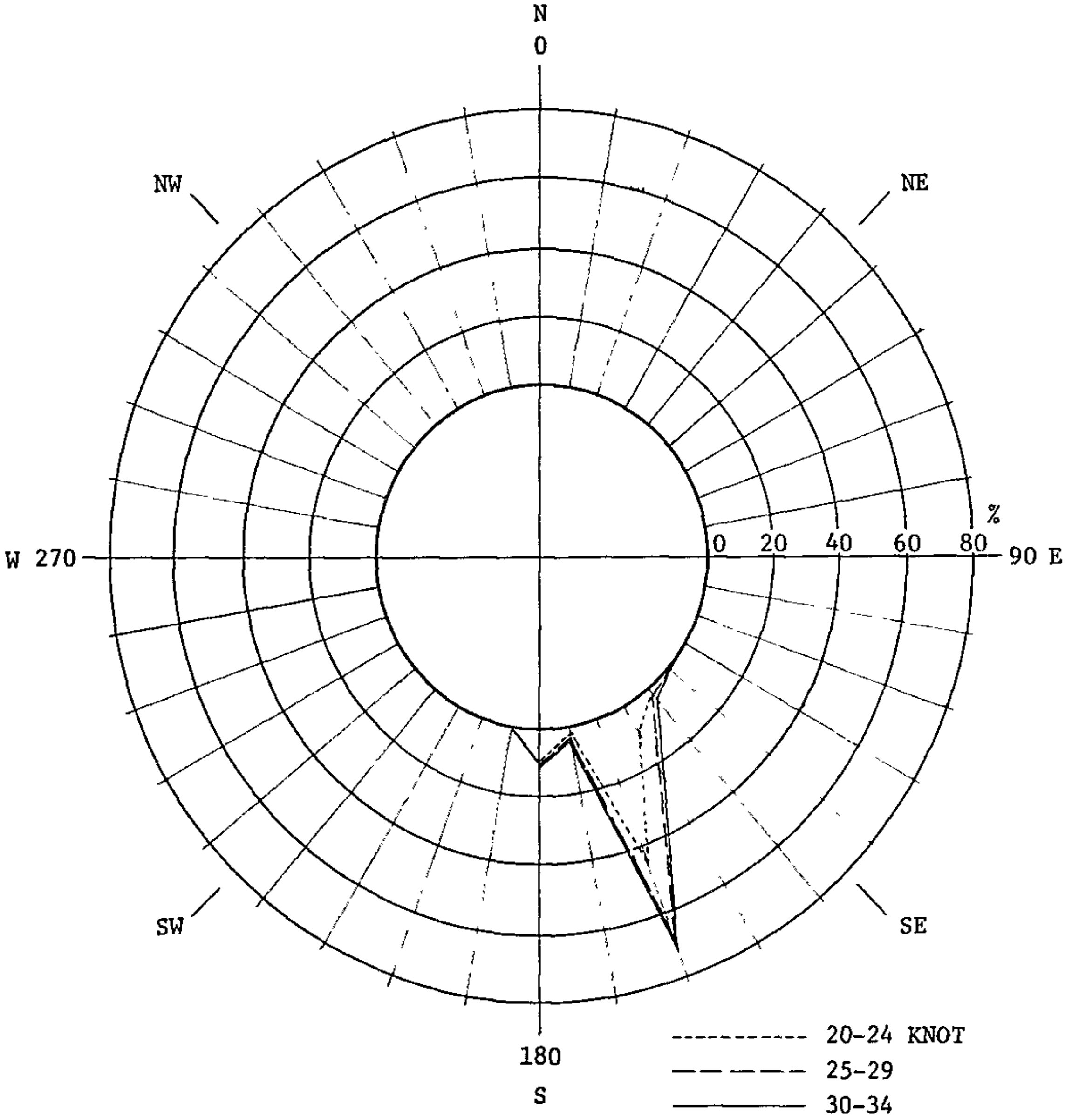


Fig. 6 - 3 Mean Monthly Relative Humidity at San Nicolas (Hierro-Peru, 1976-1978)



Wind rose prepared from the maximum daily wind speed and direction (1962-1971)

Fig. 6 - 4 Wind Rose at San Juan

(4) Tide level

In the marine chart 22183 Bahias San Nicolas and San Juan, the following tidal information is given.

Table 6-2 Tidal Information at San Nicolas

Place	Height above datum of soundings			
	Mean High Water		Mean Low Water	
	Higher	Lower	Lower	Higher
San Nicolas	0.8 m	–	–	–

Besides, the tide levels observed at San Nicolas are as follows.

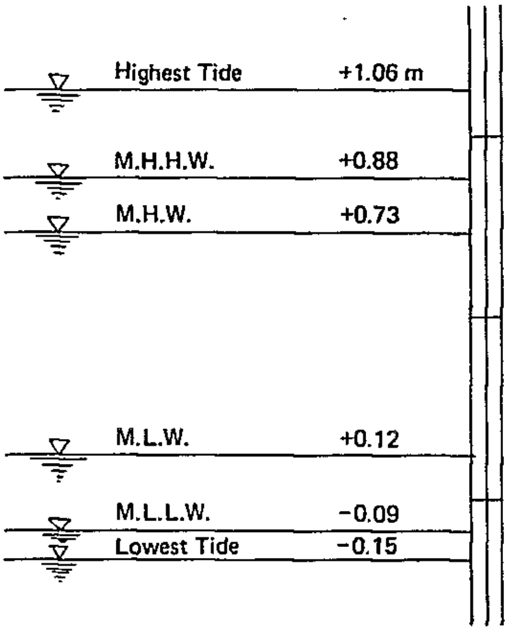


Fig. 6-5 Tide at San Nicolas

(5) Waves

The ore loading pier of the Works is located in the San Nicolas Bay and a breakwater of 800 m long is provided at the west side of the pier which faces the Pacific. Therefore, the pier has no wave problems and ships may always come alongside the pier.

(6) Earthquake

Fig. 6-6 shows the world seismogram. As seen from this map, this area belongs to the circum-pan-Pacific earthquake belt. Besides, shown on Table 6-3 are the earthquakes above magnitude 7 occurred in Peru in 1900 thru. 1976. Among them, the earthquake on 31st May, 1970, of which epicenter was off Chimbote, caused the heaviest damage in history of Latin America.

Consequently, all the structures should have earthquake resistance, and their designs are based on the Uniform Building Code - Zone III.

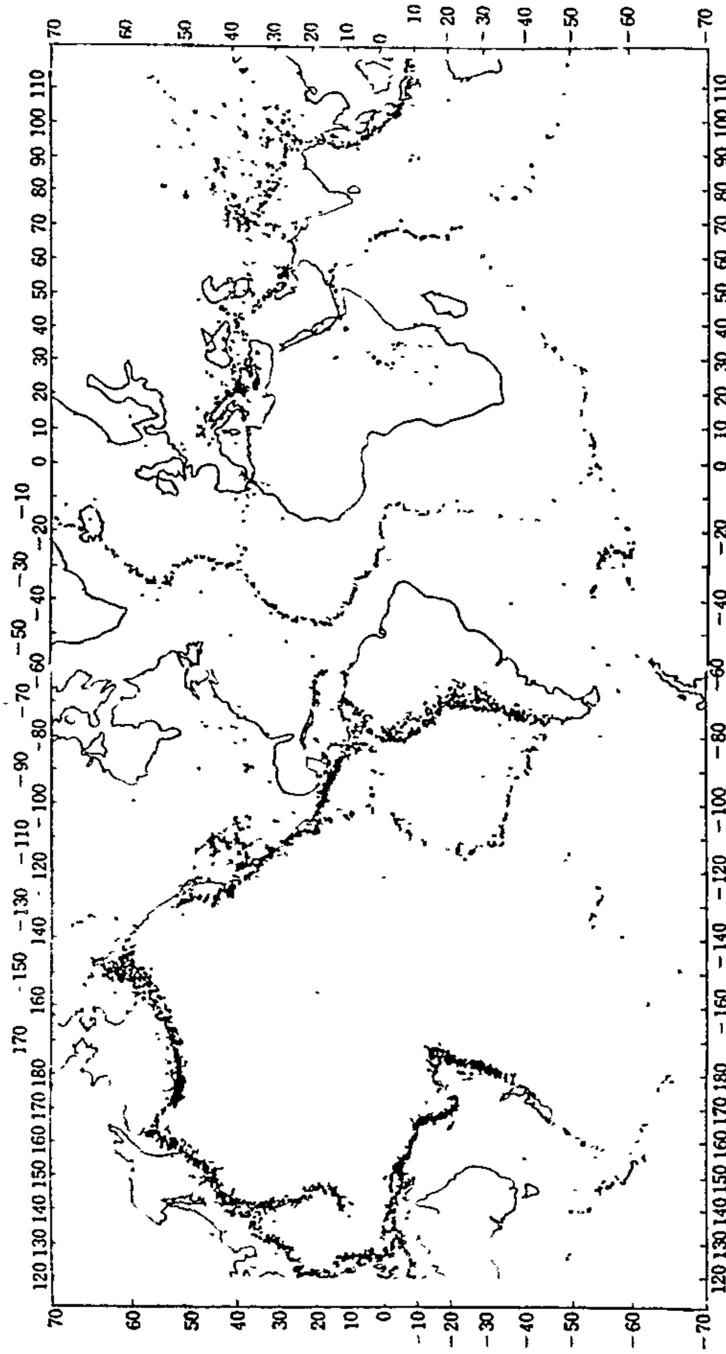


Fig. 6 - 6 The world seismogram (Dept. less than 100 km, M ≥ 4, 1961 ~ 1967)

Quoted from:

The data in U.S.C. & G.S./ESSA

M. Barazangi & J. Dorman, B.S.S.A., p 369, 1969

Table 6 - 3 Earthquakes M ⩾ 7.0 in Peru (1900 ~ 1967)

Date	M	Latitude	Longi-tude	Region and Reports
1906 12 26	7.9	18 S	71 W	Near coast of Peru
1908 12 12	8.2	14 S	78 W	Off coast of Peru
1913 8 6	7 3/4	17 S	74 W	Near coast of Peru
11 10		18 S	70 W	Peru, 120 killed
1922 1 6	7.2	16 1/2S	73 W	South Peru
1 17	7.6	2 1/2S	71 W	North Peru
10 11	7.4	16 S	72 1/2W	South Peru
1923 9 2	7.0	16 S	68 1/2W	Peru-Bolivia border region
1928 4 9		13 S	69.5 W	Southeast Peru, 10 killed
5 14	7.3	5 S	78 W	Peru-Ecuador border region
7 18	7.0	5 1/2S	79 W	North Peru
1940 5 24	8.0	10 1/2S	77 W	Peru, some hundreds killed
1941 9 18	7.0	13 3/4S	72 1/4W	Peru
1942 8 24	8.1	15 S	76 W	Near coast of Peru
1943 2 16	7.0	15 S	72 W	Peru
1944 2 29	7.0	14 1/2S	70 1/2W	Peru
1946 9 30	7.0	13 S	76 W	Near coast of Peru
11 10	7 1/4	8 1/2S	77 1/2W	Peru, buildings damaged
1947 11 1	7.3	10 1/2S	75 W	Peru, buildings destroyed
1948 5 11	7.3	17 1/2S	70 1/4W	Near coast of Peru, damage in Moquequa
7 20	7.1	17 S	75 W	Offcoast of Peru, small damage in Caraveli, etc.

Date	M	Latitude	Longitude	Region and Reports
1950 12 10	7.0	14 1/4S	75 3/4W	Peru, 4 killed 12 wounded in Ica
1952 2 26	7.0	14 S	70 1/2W	Peru
1958 1 15	7.3	16.5 S	71.5 W	South Peru, 21 killed, 90 wounded
7 26	7.5	13.5 S	69 W	Peru-Bolivia border region
1959 2 7	7.2	4 S	81.5 W	Near coast of north Peru
7 19	7.0	15 S	70.5 W	South Peru
1960 1 13	8.0	16 S	72 W	South Peru, damage in Arequipa
1 15	7.0	15 S	75 W	Near coast of Peru, 4 wounded and small damage in Ica Prov.
1961 8 19	7.0	10.8 S	71 W	Peru-Bolivia border region
8 31	7.2	10.7 S	70.7 W	Peru-Brazil border region
8 31	7.5	10.5 S	70.7 W	Peru-Brazil border region
1963 4 13	6 3/4∿7	6.3 S	76.7 W	North Peru
8 15	7 3/4	13.8 S	69.3 W	Peru-Bolivia border region
9 24	7.0	10.6 S	78 W	Near coast of Peru
11 9	7.0	9 S	71.5 W	Peru-Brazil border region
1965 11 3	6 3/4∿7	9.1 S	71.4 W	Peru-Brazil border region
1966 10 17	7 1/2	10.7 S	78.7 W	Near coast of Peru, 125 killed, more than 3000 wounded, 3 m high tidal wave
1967 2 15	6 3/4∿7	9 S	71.3 W	Peru-Bolivia border region
1968 6 19	7	5.6 S	77.2 W	North Peru, 41 killed, 100 wounded

Date	M	Latitude	Longitude	Region and Reports
1970 5 31	7.6	9.2 S	78.8 W	Near coast of north Peru 70,000 killed or missing, more than 1 million lost houses
1970 12 10	7	4.0 S	80.7 W	Peru-Ecuador border, 81 killed, many wounded
1971 7 27	7.5	2.7 S	77.4 W	Peru-Ecuador border, 1 killed
1974 10 3	7.5	12.3 S	77.8 W	Near coast of Peru, 78 killed, 2414 wounded, heavy damage in Lima, 1.8 m high tidal wave hit Callao

Quoted from:

Science Chronologies 1974 and 1978 edited by the Tokyo Astronomical Observatory.

6.1.3 Topography and Geology

Fig. 6-7 shows the topography of the periphery of the projected sinter plant site. This map has been prepared according to the topographical map made when the existing plant was constructed as well as the contour map measured at 50 m interval which were made during the site survey conducted for this feasibility study.

As seen from this map, the present ground of the proposed site is 35 ~ 60 m above sea level – the height difference amounts to 25 m. On account of this, it is assumed that the preparation of the land involves a considerably big scale civil work. When compared the topography at the existing plant construction with the present topography, it is noticeable that the present coastline near the repair shop has moved considerably toward the north, and that the level around this area has become higher. This fact indicates that this zone has been made by land filling with the tailings, etc.

For the construction of the new sinter plant, the topographical measuring is to be executed before the detailed designing, on the basis of which detailed topographical maps are to be prepared, and according to these drawings, the locations and ground levels the most suitable for the respective structures as well as the earthwork volume should thoughtfully be re-examined.

According to the geology survey made at the construction of the existing plant, there exists partially a marine alluvium near the ground surface, but the geology is mostly the conglomerate zone before the Tertiary or rock bed. However, some parts of the sinter plant site and its periphery are fill-up grounds. Although the geology of this area should be investigated for deciding the bottom positions of the various structures' foundations as well as the soil bearing capacities before commencing the detailed designing, in this study, the foundations are planned on the assumption that the soil bearing capacity would be 30 ton/m^2.

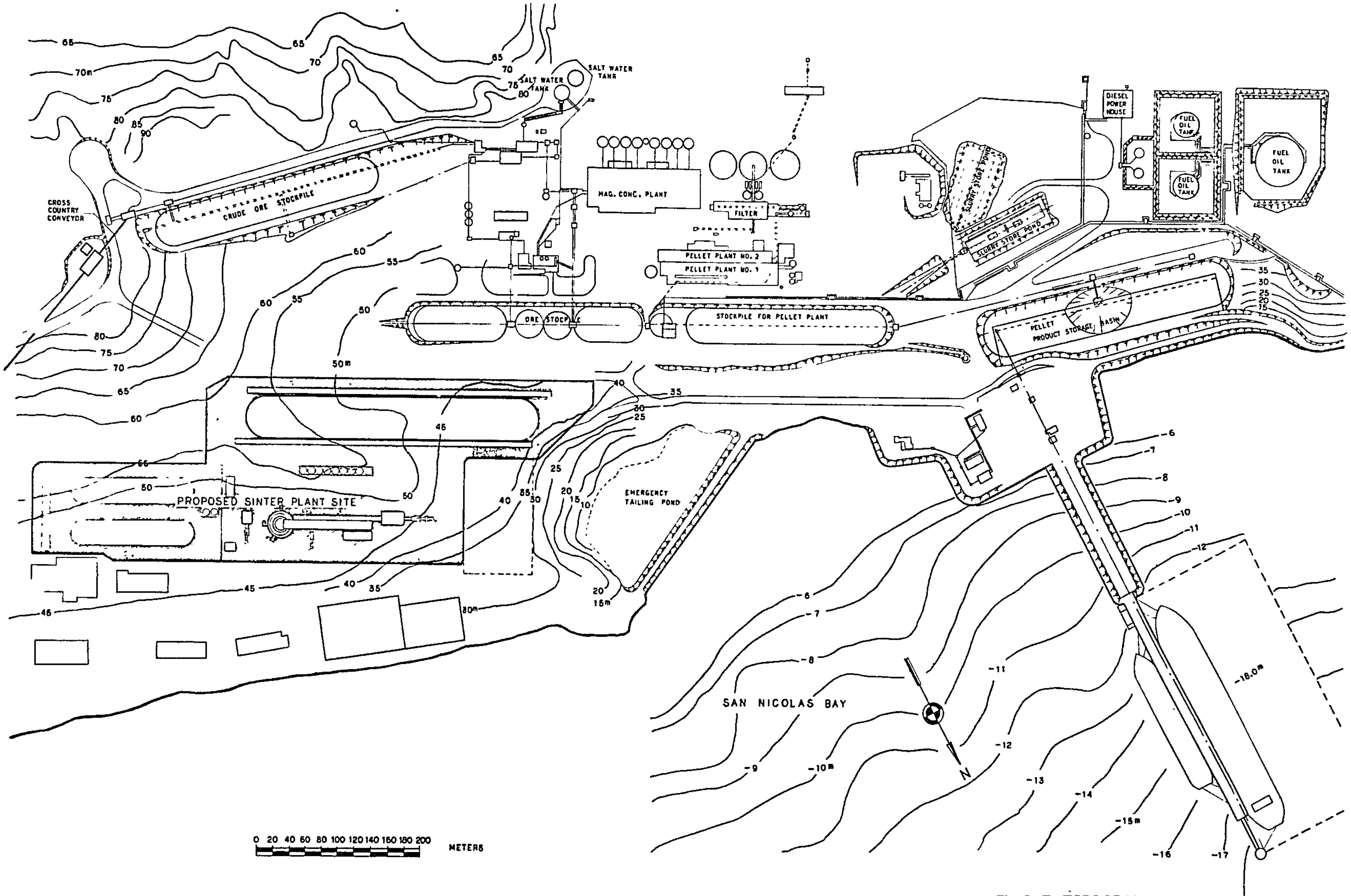


Fig. 6-7 TOPOGRAPHY OF SITE

6.1.4 Standards and Criteria

The electrical equipment and instruments are planned according to the U.S.A. standards (NEMA). The other facilities and structures are planned in principle in accordance with the Japanese standards and criteria unless otherwise specified in 6.1.1, 6.1.2 and 6.1.3 and wherever necessary, the Peruvian and U.S.A. standards also are taken into consideration.

6.2 Basic Plan for the Production

6.2.1 Plant Production Capacity

The nominal annual production capacity of the plant is planned to be 2,500,000 metric tons.

The number of the work days per year is considered to be 90% of a calendar year; this is based on the yearly work day of the existing pellet plant and other factors. Consequently, the production capacity per day is the following.

2,500,000/365 x 0.9 = 7,610 ton/day (317 ton/hr)

6.2.2 Material Balance

The material balance shown in Fig. 6-8 has been made according to the production capacity, quality, working efficiency, consumption of the raw material and the pot test results of the raw materials obtained from Hierro-Peru.

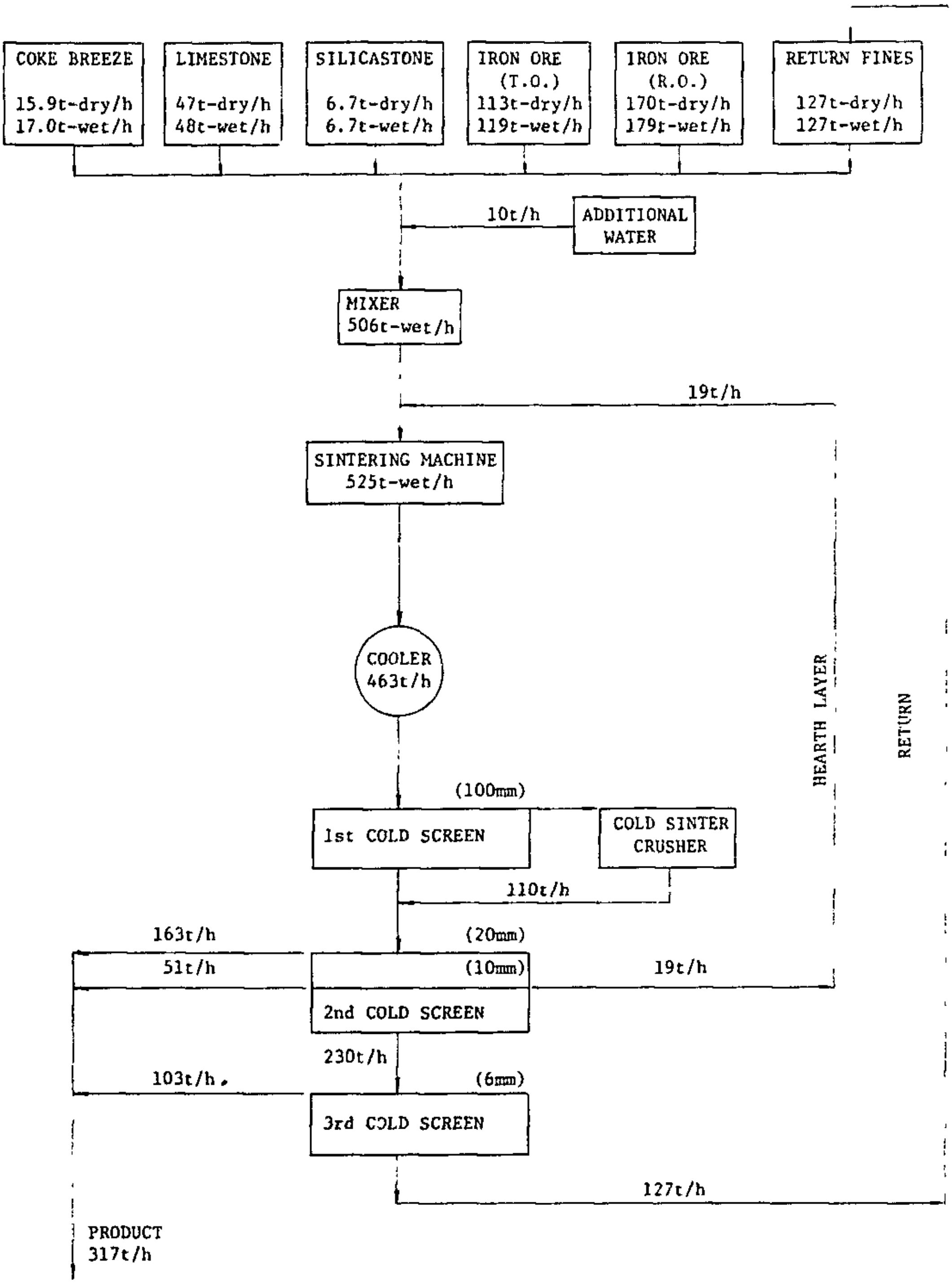


FIG. 6-8 MATERIAL BALANCE

6.2.3 Material Flow

The flows of the raw materials and sintered ore are shown in Fig. 6-9 Material Flow, of which outline is explained in the following.

(1) Receiving of the raw materials

The sinter feed is transported from the beneficiation plant through 63-96BC, B-1BC and 63-603BC and once stored in the sinter feed yard. An ore bedding system is applied to unify the quality. The sinter feed is discharged at a constant rate from the blending yard bins, the stacking is performed by the blending stacker and the reclaiming from the yard by the blending reclaimer.

The coke breeze is unloaded by ship's derricks which are equipped with clam shell buckets, transported by dump trucks and stored at the coke breeze yard.

The limestone is crushed smaller than 100 mm at the mine site, and after being transported by the cross country conveyor to and stored at the crude ore yard of the San Nicolas Works, it is crushed under 10 mm at the existing No. 1 crushing plant and stored in silos. The crushed limestone is discharged from the silos by the vibrating feeders, sized under 3 mm by the impeller breaker and screen which are newly installed in the existing scrubbing and cobbing building and stored in the existing waste truck bin.

The silicastone also is stored in the existing bin through the same route with a time lag to the limestone process.

The coke breeze, limestone and silicastone are transported by B-2BC modified from the existing underground conveyor and the new conveyors separately to the blending bin, whereas the sinter feed is transported to the blending bin through the blending yard.

(2) Blending and mixing

The coke breeze is ground by the rod mill to make the average grain size of 1 ~ 1.5 mm and then stored in the ground coke blending bin. The raw materials and return fines are discharged by the constant feed weighers at a certain blending rate and mixed and homogenized with additional water in the drum mixer.

(3) Sintering and cooling

The mixed material (sinter mix) is evenly discharged on the hearth layer which is thinly laid on the pallets beforehand, and the sinter mix layer surface is ignited by the ignition furnace. The sintering reaction proceeds gradually into the lower part of the sinter mix layer by the downdraft as the pallets travel toward the exit, and is completed at the exit. After being discharged, the sintered ore is crushed under about 200 mm by the hot sinter crusher and then air-cooled by the cooler.

(4) Sizing

The sintered ore is discharged from the cooler by the vibrating feeder and fed to the 1st cold screen. The crushed sintered ore above 100 mm is further crushed under 100 mm. The 2nd cold screen is of double deck type, of which upper screen is 20 mm mesh and the lower screen 10 mm mesh. The sintered ore over 20 mm is accepted as the product, while that of 10 ~ 20 mm is partly sent back to the sintering machine as the hearth layer. The sintered ore under 10 mm is charged to the 3rd cold screen, and the ore sized over 6 mm becomes the product, while that under 6 mm is sent back as the return fines to the blending bin.

(5) Storing of the product

The product (6 ~ 100 mm) is sampled for the quality control and afterward it is stacked on the sinter yard by the stacker.

(6) Shipment of the product

The product is discharged by the reclaimer from the sinter yard, and after being sampled for the shipment, it is loaded on vessels by the existing berth conveyor and shiploader.

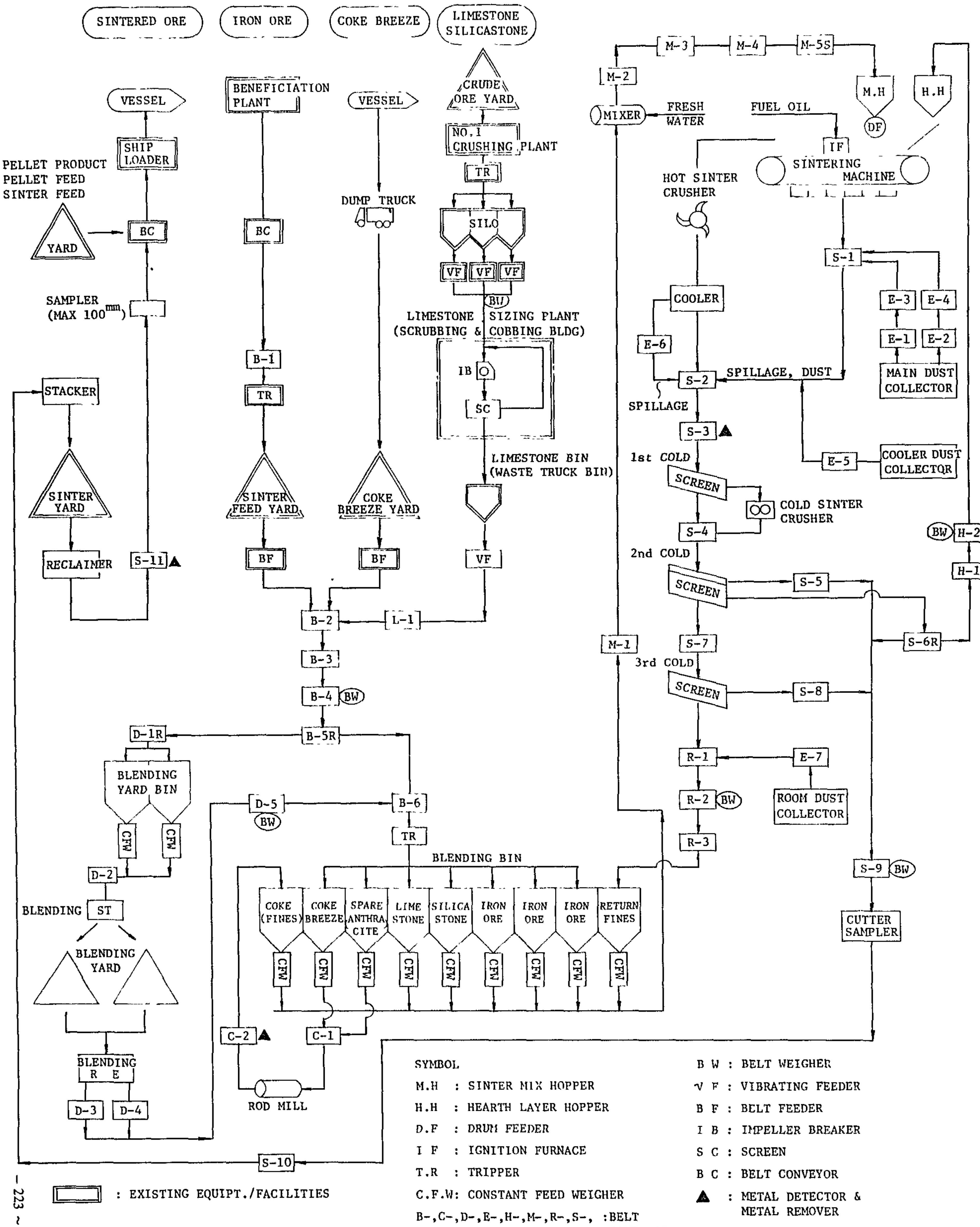


FIG. 6-9 MATERIAL FLOW

6.2.4 Prevention of Degradation of the Sintered Ore

The sintered ore is easily broken by fall impact, since it is characteristically brittle. Therefore, a hard sintering process is applied to the production, and in the transportation and handling, the falling height and frequency are minimized as much as possible to prevent the degradation. Practically, the following measures are taken for the said purpose.

(1) No. of the belt conveyors is reduced as far as possible to minimize the falling frequency.

(2) The diameter of the head pulleys are made as small as possible to reduce the falling heights at the conveyor junctions.

(3) A stone-box method is applied to the chutes.

(4) A stacker of boom luffing type is adopted and thereby the height from the stacker boom head and the stacked sintered ore is always kept low.

(5) A reclaimer with tripper is adopted to supply the sintered ore from the boom conveyor to the tripper head and thus the feeding height is reduced.

(6) Vessels with sliding chutes are preferred for the shipment to prevent the degradation.

6.2.5 Environment Protection

(1) Exhaust gas of the sinter plant is diffused into the atmosphere through a stack of 100 m high.

(2) The following three dust collectors are installed

(a) Main dust collector : for the main dust collection

(b) Cooler dust collector : for the dust collection from the coolers

(c) Room dust collector : for the dust collection from the screens, crushers, belt conveyors, etc.

(3) The main exhaust blower and the cooler fans are equipped with silencers so as to prevent the noise.

6.3 Layout of the Plant

Considering the followings in the layout plan, the sinter plant is located as shown in Fig. 6-10 at a vacant lot in the north of the existing crude ore yard.

6.3.1 Effective Use of the Existing Facilities

(1) Pier and pier facilities

Vessels of 170,000 DWT class may come alongside the west side of the pier, since the water depth there is 18 m. The nominal capacity of the shiploader is 3,000 t/hr, and so this shiploader can be used for the shipment of the sintered ore. The water depth at the pier east side is 13.7 ~ 17 m which is good enough for receiving vessels up to 60,000 DWT class, and therefore, the vessels which transport the coke breeze or the materials, machinery, equipment, etc. for the sinter plant may come alongside the pier east side.

(2) Raw material yard and limestone crushing plant

The existing sinter feed yard is partly used for storing the sinter feed and the coke breeze for the sinter plant.

While, a part of the existing crude ore yard, No. 1 crushing plant, silos, conveyors, waste truck bin, and scrubbing and cobbing building are used for the limestone crushing plant of the sinter plant.

6.3.2 Ground Level

It is preferred in view of the layout of the machinery, equipment and roads that the sinter plant, sinter yard and belnding yard are located on the same level. But the level of the ground where the sinter plant is expected to be built rises to 60 m and falls to 35 m. The earthwork volume is to be minimized as much as possible, and the raising of the land for the sinter plant and sinter yard is to be made low as far as possible, because the loads given there are relatively big. Therefore, it is planned that the sinter plant as well as the sinter yeard are located on the level of 45 m and the blending yard on 47 m.

6.3.3 Environment Conservation

The main stack is located at the west of the sinter plant, and a space wide enough to install an exhaust gas desulfurization plant in the future is kept between the main stack and the tailing pond.

6.3.4 Belt Conveyor System

In the planning, the flows of the raw materials and the sintered ore are made as simple as possible, and the number of the belt conveyors and their lengths are reduced as much as possible.

As a result, the blending yard, sinter plant and sinter yard are located more or less in parallel from the east to the west.

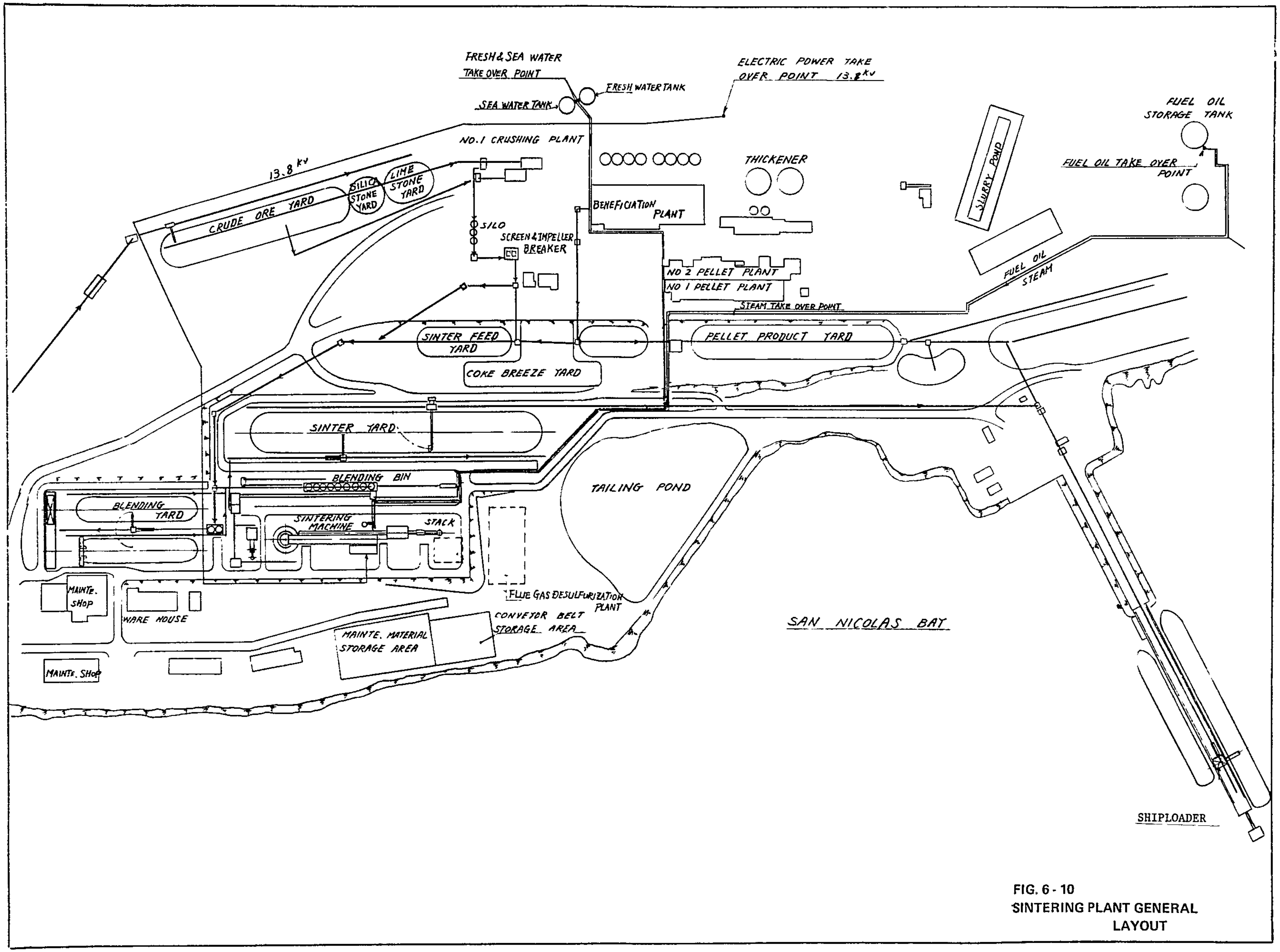


FIG. 6 - 10
SINTERING PLANT GENERAL LAYOUT

6.4 Facilities and Structures

6.4.1 Land Grading

Land of approximately 110,000 m^2 is required for the sinter plant and auxiliary facilities. The land is roughly devided in three areas, one for the sinter plant and the others for the blending yard and the sinter yard, all of which should be flat.

The lay of the land where the sinter plant is installed is such that the ground level rises to about 60 m and falls to 35 m, and therefore, land grading is required in any case. In order to make economically the land grading, it is generally advantageous to use all of the graded soil for the land filling to acquire the necessary space. In this study, however, taking the following three points into consideration, it has been decided that the blending yard is located on 47 m level and the other facilities on 45 m level.

(a) The loads given on the areas where the sinter plant is installed and the sinter yard is provided are considerably big, and therefore, in view of the soil bearing capacity, the land filling there is to be avoided as much as possible.

(b) The extent of the land filling is limited, as the existing facilities are situated in the periphery of the area where the sinter plant and its related facilties are installed.

(c) Although, each of the areas can be located on different levels, the level difference is made max. 2 m in view of the heights of the connections between the facilities.

As a result, 1/3 of the area in the west of the sinter yard and periphery of the main stack are made by land filling and most of the other areas are made by cutting.

The total volume of the cutting is about 500,000 m^3, whereas that of the land filling is about 100,000 m^3. As part of the land is of base rock, digging by blasting may be required. The standard gradients of the slopes at the cutting and land filling are made 1:1 and 1:2 respectively.

Rolling should be applied to the ground layer by layer of 30 ~ 50 cm thickness, after spraying water for the adjustment of the ground water content in order to compact sufficiently the ground. Fig. 6-7 is used to calculate the earthwork volume.

6.4.2 Roads

The width and the maximum gradient of the roads to be arranged in the periphery of the sinter plant are generally made 10 m and 8% respectively. However, the width of the road from the pier to the coke breeze yard is made 15 m, since 65-ton dump trucks pass there, and its maximum gradient is 10%, because the distance is not sufficiently available.

6.4.3 Yards

(1) Sinter feed yard

The existing sinter feed yard is partly used for the sinter feed yard of the sinter plant. The stacking on the yard is performed by the tripper equipped on the belt conveyor No. 63-603, while the discharging is carried out by the belt feeder and the belt conveyor B-2 being installed in the culvert.

Since the culvert system is applied to the discharging, gathering of the sinter feed at the discharging opening by bulldozers, etc. is necessary to discharge the total sinter feed.

(2) Coke breeze yard

A part of the existing sinter feed yard is used for the coke breeze yard. The piling is executed by dump trucks, while the discharging is performed in the same way as the sinter feed, namely by the belt feeder and the belt conveyor B-2 installed in the culvert.

The storing capacity has been decided according to the sizes of the vessels (about 20,000 ~ 30,000 DWT) which transport the coke breeze. Because the culvert system is adopted for the discharging, gathering of the coke breeze at the discharging opening by bulldozers, etc. is required to discharge the total coke breeze.

The yard is paved with non-reinforced concrete in order to protect the coke breeze against mixing with soil and sand, and to make the gathering easier.

(3) Blending yard

The blending yard is provided to unify the sinter feed quality.
Two yards are provided, and while the stacking is made on one yard, the reclaiming is performed from the other yard.

The sinter feed discharged at a constant rate from the blending yard bins is stacked by the blending stacker. And since this stacker reciprocates along the yard, the stacking is made in many layers.

The reclaiming is implemented by the blending reclaimer, and a tranfer car is provided to move the reclaimer from one yard to the other yard.

(4) Sinter yard

The stacking is made by the stacker and the reclaiming by the reclaimer. The yard width is made 50 m and railroads are provided both at the north and south sides, and the stacker is disposed on the north railroad and the reclaimer on the south railroad.

The settlement of the sinter yard and the blending yard is considered to be little, which is attributable to the ground nature, and scarce rainfall. Therefore, the yard is compacted only by rolling and any water drainage is not provided. The railroads are provided on the level 500 mm above the ground and ballasted.

Table 6-4 Specifications of the Yards

Name of Yard	Space	Stack Height (m)	Bulk Density (t/m^3)	Storing Capacity (t)	Consumption/ Production (t/d)	Storing Period (day)
Sinter feed yard	35 m x 118 m	13.7	2.4	58,300	7,150	8
Coke breeze yard	8,000 m^2	8.0	0.5	30,000	425	70
Blending yard	30 m x 150 m x 2	11.7	2.4	57,000 x 2	7.150	8 x 2
Sinter yard	50 m x 360 m	19.5	1.6	262,000	7,610	34

6.4.4 Buildings and Structures

(1) Construction

It is considered that either concrete or steel materials are used for the construction of the buildings and structures. Which one is to be adopted is decided after totally taking into consideration and thoroughly examining the shapes, loads, construction periods, costs, difficulty of the construction, maintenance and control, and repair of the buildings and structures as well as, if necessary, vibration properties thereof.

In this study, such buildings and structures as the sinter building, blending bins, etc., to which big loads are particularly given are made of steel materials in order to enable easier quality control, shorter construction period, and easier repair, maintenance and modification. On the other hand, the buildings which require airtightness and habitability, e.g. the electric room, including the analysis and control rooms, are made of concrete.

(2) Roof and wall

Because the rainfall is much less, eaves troughs and rainwater drainages are not necessarily to be considered. However, considering the wind, sand dust, etc., roofs and walls are provided where necessary. These are made of corrugated colored steel plates which can easily be constructed and repaired. And where the sun lighting is required, aluminium sashed glasses are used.

(3) The specifications of the buildings and structures considered in this study are outlined in Table 6-5 below.

Table 6-5 Outline of the Buildings and Structures Specifications

Names of Buildings and Structures	Total Area (m^2)	Outline of Specifications
1. Blending bin	900 (building area)	Steel structure, 9 bins
2. Sinter building	1,727 (building area)	Steel structure, 4-story
3. Electric room	1,848 (floor area)	Concrete building, 4-story, analysis room of 192 m^2 is included.
4. Sample preparation room	156	Concrete block building, 1-story, included in the sinter building
5. Main exhaust blower electric room	80	Concrete block building, 1-story
6. Stack		H = 100 m, made of concrete
7. Blending yard bin	200 (building area)	Steel structure, 2 bins

6.4.5 Outlines of the Specifications of the Machinery and Equipment

(1) Stacker

The stacker is of luffing type boom conveyor and has a stacking capacity of 317 t/hr. The stacker travels about 310 m on the railroad of which rail gauge is 6 m. It consists of a travelling device, boom conveyor, luffing device and tripper. The sintered ore is transferred by the tripper from S-10BC to the boom conveyor and stacked on the yard. The boom conveyor of luffing type is adopted to minimize the height from the boom conveyor head pulley to the pile.

(2) Reclaimer

The reclaimer is of bucket wheel type and has a discharging capacity of 3,000 t/hr. It travels about 375 m on the railroad of which rail gauge is 8 m, and comprises a travelling device, bucket wheel, boom conveyor, slewing device, luffing device and tripper.

The sintered ore is gathered by the bucket wheel and is discharged from the boom conveyor to S-11BC via the tripper. The height from the boom conveyor to S-11BC is reduced by adopting the tripper.

(3) Blending stacker

This stacker is of slewing and luffing type boom conveyor and has a stacking capacity of 500 ton/hr. It travels about 135 m on the railroad of 6 m gauge, and comprises the travelling device, boom conveyor, slewing device, luffing device and tripper. The sinter feed is transferred from D-2BC by the tripper to the boom conveyor and stacked on the yard. The slewing device is for the stacking of the sinter feed on two blending yards.

(4) Blending reclaimer

The blending reclaimer is of double bucket wheel type and has a discharging capacity of 700 t/hr. It trarels about 150 m on the railroad of 32 m gauge, and consists of a travelling device, two bucket wheels, two harrows, a traversing device and a relay conveyor. The sinter feed scraped down by the harrows is gathered by the two bucket wheels, and then it is discharged by the relay conveyor either to D-3BC or D-4BC.

(5) Blending bin

The effective volume is about 600 m^3. Except for the return fines bin, the bins are of 40° conical shape, and each has two vibrators to prevent the raw material chocking.

In total 9 bins are provided, one for the return fines, three for the iron ore, one for the silicastone, one for the limestone, two for the coke breeze, one of which can be used for anthracite, and one for the coke breeze ground by the rod mill. The return fines bin is equipped with load cells, and the other bins with limit switches of tilt type to detect the level of the material in each bin.

(6) Blending yard bin

Two bins, each has an effective volume of 600 m^3. are installed. The construction is the same as that of the blending bin.

(7) Rod mill

This mill is used to crush the coke breeze into an average size of 1 ~ 1.5 mm. The capacity is 29.5 t/hr. The mill is equipped with a screw feeder which serves for the charging.

(8) Mixer

This mixer is of rotary drum type and serves to add water of adequate quantity to the raw materials and mix them. The capacity is 506 t/hr. Material lifting plates are provided at about a half part from the drum entry to have better mixing efficiency. For supporting the drum, two tyres are provided and each of the tyres mounts on two rollers. A water spray pipe is provided in the drum to spray water on the raw materials.

(9) Sinter mix hopper

The hopper is of pyramid type, supported by load cells and has an effective volume of 27 m^3. A damper is provided at the lower end of the hopper to adjust the discharging quantity of the raw material (sinter mix).

(10) Drum feeder

This is used to discharge from the sinter mix hopper the sinter mix at a constant rate. The feeder is of rotary drum type and has a capacity of 506 t/hr. The drum surface is lined with stainless steel sheet to protect the surface against the wear and sticking of the sinter mix. The feeder is driven by a D.C. motor.

(11) Sinter mix chute

The chute is of deflector plate type, equipped with cut-off plate and auto-cleaner, and serves to control the filling density and segregation of the sinter mix on the pallets. This chute is located under the drum feeder. The auto-cleaner is provided to clean the deflector plate, whereas the cut-off plate is disposed to control the filling density of the sinter mix charged on the pallets.

(12) Hearth layer hopper

The hopper is of pyramid type, supported by load cells, and has an effective volume of about 30 m^3. A gate and a chute are provided at the bottom of the hopper.

(13) Ignition furnace

The furnace is of box and roof burner type ; the maximum combustion capacity is 12×10^6 Kcal/hr and the furnace volume is about 19.5 m^3. The burner uses Bunker-C oil for burning and is high pressure nozzle mixing type. Each burner is equipped with a propane gas pilot burner which ignites the oil burner.

The temperature inside the furnace rises up to 1,100 ~ 1,300°C, and therefore, the inner surface is lined with refractory. A heat-holding hood is provided to prevent the sinter mix surface ignited by the furnace from sudden cooling. The hood is of box type, of which heat-holding area is 3.1 m x 3.5 m, and the inner surface is lined with refractory.

(14) Sintering machine

The sintering of the sinter mix ignited by the ignition furnace is performed by the down-draft as the pallets proceed to the exit of the sintering machine and completed before the exit. The machine is of Dwight-Lloyed type and has an effective grate area of 249 m^2. The machine mainly consists of the pallets, a pallet drive unit and machine supporting frame. The pallets are endlessly provided between the entry and exit of the machine. Each pallet is composed of the pallet body, side walls, air seals, insulation pieces, grate bars, rollers, wheels and wheel shafts. The driving of the pallets is performed by a D.C. motor through the entry side sproket.

(15) Wind box and main waste gas exhaust duct

These equipment serve to collect the waste gas generated in the sintering process and lead it to the main exhaust blower. The wind box is provided with slide beds for the air seal as well as with air seal devices of balance-weight type between the entry and·exit of the sintering machine. The main waste gas duct is equipped with wind legs, double-cone dampers and expansion joints.

(16) Hot sinter crusher

This machine is used to crush the sintered ore (cake) discharged from the sintering machine under about 200 mm. The machine is of single spiked roll type, composed of the crushing cutters, a main shaft, driving unit, breaker bars and a breaker supporting wagon, and has a capacity of 463 t/hr. The crusher cutter has three blades, and wear resistant linings (white pig iron) are applied to the blade edges. When the breaker bars are to be changed, they are mounted on the supporting wagon and pulled out of the crusher casing.

(17) Cooler

The cooler is used to cool the sintered ore to such an extent that the equipment in the down-stream, particularly the conveyor belt, are rot badly affected by the heat of the sintered ore. The cooler is of pressure circular type, and has an effective cooling surface of 210 m^2. It consists of troughs, a trough rotating frame, driving units, air chambers, hoods and a sintered ore discharging chute. A friction plate is attached to the outer surface of the rotating frame, and two friction follers are disposed, one each at upper and lower surfaces. The upper friction roller is driven by a D.C. motor, and thus the driving of the cooler is performed. The air chamber is made of reinforced concrete, and this also serves as the cooler supporting structure.

(18) Air cooling fan

The fan is of double suction turbo type, driven by a 630 kw motor, and has a capacity of 6,500 m^3/min at 400 mmH_2O. Three fans are installed, and a silencer is provided at the suction side of each fan.

(19) Cooler dust collector

The dust collector is of cyclone type, and has a capacity of 3,000 m^3/min. The collected dust is discharged by double-cone damper provided at the bottom of the cyclone. The exhaust fan is of double suction turbo type, and has a capacity of 3,000 m^3/min at 200 mmH_2O and 300°C.

(20) Main dust collector

This dust collector is of cyclone type, and has a capacity of 18,000 m^3/min. The collected dust is discharged by double-cone damper provided at the bottom of the cyclone.

(21) Main exhaust blower

The blower is of double suction turbo type, and has a capacity of 18,000 m^3/min at 1,600 mmH_2O and 150°C. The driving motor of 6,500 kw is forcibly cooled by the air which is cooled by cooling water and circulated through the motor. An oil-lifter system is applied to the bearings of the blower and motor to reduce the starting torque and the load given to the motor. A silencer is provided at the delivery side of the blower.

(22) Main stack

The stack is made of reinforced concrete, has a height of 100 m above the ground level, and the inner diameter at the top is 3.6 m.

(23) 1st cold screen

This equipment is used to screen the sintered ore over 100 mm discharged from the cooler. The screen is of stationary grizzly type and has a capacity of 463 t/hr. The dimensions are 2.5 m wide and 6 m long.

(24) Cold sinter crusher

This machine serves to crush the oversize sintered ore discharged from the 1st cold screen under 100 mm. The crusher is of double spiked roll type, and has a capacity of 110 t/hr. The roll distance is adjustable by screws.

(25) 2nd cold screen

This equipment is used to screen the sintered ore of 20 mm and 10 mm. The screen is of double deck ripl-flo type, and has a capacity of 463 t/hr. The dimensions are 2.7 m wide and 7.2 m long.

(26) 3rd cold screen

This serves to screen the sintered ore of 6 mm. The machine is of single deck ripl-flo type, and has a capacity of 230 t/hr. The dimensions are 3 m wide and 7.2 m long.

(27) Room dust collector

This collector is of cyclone type, and has a capacity of 6,500 m^3/min. The collected dust is discharged by flow conveyors and double-cone dampers provided below the cyclone.

(28) Operation plan

(a) General

(i) The objectives of the master control system are the sinter plant, raw material yard and sinter yard.

(ii) In principle, the process machinery and equipment, such as the sintering machine, cooler, belt conveyors, etc. can be remotely operated and controlled from the control room provided on the 4th floor of the electric room. However, the local operation of these machinery and equipment at the respective sites has priority over the above remote operation.

(iii) Sequence controllers are applied to control the process machinery and equipment.

(iv) The sequence control is devided into the following groups, and each group can be also independently operated.

- Sinter feed yard stacking group
- Sinter feed and coke breeze yards discharging group

- Limestone sizing plant group
- Blending yard group
- Coke grinding equipment group
- Bin blending equipment and mixing equipment group
- Sintering and cooling equipment group
- Sinter screening and sinter yard stacking group
- Hearth layer, return fines and collected dust transportation group
- Sinter yard discharging equipment and ship loading equipment group

(b) Start and stop operations

(i) Start operation

The process machinery and equipment are started sequentially from the down-stream by the sequence controllers in an interlock mode.

(ii) Stop operation

The stop operation is classified in the following three ways.

- Time delay stop (Normal stop)
- Simultaneous stop (Emergency stop)
- Trouble stop

(29) Instrumentation

(a) Raw material feed rate control

The total feed rate is set by the total feed rate setter, and adjusted manually, watching the level of the sinter mix in the hopper.

(b) Sinter mix moisture control

The flow rate of the water added to the mixer is adjusted in proportion to the raw material feed rate, raw material water content and preset sinter mix moisture.

(c) Sinter mix hopper level control

The level of the sinter mix in the hopper is continuously detected. During the operation, the preset total feed rate of the raw material is manually adjusted to minimize the level variation.

(d) Sinter mix height on pallet control

The control is performed by setting the height of the cut-off plate. The sinter mix height is detected by electrodes and the sinter mix feed rate is manually adjusted accordingly.

(e) Hearth layer hopper level control

The hearth layer level in the hopper is controlled by operating S-6R,BC (reversible conveyor) in the normal or reverse direction.

CHAPTER 7

UTILITIES

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7.1 Electric Power

Hierro-Peru has the following electric power generation plants.

No.	Type	Capacity (kw)	Tension (kv)
1	Thermal power generation	18,750	13.8
2	– ditto –	18,750	13.8
3	– ditto –	25,000	13.8
4	Diesel power generation	2,500	4.16
5	– ditto –	2,500	4.16

The deficiency is expected to be supplied by the Electro-Peru and thereby the demand of about 15 MW for the sinter plant can be secured. This electric power is supplied at a place near the existing chemical laboratory, of which tension is 13.8 kv.

An aerial system is applied to the wiring between the take-over point and the electric room of the sinter plant. Bare cables are used from the take-over point to the east side of the crude ore yard, and from there to the said electric room, insulated cables are used.

7.2 Fuel Oil

The fuel oil is used for the combustion of the ignition furnace. Actually, the oil of Petro-Peru Industrial No. 6 (equivalent to Bunker–C) is expected to be used, of which specifications are as follows.

Calorific value : 10,000 Kcal/kg (18,500 BTU/ lb)
Viscosity (SSF) 170 at 50°C (122°F)
Sulfur content : 0.74 %
Temperature in the existing oil storage tank : About 43°C (108 ~ 110°F)

The oil is supplied from the existing oil storage tank. The oil consumption is about 600 l/hr.

Propane

The propane is used for the pilot burners of the ignition furnace. Since the propane is used only when the oil burners are to be ignited, the propane consumption is quite low. The propane is to be supplied by cylinder and the calorific value is expected to be 20,000 Kcal/Nm^3 (at 0°C, atmospheric pressure).

7.3 Steam

The steam is used for heating the fuel oil and the atomization for the oil burners. The steam is to be supplied from the existing pipe laid at the north side of the No. 1 Pellet Plant and the specifications at that take-over point are expected to be as follows.

Pressure = 6.3 ~ 8.4 kg/cm^2 G (90 ~ 120 PSIG)

Temperature = 160 ~ 172°C, saturated

The steam consumption is about 1000 kg/hr.

7.4 Water

7.4.1 Fresh Water

The sources of fresh water are the wells at Jahuay and the desalination plants existing in the San Nicolas Works. Jahuay is located about 45 km east-southeast of the Works, and there No. 1, No. 3 and No. 4 wells exist. Among them, No. 1 and No. 3 wells presently supply the water at a rate of 140 m^3/hr in total to San Juan through a pipe line. No. 4 well is scheduled to be put into operation in the near future, and when it starts to work, the water is supplied at a rate of 191 m^3/hr in total from No. 3 and No. 4 wells, and No. 1 well is expected to become a stanby. The majority of water supplied from the wells is consumed by people living in San Juan, and the rest is supplied daily by tank lorry to the Works and consumed as drinking water.

In the existing beneficiation plant, sea water had been used for the process However, in order to change it to fresh water for the improvement of the product quality, the desalination plants were installed. At present, two plants, each having a capacity of 18 m^3/hr, are being operated, and two more are expected to be added in the near future. Future increment up to ten numbers is now under study, but all of them are for the existing beneficiation plant and pellet plants and they may have no surplus capacity for other facilities.

Fresh water for the sinter plant are used for cooling the machinery and equipment and also as the additional water. Although, the water for cooling the machinery and equipment is circulated for reuse, if a cooling tower is used to recool the fresh water, 3 ~ 6% is lost by evaporation. Therefore, to minimize loss of fresh water, shell and tube type heat exchangers are designed, in this study, to cool circulating fresh water (250 m^3/hr) utilizing sea water. By this way, the fresh water consumption in the sinter plant becomes about 10 m^3/hr, of which major portion is used as additional water.

As mentioned above, the existing plant has no surplus capacity of supplying the fresh water to the projected sinter plant. In order to increase the capacity of fresh water supply not only to the new sinter plant but also to the whole plant, underground water sources are being searched by Hierro-Peru. According to that result, the plan for the fresh water supply to the whole plant is to be decided. The examination of the water supply source is, therefore, excepted from this study, and supply of fresh water from the existing tank is made a precondition of this study.

7.4.2 Sea Water

Sea water is used for the beneficiation and other processes, and the intake facility has a capacity of 6,790 m^3/hr in total.

Sea water is used to cool the water circulated for the cooling of the machinery and equipment of the new sinter plant, of which required quantity amounts to 625 m^3/hr, which is to be supplied from the existing sea water tank. The heat exchanger of shell and tube type are designed based on the condition that the sea water temperature is 17°C.

CHAPTER 8

INFRASTRUCTURE

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CHATER 8 INFRASTRUCTURE

8.1 Port

The ports in the neighbourhood of the San Nicolas Works are San Nicolas Port and San Juan Port. The San Nicolas Port was constructed when the Works was built, and is used mainly for the shipments of the products which center on the iron ore and pellet. This port is situated at the south end of the San Nicolas Bay, and the pier directly connected to the Works is located from the south to the north and capable of receiving the following vessels.

West side of the pier :

LOA : 320 m
Draft : 17.98 m
Width : 49.0 m in the case of ore vessel
Max. Tonnage : 170,000 DWT

East side of the pier :

LOA : 300 m
Draft : Bow 13.1 m, Stern 15.23 m
Max. Tonnage : 60,000 DWT

The pier being made of pre-stressed concrete is supported by steel pipe piles; the width is 15 m, the length 300 m and the height of the slab is on 3.37 m above average sea level. Dolphin is provided about 60 m away from the tip of the pier, which is used for the mooring of vessels of longer than 270 m. Installed on the pier is a ship loader having a nominal capacity of 3,000 t/hr and used for the loading of iron ore and pellet.

There is, at the west side of the pier, a breakwater of which total length is 800 m and thereby the sea surface is kept calm. The materials and the machinery and equipment for the projected sinter plant can be unloaded at this pier by using truck cranes, etc.

The San Juan Port had been used for the shipment of the iron ore of the Marcona Mine and the Acari Mine, but it appears to be scarcely used nowadays, because the San Nicolas Port was completed and the Acari Mine was exhaused.

8.2 Road

There are two roads from the San Nicolas Works, one to the Marcona Mine and the other to San Juan, and the employees pass along these roads every day either to the Works or the Mine. These roads are further extended toward the east and connected with the Pan American Highway. This highway devides longitudinally the whole Peru, connecting the respective cities, and plays together with the sea and air routes an important role in the peoples' movement, material transportation, etc. It is presumable that these existing roads are effectively usable for the transportation of local made materials, movement of workers, etc. when the new sinter plant is constructed.

8.3 Welfare Facilities

No living houses are seen in the neighbourhood of the Works other than San Juan which has a population of about 22,000, being centered by the employees of Hierro-Peru and their families. Such welfare facilities as company residences, medical facilities, etc. are quite essential for the employees to be newly adopted for the sinter plant projected in this area. As a matter of fact, Hierro-Peru has provided for the employees of the mine and pellet plant which are currently in operation.

Company residence:

All the employees live either in the company residences or dormitory for unmarried persons. Further, 96 houses are presently under construction for the workers and additional 50 houses for the employees are being planned.

School:

Two schools exist, and the children of the employees may finish the compulsory education there; it seems that a plan for a professional school exists.

Hospital:

There exists a hospital with superior medical facilities and 113 beds, where 16 regular doctors and about 10 part-time doctors are working, and the employees may sufficiently take medical advices there.

Shopping:

Although, the building of a shopping center has been completed, it has not yet been opened. Apart from this, there is a big supermarket in the neighbourhood, being privately operated by the owner who has no relation with Hierro-Peru.

Club:

A membership club exists and there various entertainments are offered.

Other facilities:

There are open cinemas, restaurants, golf courses, etc.

The police station, post, telegram and telephone offices are controlled and operated by the government and their branches are situated in the area where the company residences are located.

The planning for the welfare facilities is to be made, considering the abovementioned facilities as the bases. Nevertheless, it has been decided that such planning is undertaken by Hierro-Peru itself, and therefore, the welfare facilities are excluded from this study.

CHAPTER 9

CONSTRUCTION PLAN

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