5.1.5 Shipment facilities

(1) Equipment conditions

No corrosion was found on the structure which is protected by electricity protection and no damage was on the painting. This can be operated with lubrication and a small amount of maintenance work.

(2) Estimation of the time to restart (without modification)

It can be operated easily within a short period.

5.2 INFRASTRUCTURE AND UTILITIES

5.2.1 Transportation

(1) Roads

The national road No.3 which is a very good paved road runs from the capital city Buenos Aires to Rio Gallegos in Santa Cruz Province through San Antonio de Oeste and Sierra Grande in Rio Negro Province.

The distances between these cities are as follows.

• Buenos Aires to Sierra Grande:	1,290 km
• Buenos Aires to Viedma:	967 km
• Viedma to San Antonio de Oeste:	178 km
• San Antonio de Oeste to Sierra Grande:	131 km
• Sierra Grande to Puerto Madryn:	136 km
• Puerto Madryn to Trelew:	63 km

The road from Sierra Grande to Punta Colorada where the Pelletizing plant is located is not paved but is a good road like a national one. The natural gas pipeline and the slurry pipeline that sends pellet feed run along the road and this road also functions as their maintenance road. It is 32 km from Sierra Grande to Punta Colorada.

(2) Railway

The railway 1,676 mm between rails, runs from Buenos Aires to San Carlos through Bahia Blanca and San Antonio de Oeste. There is no railway to Sierra Grande. So instead of railway, the road is used for transportation between Sierra Grande and San Antonio de Oeste.

(3) Airway

The nearest airport to the Pelletizing plant is not in Sierra Grande but in Viedma and Trelew. Airplanes fly from Buenos Aires to these airports every day.

5.2.2 Electricity

(1) Power supply

The first industrial area (mine, concentration plant, maintenance shop) and the second industrial area (Pelletizing plant) receive 132,000 V, respectively from the electricity company EDERSA (see **Attachment-5**). The received power is transformed to 132,000 V/6,600V or 6,600V/380-220V according to the facility requirements.. The transformer capacities of the power receiving stations are as **Table-77.**

Table-77 The transformer capacities of the power receiving stations

	Transformer capacity substation	Actual demand (For pellet 600,000t)	Load factor (For pellet 600,000t)
The first industrial area	25MW×2=50MW (One is 16MW at the time of our study)	11.4MW	28%
The second industrial area	16MW×2=32MW	7.7MW	24%

When the annual production of pellets reaches about 2,000,000 t/year, the maximum demand will be about 40 MW and the load factor will be about 80% in the first industrial area and about 26 MW and about 80% in the second industrial area.

(2) Actual power consumption

The study result is shown as **Table-78**, where actual power consumption for the mine, the concentration plant and the Pelletizing plant is summarized. The unit consumption for annual production of about 600,000 t/year of pellets as the final products is about 183 kWh/pellet-t as can be seen in the table.

As the pellet production increases the unit consumption will lower. Up to 1,000,000 t/year of pellet production a year however similar unit consumption will continue.

Table-78 Actual power consumption

		Unit consumption for each shop		Max. demand
		(kWh/shopwise-t)	kWh/pellet-t	(MW)
Mine	Mine	7.74	17.06	1.1
	Crusher	0.87	1.92	0.5
	Compressor	3.87	8.54	0.7
	Elevator	2.33	5.14	1.1
	Total	14.81	32.66	3.4
Concentration plant	Preconcentration	1.94	1.91	0.5
	concentration	55.51	54.83	5.9
	Slurry	6.20	6.13	1.4
	Total	63.65	62.87	7.8
Maintenance shop		3.00	2.97	0.2
Pelletizing plant		84.01	84.01	7.7
Grand Total			182.51	19.1

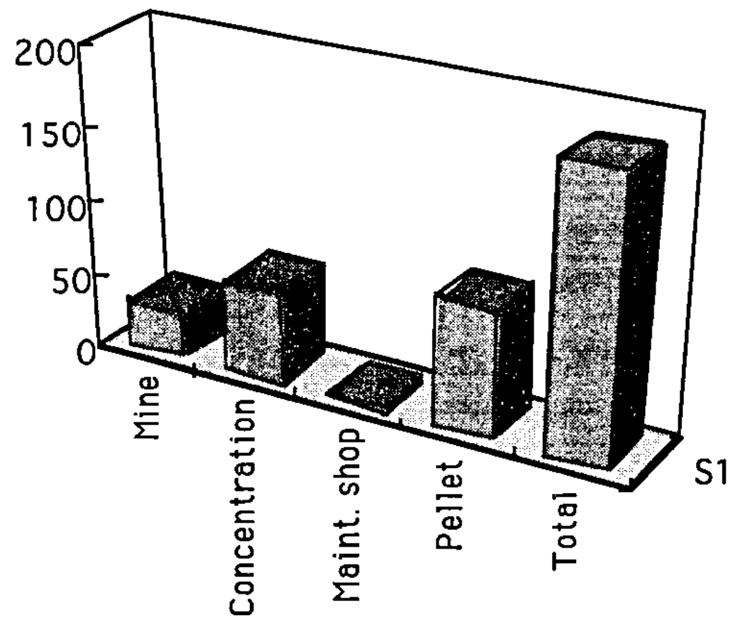
The power consumption of a similar complex is shown in **Table-79** for reference. The power consumption of its concentration plant is nearly equal to that of HIPARSA, but the power consumption of its Pelletizing plant is less than a half of that of HIPARSA.

Table-79 The power consumption of a similar complex

	(1) HIPARSA	(2) Other similar plant
Concentration Plant	55.5 kWh/conc.	56.1 kWh/conc.
Pelletizing Plant	84.0 kWh/pellet	32.2 kWh/pellet

Graph-18 shows the power consumption for each shop for annual production of about 600,000 t/year of pellets. The graph clearly shows the unit consumption for the Pelletizing plant occupies about a half of the power unit consumption for the whole complex.

Graph-18 The power consumption
Unit consumption (kWh/pellet ton)



(3) Demand of a new HBI plant for electricity

The power demand of the second industrial area will be 29.72 MW when pellet production is 1,100,000 t/year and HBI production is 750,000 t /year as shown in **Table-80.** This will cause no problem because the capacity of the power receiving station is 32 MW. The power demand of the first industrial area is conventionally 25.0 8MW and this too will cause no problem because the capacity of the power receiving station is 50 MW.

Table-80 Power demand of the second industrial area

Production	Actual demand of existing p.		HBI Plant (130 kWh/HBI-t)				Total	
	600 kt/year (MW)	1100 kt/year (MW)	600kt/year (7500h/year)		750kt/y (7500h/year)		Pellet: 100kt/year	HBI: 750 kt/year
			Ave. (MW)	Max. (MW)	Ave. (MW)	Max. (MW)	Ave. (MW)	Max. (MW)
1st Industrial area (Mine, Concentration)	11.40	20.90					20.90	25.08
2nd Industrial area (Pellet)	7.70	14.12	10.40	12.48	13.00	15.60	27.12	29.72

(4) Emergency power supply

The second industrial area has three diesel-engine generators (500 kVA each) for emergency power. They are reported to be given maintenance operation and overhauled as needed.

The first industrial area has two gas-turbine generators (16 MW each) and three diesel- engine generators (350 kVA) for emergency power. They are reported to be given maintenance operation and overhauled as needed, too. When we visited the area, one of them was being overhauled.

5.2.3 Industrial water

(1) Water supply sources

Industrial water is taken from two springs some distance from the plant and is sent through pipelines taking advantage of the altitude difference of about 400 m. One point is about 170 km away about 120 km from HIPARSA in Sierra Grande to La Ventana and then about 50 km beyond. The supply capacity is 135,826 m^3/month (52.40 liters/sec.). The other is about 150 km away about 100 km from HIPARSA to Los Berros and then about 50 km beyond. The supply capacity is 154,154 m^3/month (59.47 liters/sec.).

A reservoir of 30,000 m^3 is installed at the mine to prevent shortage of water due to pipework repair etc., a natural reservoir (about 6 ha, 350,000 m^3) is used. (Refer to **Attachment-6**.)

The water supply capacity is as low as 112 liters/sec. in total. If the water not utilized is collected only 20 liters/sec. will be added.

(2) Water supply pipelines

Hume pipes are used. One Hume pipe is 5 m long outside diameter is 250-450 mm, and thickness is 9-40 mm. All the pipes are buried. It seems that simple digging and backfilling was carried out and no compaction was applied which may explain the recent frequent repairs due to water leakage.

(3) Cost of industrial water

HIPARSA is basically in charge of maintenance and control of the industrial water supply pipes and the maintenance cost is the only cost of the industrial water. It is US$ 0.096/m^3. Refer to **Attachment-7** for detail.

(4) Water quality

The analysis result of the spring water is shown in **Attachment-8** . pH of both springs is 7.0, neutral. The analyzed values such as corrosiveness and scaling rate are important factors for industrial water and are within the allowable range.

(5) Actual consumption of industrial water

Industrial water consumption of each shop and the unit consumption is shown in **Table-81** in accordance with our study results.

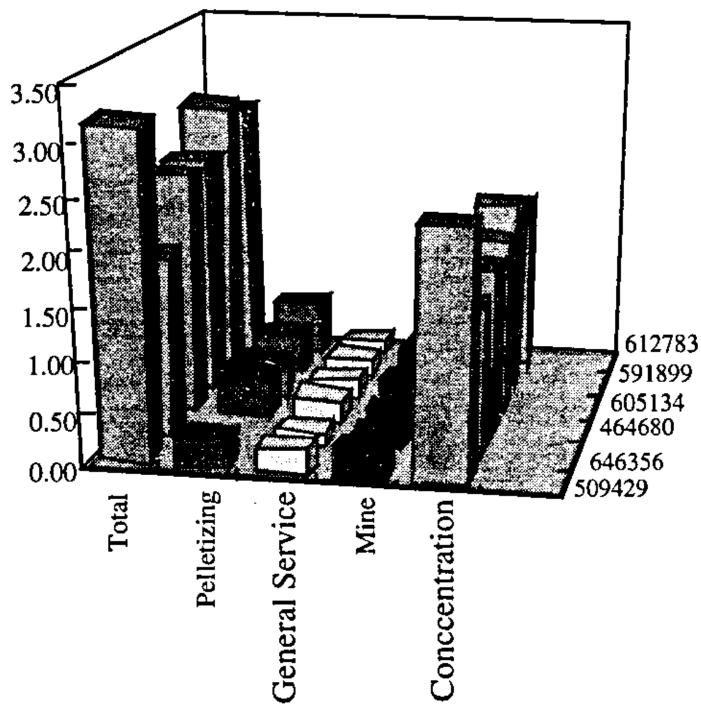
As seen in **Table-81,** the unit consumption (including make-up water) for pellet production of about 600,000 t/year is about 2.55 m^3/pellet-t.

As the pellet production increases the unit consumption will naturally increase. Up to about 1,000,000t/year of pellets however a similar unit consumption will continue (**Graph-19**).

Table-81 Water consumption in the passed five years

		1985	1986	1987	1988	1989	1990
Water consumption of each shop (m³/month)	Concentration	101447	78033	62104	84826	92866	86165
	Mine	12006	8878	5841	9559	12230	10716
	General Service	8807	7507	7975	9362	8965	7408
	Pelletizing	11504		15990	14227	20129	25793
Pellet production/year		509429	646356	464680	605134	591899	612783
Unit (m³/month)	Concentration	2.39	1.45	1.60	1.68	1.88	1.69
	Mine	0.28	0.16	0.15	0.19	0.25	0.21
	General Service	0.21	0.14	0.21	0.19	0.18	0.15
	Pelletizing	0.27		0.41	0.28	0.41	0.51
	Total	3.15	1.75	2.37	2.34	2.72	2.56

Graph-19 Unit consumption (m^3/pellet-t)



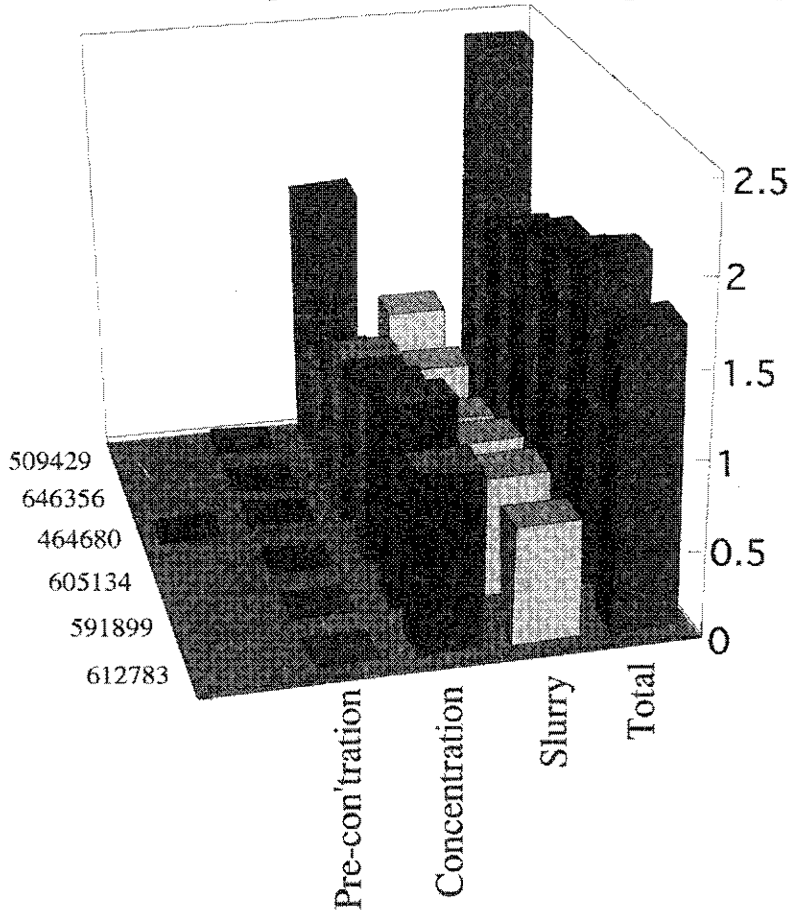
(6) Details of water consumption in the concentration plant

Actual water consumption for the concentration plant which consumes most water in HIPARSA is detailed below. To save water the water for transporting slurry may be neutralized (this water, ph 11, is not effectively used now) and its 70% (0.46 m^3/pellet-t) may be used in the plant but it will be 14 liters/sec. at most and the effect on the total required quantity of water will be small as explained later.

Table-82 Actual water consumption for the concentration plant

Actual water consumption for Concentration (m3/month)							
		1985	1986	1987	1988	1989	1990
Water consumption of concentration plant (m3/month)	Pre-concentration	1061	817	1562	734	621	881
	Concentration	66195	42240	38185	50904	57804	51432
	Slurry	34191	34976	22357	33188	34441	33853
	Total	101447	78033	62104	84826	92866	86166
Production of Pellet (ton/year)		509429	646356	464680	605134	591899	612783
Unit consumption (m3/ pellet ton)	Pre-con'tration	0.02	0.02	0.04	0.01	0.01	0.02
	Concentration	1.56	0.78	0.99	1.01	1.17	1.01
	Slurry	0.81	0.65	0.58	0.66	0.70	0.66
	Total	2.39	1.45	1.60	1.68	1.88	1.69

Graph-20 Unit consumption for concentration plant (m^3/pellet-t)



(7) Water balance

As the water balance tabled below shows the water quantity supplied from the springs is fairly stable at 112 liters/sec. in total. According to the original agreement between HIPARSA and the Government of the Rio Negro Province, it seems that 70 liters/sec. is for the industrial areas and the remaining 41 liters/sec. is for the villages, company houses and farms. In our study this time however the water consumption for the village, company houses and farms has increased about two times to 83 liters/sec. maybe due to shutdown of HIPARSA. This means that only 350,000 t of pellets can be produced a year when HIPARSA resumes operation. When HIPARSA yearly produced about 600,000 t of pellets in 1985-1990, the demand-supply condition for industrial water was very tight.

Though partly because the production was not stable in HIPARSA during those years, it seems that to secure the agreed 70 liters/sec. was difficult according to **Table-83**. To resume operation therefore it is necessary to open up the prospect of securing the required larger quantity of industrial water. (Refer to **Attachment-9**.)

Table-83 Water balance

Water Balance								
		Inlet		Actual outlet in 1985-1990		Outlet to be expected at re-operation in 1998		
		m3/month	l /sec.	m3/month	l /sec.	m3/month	l /sec.	Remark
Pellet production/ year				600000		350000		
Inlet	Los Berros	154154	59					
	La Ventana	135826	52					
	total	289980	112					
Outlet	Leakage on the pipeline			6421	2	9072	4	as of 1998.3
	Water supply to the farm			13545	5	37926	15	as of 1998.3
	Water supply to Sierra Grande			49876	19	93300	36	as of 1998.3
	Water supply to HIPARSA Re.			57125	22	57125	22	
	Camp			9551	4	9551	4	
	Forest			7930	3	7930	3	
	Industrial area 1 (incld.area 2)			145482	56	74375	29	
	Total			289930	112	289279	112	

(8) Water demand if the new HBI plant is erected

Table-84 indicates our calculated results if the planned 750,000 t/year HBI plant and 1,100,000 t/year for the Pelletizing plant go ahead.

In the calculations the actual production of 2.55 m^3/pellet-t in 1990 is used for the Pelletizing plant which gives 175 liters/sec. for the total water demand of HIPARSA. Since the demand for water outside the two industrial areas has increased to 100 liters/sec. as explained above the overall demand will be 275 liters/sec. Considering the desired increase in production and possible increase in water consumption in Sierra Grande it is quite clear that the present water supply sources cannot meet the required future demand. To reactivate HIPARSA therefore securing the necessary quantity of water is very important.

What other sources of underground water may be used? The underground water near Punta Colorada contains arsenic and cannot be used which we have confirmed. Other possibilities are to utilize the canal that runs from Pomana in Rio Negro Province to near San Antonio de Oeste about 120 km away from Sierra Grande. The water supply is 4,000 liters/sec. and this would be sufficient. The provision of the required water pipeline however will be costly.

Table-84 Water demand

Name of plant	HBI		Actual demand of existing plant		
Unit consumption	Industrial water (1.5m^3/t)		Industrial water (2.55m^3/t)		Consumption for others
Products	601 kilo-t/year (7,500h/year)	750 kilo-t/year (7,500h/year)	613kilo-t/year (7,500h/year)	1,100kilo-t/year (7,500h/year)	
Industrial water (liter/sec.)					
Av.	33	42	58	104	83
Max. (20% up)	40	50	69	125	100
Total:275 liters/sec.					

5.2.4 Telecommunications

As for telecommunications system between the first industrial area and the second industrial area, it is observed that the telegraph system is equipped at present time. In the case of reactivation of HIPARSA, mobile phone is convenient.

5.2.5 Natural gas

(1) Natural gas pipelines

Natural gas obtained from Pico Truncado in Santa Cruz Province is carried to Buenos Aires through a 30 inch diameter pipeline. In Sierra Grande it branches to the town and to HIPARSA (Refer to **Attachment-10**) . The branch pipeline runs 47 km to the Pelletizing plant. The gas pressure is decreased in a valve station at the branch point and in a valve station near the entrance to the Pelletizing plant from 70 to 20～40 kg/cm^2 in each station for the first stage and the gas is carried to the entrance of the Pelletizing plant in 6 inch pipe.Then its pressure is further decreased to 5.5 kg/cm^2 in the second stage. The gas company is responsible for the pipeline up to the entrance of the Pelletizing plant.

(2) Actual consumption of natural gas

The actual consumption of natural gas is tabled below.

Table-85 The actual consumption of natural gas

Natural gas actual consumption			
	Unit consumption for each shop		Design base
	(Nm^3 / concentration ton)	(Nm^3 / pellet ton)	(Nm^3 /pellet ton)
Mine and Concentration plant area	1.25	1.22	-
Pelletizing plant area	30.00	30.00	23.7
Total	31.25	31.22	-

As seen in **Table-85**, HIPARSA consumed 31.22 Nm^3/pellet-t which is rather high compared with the design base of 23.7 Nm^3/pellet-t for one Pelletizing plant (production: 67.5 t/h per one furnace). This may be because the Pelletizing plant was not in stable operation.

Though iron ores in use and furnace types are different for reference consumption is recorded at 29.0 Nm^3/pellet-t of natural gas unit in a grate-kiln type furnace.

(3) In the case of the new HBI plant

Unit consumption of natural gas will be 2.6 gcal/HBI-t when the new HBI plant is erected. In HIPARSA, 1 m^3=8,843 kcal as shown in **Attachment-12**. Then as much as 294 m^3/HBI-t will be required for the new HBI plant.

As can be seen in **Table-86**, a total of 11.33 Nm^3/sec.will be required for the HBI plant and the Pelletizing plant which means about 6.5 times the design base of 1.76 Nm^3/sec. for the Pelletizing plant. Therefore erection of the new HBI plant needs an initial investment including expansion of the existing 6 inch pipeline.

Table-86 Natural gas demand

Name of plant	HBI plant (MIDREX)		Pelletizing Plant		
Unit consumption	2.6 gcal/HBI-t (8843 kcal/Nm^3)		(8843 kcal/Nm^3)		2000kilo-t/year (Design base)
	294Nm^3/HBI-t		31.22 Nm^3/pellet-t		
Products	600 kilo-/year (7500h/year)	750 kilo-/year (7500h/year)	506 kilo-/year (7500h/year)	1100 kilo-/year (7500h/year)	
Natural gas :	(Nm^3/sec.)				
Av.	6.53	8.17	0.59	1.27	
Max.	7.84	9.80	0.70	1.53	1.76
Total: 11.33 Nm^3/sec.					

(4) Cost of natural gas

It was difficult to obtain reliable data of the cost of natural gas. According to the data we received from the person in charge in HIPARSA the unit cost of natural gas is US$0.062179/$m^3$ as shown in **Attachment-11**. It is necessary to confirm this at our next study in Argentina.

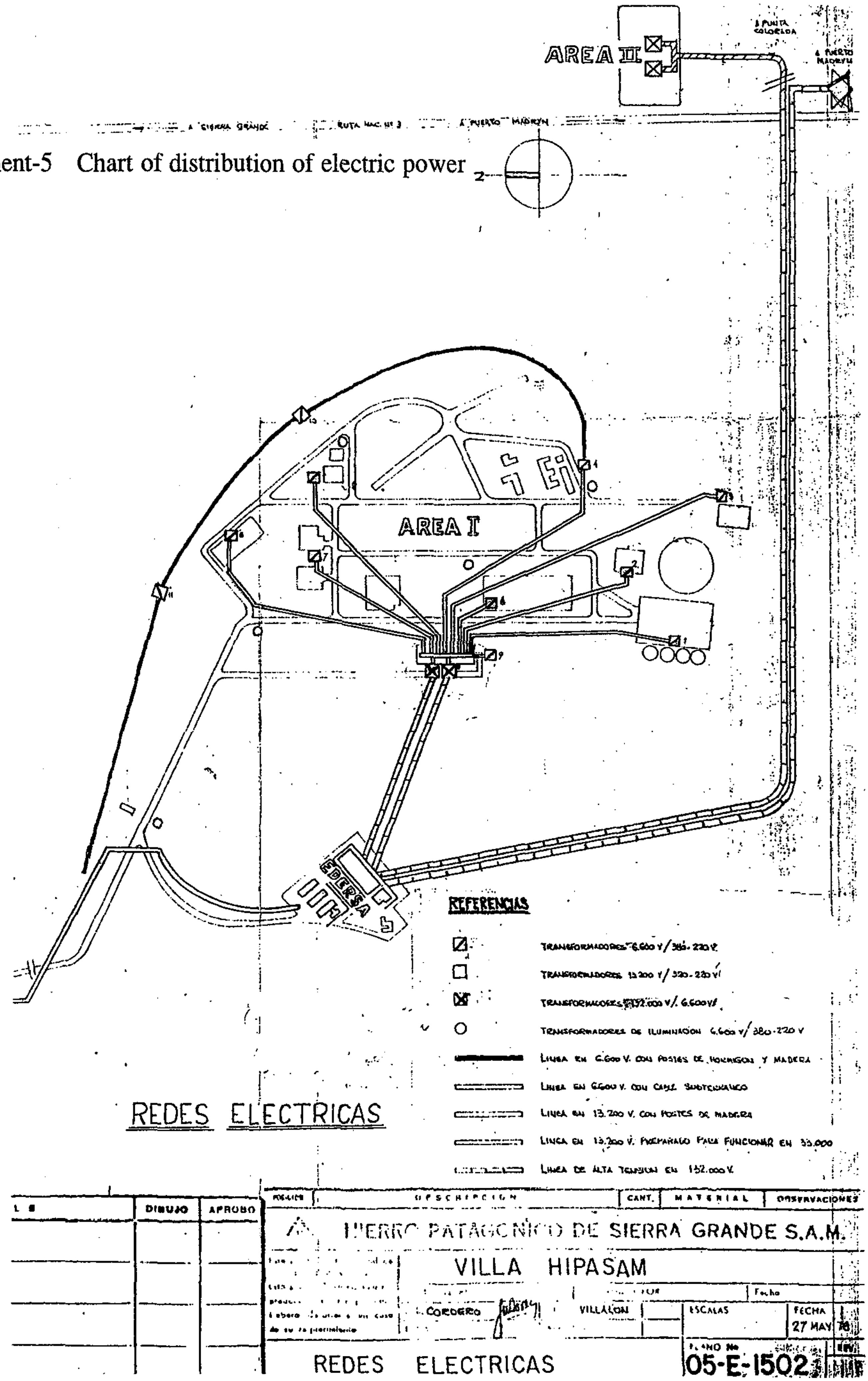
(5) Analysed value of natural gas and its calorific value

HIPRSA uses 9,700 kcal/m^3 as the calorific value as **Attachment-12** shows. It mainly consists of 90 % CH_4 and 5% C_2H_6.

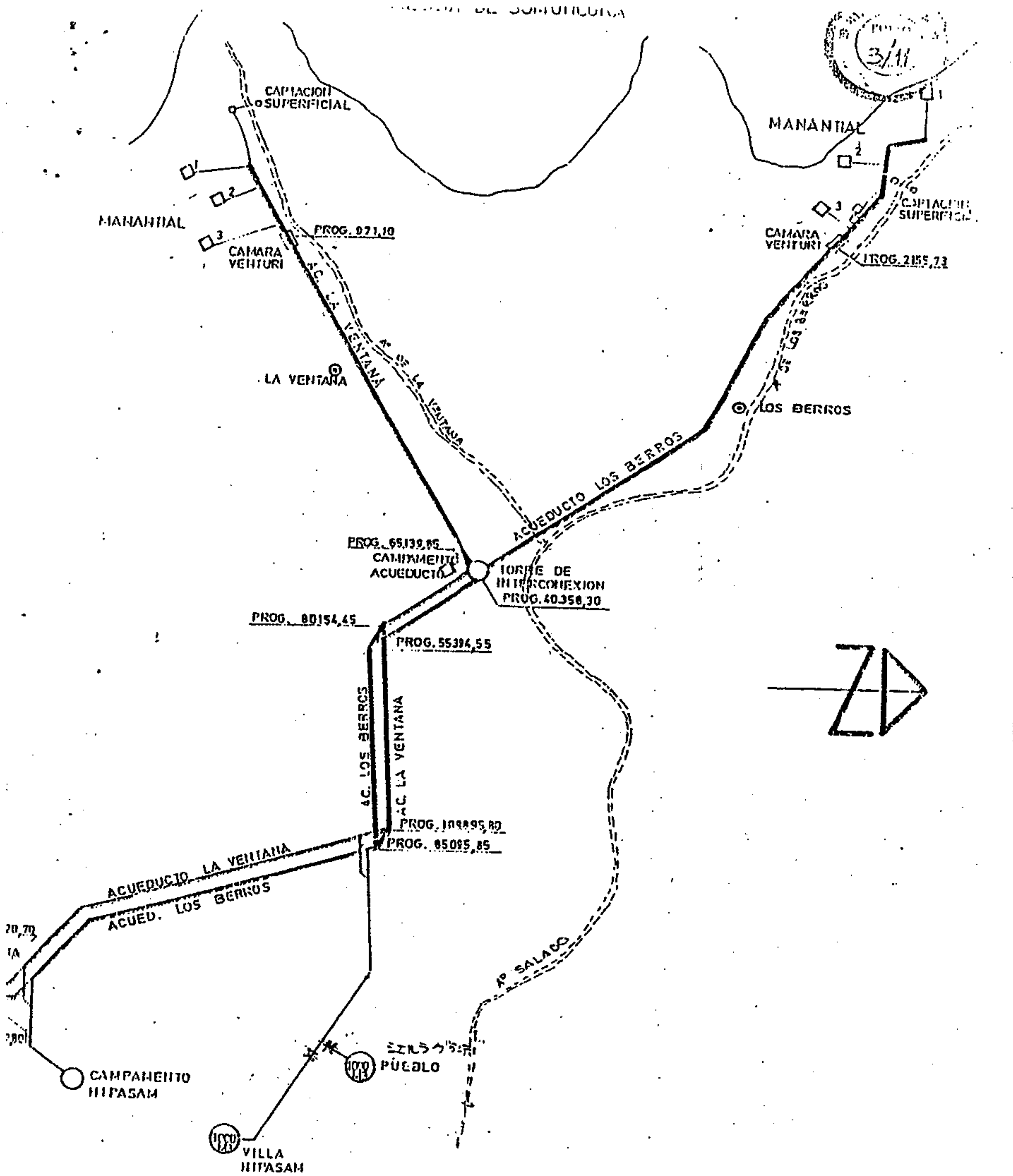
5.2.6 Data and information on utilities which the Team received at the time of the first study in HIPARSA

Attachment-5.	Chart of distribution of electric power
Attachment-6.	General flow chart of water
Attachment-7.	Water consumption of each shop
Attachment-8.	Water analysis
Attachment-9.	General water supply balance
Attachment-10.	General flow chart of natural gas
Attachment-11.	Unit price of natural gas
Attachment-12.	Analysis of natural gas

Attachment-5 Chart of distribution of electric power



Attachment-6 General flow chart of water



Attachment-7 Water consumption of each shop

Mision JICA 02/03/98

Consumos de Agua APPENDIX III - (7)

Año	1985	1986	1987	1988	1989	1990	
Planta de Concentracion							
Preconcentracion	1061	817	1562	734	621	881	m3/mes
Concentracion (Proceso)	66195	42240	38185	50904	57804	51432	m3/mes
Ferroducto (Dilucion+Lavado)	34191	34976	22357	33188	34441	33853	m3/mes
Total	101447	78033	62104	84826	92866	86169	m3/mes
Mina							
Mina	5193	4421	1789	3417	499	2990	m3/mes
Trituracion	975	610	666	914	581	667	m3/mes
Pique Central	5938	3847	3386	4516	5090	3264	m3/mes
Torre Pique				713	6060	3795	m3/mes
Total	12006	8878	5841	9559	12230	10716	m3/mes
Servicios							
Mantenimiento	983	782	1021	1354	930	1201	m3/mes
Almacenes	1279	1035	596	857	1453	1045	m3/mes
Administracion	6545	5240	6358	7151	6583	5162	m3/mes
Total	8807	7057	7975	9362	8965	7408	m3/mes
Area Industrial II							
Peletizacion Industrial	8531		12880	11790	16623	22567	m3/mes
Peletizacion Humano	2973		3110	2437	3506	3225	m3/mes
Total	11504		15990	14227	20129	25793	m3/mes
Produccion Pelets	509429	646356	464680	605134	591899	612783	tp/año
Consumo Especifico Agua							
Planta de Concentracion	2.39	1.45	1.60	1.68	1.88	1.69	m3/tp
Mina	0.28	0.16	0.15	0.19	0.25	0.21	m3/tp
Servicios	0.21	0.13	0.21	0.19	0.18	0.15	m3/tp
Area Industrial II	0.27	ND	0.41	0.28	0.41	0.51	m3/tp
Total	3.15	1.74	2.37	2.34	2.72	2.55	m3/tp

Observaciones -El consumo Peletizacion Industrial puede reducirse a cero para niveles de produccion mayores de 600000 tp/año si los sistemas de recuperacion de agua del Area Industrial II funcionan adecuadamente.

-Es probable la interrupcion del servicio de acueductos pero se cuenta con una capacidad de reserva de 380000 m3 compuesta por la cisterna y el reservorio del Area Industrial.

Ing. Carlos Eduardo Mac Kenzie

Ing. [illegible] Enrique Cariac

COSTOS MANTENIMIENTO ACUEDUCTOS Equipos Mantenimiento Acueductos	Tiempo Medio Trabajo	Horas/mes	U$S/hora	U$S/mes	U$S/mes	U$/m3
Hitachi	50.00%	100	51.67	5166.58		
Fiat	50.00%	100	28.85	2885.13		
Carreton	50.00%	100	3.35	335.42		
Cat 950	50.00%	100	33.03	3302.56		
Camioneta	100.00%	200	14.43	2885.13		
F-7000	50.00%	100	28.85	2885.13		
Costo Total Mensual Equipamiento					17459.93	
Costo Especifico Equipamiento						0.060
Costo De Personal						
Agentes			6			
Tiempo Mensual			200	horas/mes		
Costo Promedio			7.01	U$S/hh		
Costo Mensual Mano de Obra Directa			8406.91	U$S/mes		
Total Mensual Mano de Obra					8406.81	
Costo Especifico Mano de Obra						0.029
Costo Materiales	88-91		984.38	U$S/mes		
Imprevistos			984.39	U$S/mes		
Total Mensual Materiales y Repuestos					1968.76	
Costo Especifico Materiales y Repuestos						0.007
Costo Especifico Mantenimiento					27835.5	0.096

Provincia de Río Negro
República Argentina
Departamento Provincial de Aguas

Viedma, 02 de Diciembre de 1.997

ANALISIS DE AGUA Nº: 7.991-Q

PROCEDENCIA: Los Berros

Sitio de extracción: Red

Extraída por:

Fecha de extracción: 21.10.97 Llegada: .97

Condiciones: Buenas

A N A L I S I S Q U I M I C O

Color:........................		
Turbiedad:....................		
Olor:.........................		
pH:...........................		
Conductividad:................	569	umhos/cm
Sólidos Disueltos totales:....	-	mg/l
Dureza Total..................	128	mg/l
Alcalinidad total.............	124	mg/l
Cloruros (Cl^-).............	50	mg/l
Sulfatos (SO^{4-}):.........	94	mg/l
Nitratos (NO^{3-}):.........	10	mg/l
Nitritos (NO^{2-}):.........	inf. a 0,005	mg/l
Amoníaco (NH^{4-}):.........	-	mg/l
Calcio (Ca^{++}):...........	25	mg/l
Magnesio (Mg^{++}):.........	16	mg/l
Sodio (Na^+):...............	-	mg/l
Potasio (K^+):..............	-	mg/l
Cloro Residual:...............	1	mg/l
Hierro Total (Fe):............	inf. a 0,1	mg/l
Manganeso (Mn):...............	-	mg/l
Plomo (Pb):...................	-	mg/l
Flúor (F):....................	1,3	mg/l
Arsénico (As):................	inf. a 0,05	mg/l

Agua químicamente Apta para el consumo humano

Attachment-8 Water analysis

Provincia de Río Negro
República Argentina
Departamento Provincial de Aguas

Viedma, 02 de Diciembre de 1.997

ANALISIS DE AGUA N°: 7.995-Q

PROCEDENCIA: Arroyo Ventana

Sitio de extracción: Red

Extraída por:

Fecha de extracción: 21.10.97 Llegada: .97

Condiciones: Buenas

A N A L I S I S   Q U I M I C O

Color:........................		
Turbiedad:....................		
Olor:.........................		
pH:...........................		
Conductividad:................	489	umhos/cm
Sólidos Disueltos totales:...	-	mg/l
Dureza Total..................	170	mg/l
Alcalinidad total.............	147	mg/l
Cloruros (Cl^-).............	35	mg/l
Sulfatos (SO^{4-}):.........	66	mg/l
Nitratos (NO^{3-}):.........	8	mg/l
Nitritos (NO^{2-}):.........	inf. a 0,005	mg/l
Amoníaco (NH^{4-}):.........	-	mg/l
Calcio (Ca^{++}):...........	26	mg/l
Magnesio (Mg^{++}):.........	25	mg/l
Sodio (Na^+):...............	-	mg/l
Potasio (K^+):..............	-	mg/l
Cloro Residual:...............	-	mg/l
Hierro Total (Fe):............	inf. a 0,1	mg/l
Manganeso (Mn):...............	-	mg/l
Plomo (Pb):...................	-	mg/l
Flúor (F):....................	1,2	mg/l
Arsénico (As):................	inf. a 0,05	mg/l

Agua quimicamente Apta para el consumo humano

[illegible]
[illegible]
[illegible]
DEPARTAMENTO PCIAL. DE AGUAS

Attachment-8 Water analysis

República Argentina
Provincia de Río Negro
Departamento Provincial de Aguas

Viedma, 07 de Enero de 1.998.-

ANALISIS DE AGUAS Nº 16.880-B

Procedencia: Sierra Grande

Sitio de extracción: Red

Solicitada por:

Muestra extraída el: 17.12.97

Fecha de análisis: 18.12.97

Condiciones: Buenas

Muestra Nº: 04

EXAMEN BACTERIOLOGICO

Bacterias aerobias UFC/ml 05
Agar 37º C-24 hs.

Bacterias coliformes Totales.. inf. a 2
N.M.P. por 100 ml.

Bacterias Coliformes Termotolerantes.. inf. a 2
N.M.P. por 100 ml

C.R. 1 mg/l

Agua Bacteriológicamente Apta para el consumo humano

Bioq. DALIA MIRTA MACARRI
JEFE del DPTO. TECNICO
CONTROL DE CALIDAD
DEPARTAMENTO PCIAL. DE AGUAS

Attachment-9 General water supply balance

HIERRO PATAGONICO RIONEGRINO
SOCIEDAD ANONIMA
HIPARSA

Sierra Grande, 20 de Enero de 1998

ACUEDUCTOS

1) Memoria Descriptiva

El Yacimiento de Sierra Grande se abastece de agua por medio de dos acueductos cuyas características son:

Acueducto La Ventana :

Ubicación de las tomas	: Meseta de Somuncura - Paraje la Ventana.
Cantidad de Tomas	: Cuatro - Una por captación superficial más tres manantiales.
Longitud total	: 118,520 km.
Diametro y Tipo de Tubo	: De 250 a 450 mm Asbesto Cemento C3 a C7.
Caudal Promedio	: 135826 m3/mes - Promedio Años 1985 a 1990. 52.40 l/seg
Flujo	: por gravedad.

Acueducto Los Berros :

Ubicación de las tomas	: Meseta de Somuncura - Quebrada Los Berros.
Cantidad de Tomas	: Cuatro - Una por captación superficial más tres manantiales.
Longitud total	: 98,732 km.
Diametro y Tipo de Tubo	: De 250 a 450 mm Asbesto Cemento C3 a C7.
Caudal Promedio	: 154154 m3/mes - Promedio Años 1985 a 1990. 59,47 l/seg
Flujo	: por gravedad.

2) Servicios

2.1 Usuarios en Ruta.
Existen concesiones otorgadas por el Departamento Provincial de Aguas a lo largo del recorrido de ambos acueductos para abastecimiento de establecimientos rurales ubicados sobre las trazas de los mismos.

2.2 Abastecimiento de Agua Sierra Grande.
A la altura de la progresiva 85,095 del Acueducto Los Berros se deriva una tubería de 200 mm de diámetro a fin de suministrar agua a la Cisterna de 1000 m3 ubicada en el Barrio 25 de Mayo y a la Cisterna de 1000 m3 ubicada en Villa HIPASAM.
Mediante la primera se abastece la localidad de Sierra Grande siendo administrada y mantenida por el DPA.
Mediante la segunda se abastece:
Villa HIPARSA.
Policlinico Sierra Grande.
Polideportivo Municipal.
Escuela Primaria Nº 60.

CEM Nº67 (Ex Escuela Técnica).
CEM Nº39 (Ex Escuela Comercial).
Barrio Modulares Chacrita.
Escuela de Policía Rio Negro.
Club Comunicaciones.

El flujo de agua para cada cisterna es actualmente controlado mediante caudalímetros del DPA.

2.3) Campamento.
Previo al ingreso al Area Industrial I existe una derivación al Campamento administrada y mantenida por HIPARSA, cuyo consumo actual es mínimo debido a que solamente se mantiene una guardia de prevención.

3) Area Industrial I .
Posee una Cisterna con una capacidad de almacenamiento de 30000 m3 mas un Resevorio de 350000 m3 destinado a recoger eventuales exesos de agua temporarios y servir como acumulador de compensación. Debido a que actualmente no existe consumo industrial, los exesos de agua son derivados al Reservorio y de éste al campo.

4) Estadísticas de Consumo .

Estadísticas de Captaciónes y Consumos de Agüa.

Período 1985-1990	Ingresos m3/mes	Egresos m3/mes	Egresos Actuales m3/mes
Acueducto Los Berros	154154		
Acueducto La Ventana	135826		
Roturas		6471	9072 1)
Sobre Acueductos		13545	37926 2)
Pueblo		49876	93300 3)
Villa		57125	~~6480~~ 4)
Campamento		9551	~~45~~ 5)
Forestación		7930	~~0~~ 6)
Area Industrial I		145482	2165 7)

1) Estimado un incremento del 40% debido a la dificultad de obtención de repuestos en tiempo y forma.

2) Estimado un incremento del 180% en función de las nuevas tomas sobre las trazas autorizadas por el DPA desde 1990 a la fecha.

Pág : 2/3

Attachment-9 General water supply balance

3) 4) Valores medios medidos hasta mediados de 1997.

5) Consumo estimado de la guardia de prevención.
6) El riego en el area forestada está desactivado.

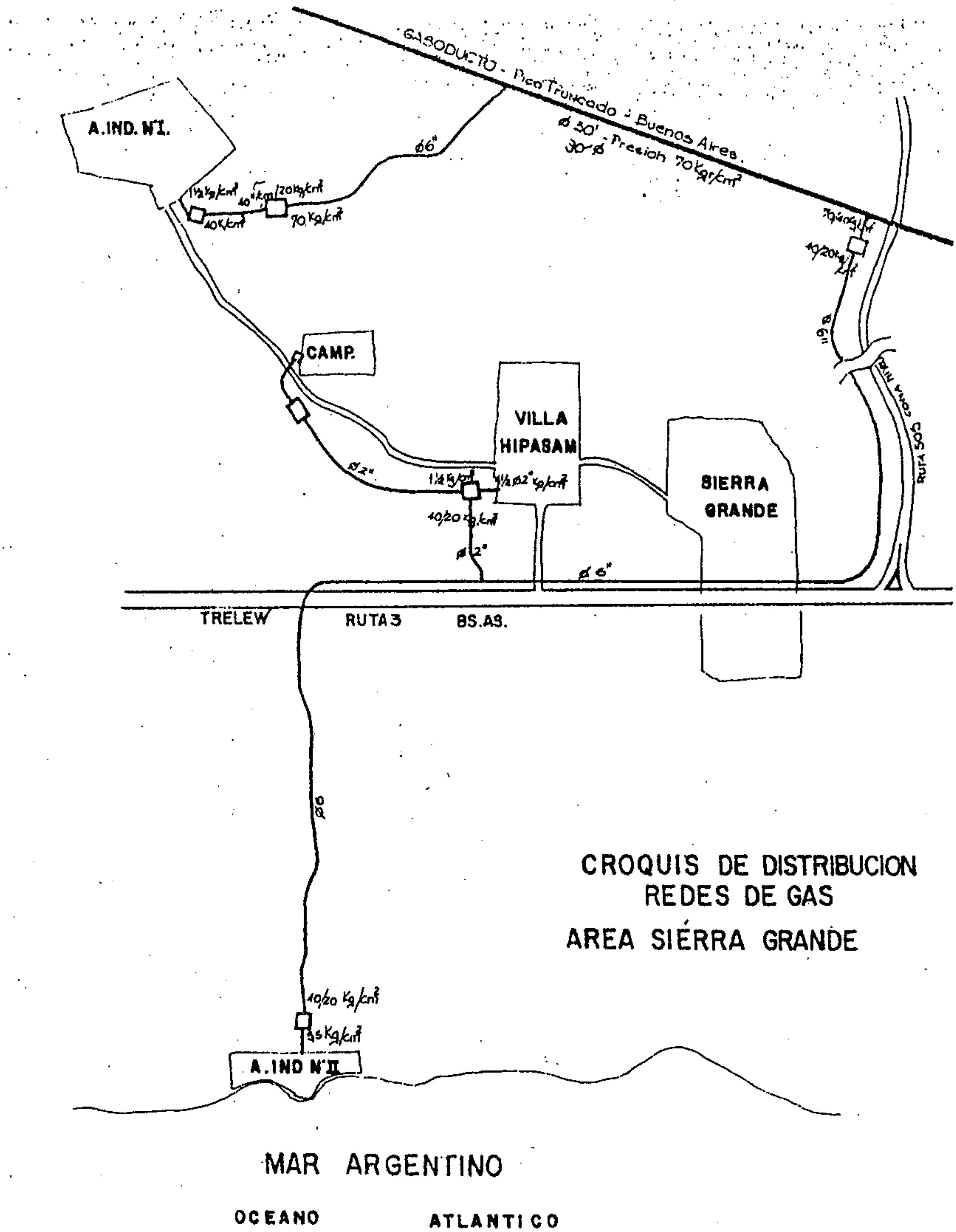
7) El Area Industrial I se alimenta con el acueducto alternativo que no está alimentando las cisternas 25 de Mayo y Villa, por lo cual no, afecta el suministro de agua a las mismas. El valor de consumo estimado es el equivalente a la quinta parte del período 85-90 con el consumo industrial desactivado.

Se adjunta copia de croquis con la traza de los Acueductos Los Berros y La Ventana con identificación de las principales derivaciones.
Atentamente

Ing. Amilcar E. Cariac

Ing. Carlos Mac Kenzie

Attachment-10 General flow chart of natural gas



Attachment-11 Unit price of natural gas

ANEXO I

CAMUZZI GAS DEL SUR S.A.

TARIFAS FINALES A USUARIOS - SIN IMPUESTOS

VIGENTES A PARTIR DEL : 1 DE ENERO DE 1998

CATEGORIA /CLIENTE	SUB-ZONA	en $ convertibles ley 23.928

RESIDENCIAL		Cargo fijo por factura	Cargo por m3 de consumo	Factura mínima
R	Neuquén (7)	7,937791	0,065779	10,308818
	Tierra del Fuego	7,937791	0,071409	10,308818
	Sta. Cruz Sur	7,937791	0,073849	10,308818
	Chubut Sur	7,937791	0,079054	10,308818
	Buenos Aires Sur	7,937791	0,105379	11,339702

SERVICIO GENERAL (2)		Cargo fijo por factura	Cargo por m3 de consumo			Factura mínima
			0 1.000 m3	1001 a 9.000 m3	más de 9.000 m3	
P	Neuquén (7)	11,339702	0,082727	0,077572	0,072418	10,308818
	Tierra del Fuego	11,339702	0,067331	0,062179	0,057022	10,308818
	Sta. Cruz Sur	11,339702	0,064618	0,060494	0,055341	10,308818
	Chubut Sur	11,339702	0,072541	0,067389	0,061204	10,308818
	Buenos Aires Sur	11,339702	0,081827	0,075641	0,069457	11,339702

SERVICIO GENERAL (2)		Cargo fijo por factura	Cargo por m3/día (3)	Cargo por m3 consumido	
				0 a 5.000 m3	más de 5.000 m3
G	Neuquén (7)	11,339702	0,565562	0,059109	0,054985
	Tierra del Fuego	11,339702	0,441653	0,054036	0,048883
	Sta. Cruz Sur	11,339702	0,524123	0,050292	0,046168
	Chubut Sur	11,339702	0,665754	0,052535	0,048409
	Buenos Aires Sur	11,339702	0,849980	0,052304	0,048178

(1) Composición del precio del gas incluido en cada uno de los cargos por m3 consumido (en $/m3)

	Neuquén	T. del Fuego	Sta Cruz Sur	Chubut Sur	B.A Sur
Punto ingreso al sist. de transp.	0,046492	0,035277	0,035703	0,035966	0,035432
Diferencias diarias acumuladas	(0,000023)	0,000005	(0,000046)	(0,000029)	0,000235
Precio incluido en los cargos por m3 consumido	0,046468	0,035282	0,035657	0,035937	0,035667

(2) Los usuarios tienen derecho a elegir el servicio y régimen tarifario aplicable, siempre que se contraten los siguientes mínimos

G: 1.000 m3/día — *FD-FT: 10.000 m3/día* — *ID-IT: 3 000.000 m3/año*

y sujeto a disponibilidad del servicio.

Las tarifas ID e IT no requieren cargo por reserva de capacidad.

Las tarifas FD y FT requieren cargo por reserva de capacidad más cargo por m3 consumido.

(3) Cargo *mensual por cada m3 diario de capacidad de transporte reservada*

(4) Los usuarios conectados a las redes de distribución.

(5) Los usuarios conectados a los gasoductos troncales.

(7) En la subzona Neuquen para las localidades servidas por el Gasoducto Cordillerano en el tramo perteneciente a la Distribuidora el precio incluido en los cargos por m3 consumido será de $ 0,051341 por m3 de 9.300 Kcal.

Attachment-12 Analysis of natural gas

TGS

Buenos Aires Marzo

HIPARSA

Sr. Gerente de Mantenimiento

Ing. Carlos Mac Kenzie

De acuerdo a lo solicitado se informa:

平均 値

Comp. (%mol)	Máx.	Mín.	Promedio
CH4	90.15	89.80	90.02
C2H6	4.89	4.71	4.81
C3H8	2.01	1.87	1.91
C4 Y SUP.	1.29	1.11	1.20
CO2	0.20	0.13	0.17
N2	1.96	1.80	1.90
H2	0.00	0.00	0.00
O2	0.00	0.00	0.00
P.CAL SUP.(KCAL/M3)	9731	9658	9692
P.CAL.INF.(KCAL/M3)	8875	8809	8843

Atentamente.-

GUILLERMO RUSSO
GERENTE DE MEDICION
DIRECCION DE OPERACIONES

5.3 MAINTENANCE ACTIVITIES OF HIPARSA

5.3.1 Maintenance situation of HIPARSA's facilities and equipment in shutdown

The maintenance situation of the facilities and equipment in shutdown we observed this time is similar to that reported by the preliminary study mission (November 3 to 22, 1997) maybe because not much time has passed since then. There are about 100 people assigned to maintenance activities; about 10 people for the mine, 30 people for the concentration plant, 20 people for the Pelletizing plant, and 40 people for the workshops and administration. These people carry out maintenance and inspection jobs on the facilities and equipment. This mainly involves greasing and overhauling the gas-turbine generator and diesel-engine generators for emergency electric power. But most of the time they are carrying out side jobs such as supportive jobs at the nearby airports or guide jobs for sightseers in the mine drifts.

The mine, concentration plant, and Pelletizing plant are in a fairly good maintenance condition in spite of the 7 year shutdown. According to what we have been told by the people involved there were actual negotiations for sales of the whole plant about three years ago and the main facilities were repaired and operated to demonstrate to the buyer.

The shipping and loading facilities are sometimes operated for loading materials from outside the company as a side job and these facilities can be operated at anytime.

In the concentration plant most facilities are installed indoors and pumps seem to be maintained regularly and therefore the concentration plant can quickly resume operation after a short time for repair. The reduction rate of the wall thickness of the long-distance slurry pipeline which was one of our main concerns was found to be only 0.05 mm in 15 years which poses no problem to use again.

In the mine (excluding heavy vehicles) and the Pelletizing plant some parts such as small motors are missing and some parts such as conveyor belts and refractories have deteriorated and need to be renewed for reactivation. The repair period before reactivation therefore will take about half a year including the procurement period for the firebricks. The whole facilities are in a good maintenance condition.

5.3.2 Maintenance conditions of HIPARSA during operation

There are not many people who know the past operating situation and there is not much data that records the maintenance conditions and so it is difficult to make judgment on the maintenance conditions of HIPARSA during operation.

The facilities and equipment, which have been used for 15 years since start-up though including 7 years of shutdown seem to have been maintained with considerable conscious effort. The present maintenance conditions including the stock of spare parts, clean facilities, equipment and lack of dirt inside the plants indicate this.

However operational problems in the Pelletizing plant constantly required improvements which did not allow time for preventive maintenance and breakdown maintenance of the facilities and equipment which seems to have led to the corrective maintenance up to the time of shutdown of the plant.

For reactivation therefore in addition to improvement and repair of damaged facilities and equipment, small computers such as personal computers, should be installed. An inspection management system incorporating preventive maintenance, spare parts control system, equipment history card system, and preparation of standards are required in order that a high operation rate of the facilities and equipment can be kept with a small number of maintenance personnel.

For reference the following are the main maintenance methods.

(1) Main maintenance methods

In order to prevent failure and to maintain equipment accuracy methods of equipment maintenance are roughly divided into the following, depending on the degree importance of the equipment.

1) Preventive Maintenance (P.M.)

This method means that repair and exchange are made in a specified maintenance cycle. This cycle should be fully examined in order to establish whether or not it brings enough merit and decisions made from the various aspects of past inspection results, data on deterioration, theoretical values, the degree of equipment importance (extent of deterioration loss), regulations (on safety, fire, pollution,) etc.

2) Inspection and Repair (I.R.)

This method means repair and exchange are made on the basis of results of deterioration inspections. The equipment subject to I.R.will be subject to inspection costs. Therefore whether or not this method has advantages should be fully examined, and an inspection cycle should be properly set up according to the deterioration state.

3) Breakdown Maintenance (B.M.)

This method means repair or exchange are made after failure or abnormalities have happened. For the applicable equipment for B.M. the total maintenance cost and deterioration loss should be equal or lower than maintenance cost for P.M. or I.R.

These three methods are summarized as follows.

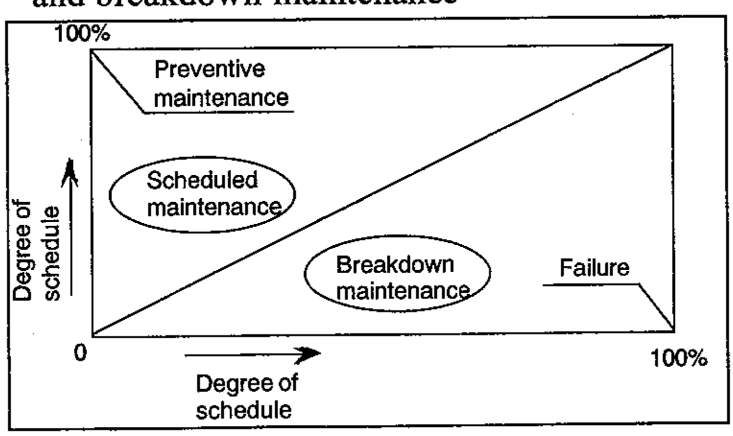
- Method of productive maintenance
  - (1) Scheduled maintenance
    - ① Preventive maintenance
    - ② Inspection and repair maintenance
  - (2) Break down maintenance

The scheduled maintenance in (1) above is a maintenance method in which failures are prevented by having a regular maintenancce schedule.

The relationship between the period of the regular maintenance schedule and the degree of emergency and the relationship between period of the regular maintenance schedule and breakdown maintenance are shown in **Fig.-16**.

Whilest preventive maintenance with 100% scheduled means 0% emergency, maintenance with no schedule means 100% emergency. This is failure.

Fig.-16 The relationship between scheduled maintenance and breakdown maintenance



(2) Other classification of maintenance methods

1) Corrective Maintenance (C.M.)

This method demands improvements, modifications and renewals of materials and parts in order that equipment has a long life with less failure and less maintenance. Therefore, this method reduces deterioration loss and maintenance cost. More precisely the improvements by this means of maintenance method are as follows. Since the corrective maintenance often requires rather a large amount of investment the economics should always be considered.

2) Maintenance Prevention (M.P.)

This is the method in which new equipment is designed and constructed in such a way that future maintenance cost and deterioration loss will be lowered. In this case it is necessary to consider the economics in the long term even if the initial construction cost is higher.

5.4 HIPARSA REACTIVATION PLAN BY ARGENTINE PARTY

In 1996, a feasibility study was conducted on HBI production based on Lurgi process. The study was based on the HBI production capacity of 500,000 metric-t per annum, with a plant construction cost of US$ 70-million plus US$ 5-million for additional investment for gas pipeline. The transfer cost of the existing HIPARSA assets was set at US$15-million. All of the product was expected to be exported.

As the proposed process uses concentrates directly, pelletizing plant was not included in the scope. The price of the concentrate was set at US$ 23 per metric-t. This price was based on the figure taken from the separate study conducted by HIPARSA Project Advisory Committee (**Table-87**). (There are some points to be clarified further by HIPARSA).

The study showed FIRR of 21.30% based on the sales structure of 100% export of HBI at US$130 ex works (**Table-88**). The Ministry of Economy of the Province of Rio Negro - after a public offer to private companies to reactivate the HIPARSA's facilities-preadjudicated the proposition of an Argentina private investor on February 2, 1996 by Resolution 141.

The awarded party had to carry out several commiment assumed in her offer to achieve the definitive adjudication. At the same time, a commission integrated by HIPARSA and the awarded in order to study in depth the association of both companies, according to the proposal of the pre-adjudicated.

The commission carried out his commiment, visiting the main suppliers of HBI technology, and making comparative studies of each one, and over its viability to process the Sierra Grande's iron ore.

As a result of those studies, the private investor signed a contract with Lurgi Metallurgie GmbH to make a pre-engineering study, as he had carried out in his original offer. As the study was not paid for the awarded, the therefore it was not made, the pre-adjudicate lost the possibility to obtain the definitive adjudication. Rio Negro provincial government is currently bearing the cost of maintenance of HIPARSA facilities, $200,000 per month.

After the above study, there was no reactivation plan studied by the Federal Government, Provincial Government or HIPARSA Project Advisory Committee.

Table-87 Iron ore mining and concentration cost study by HIPARSA project advisory committee

($/Metric-t of Concentrate)

1	MANO DE OBRA		5.79
	MANO DE OBRA PROPIA	4.47	
	TRANSPORTE DE PERSONAL	0.06	
	SERVICIOS CONTRATADOS	1.26	
	MANO DE OBRA NO CALIFICADA	0.46	
	MANTENIMIENTO	0.80	
2	ENERGIA ELECTRICA		2.87
3	INSUMOS		7.27
	(MATERIALES AFECTADOS A PROCESOS PRODUCTIVOS)		
	EXPLOTACION MINA	5.62	
	MANTENIMIENTO CENTRAL	0.43	
	CONCENTRACION	1.22	
4	MATERIALES Y REPUESTOS		1.08
	MATERIALES VARIOS	0.67	
	REPUESTOS CONCENTRACION	0.41	
5	SEGUROS		0.29
	INCENDIO	0.15	
	ACC DE TRABAJO	0.11	
	VEHICULOS	0.03	
	VIDA OBLIGATORIO	0.00	
	RESPONSABILIDAD CCIVIL	0.00	
6	SEIVICIOS CONTRATADOS		2.44
	EVACUACION DE ESTERIL	0.26	
	REPARACIONES	1.33	
	FLETES	0.46	
	PROVISION DE GAS	0.05	
	PROVISION DE AGUA	0.17	
	IMPUESTOS MUNICIPALES	0.17	
7	GASTOS DE ADMINISTRACION		1.82
	ADM DE PLANTA	0.82	
	MANO DE OBRA	0.65	
	TRANSP. PEERSONAL	0.01	
	GCIA. GRAL.	0.16	
	ADM CENTRAL	1.00	
	TOTAL GENERAL		21.56

(Source: HIPARSA Project Advisory Committee)

Table-88 Yearly Spreadsheet - Feasibility Study on HIPARSA Reactivation with HBI Production

	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	TOTAL
1 HBI PLANT INVESTMENT, NET OF IVA	-75,000															9,298	-65,702
2 EQUIPMENT OF HIPARSA	-15,000															620	-14,380
3 STARTUP EXPENSES	-1,904	-1,904															-3,808
4 RESEARCH AND DEVELOPMENT	-500																-500
5 WORKING CAPITAL		-4,854														4,854	0
6 IVA CREDIT	-9,450	8,958	492														0
7 SALES - DOMESTIC		0															0
8 SALES - EXPORT		42,656	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	952,656
9 REIMBURSEMENTS		1,280	1,300	650	0	0	0	0	0	0	0	0	0	0	0	0	3,230
10 PRODUCTION COST		-21,246	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-32,375	-474,496
11 SALES EXPENSES		-853	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-19,053
12 ADMINISTRATION		-1,280	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-1,950	-28,580
13 INSURANCE		-395	-395	-395	-395	-395	-395	-395	-395	-395	-395	-395	-395	-395	-395	-395	-5,926
14 LURGI LICENSE FEE	-1,400	-1,100															-2,500
15 EMVIRONMENTAL COST		-701	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-1,069	-15,664
16 MINERAL TAX		-138	-170	-170	-170	-170	-170	-170	-170	-170	-170	-170	-170	-170	-170	-170	-2,515
17 PORT CHARGES		-263	-400	-400	-400	-400	-400	-400	-400	-400	-400	-400	-400	-400	-400	-400	-5,863
18 PROFIT BEFORE TAX	-103,254	20,159	29,134	27,991	27,341	27,341	27,341	27,341	27,341	27,341	27,341	27,341	27,341	27,341	27,341	42,113	316,899
19 TAX	0	0	0	0	-1,031	-6,714	-7,047	-7,047	-7,047	-7,047	-7,047	-7,047	-7,047	-7,047	-7,047	-19,579	-90,747
20 PROFIT AFTER TAX	-103,254	20,159	29,134	27,991	26,310	20,627	20,294	20,294	20,294	20,294	20,294	20,294	20,294	20,294	20,294	22,535	226,152

HBI Plant 70000 Lurgi estimate

Gas Pipeline 5000 Hiparsa estimate

Source: Hiparsa Project Advosory Committee

Chapter 6

APPLICABLE TECHNOLOGY, FACILITIES AND UTILITIES FOR HIPARSA REACTIVATION

6.1 STUDY OF ECONOMICAL MINING METHODS

(1) General

Sub level stoping method is applicable for a simple structure drift which enable easy standardization of work and mechanization. Especially high productivity may be expected for a drift which employed a truckless system by bringing high performance loading machines and mine trucks.

The south deposit employed a truckless system from the beginning and had tried to increase productivity partially by bringing loading machines and mine trucks however operation results showed the rather low productivity of 190 t/man-month for the mining division. The reason why productivity was so low was considered to be mainly labour union problems in that particular era and other reasons such as intermittent operation caused by the intermittent operation of the concentration plant and pelletizing plant.

It is definite requirement to re-start the mining of the south deposit at the time of reactivation by introducing completely new manpower deployment and allocation under a modern style management and organization. Furthermore increase in productivity can be achieved by introducing a mechanized mining method.

(2) Production capacity

1) General

The following four major factors are considered to be the deciding factor for production capacity by omitting external factors which interrupted the mining production at the time when HIPASAM was in operation.

$1.8m^{*1} \times 9m^{*2} \times 23m^{*3} \times 4.5^{*4} \times 2 \times 0.85^{*5} = 3{,}000\ t\ /\ blasting$

*1: spacing distance
*2: average width of the deposit
*3: sub-level distance
*4: gravity of ore
*5: mining recovery

Excavated ores were loaded and transported by LHD from the face and thrown into the ore pass. The transportation efficiency of LHD of 1,000 t/shift was employed by hearing of actual working conditions.

Mining work at one face is calculated with 1 shift of charging and blasting, 1-2 shift of scaling work of wall and roof and 3 shifts loading and transportating by LHD for a 48 hours cycle. Thus production capacity of one face is calculated at 1,500 t per face per day.

The arrangement of a face at the south deposit is vertical setting proceeding to the strike level by reason of the existence of ore body. In order to ensure the targeted production volume multiple faces are made at each sub-level.

The stoping work is actually carried out in a different work cycle. A number of face for charging and blasting work are made at the same sub-level with the distance of 3,000 m deposit will be about four faces with the distance of 600m～900 m, considering a balance with the loading and transportation work drilling drift and transportation drift of each level (gas exhaust work after blasting and from LHD) and others.Three sub-levels are made in the ore block, therefore a maximum of 12 faces are available in the same ore block.

In actual working production capacity of each face differs by the condition of the wall rock, progress of different jobs, etc. Further the number of faces actually under operation differs by the occurrence of the face to be stoped due to too the close distance between two faces or the end of ore reserve or other conditions. These fluctuation in production can be to some extent absorbed by stocked ore in the stockyard at ground level (approximately 20,000 t) and ore storage in the mine (approximately 16,000 t) however the best operation is stable production with a built in allowance.

When 9 to 12 faces are prepared and production activity carried out on 5 to 6 faces constantly an average annual production capacity of the face of the south deposit is approximately 2,100,000 t per year (1,500 t/face-day × 5～6 face/day × 20.8 days/month × 12 months).

Further, production volume of approximately 500,000 t/year can be expected by the preparation work for face development. 2,600,000 t/year production would be expected in total (2,100,000 plus 500,000 t/year)

3) Secondary transportation by mine dump trucks

Ores from each face are transported by LHD through the ore pass and stocked in the ore bins installed at a distance of 200 meters at the main level. Then ores are further transported by 40 to 42 t mine dump truck to the ore pass fed to No.1 crusher. The transportation efficiency of these mine dump trucks in each shift greatly depends upon the number of mine dump trucks and of the location of the ore bins. Further factors which impact upon the transportation efficiency are drift condition (section, road surface, structure whether or not straight portion is main), ventilation of drift (ventilation capacity of mine dump truck exhaust gas), etc.

Average transportation capacity is estimated to be 400～500 t per shift per one truck from the information of three years (1988-1990) obtained at the time of first site survey of JICA survey team.

Transportation capacity seems sufficient to handle the average annual production capacity of 2,600,000 t/year by proper allocation of mine dump trucks.

4) No.1 crusher and tertiary transportation by skip

No. 1 crusher installed at the level of 410 ML is a jaw crusher with feeding gate dimensions of 1,800 mm width×1,470 mm gap. Motor power output is 300 kW and crushing capability is 800 t/h which seems sufficient to treat ores to meet the annual production capacity.

The loading station is at the level of 480 ML. The skip has a capacity of 17 t per skip and there are 2 skips. Operational speed is 12 m/sec., cycle time is 90 seconds including loading and discharging. Transportation capacity is reported to be 800 t/h which corresponds to the No.1 crusher.

Both No.1 crusher and the skip have sufficient capacity and are deemed capable of handling 2,600,000 t/year production. However it must be pointed out that the crushing capacity of the crusher varies with feeding ores, feeding volume and width of outlet. It is estimated that an occurrence of large ore more than spacing (1.8m) and spacing of holes (1.0～1.2m) is rare. Irregularities like blocking of crusher exit were not reported by the hearing of operation when HIPARSA was in operation.

(3) Underground mobile equipment

1) Fan drill jumbo

Fan drill jumbo used at HIPASAM is equipped with pneumatic drifter, and the power source is a pneumatic motor both for driving and boom moving oil-hydraulic pack. A modern drill jumbo is equipped with oil-hydraulic drifter and the power source is a diesel engine or electric motor with high performance tyres or caterpillar.track.

The merits of introducing this modern drill jumbo is as follows:

① increase in performance of drilling by higher drilling speed
② decrease in operating cost by longer life of drill steel
③ improvement of working conditions such as noise, dust or vibration

It is recommended to introduce this modern type oil-hydraulic fan drill jumbo to obtain the above mentioned merits at the time of reactivation.

2) LHD and mine dump truck

Approximately 70% of LHD and mine dump trucks exceeded their designed life (25,000~30,000 hours). Thus decreasing operational efficiency and increasing maintenance/repair costs.

LHD and mine dump trucks are supplied to a special technical specification for engine, transmission, frame strength, dimension and exhaust gas purification to meet with the condition of underground mining.

To keep high productivity of production when reactivation is made, introduction of larger size LHD allowable to run drifts shall be considered. Furthermore in order to increase mine recovery and safety it would be better to consider employing radio controlled no-operator machines.

With regard to the mine dump trucks it would better to be considered employing low height and high running performance machines with less exhaust gas discharge for the smaller section of the drift and increase the number of trucks running in one drift.

(4) Main level drift

3 drifts (drilling, loading and transportation) are used for main level (70m distance). Reduction of number of drift by using loading and transportation drifts in parallel and introduction of sidetracks for more transportation convenience after reactivation is recommended.

(5) Others

Excavation faces move deeper at the Sierra Grande iron ore mine. Time to move to the working place by the workers will increse. It is recommended to make waiting place for workers in order to keep the actual working hours.

It is further recommended to make a service area of mobile equipment in the mine and the repair work of them except OVH shall be carried out at the abovementioned service area in the mine.

6.2 STUDY OF ECONOMICAL MINERAL DRESSING PROCESS

A most important technical subject to be solved at the concentration plant is to decrease the phosphorus content in the iron ore. A judgement as to whether or not Sierra Grande iron ore deposit is feasible is greatly dependent upon whether or not phosphorus content in the iron ore can be decreased to commercially acceptable levels.

6.2.1 Countermeasures tried or proposed in the past

The followings are countermeasures tried or proposed to reduce the phosphorus in the iron ore at the mineral dressing process. Unfortunately a definitely effective countermeasure has not so far been found.

(1) Reagents for flotation

An emulsion of tall oil and fuel oil had been used in the past as the collector. It is a typical reagent for flotation of apatite. There were a number of trials using various reagents to find an optimum reagent for flotation but no other reagents more effective than these two were found so far. There may be a slight possibility to find better a reagent for flotation. It seems very difficult to find more an effective reagent in rather a short laboratory tests period as the operation results of more than 10 years have shown.

(2) Fine grinding for liberation of magnetite and apatite

It has already been confirmed that the phosphorus in the iron ore can be reduced if a liberation of magnetite and apatite becomes greater by fine grinding. It was confirmed by a plant test that fine grinding of minus 44 micron 100% is possible. Actual production was carried out at the level of minus 44 micron 90% with the limitation of acceptance by the pelletizing plant.

(3) 10 inch cyclones instead of 15 inch cyclones

A plant test to replace 15 inch cyclones to 10 inch cyclones was tried. The purpose for this replacement is not clear as there is no engineer available who was engaged on the replacement test. It is assumed that the purpose of the test was to deduct a generation of ultra fine particles by an increase of circulating road of the pebble mill. It is supposed that there was little effect by the replacement test as the 15 inch cyclones have been reinstalled.

(4) Trials on magnetic separation

It is reported that an increase of water volume and number of stages at magnetic separation is effective for deduction of phosphorus. A plant test to carry out magnetic separation in two stages was carried out and its effectiveness in reducing the phosphorus might have been confirmed. There is a report that an application of 6 set secondary magnetic separators in one line is effective for the deduction of phosphorus however there is no evidence as to whether or not this trial was done.

(5) Conversion of pebble mills to ball mills

A disadvantage of pebble mills which use grinding media containing phosphorus is known and the conversion of the pebble mill to a ball mill has already been proposed. The effectiveness of this conversion is to be expected but there was no evidence of trial at conversion.

6.2.2 Other important countermeasures

The following three countermeasures are considered to be more effective for deduction of phosphorus.

(1) Two-stage processing

This is a process to grind iron ore to flotation size for execution of primary stage concentration and removal of impurities of magnetite and to execute flotation and magnetic separation of pellet feed size at secondary stage. This two stage process was effective in greatly reducing refractory pyrrhotite sulphur at Marcona mine in Peru in 1992. This process is suitable for the production of pellet feed from iron ores which shall be subjected to the elimination of impurities by flotation. This process would be a suitable countermeasure for Sierra Grande iron ores. A detailed application method will be discussed later in this report. The summarized explanation is as follows.

Production technology of iron ores for pellet has advanced remarkably in USA for treatment of taconite. The production technology we are now using for production of pellet can be said a result of development of taconite as a raw material for iron making. The development of taconite was carried out in the Mines Experiment station of Minnesota University under the leadership of U.S. Bureau of Mines. Materials used in the experiments were fine ground taconite concentrate.

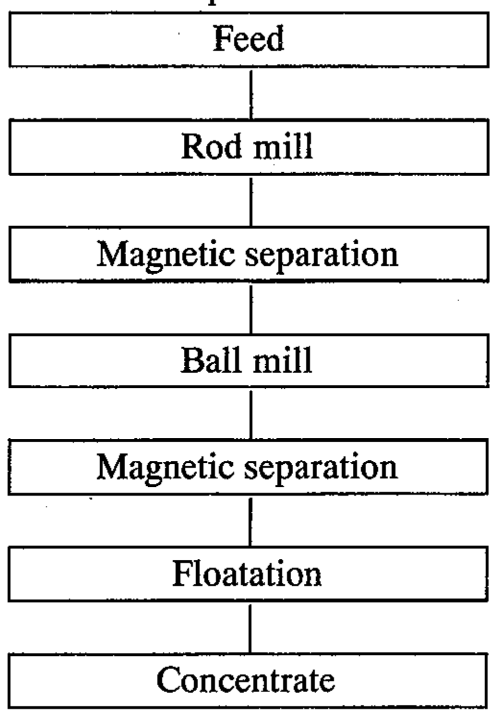
Taconite contains approximately 30% Fe in a form of fine magnetite or hematite. Taconite was deemed just rock before development of mineral dressing technology as it seemed to be no commercial value as a raw material for iron making. Taconite exists widely in Lake Superior district and the name itself is from that district. Demand saw the development of taconite as raw material for iron making generated by the development of mineral dressing technology. Recovery of high grade iron ore was achieved by the fine grinding and magnetic separation for magnetite type taconite.

Iron ore fine grained from taconite contains high Fe % with low impurities and is fit for iron making however 80% or more is of a very fine size of minus 200 mesh or minus 325 mesh. This small particle size makes it difficult to make taconite by the sinter process as a raw material for iron making. Taconite became an important raw material for iron making with the development of the pelletizing process. Erie Mining Company started a commercial production of pellet by using taconite in 1955.

Pellet as the raw material for iron making has rather a short history and from the beginning it has a close relationship with taconite. A mineral dressing of pellet feed seemed to be a process for taconite treatment irrespective of the impurities content. Iron ore is ground to pellet feed size and brought to magnetic separation process. If magnetic concentrate contains sulphur or phosphorus flotation is executed. This treatment is the same at Marcona and Sierra Grande.

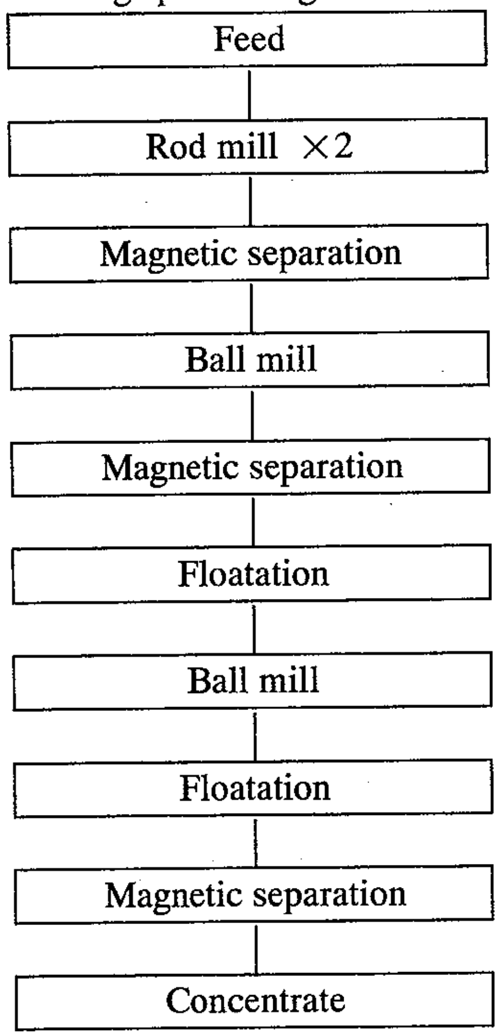
Skeleton of original process flow of Marcona is shown in **Fig.-17**.

Fig.-17 Skeleton of process flow of Marcona



Two stage processing with a combination of two lines was carried out with a process flow shown in **Fig.-18**.

Fig.-18 Two stage processing with a combination of two lines



Two stage processing at Marcona was carried out for the purpose of reducing sulphur content in the pellet feed for export. Sulphur content at that time was about 0.25% which exceeded the specified upper limit of 0.22% by the deterioration of iron ore quality. By introduction of the two stage processing sulphur content in the pellet feed became less than 0.04% and a figure of 0.02% was also recorded. By this two stage processing iron ore containing high pyrrhotite was confirmed to be a suitable iron ore for pellet feed for export. Before success of the two stage processing iron ore containing high pyrrhotite was recomended to reject as waste.

Generally speaking, pellet feed is too fine as flotation feed. Primary magnetic separation concentrate now being treated in two lines will be done in one line and ground by a ball mill. Then the products will become coarser than one stage processing and will become an appropriate size for flotation. With this size magnetic separation and flotation will be carried out and then ground by another ball mill to the pellet feed size and secondary flotation and magnetic separation will be carried out. This will produce good results.

(2) Closed circuit grinding with sieve bends

Another countermeasure considered to be effective is a closed circuit grinding with sieve bends. This methods is to sieve magnetic separated concentrate with sieve bends and over 200 mesh or 325 mesh size particles are subjected for re-grinding and re-magnetic separation to increase purity. This method is also developed by Erie Mining Company for taconite in 1967.

Process flow is shown in **Fig.-19** which was taken from E/MJ-April, 1967.

Usually cyclone is applied for closing grinding circuit. Sierra Grande is also using cyclone. Cyclone causes a similar effect of heavy medium separation. Gangue minerals which are less in specific gravity than magnetite tends to move to overflow, i.e. to the side of the products of the closed grinding circuit. Therefore middling particles of magnetite and gangue minerals gather in the coarse grain portion of magnetic concentrate. When the magnetic concentrate is brought to sieves, magnetite which gravity is heavier than gangue goes to undersize and lighter gangue goes to oversize. This movement is the reverse movement to cyclone. The oversize will be re-ground and re-magnetic separated for the purpose of reducing impurities and upgrading Fe content.

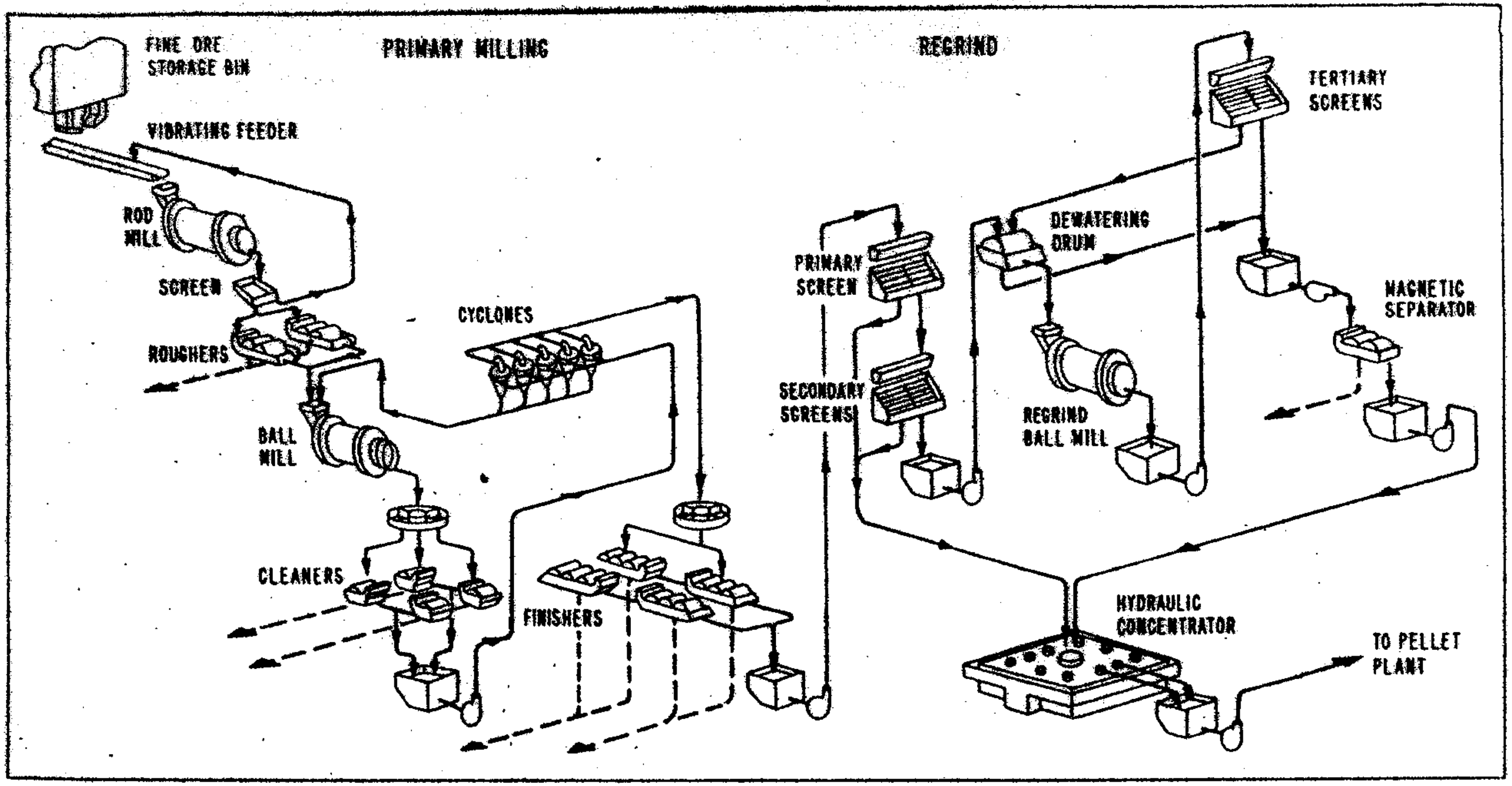
This process was widely used in USA and Canada. The original of Erie Mining Company was flat sieve, but sieve bends which have more capacity were usually used. Erie type flat sieve process was used in China in 1977 when it was still closed to other countries.

(3) De-sliming by hydraulic concentrator

A known technology for concentration of taconite which does not exist at HIPARSA is de-sliming by hydraulic concentrator. Very fine inpurities are very difficult to eliminate not only by flotation but also by magnetic separation. It was reported that the effect of magnetic separation increases when water volume increased and the number of magnetic separation increased. This phenomenon indicates that the de-sliming was effective.

De-sliming equipment using pressurized water like syphonsizer is cheap and effective for elimination of such very fine particles. Syphonsizer was introduced to Erie in 1962 by confirming its effect. Hydraulic concentratior shown in **Fig.-19** is the one which has syphons.

Figure-19



▲ **PRIMARY-SECONDARY SCREENS** upgrade concentrate from finisher magnetic separators; oversize is reground for tertiary screens.

6.2.3 Problems of two stage processing in Sierra Grande

There are three lines in the Sierra Grande concentration plant. Grinding capacity of the plant is more than sufficient therefore two stage processing is deemed applicable by using two lines out of the three lines. At the first site survey, however, existence of basic obstacles was found.

(1) No engineers experienced in the actual operation

Currently there are no engineers around who have experience of the actual operation in HIPASAM or HIPARSA, as stated in Chapter 5 and operation results can not clearly be understood. The best way to find an appropriate countermeasure could be by discussion with experienced engineers however this was found difficult at the first site survey. An appropriate process was established by discussion with experienced engineers in the case of Marcona.

(2) Impossible to carry out operation test at the plant

It was expected that an operation test be executed at the concentration plant at the time of first site survey as there was information that the concentration plant still has approximately 30 employees. It became clear that these 30 employees are nominal and 3 maintenance persons are actually working on a daily basis at the concentration plant. Furthermore there were found to be many problems in actually operating the concentration plant mainly created by how to finance even a temporary short operation.

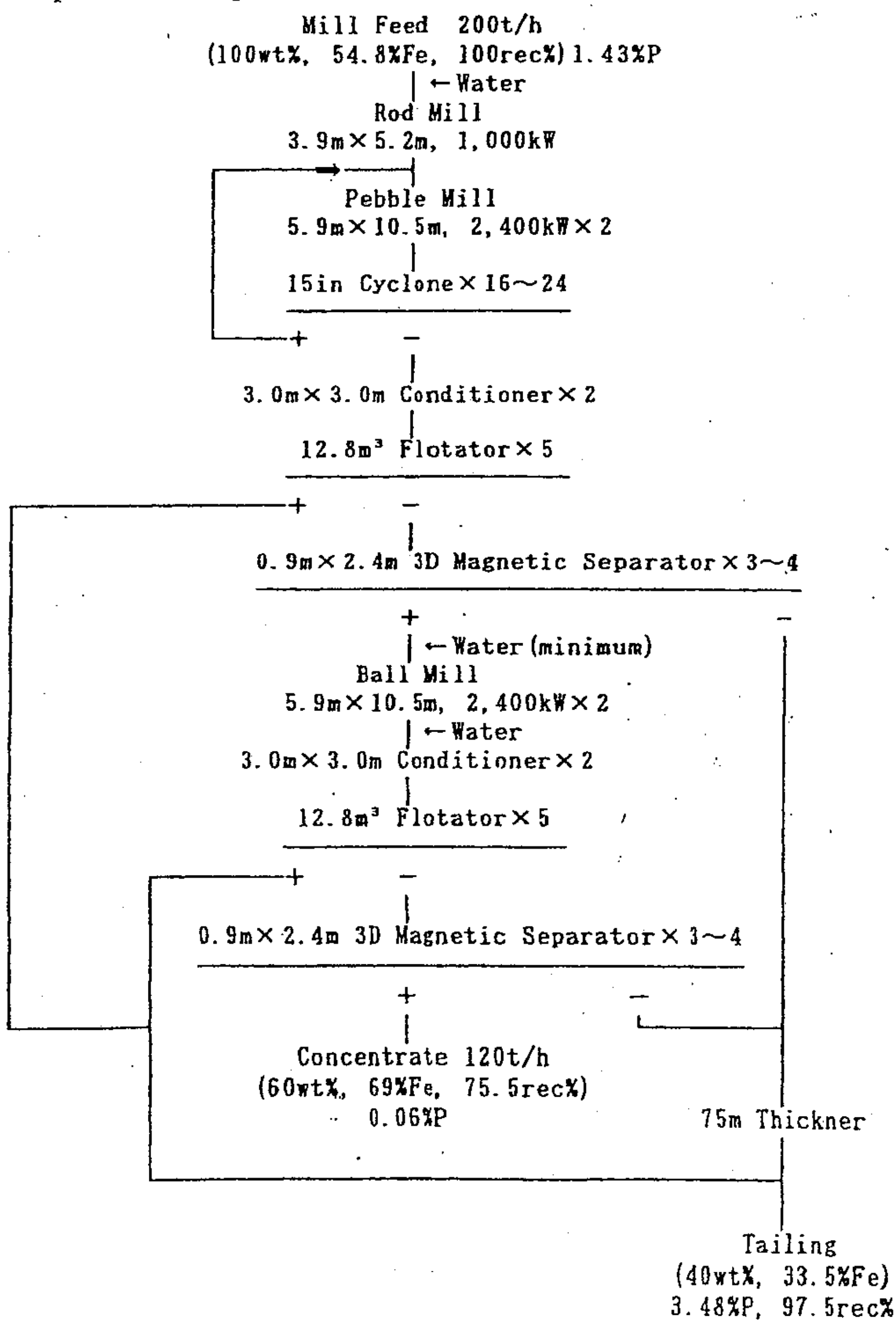
(3) Too big pebble mills

Almost no operation results for the concentration plant were obtained at the first site survey.Actual operational conditions are estimated by an analysis of several data obtained and by a simulation calculation to some extent. The result shows that the capacity of pebble mill is too big. Two stage processing is difficult to carry out by simply unifying two lines in one.

6.2.4 Operation test plan for two stage processing

Fig.-20 is prepared for the purpose of detailed discussion at the time of the first site survey. This shows the major part of flowsheet shown in the Appendix of the Inception Report. As stated in (1) and (2) of 6.2.3, discussion on this flowsheet was not executed at Sierra Grande.

Fig.-20 Operation test plan



6.2.5 Past records of grinding mills

Detailed study of the past flowsheet on the basis of actual operation results is needed for determination of new two stage processing flowsheet. As stated before there is a shortage of actual operation results to do this and of having actual operation experience engineers. There are many discrepencies amongst the data obtained.

Minimum requirements for the study of new two stage processing are, operation results of grinding mills, operation results of each magnetic separation and flotation. Unfortunately, there exists no data which is most important relations on feed rate, power consumption, feed size and product size of the grinding mill.

Although the data so far obtained is as mentioned above a study was made with assumptions and estimations of the past operation to try to establish a new two stage process.

(1) Work index of rod mill

Work index for years between 1988 and 1990 was monthly recorded according to the data obtained at the first site survey. Annual average and monthly data were as shown in **Table-89**. 3 years average was 12.76 kWh/t. Nobody of HIPARSA presently engaging in the concentration plan knows the meaning of work index at the first site survey and thus measurement method was unknown. It was thought at the first site survey that the work index was recorded as one index to show the characteristics of the iron ore. It was assumed that HIPARSA laboratory took data for recording the fluctuation of hardness of iron ore.

Table-89 Record of work index

Year	1988	1989	1990
Work Index range	12.24 to 14.35	11.57 to 13.92	11.31to 13.97
Average	13.22	12.63	12.43

It became clear that this index was operating work index taken from the operation data of the rod mill. Measurement was made every day and the monthly figure recorded was an average of daily measurement. Work index is an index proportionally increase with the iron ore hardness and reverse-proportionally decreases with the grinding efficiency of grinding mill. The efficiency of rod mill varies largely, therefore it is not proper to use the operational work index of rod mill as an index of iron ore hardness, however, operation conditions of rod mill could be estimated from these figures.

Work index of rod mill in November 1986 was between 11.70 and 15.16. The average of them was 13.11 kWh/t. An analyzed quality and the size distribution was shown in **Table-48** and **Table-49**. Size distribution of rod mill products was in a range of minus 100 mesh 50.7% and 62.7% according to **Table-49** and the average was 58.2%. 80% passing size corresponded to 280 to 290 micron.

Hand written information on power consumption was obtained at the first site survey. Power consumption of the rod mill was 799 kW according to that information. Another information was 850 kW. Estimated operation condition of the rod mill is shown in **Table-90** referring those data obtained from HIPARSA.

(2) Operation record of pebble mill

There are almost no data on the pebble mill and difficult to know the operation condition of the pebble mill. Power consumption was especially not clear. Hand written information recorded 2064 kW was found at the first site survey, however another hand written information of 2880 kW was also found. A difference of these two figures is too large to ignore. No confirmation could be done at the second site survey and there are no people engaged in the actual operation of the concentration plant.

There found a record written by KURIMOTO at the trial run of the plant (Report on construction of iron ore concentration plant in the Argentina : by Akio Kitao ; page 25-31, Flotation Vol.29, No.1 (1982 - Spring). According to this report, the target grinding size was minus 44 micron 95%. This was achieved by power consunmption of 3300 kW by the pebble mill, however, blaine index exceeded 3000 cm^2/g. It was reported that blaine index of less than 2400 cm^2/g was obtained by aming minus 44 micron 92 to 93%, at a level of 2400 kW. It is considered that 2064 kW is proper if minus 44 micron 90%, therefore, 2880 kW is considered to be a cumulative figure with the rod mill.

Ground products equals cyclone overflow of pebble mill was not shown in **Table-49** which was sizing record but magenic separation concentrate was recorded. 86.0 to 93.1% at minus 325 mesh and the average was 89.1%. It corresponds to about 32 to 35 micron at 80% passing size.

Newly fed ore volume could be estimated from **Table-48**. Analyzed quality varied largely, which brought a doubt of sampling level, however no other data existed. Iron content in the feed, concentrate and tailing of primary magnetic separation was averagely 53.87%, 60.82% and 22.06% respecrtively. Yield of concentrate is estimated to be 82% from these figures. Phosphorus content was 1.360%, 1.009% and 2.470% respectively. Yield estimated from these figures is 81%. 98 t/h out of 120 t/h rod mill discharge was new feed to pebble mill. In addition to that 18 t/h pebble as consumed should be added to the pebble mill products.

Estimated operation of pebble mill is also shown in **Table-90**.

Table-90 Estimated grinding mill performance in the past

Rod Mill:	Feed rate t/h	120	
	Power consumed kW	810	
	Power consumption kWh/t		6.75
	Feed size, F_{80} micron	21,400	
	Product size, P_{80} micron	287	
	Work index kWh/t		12.94
Pebble mill:	Pebble t/h	18	
	Feed rate t/h	98	
	Power consumed kW	2,064	
	Power consumption kWh/t		21.06
	Feed size, F_{80} micron	287	
	Product size, P_{80} micron	33	
	Work index kWh/t		18.31

6.2.6 Study on flowsheet of two stage processing

(1) Typical Marcona type two stage processing

Annual crude iron ore volume and concentrate volume is to set 2,600,000 t/year and 1,100,000 t/year respectively as premises for HIPARSA reactivation. Volume of preconcentrate on the basis of above is 1,900,000 t/year. When counting 330 days is operation days per year, t/h is 250.

The present processing volume of one line of the concentration plant is 138 t/h which corresponds to slightly more than half of the required capacity. It seems possible that the typical two stage processing could be realized by unifying two lines in one line as shown in **Fig.-21**. Secondary grinding will be ball mill by reducing the speed of pebble mill in order to avoid incoming of new phosphorus and further will be open circuit to avoid heavy medium concentration effect by cyclone. Also, re-grinding circuit of froth of flotation will be both magnetic separation and flotation to reduce further phosphorus content.

When two lines will be unified to one line, rod mill feed will be 258t/h (120t/h×2 plus 18t/h pebble for 1 unit). Grinding operation is estimated on this premise, result is as shown in **Table-91**.

Rod mill does not change from the existing ones as shown in **Table-90**. The difference of first stage pebble mill is the size of products only. 80% passing size moves from 33 micron to 74 micron and this would be the oprimum flotation size.

When second stage mill will be changed to ball mill, work index will be smaller by the improvement of grinding efficiency, however, this factor is not considered at this estimation. Although the improvement as abovementioned is neglected, size of products will become finer as the reject at flotation size will be removed. When the filter of the pelletizing plant will be improved and the acceptance of pellet feed of this size will become possible, then the decrease of phosphorus by two stage processing will be better.

The problem for realization of the the typical two stage processing is the existing too big sized pebble mill.

Figure-21 Flowsheet of typical two stage processing plan

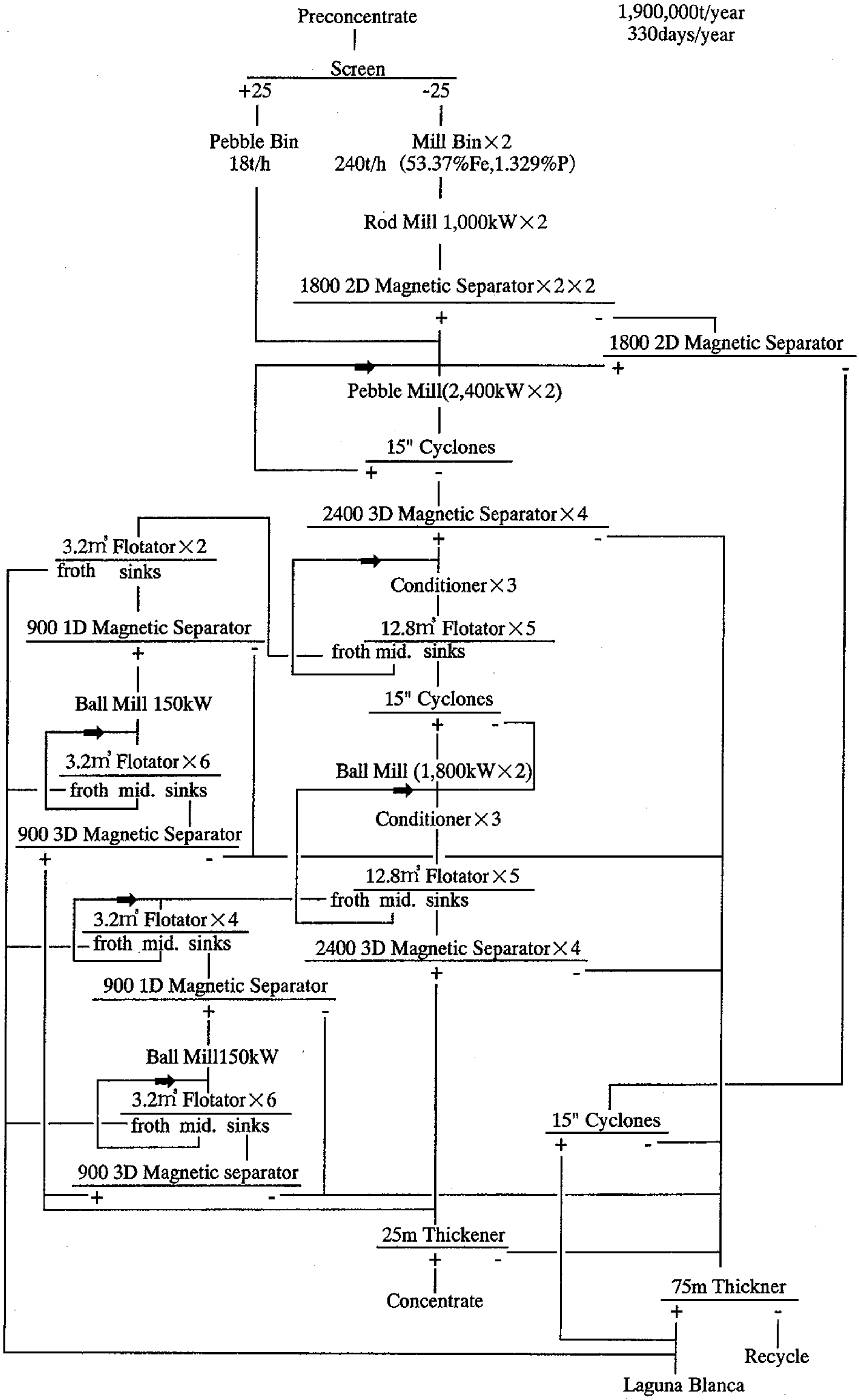


Table-91 Expected grinding performance of typical two stage processing

Rod Mill:	Feed rate	t/h	120×2
	Power consumed kW		810×2
	Power consumption kWh/t		6.75
	Feed size, F_{80} micron		21,400
	Product size, P_{80} micron		287
	Work index kWh/t		12.94
Pebble mill:	Pebble	t/h	18
	Feed rate	t/h	196
	Power consumed kW		2,064
	Power consumption kWh/t		10.53
	Feed size, F_{80} micron		287
	Product size, P_{80} micron		74
	Work index kWh/t		18.31
Ball mill:	Feed rate	t/h	165
	Power consumed kW		2,064
	Power consumption kWh/t		12.51
	Feed size, F_{80} micron		74
	Product size, P_{80} micron		29
	Work index kWh/t		18.31

(2) Two stage processing at Sierra Grande

An estimated power consumption of the existing pebble mill is 2064 kW. It is only 43% of the power installed of 4800 kW. Power consumption almost changes in proportion to the volume of pebble in the mill. It is estimated that the volume of pebble in the pebble mill was below the proper volume for stable operation of the pebble mill.

A more important problem is the grinding at the second stage. For deduction of phosphorus content in the pellet feed, secondary grinding shall be carried out by ball mill. As the specific gravity of ball is heavier than pebble power consumption will become higher. There is a countermeasure against this problem by reducing velocity however power consumption will become approximately 3000 kW.

If the simple countermeasure by unifying two lines to one line seems difficult we would introduce another countermeasure to be studied even if it is unorthodox. That is to convert one rod mill to a ball mill to carry out secondary grinding. This countermeasure is estimated to be a minimum volume of work required and seems most appropriate. A flow sheet idea is shown in **Fig.-22** and an estimated grinding performance is shown in **Table-92.**

Figure-22 Idea of new flowsheet

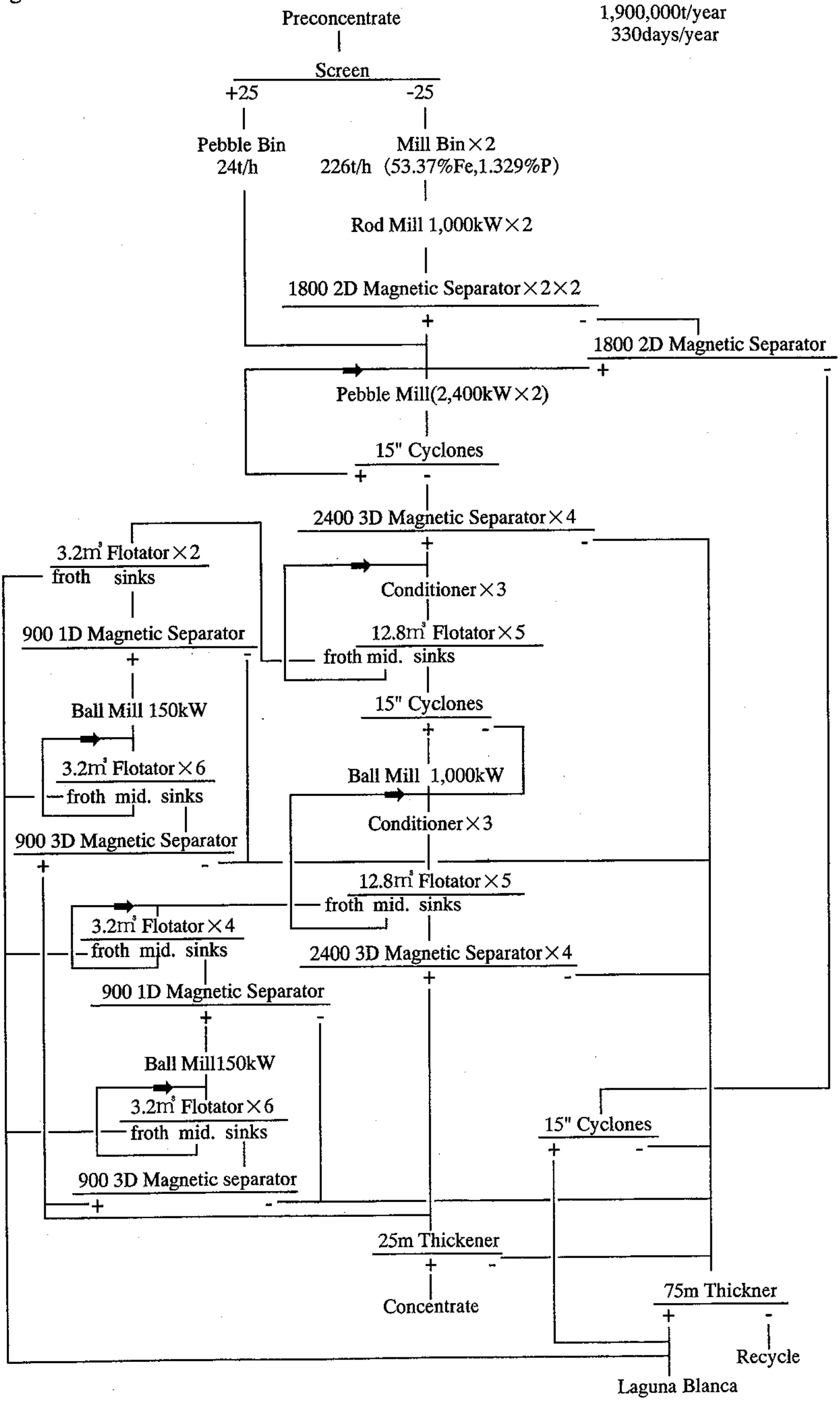


Table-92 Grinding mill performance expected

Rod Mill:	Feed rate t/h	113×2
	Power consumed kW	810×2
	Power consumption kWh/t	7.17
	Feed size, F_{80} micron	21,400
	Product size, P_{80} micron	258
	Work index kWh/t	12.94
Pebble mill:	Pebble t/h	24
	Primary mag. conc. t/h	180
	Power consumed kW	2,660
	Power consumption kWh/t	14.76
	Feed size, F_{80} micron	258
	Product size, P_{80} micron	49
	Work index kWh/t	18.31
Ball mill:	Feed rate t/h	161
	Power consumed kW	780
	Power consumption kWh/t	4.84
	Feed size, F_{80} micron	49
	Product size, P_{80} micron	33
	Work index kWh/t	15.46

6.2.7 Concentration test at HIPARSA laboratory

Batch test at HIPARSA laboratory was carried out as an operation test using existing concentration plant was not possible to execute. Static tests such as comparison of reagents or effect of grinding size are possible at the laboratory. It was considered difficult to realize effect of two stage processing including dynamic factors at the laboratory test level, however, there was no other way.

Preliminary tests (Test 1 and 2) were executed during the stay of JICA first site survey team and Test 3 and 4 were carried out by HIPARSA after JICA first site survey team left Argentina under the instruction of JICA specialist. Deterioration of the standard sieves (200 and 325 mesh) was found on the said sieves, which caused larger grinding size than planned and test results were not satisfactory. Test 5 for confirmation of one stage concentration was carried out too and the result of this test was satisfactory.

It was decided jointly by Federal Government and JICA to execute concentration test at HIPARSA laboratory thenafter. JICA expert brought necessary equipment such as sieves etc., and carried out two stage processing test together with INTEMIN. INTEMIN fully cooperated to carry out the two stage processing test at HIPARSA's laboratory.

The first test (Test 6) was aimed a typical two stage processing as shown in **Fig.-21,** and executed for the purpose of comparison of Test 5. Phosphorus content was reduced by two stage processing more than expected. Phosphorus content of final concentrate at Test 6 was 0.036% as compared with 0.066% at Test 5.

Typical result of test for two stage processing for Sierra Grande was obtained at Test 10. Phosphorus content of final concentrate was 0.035%. **Table-93** shows the data on final concentrate of Test 5,6,10 and 7. Test 7 is also two stage processing test same to Test 10 as shown in **Fig.-22.**

Test 7 was carried out for the purpose of further decrease of phosphorus content regardless of othe factors, therefore yield of concentrate is low but phosphorus content showed 0.026%.

INTEMIN analysis data of size distribution, phosphorus % and Fe % of final concentrate were employed for all the test. Size distribution data is shown in **Table-94**.

Test results on the distribution of weight, iron and phosphorous are shown in **Fig.-23** to **Fig.-25**. Sizing, Fe % and P % of the concentrate were also showin in the said figures. Froth is separated at actual operation for concentrate and tailing by re-grinding and re-treatment. Test flows describing the details of test results are shown in **Fig.-26** to **Fig.-29**.

Table-93 Property of final concentrate

		Test 5	Test 6	Test 10	Test 7
Yield (weight recovery)	%	46.95	48.81	46.26	29.23
Size - 45 micron	%	90.44	86.34		75.59
Assay T.Fe	%	70.73	69.87	70.39	70.84
P	%	0.066	0.036	0.035	0.026
Distribution into concentarte Fe recovery	%	56.60	58.99	57.49	35.80
P recovery	%	2.83	1.49	1.44	0.70

Table-94 Size distribution of final concentrate

Size	% of Passing			
micron	Test 5	Test 6	Test 10	Test 7
250	99.96	99.96		99.98
150	99.92	99.94		99.96
75	99.65	99.74		99.66
45	90.44	86.34		75.59
25	43.82	43.91		36.78
20	30.88	25.78		22.74

Figure-23 Distribution of weight in laboratory tests

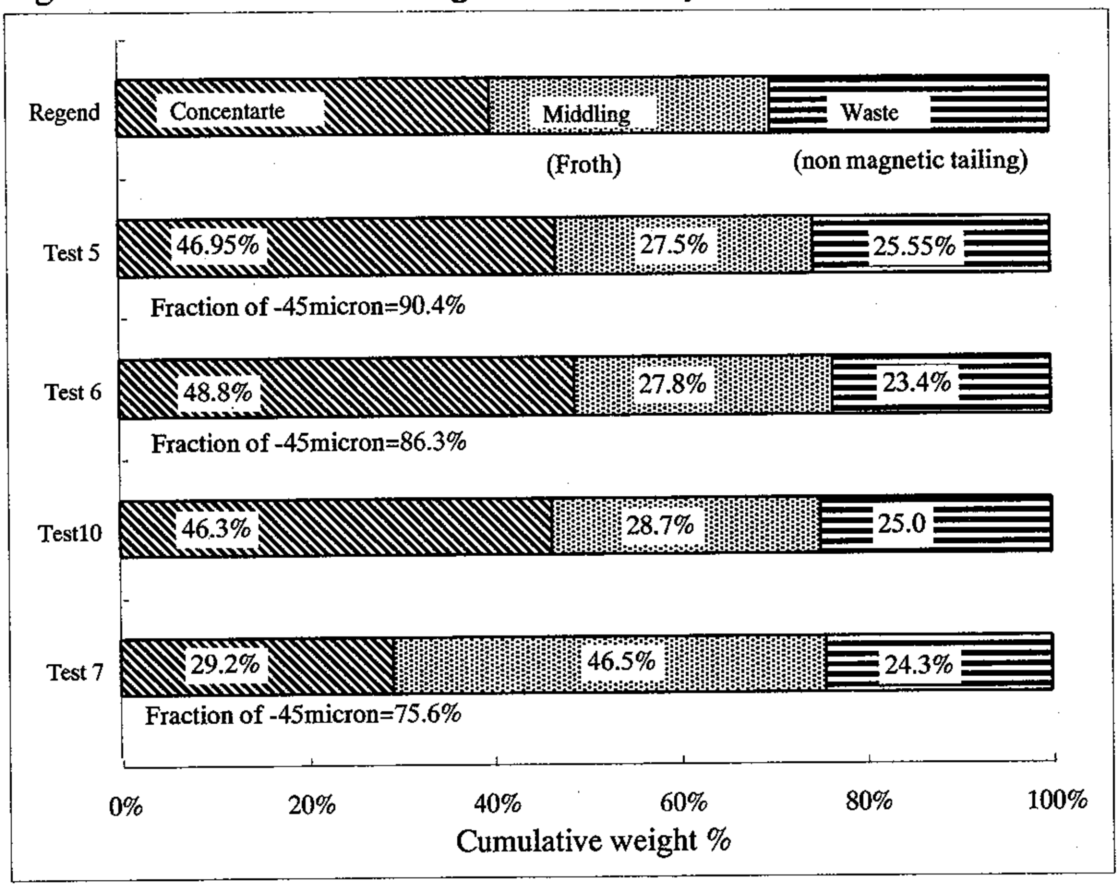


Figure-24 Distribution of iron in laboratory tests

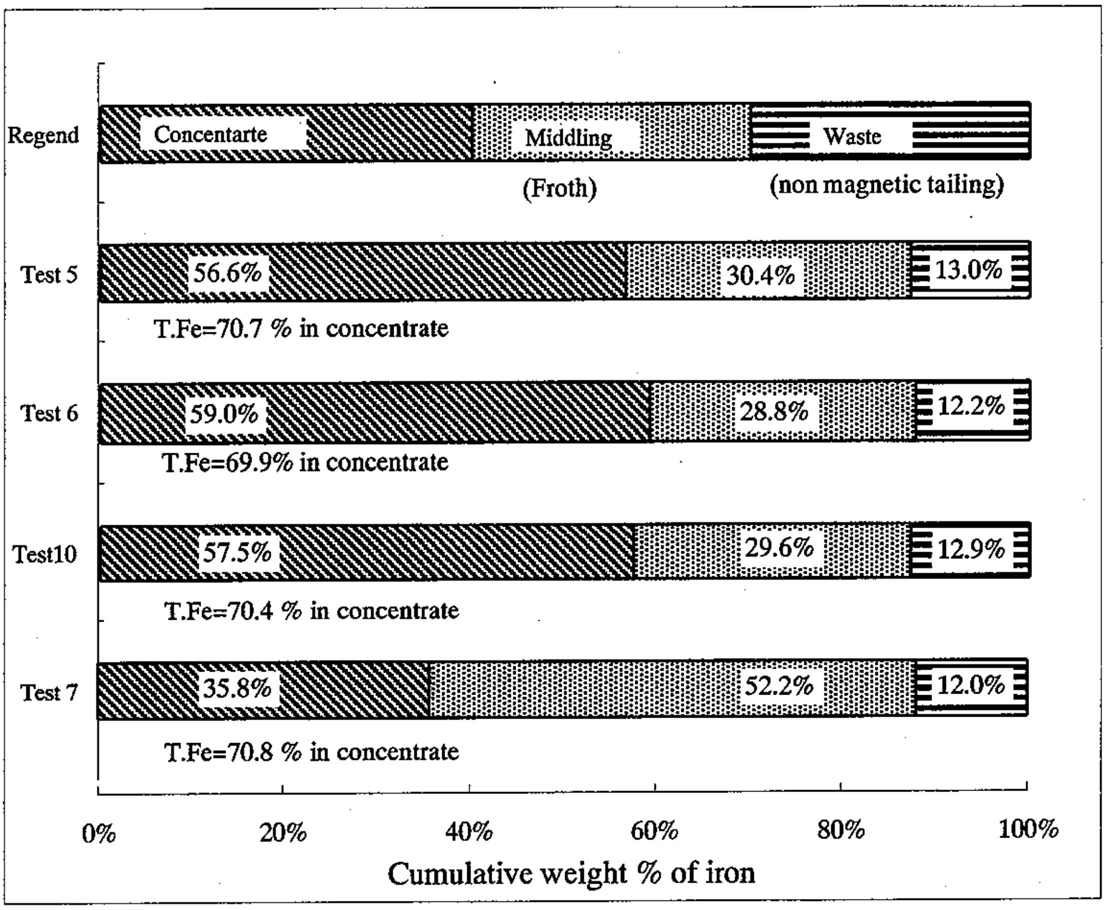


Figure-25 Distribution of Phosphorous in laboratory tests

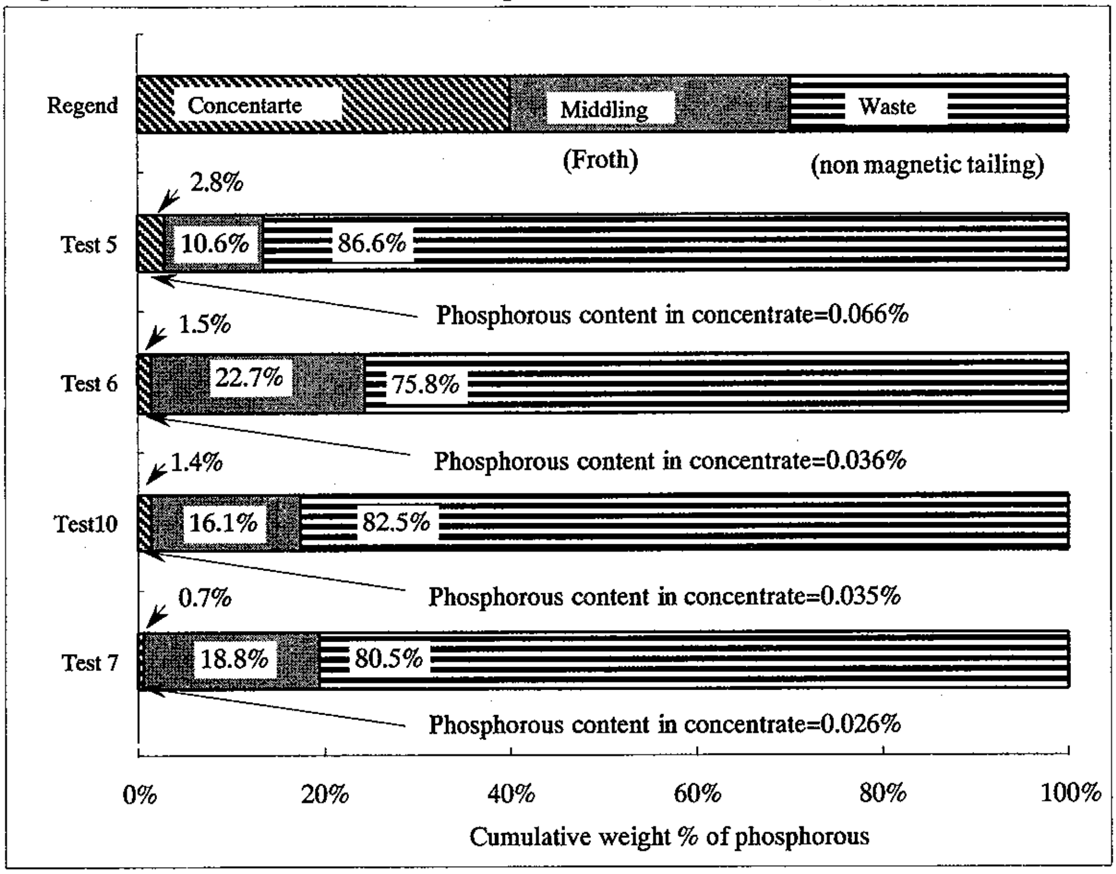


Figure-26

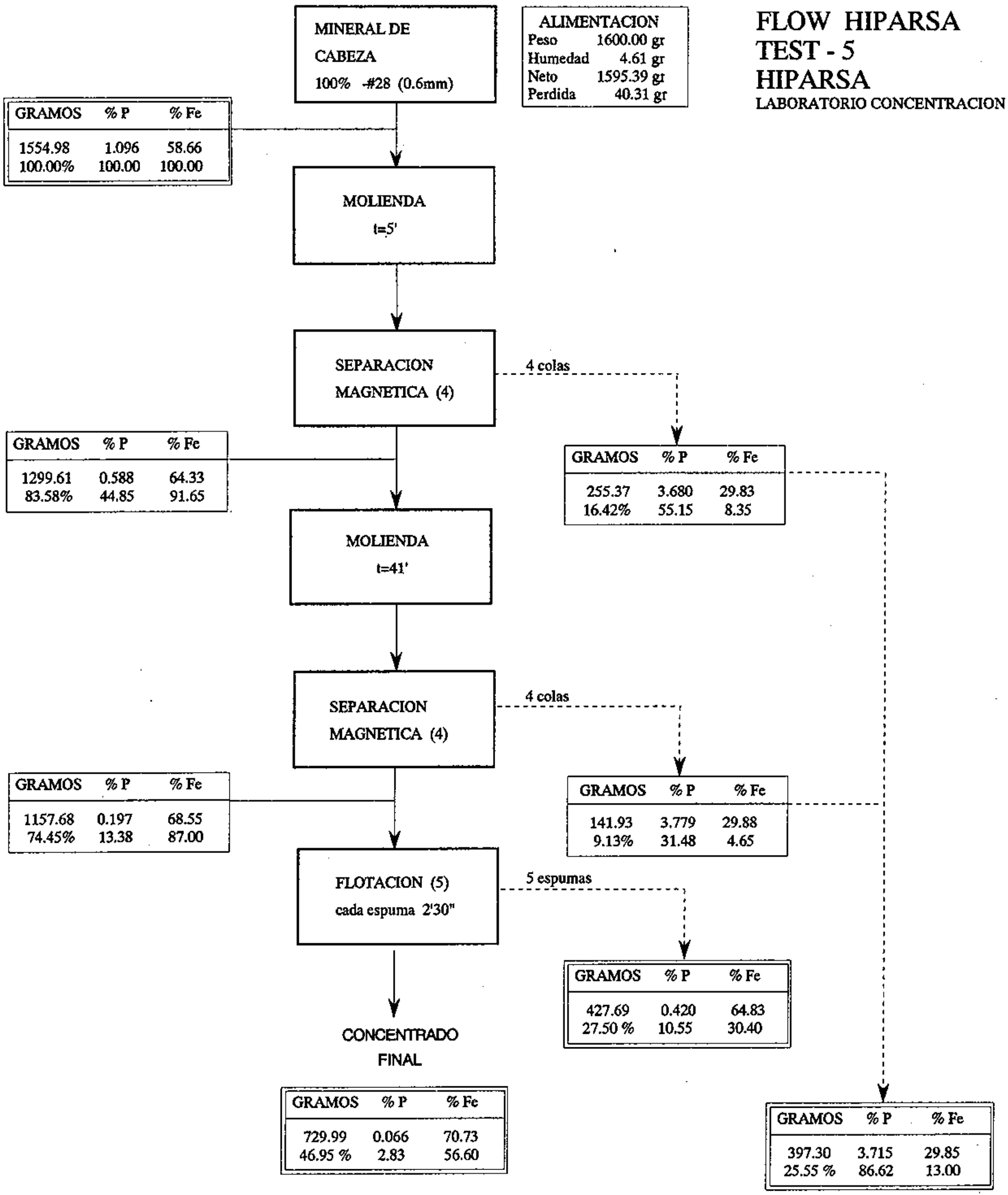

FLOW HIPARSA
TEST - 5
HIPARSA
LABORATORIO CONCENTRACION
MINERAL DE CABEZA
100% -#28 (0.6mm)
ALIMENTACION
Peso 1600.00 gr
Humedad 4.61 gr
Neto 1595.39 gr
Perdida 40.31 gr
GRAMOS %P %Fe
1554.98 1.096 58.66
100.00% 100.00 100.00
MOLIENDA
t=5'
SEPARACION MAGNETICA (4)
4 colas
GRAMOS %P %Fe
1299.61 0.588 64.33
83.58% 44.85 91.65
GRAMOS %P %Fe
255.37 3.680 29.83
16.42% 55.15 8.35
MOLIENDA
t=41'
SEPARACION MAGNETICA (4)
4 colas
GRAMOS %P %Fe
1157.68 0.197 68.55
74.45% 13.38 87.00
GRAMOS %P %Fe
141.93 3.779 29.88
9.13% 31.48 4.65
FLOTACION (5)
cada espuma 2'30"
5 espumas
GRAMOS %P %Fe
427.69 0.420 64.83
27.50 % 10.55 30.40
CONCENTRADO FINAL
GRAMOS %P %Fe
729.99 0.066 70.73
46.95 % 2.83 56.60
GRAMOS %P %Fe
397.30 3.715 29.85
25.55 % 86.62 13.00

Figure-27

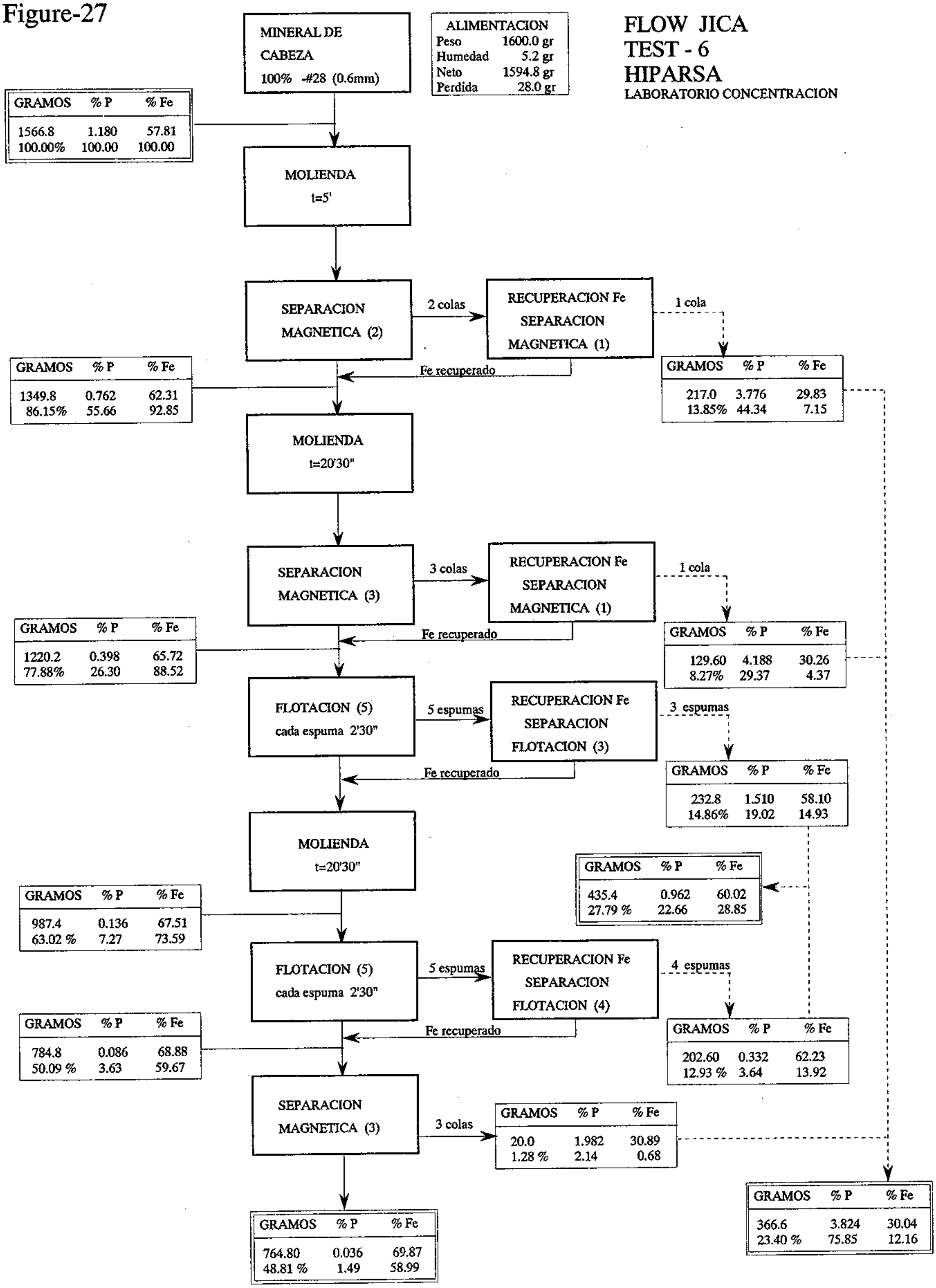

MINERAL DE CABEZA
100% -#28 (0.6mm)
ALIMENTACION
Peso 1600.0 gr
Humedad 5.2 gr
Neto 1594.8 gr
Perdida 28.0 gr
FLOW JICA
TEST - 6
HIPARSA
LABORATORIO CONCENTRACION
GRAMOS %P %Fe
1566.8 1.180 57.81
100.00% 100.00 100.00
MOLIENDA
t=5'
SEPARACION MAGNETICA (2)
2 colas
RECUPERACION Fe SEPARACION MAGNETICA (1)
1 cola
Fe recuperado
GRAMOS %P %Fe
1349.8 0.762 62.31
86.15% 55.66 92.85
GRAMOS %P %Fe
217.0 3.776 29.83
13.85% 44.34 7.15
MOLIENDA
t=20'30"
SEPARACION MAGNETICA (3)
3 colas
RECUPERACION Fe SEPARACION MAGNETICA (1)
1 cola
Fe recuperado
GRAMOS %P %Fe
1220.2 0.398 65.72
77.88% 26.30 88.52
GRAMOS %P %Fe
129.60 4.188 30.26
8.27% 29.37 4.37
FLOTACION (5)
cada espuma 2'30"
5 espumas
RECUPERACION Fe SEPARACION FLOTACION (3)
3 espumas
Fe recuperado
GRAMOS %P %Fe
232.8 1.510 58.10
14.86% 19.02 14.93
MOLIENDA
t=20'30"
GRAMOS %P %Fe
435.4 0.962 60.02
27.79 % 22.66 28.85
GRAMOS %P %Fe
987.4 0.136 67.51
63.02 % 7.27 73.59
FLOTACION (5)
cada espuma 2'30"
5 espumas
RECUPERACION Fe SEPARACION FLOTACION (4)
4 espumas
Fe recuperado
GRAMOS %P %Fe
784.8 0.086 68.88
50.09 % 3.63 59.67
GRAMOS %P %Fe
202.60 0.332 62.23
12.93 % 3.64 13.92
SEPARACION MAGNETICA (3)
3 colas
GRAMOS %P %Fe
20.0 1.982 30.89
1.28 % 2.14 0.68
GRAMOS %P %Fe
366.6 3.824 30.04
23.40 % 75.85 12.16
GRAMOS %P %Fe
764.80 0.036 69.87
48.81 % 1.49 58.99

Figure-28

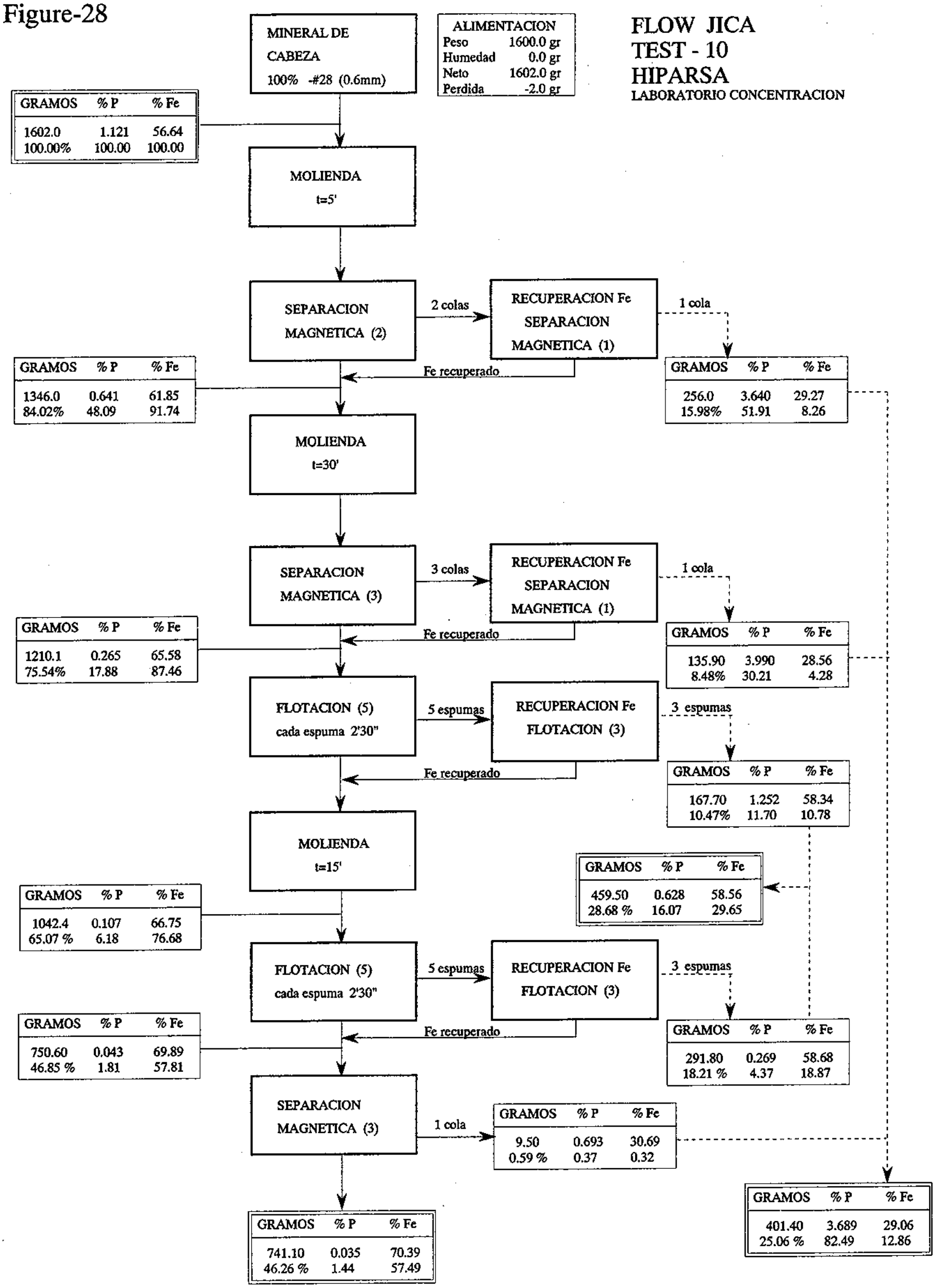
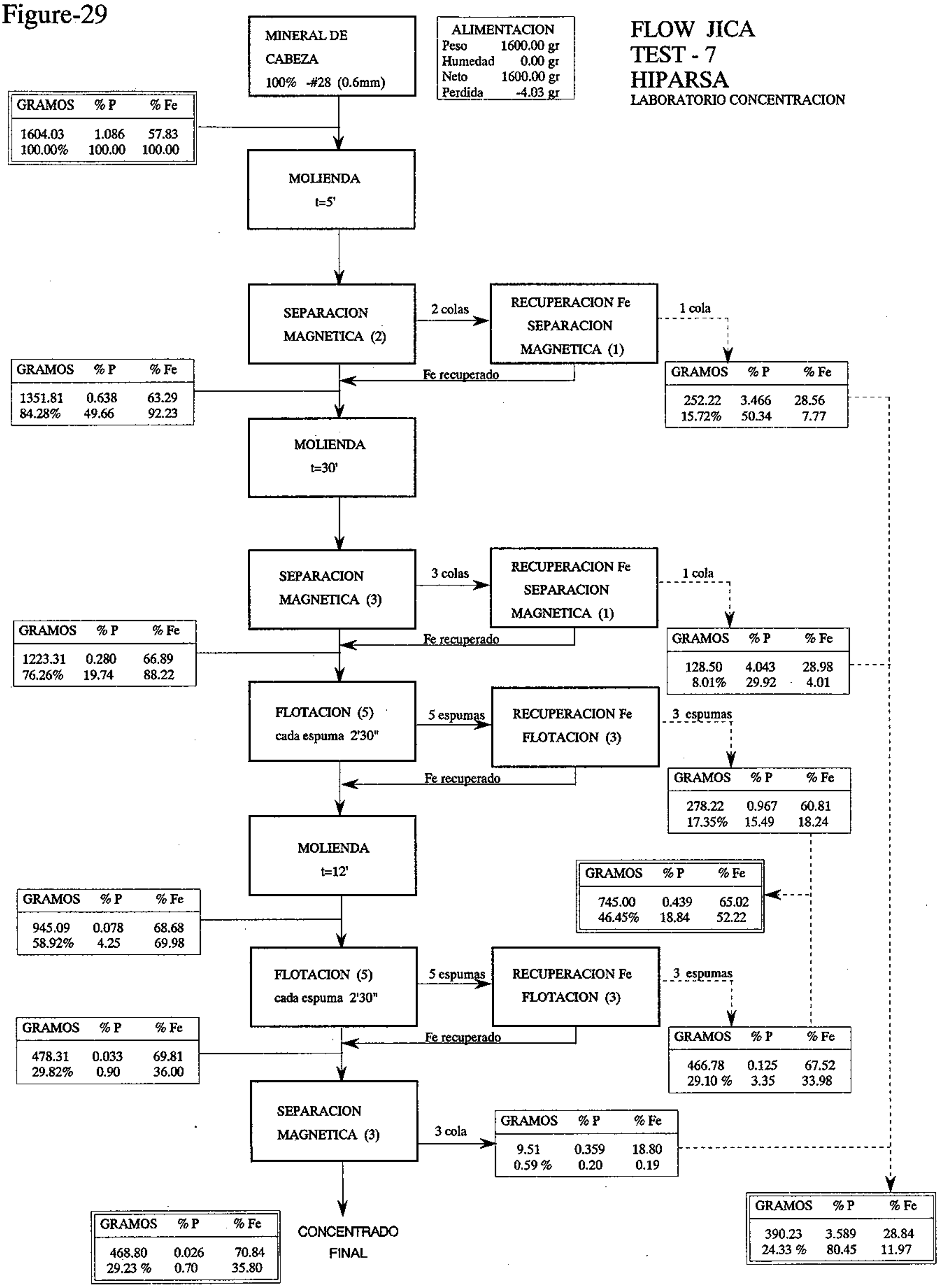

FLOW JICA
TEST - 10
HIPARSA
LABORATORIO CONCENTRACION
MINERAL DE CABEZA
100% -#28 (0.6mm)
ALIMENTACION
Peso 1600.0 gr
Humedad 0.0 gr
Neto 1602.0 gr
Perdida -2.0 gr
GRAMOS %P %Fe
1602.0 1.121 56.64
100.00% 100.00 100.00
MOLIENDA
t=5'
SEPARACION MAGNETICA (2)
2 colas
RECUPERACION Fe SEPARACION MAGNETICA (1)
1 cola
Fe recuperado
GRAMOS %P %Fe
1346.0 0.641 61.85
84.02% 48.09 91.74
GRAMOS %P %Fe
256.0 3.640 29.27
15.98% 51.91 8.26
MOLIENDA
t=30'
SEPARACION MAGNETICA (3)
3 colas
RECUPERACION Fe SEPARACION MAGNETICA (1)
1 cola
Fe recuperado
GRAMOS %P %Fe
1210.1 0.265 65.58
75.54% 17.88 87.46
GRAMOS %P %Fe
135.90 3.990 28.56
8.48% 30.21 4.28
FLOTACION (5)
cada espuma 2'30"
5 espumas
RECUPERACION Fe FLOTACION (3)
3 espumas
Fe recuperado
GRAMOS %P %Fe
167.70 1.252 58.34
10.47% 11.70 10.78
MOLIENDA
t=15'
GRAMOS %P %Fe
459.50 0.628 58.56
28.68 % 16.07 29.65
GRAMOS %P %Fe
1042.4 0.107 66.75
65.07 % 6.18 76.68
FLOTACION (5)
cada espuma 2'30"
5 espumas
RECUPERACION Fe FLOTACION (3)
3 espumas
Fe recuperado
GRAMOS %P %Fe
750.60 0.043 69.89
46.85 % 1.81 57.81
GRAMOS %P %Fe
291.80 0.269 58.68
18.21 % 4.37 18.87
SEPARACION MAGNETICA (3)
1 cola
GRAMOS %P %Fe
9.50 0.693 30.69
0.59 % 0.37 0.32
GRAMOS %P %Fe
741.10 0.035 70.39
46.26 % 1.44 57.49
GRAMOS %P %Fe
401.40 3.689 29.06
25.06 % 82.49 12.86

Figure-29


MINERAL DE CABEZA
100% -#28 (0.6mm)
ALIMENTACION
Peso 1600.00 gr
Humedad 0.00 gr
Neto 1600.00 gr
Perdida -4.03 gr
FLOW JICA
TEST - 7
HIPARSA
LABORATORIO CONCENTRACION
GRAMOS %P %Fe
1604.03 1.086 57.83
100.00% 100.00 100.00
MOLIENDA
t=5'
SEPARACION MAGNETICA (2)
2 colas
RECUPERACION Fe SEPARACION MAGNETICA (1)
1 cola
Fe recuperado
GRAMOS %P %Fe
1351.81 0.638 63.29
84.28% 49.66 92.23
GRAMOS %P %Fe
252.22 3.466 28.56
15.72% 50.34 7.77
MOLIENDA
t=30'
SEPARACION MAGNETICA (3)
3 colas
RECUPERACION Fe SEPARACION MAGNETICA (1)
1 cola
Fe recuperado
GRAMOS %P %Fe
1223.31 0.280 66.89
76.26% 19.74 88.22
GRAMOS %P %Fe
128.50 4.043 28.98
8.01% 29.92 4.01
FLOTACION (5)
cada espuma 2'30"
5 espumas
RECUPERACION Fe FLOTACION (3)
3 espumas
Fe recuperado
GRAMOS %P %Fe
278.22 0.967 60.81
17.35% 15.49 18.24
MOLIENDA
t=12'
GRAMOS %P %Fe
745.00 0.439 65.02
46.45% 18.84 52.22
GRAMOS %P %Fe
945.09 0.078 68.68
58.92% 4.25 69.98
FLOTACION (5)
cada espuma 2'30"
5 espumas
RECUPERACION Fe FLOTACION (3)
3 espumas
Fe recuperado
GRAMOS %P %Fe
478.31 0.033 69.81
29.82% 0.90 36.00
GRAMOS %P %Fe
466.78 0.125 67.52
29.10 % 3.35 33.98
SEPARACION MAGNETICA (3)
3 cola
GRAMOS %P %Fe
9.51 0.359 18.80
0.59 % 0.20 0.19
GRAMOS %P %Fe
390.23 3.589 28.84
24.33 % 80.45 11.97
GRAMOS %P %Fe
468.80 0.026 70.84
29.23 % 0.70 35.80
CONCENTRADO FINAL

6.2.8 Estimated concentration operation

(1) Past concentration performace

Operation record from 1980 to 1990 is shown in **Table-64** and **Table-65**. Separately from this the more detailed record between 1988 and 1990 was obtained. Total of these 3 years is shown in **Table-95** and **96.**

Table-95 Operation Performance (1988-1990)- Preconcentration plant

Product	Weight	
	t	%
Run-of-mine ore	3,912,946	100
Waste	1,098,663	28.1
Preconcentrate	2,814,283	71.9

Table-96 Operation Performance (1988-1990)- Concentration plant

Product	Weight		Assay		Distribution %	
	t	%	% Fe	% P	Fe	P
Preconcentrate	2,845,056	100	52.98	1.315	100	100
Non-magnetic tail	914,862	32.2	23.61	3.095	14.3	75.7
Flotation tail	208,992	7.3	51.82	3.269	7.2	18.3
Concentrate	1,721,202	60.5	68.73	0.131	78.5	6.0

(2) Estimated concentration operation

Estimated concentration performance taking the consideration of past operation records shown in **Table-64,65** and **Table-95,96,** and the results of laboratory tests is shown in **Table-97,98**. Quality of pre-concentrate was taken from **Table-64**, i.e. average of 1980 to 1990. An alteration of mining method of decrease of drifting in mother rock is a little considered.

Table-97 Estimated concentration operation-1

Preconcentration plant

Product	Weight	
	t/year	%
Run-of-mine ore	2,600,000	100
Waste	700,000	26.9
Preconcentrate	1,900,000	73.1

Table-98 Estimated concentration operation-2

Product	Weight		Assay		Distribution %	
	t/year	%	% Fe	% P	Fe	P
Preconcentrate	1,900,000	100	53.37	1.329	100	100
Non-magnetic tail	637,000	33.5	24.40	3.260	15.3	82.2
Flotation tail	163,000	8.6	57.69	2.434	9.3	15.7
Concentrate	1,100,000	57.9	69.50	0.047	75.4	2.1

(3) Comparison of estimated operation and laboratory test

Estimated operation is shown in **Fig.-30** to **Fig.-32** in the form of weight %, Fe % and P % in comparison with the operation record in **Table-96** and Test 10. It is difficult to directly compare the data as the quality of pre-concentrate differs. Quality of feed is also shown in the figures.

Figure-30 Distribution of weight

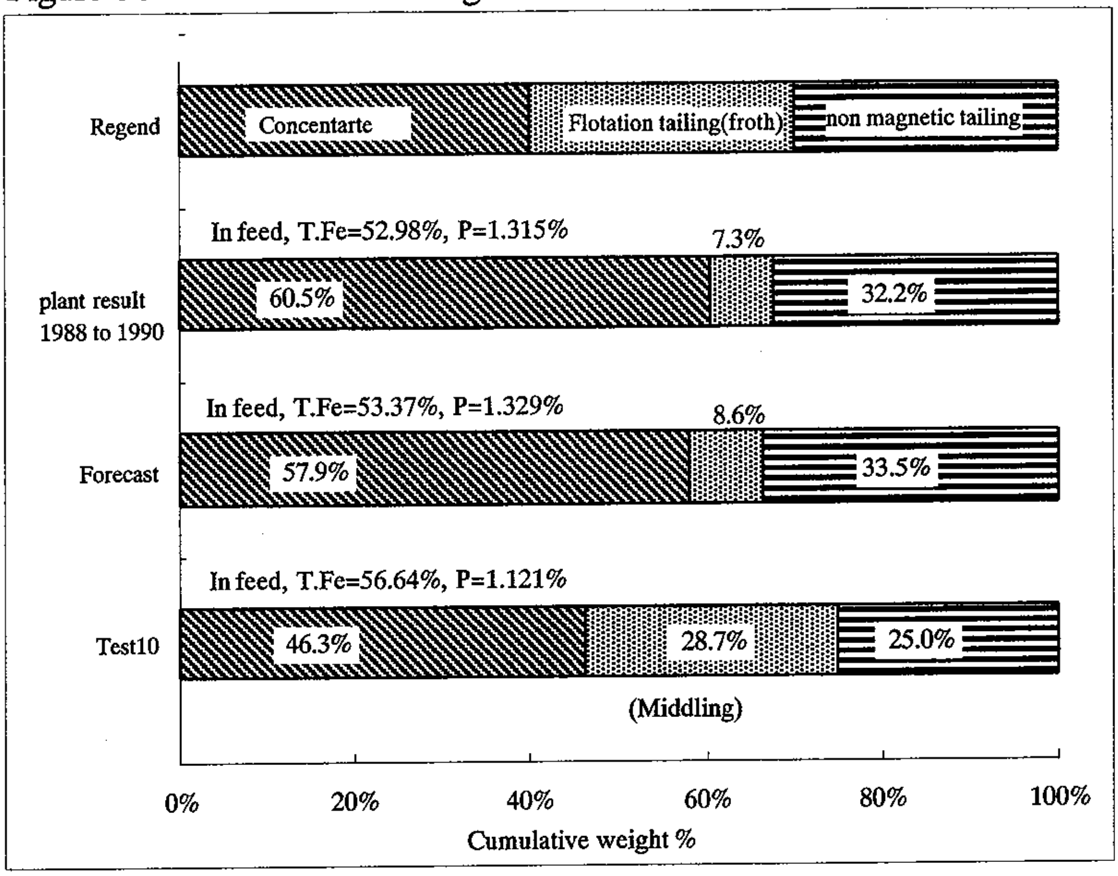


Figure-31 Distribution of iron

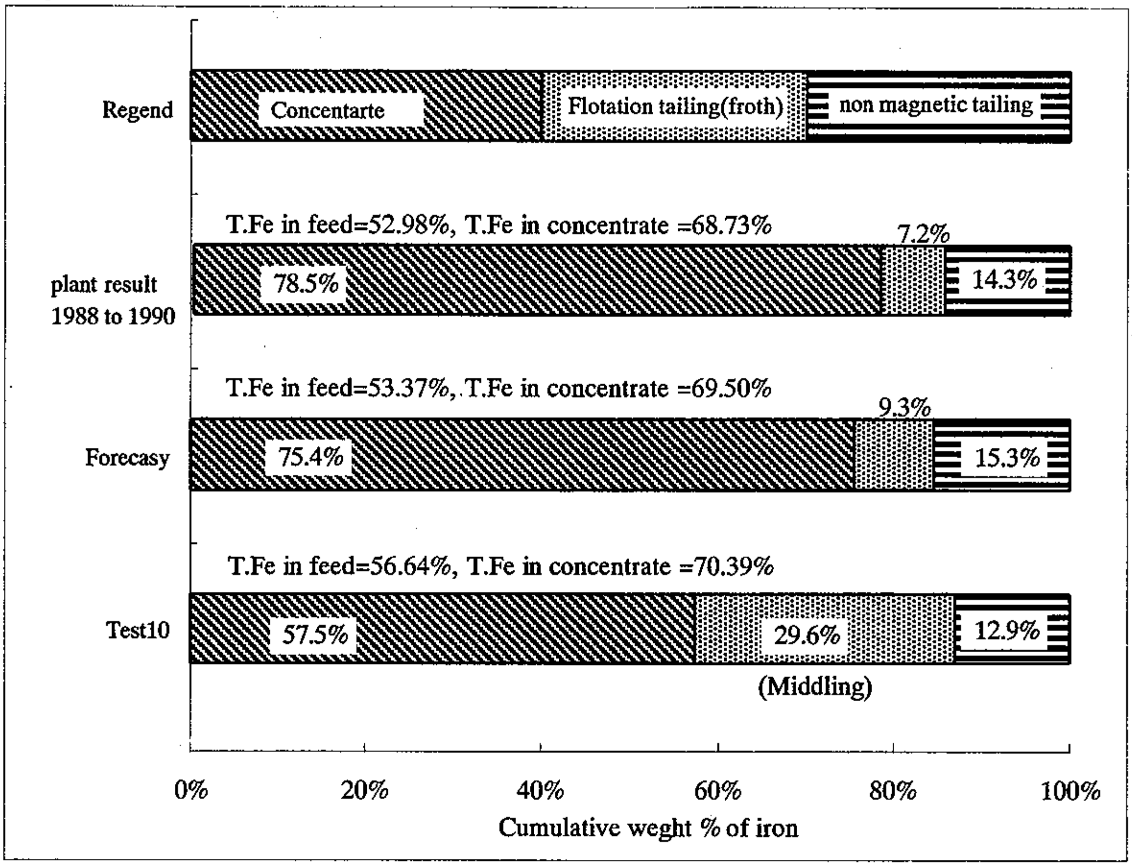
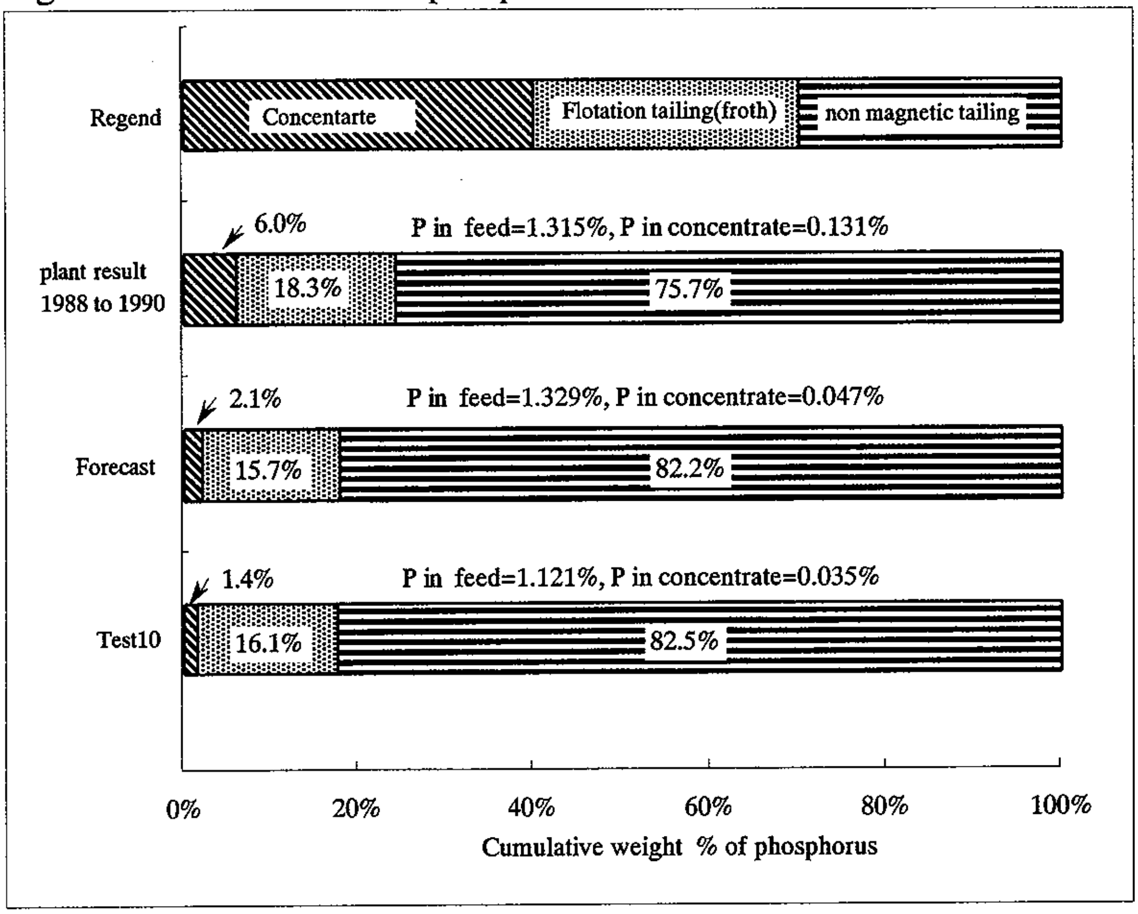


Figure-32 Distribution of phosphorus



6.2.9 Further development

(1) Decrease of phosphorus by fine grinding

To ensure the decrease of phosphorus will be a further study subject. Most effective countermeasure for decrease of phosphorus is fine grinding. Phosphorus will be further decreased if ore will be ground to minus 44 micron 95% which is the design basis when HIPASAM started operation. Filtration of concentrate was the problem in the past, however, this problem is expected to be solved if improvement of filter will be made. There is sufficient capacity of grinding. **Table-99** shows a result of calculation of grinding performance of pebble mill and ball mill to grind minus 44 micron 90% **(Table-92)** to 92.5% and 95%.

Table-99 Grinding result estimation in fine grinding

- 44 micron % in final concentrate		90	92.5	95
Pebble mill				
Pebble	t/h	24	24	24
Primary mag. conc.	t/h	180	180	180
Power consumed	kW	2,660	2,930	3,260
Power consumption	kWh/t	14.76	16.28	18.11
Feed size (F80)	micron	258	258	258
Product size (P80)	micron	49	44	38.5
Work index	kWh/t	18.31	18.31	18.31
Ball mill				
Feed rate	t/h	161	161	161
Power consumed	kW	780	780	780
Power consumption	kWh/t	4.84	4.84	4.84
Feed size (F80)	micron	49	44	38.5
Product size (P80)	micron	33	30	27
Work index	kWh/t	15.46	15.46	15.46

De-sliming by syphonsizer can be expectable for decrease of phouphorus to some extent. Final magnetic separation in two stage processing is so effective for de-sliming that syphonsizer may not be necessary. However, strengthening of de-sliming is useful for decrease of blaine index of concentrate. Syphonsizer would be one possible alternative.

Same effect can be expected for sieve bend. Flotation at two stage processing and fine grinding will reduce phosphorus content, but closed circuit grinding by sieve bend will greatly contribute to decrease of blaine index. It will be also one of further consideration.

(2) Recovery of phosphorus concentrate

This study is out of scope at this contract. Recovery of phosphorus concentrate would be one of significant subject for Sierra Grande if possible. A study for production of phosphate fertilizer from magnetic separateion tailing was carried out at Sierra Grand in 1984. Not positive conclusion was obtained at that time. High cost of recovery, high iron percentage or low recovery rate were discussed.

There are several problems if phosphorus concentrate will be recovered from magnetic separation tailing. Tailing of primary magnetic separation is too coarse for flotation and tailing of secondary magnetic separation is too fine for flotation. Too coarse tailing needs grinding cost and too fine tailing is a obstacle for increase of purity of phosphorus concentrate.

When concentration will be carried out in two stage, it is convenient for recovery of phosphorus concentrate as the first stage grinding will be made to flotation size. First stage of recovery of phosphorus concentrate will be executed as the part of rejection of phosphorus content without additional cost. Primary magnetic separation after rod mill will not be executed and all the materials will be ground for flotatin size and then magnetic separation will be carried out after flotation for phosphorus. Flotation at pellet feed size after secondary stage grinding is difficult to carry out recevery of phosphorus content as the size is too fine and phosphorus content is low.

Flotation size at first stage is already too fine at two stage processing of Sierra Grande (**Fig.-22**) is the problem. Test 6 is a typical two stage processing (**Fig.-21**) and Test 10 is a laboratory test corresponding to two stage processing of Sierra Grande (**Fig.-22**). It seems there is not so much difference in these two tests, howver, there is a possibility of great difference at the actual plant operation. First stage flotation shall be carried out as much as possible with standard flotation size, especially at the recovery of phosphorus content.

6.3 STUDY OF ECONOMICAL IRON ORE PELLETIZING

6.3.1 Points to be considered and problems in the past

(1) Chemistry of raw material (concentrate)

Phosphorus Al_2O_3 and Na_2O+K_2O content in concentrate or pellets of HIPASAM were higher than general quality requirement for BF pellets. The new beneficiation method will reduce phosphorus and Al_2O_3 content.

Fig.-33 shows the relation between iron content and phosphorus content of concentrate produced by HIPASAM. It can be concluded that if phosphorus content in concentrate is decreased to 0.04%, iron contents would be increased higher than 70% in the concentrate. Limitation of iron content for DR grade pellets is higher than 67% which is equivalent of 68.83 % Fe content in concentrate.

Limitation of metallic iron (M.Fe) content for HBI is higher than 85% which is equivalent of 68.52 % Fe content in concentrate. (refer to **Fig.-34**) If iron content in concentrate is higher than 68.83 limitation of iron content in DR grade and M.Fe content in HBI will be satisfied. From the view point of iron content limitation for pellets is more serious than the limitation for HBI.

If phosphorus content in concentrate is decreased to 0.04% phosphorus content in pellets becomes 0.04% which is a maximum level for limitation of DR and BF pellets quality requirement. (refer to **Fig.-35**) If phosphorus content in concentrate is decreased to 0.052 to 0.06% phosphorus content HBI becomes 0.07 to 0.08 % respectively which are maximum levels for HBI. From the view point of phosphorus content limitation for pellets is harder than the limitation for HBI.

Alkaline content in concentrate is higher than limitation for BF grade. Nothing can be concluded about alkaline content without results of new beneficiation method. On the other hand, there is no limitation about alkaline content for DR grade pellets and HBI presently.

Chemistry of concentrate will be improved to a great degree by the new beneficiation method.

Fig.-33 Relation between P and T.Fe in Conc.

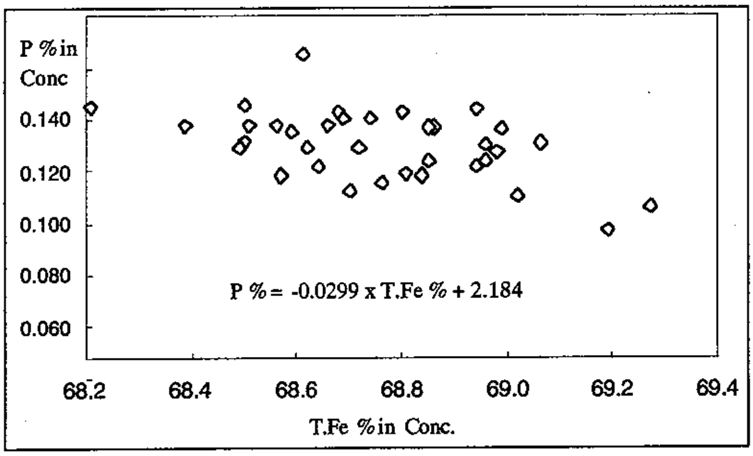
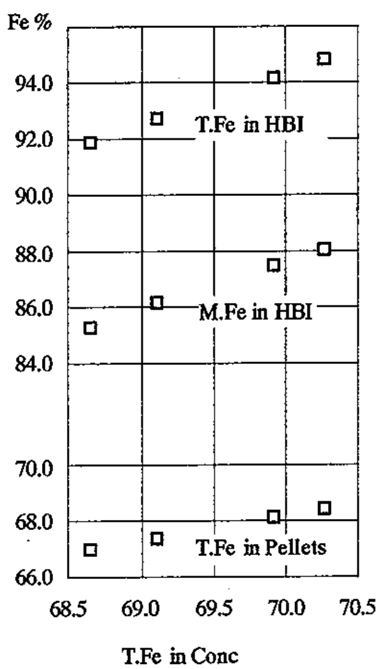


Fig.-34
Relation of iron contents in Pellets, HBI and Conc

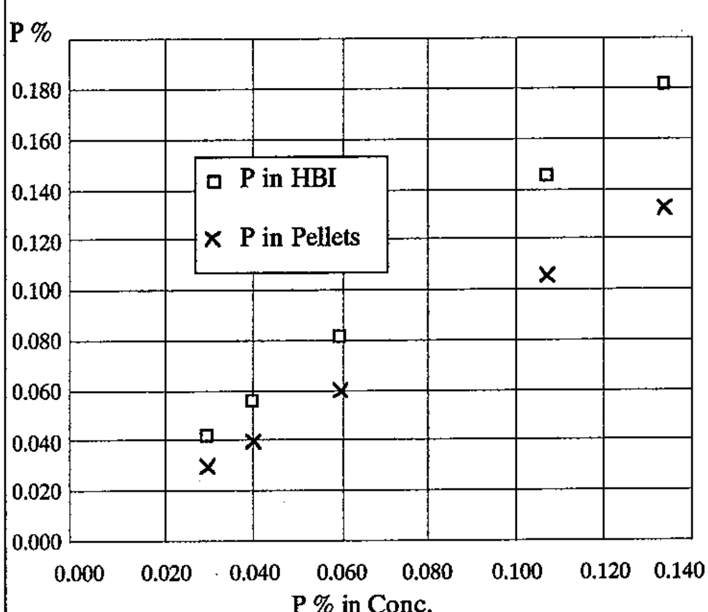


Pellets is produced with 10kg/t bentonite addition
If T. Fe in Pellets should be 67%, T.Fe in Conc should be 68.83%.

If M. Fe in HBI should be 85%, T.Fe in Conc should be 68.52%.

If T. Fe in HBI should be 91.5%, T.Fe in Conc should be 68.52%.

Fig.- 35
Relation of P contents in Pellets, HBI and Conc



Pellets is to be produced with 10kg/t bentonite addition

If P in Pellets should be 0.04, P in Conc. should be 0.04.
If P in HBI should be 0.08, P in Conc. should be 0.06.
If P in HBI should be 0.07, P in Conc. should be 0.052.

(2) Physical properties of concentrate

Concentrate is a little bit coarser. This is due to higher content of the size fraction 75 to 105 micron and almost same if this fraction is same as A. If this size fraction is same, the content of -4.7 micron is high. This would point out that HIPASAM ore has high content of ultra fine material like as slime with high viscosity it indicates low efficiency in the filtering process for dewatering. Generally the coarse grain has low oxidizing speed but this ore has higher speed compared with A ore as shown in 6.3.2 (1). In other words, oxidization will happen at upper part of shaft furnace.

Size will become coarser than past by new beneficiation method.

Table-100 Size distribution of concentrate

Size	106-75	75-53	53-38	38-27	27-13	13-9.4	9.4-4.7	-4.7	Blaine No
A	0.4	10.2	12.8	16.7	29.3	10.9	14.3	5.3	1600
HIPASAM	4.3	12.4	18.8	17.8	25.2	7.1	9.1	5.3	1600

(3) Problem of physical properties of pellets

Though the compressive strength of fired pellets was kept within the limitation, index of swelling tumbler strength and L.T.D showed inferior levels than limitation. This may indicate that there were some pellets containing cracks which made tumbler strength and L.T.D low or some pellets with very weak strength and weak pellets were mixed with strong pellets due to unhomogeneous induration. Usually high compressive strength pellets show high tumbler strength and L.T.D if pellets are indurated homogeneously but low tumbler strength and L.T.D are shown though compressive strength is high when samples for the test of compressive strength are selected from well fired pellets without crack. This kind of wrong selection of samples happens frequently if standard procedure for sample preparation are not established.

Crack is thought to be generated due to the deformation and sudden evaporation which occurs under high heating or sudden exposure of pellets with high moisture against high temperature gas. When high moisture green pellets was stacked in the furnace at high temperature, it is to have big contraction difference between inner part and surface leading to the generation of crack. During drying with hot gas, high moisture green pellets will generate crack due to the deformation by the weight of upper pellets. High speed heating makes water evaporate suddenly and high volume of vapor make crack for out-going from pellet particle and it make crash pellet-particle to small pieces (bursting) when evaporation speed is too high.

Unhomogeneous firing will occur easily if permeability is disturbed with fine generation and deformation of pellets. In shaft furnace operation, it is inevitable to adjust furnace conditions to avoid rapid heating and unhomogeneous firing and mis-control of furnace conditions leads to low quality.

Swelling occurs when alkaline content is high and pellets are indurated insufficiently.

Rapid heating and unhomogeneous firing leads to chunk formation through fine generation. As for chunk formation cause is explained in (5).

For the prevention of above, it is required

- to decrease of moisture.
- to indurate gradually.
- to keep homogeneous permeability to indurate homogeneously.

(4) Low availability

As explained in (2)-2 of **4.2.3**, plant availability was very low.

This plant is designed to produce 2 million-t of pellets per year with 7500 hours per year (312.5 production days per year).

Actual time analysis is shown in the column with the mark "*1" in **Table-101**. Under new management it is expected that there is no stoppage due to the cause of "out of control". Modified actual result is shown in the column with the mark "*2" by removing the stoppage time of "out of control". Then availability becomes 78.9 %. By taking the expected reduction of stoppage time mentioned in **b)** of (")-2 in **4.2.3** in to consideration, estimated improvement figure is shown in the column with the mark "*3". Then available operating hours per year becomes 7509, which is almost the same as design.

For improvement basic adjustment and small modification of much equipment is required.

Table-101 Time analysis of actual result and estimation

Items for time	h/year*1	%*1	h/year*2	%*2	h/year*3	%*3
Available hours for production	5244.5	59.8	6913.9	78.9	7509.8	85.7
Stoppage due to Initial stage trouble	399.1	4.6	526.3	6.0	128.6	1.5
Stoppage due to Control system trouble	41.0	0.5	54.1	0.6	13.6	0.2
Stoppage due to peculiar cause for this plant	960.2	11.0	1265.8	14.5	100.0	1.1
Stoppage due to the cause of "out of control"	2115.1	24.1				
Minor scheduled shut down					288.0	3.3
Major scheduled shut down					480.0	5.5
Operating time loss for cooling down and heating before and after scheduled shut down					240.0	2.7
Total	8760.0	100.0	8760.0	100.0	8760.0	100.0

*1: Before correction

*2 After correction by removing out of control stoppage

*3: After correction by adding scheduled major and minor shut down

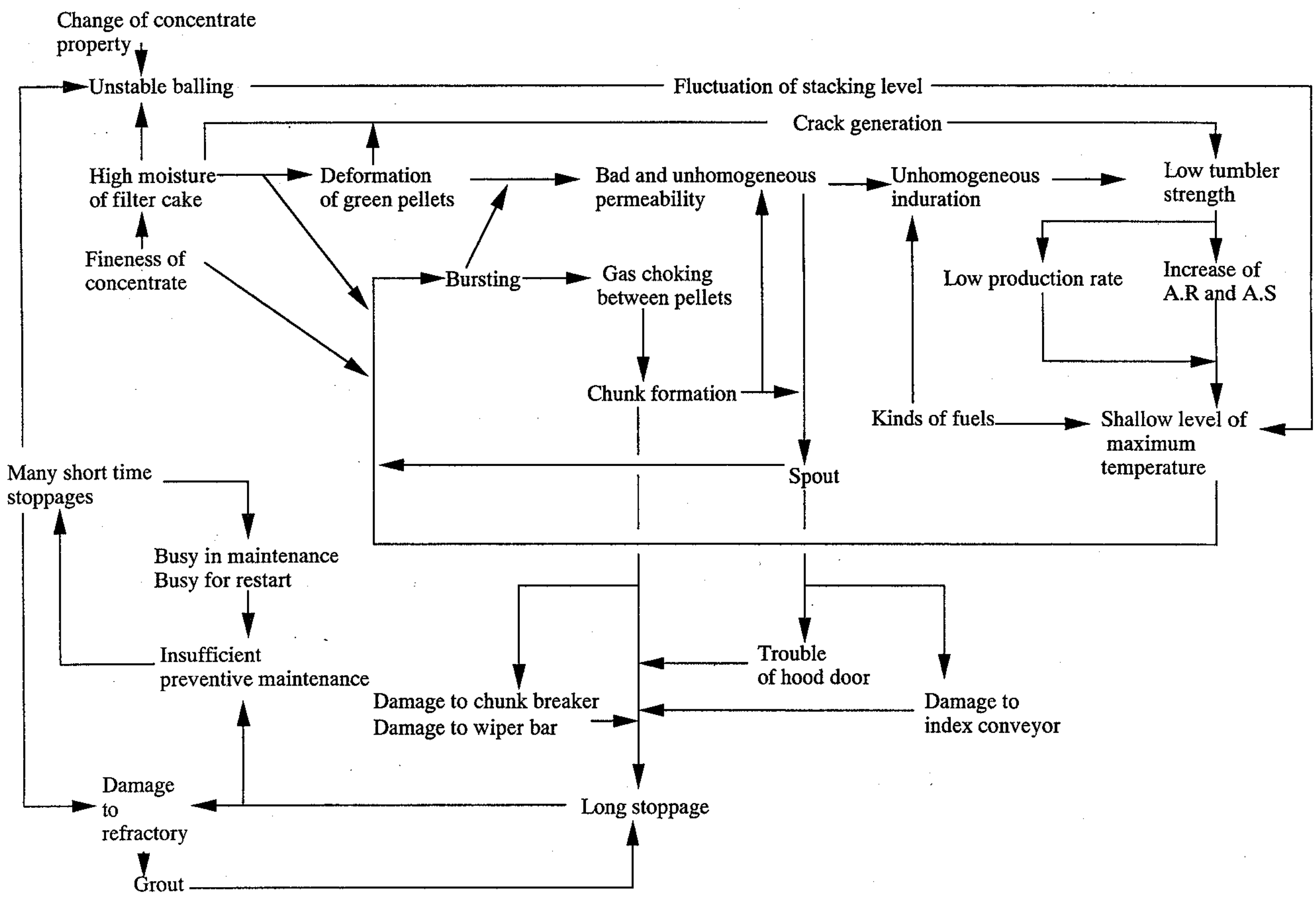
(5) Peculiar problems in this plant

1) General description of the problems in the plant

In the initial stage of production, deterioration of green pellets was reported to occur and it was solved by changing additive blend ratio. But chunk formation, fine generation might be main reason for which, was not solved. Wiper bar trouble, spout and damage of fire brick happened frequently due to chunk formation. As shown in **Fig.-36** there were many cause and phenomenon for many troubles and they interlaced themselves with each other.

Some of them, which gave serious affection to quality, availability and facilities, are picked up as followings.

Figure-36 Flow of cause and results



2) Bursting

Bursting which happens when pellets indurated with rapid heating and sudden evaporation of water occurs destroy pellets particle to small pieces. Basic cause of bursting is summarized as followings;

- pellets are produced with fine material.
- green pellets contain high moisture.
- pellets are heated rapidly.

As shown in **Table-59-2,59-7** and **Table-100,**

(A) material was fine (ultra-fine contained or much slime contained)

(B) moisture was high

(C) heating was very rapid estimated from high temperature of exhausted gas and shallow level of firing zone

This plant was operated with the condition which made bursting happen easily.

Addition to above mentioned,

(D) fluctuation of green pellets-stock-level

There were big fluctuations of green pellets-stock-level due to the fluctuation of green pellets production and green pellets were exposed to higher temperatures than expected and bursting might occur more ridiculously than expected.

(A) is not possible to control in pelletizing plant and (B),(C)and (D) are possible to control.

With regard to (A) some improvement can be expected because of the new beneficiation method to be introduced.

3) Chunk formation

Main causes of chunk formation are summarized as followings.

- Chemical composition of pellets is situated in the zone of low melting point.
- Under special conditions, composition shifts to low melting zone.

From the view point of chunk formation, operating conditions in HIPASAM are summarized as followings.

a) As shown in **Fig.-37-1** average chemical composition of pellet exists near A point with high melting temperature. It was estimated that chunk formation did not occur in No.3 furnace from 3 to 21 October 1989 from the data of stable and good tumbler results, stable exhausted gas temperature at top hood and stable temperature difference between North and South of the entrance to cooler.

This means that chunk is not formed under normal indurating condition.

b) Fines generated by bursting promote chunk formation.Fines existing between pellet particles lowers permeability and decrease oxygen supply to pellet particles. Under this condition, some part in pellet particle with higher FeO and SiO_2 has low melting composition. Also, fines can make the bond between pellets particles strong. **(Fig.-37-2)**

Fig.-37 Tertiary phase diagram

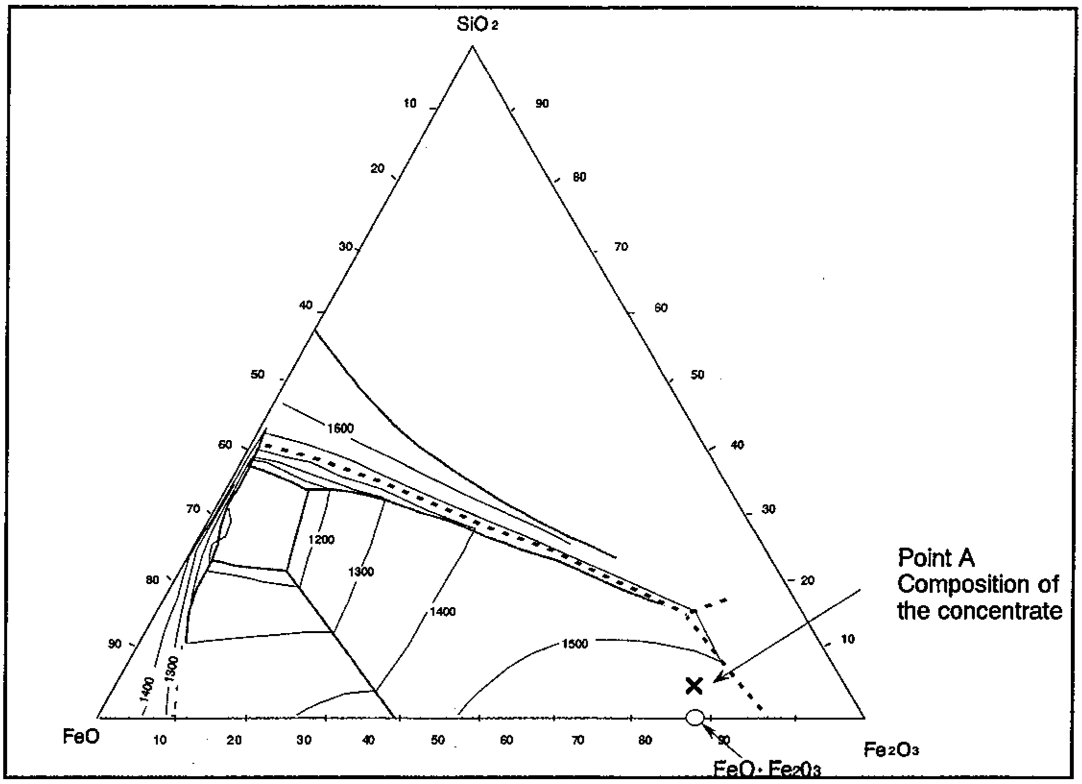


Figure-37-1

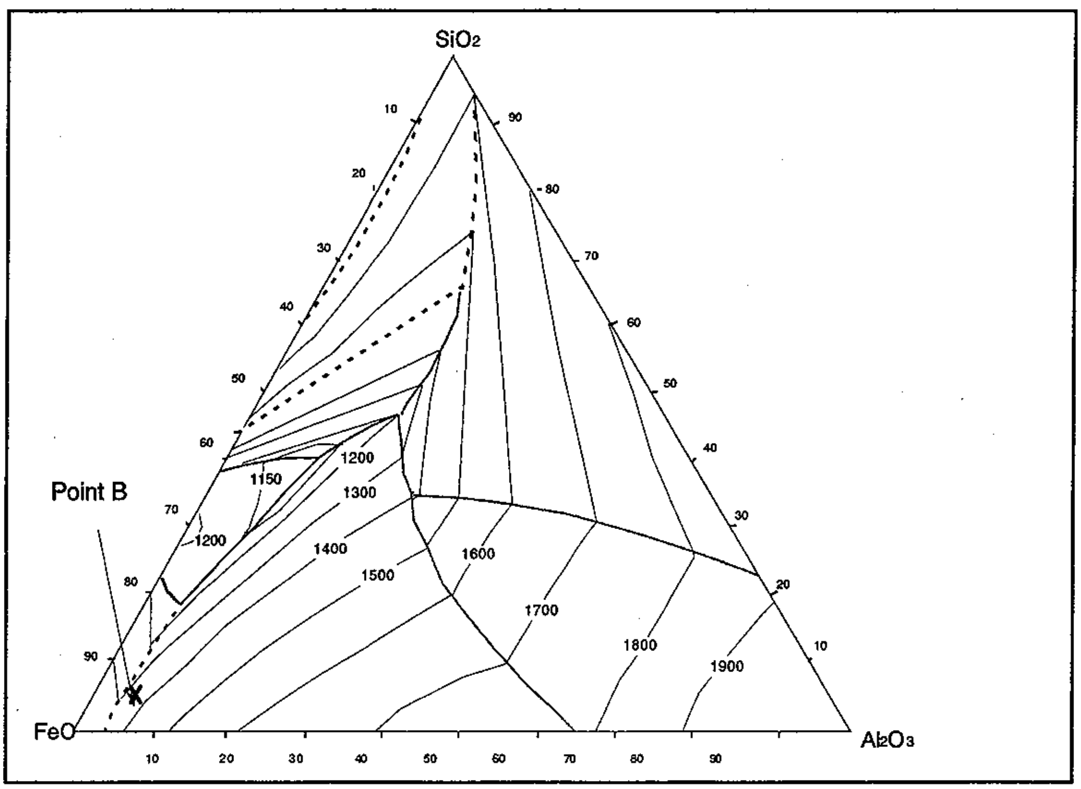


Figure-37-2

There were many phenomenon which indicate that chunk was formed or existence of chunk.

- As shown in **Table-59-6**, Fe_3O_4 in fired pellets is 5.1% and this means FeO in concentrate was not oxidized sufficiently. On the other hand, there was explanation that unloading port analysis showed 0.5% Fe(equivalent of FeO=1.6%). This difference could not be considered to be analysis error because it is too big. This may be due to the fluctuation of FeO content and there was cases that FeO was high actually.

- As shown in **Table-59-8**, oxygen content in waste gas was a little bit low compared with plant A.

- As mentioned in **4.4.3**, alkaline content is high and alkaline element makes melting point low

- Descending speed of burden was low partially in furnace. Surface contact between pellets makes hematite bond by magnetite oxidization to form chunk when pellets are kept for long time without movement. As shown in **Table-56**, big difference between north and south as the temperature at the entrance to cooler indicates that there was some part where descending flow of burden stopped.

- Under insufficient oxygen, FeO and silica rich part in pellet particle had possibility to compose chemical composition with low melting temperature as shown in **Fig.-37**.

There were many cause and phenomenon and possible method to prevent chunk formation is "to prevent bursting" .

4) Grout

The reason for the necessity for grout is mentioned in b)-3 of (2)-2 in 4.2.3. It was explained through being told that upper brick of hot gas duct from combustion chamber to furnace was damaged frequently and a gap is made between steel shell and brick. Hot gas penetrates through the gap and reached the gap between side shell and brick of furnace and made a hot spot.

This indicates that upper-hot-gas-duct-shell was deformed due to expanded shell of the duct, furnace and combustion chamber as shown in **Fig.-38**. Frequent repetition of expansion and contraction in the upper-hot-gas-duct-shell damaged the bricks and to make a gap in bricks and between shell and bricks.

To prevent damage to fire brick,

- first of all it is required to reduce the stoppage frequency and time.
- it is further required to improve absorb system of strain produced temperature change of furnace and combustion chamber body raised by cooling and heating for every stoppage.

Fig.-38 Upper hot gas duct shell

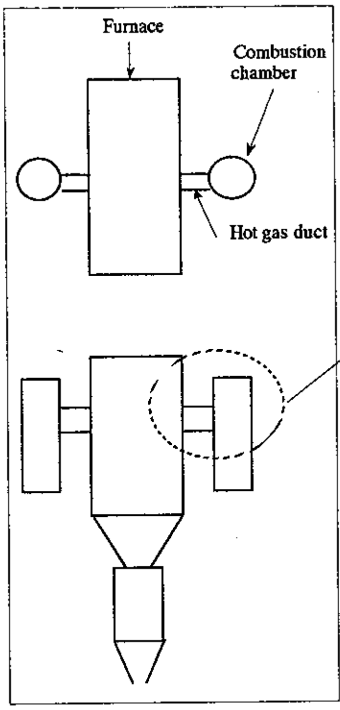


Figure -38-1
Duct, combustion chamber and furnace

Magnification

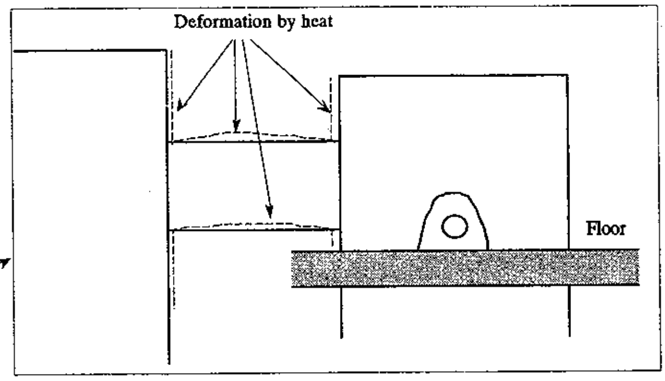


Figure-38-2 Connection by duct

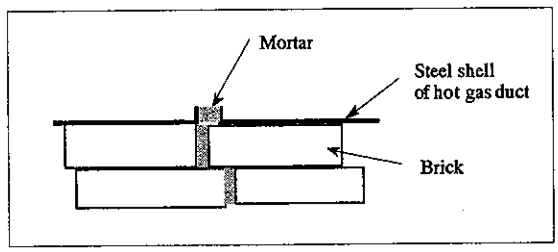


Figure -38-3 shell and brick structure

6.3.2 Pot grate tests

(1) Pre analysis for the test

1) Chemical analysis

Table-102 shows the results of analysis of the samples taken at the plant.

Pellets, chunk bond and pellets in chunk have almost same results and this means that there was not condensation of alkaline elements which makes melting point low and promote chunk formation.

2) Observation of sample

As shown in **Photo-1**, almost pellet particles have cracks and small (hair) cracks which are generated during drying.

As shown in **Photo-2**, chunk is formed with chips and fines in the gap of pellet particle. This means that main reason of chunk formation is the generation of chips and fines.

Table-102 Analysis of the samples

	T.Fe	Fe++	FeO	SiO_2	Al_2O_3	CaO	P	S	V	Na20	K2O	CO_2	Igloss	C.W
HIPASAM conc*1	69.14		30.12	1.47	1.46	0.30	0.134	0.100	0.080	0.10	0.03	0.04	-2.54	0.47
HIPASAM pellets*2	65.49		0.14						0.106	0.06	0.05			
Chunk bond*3	65.35		0.14	2.77	1.63	0.72				0.06	0.05			
Pellets in chunk*4	65.41		0.11							0.06	0.05			

*1: Concentration samples for pot test at Kobe
*2:Pellets sample taken from stock at HIPARSA plant
*3:Filling up material of the gap between pellets particles in chunk, consisting of chips and fines
*4:Pellets

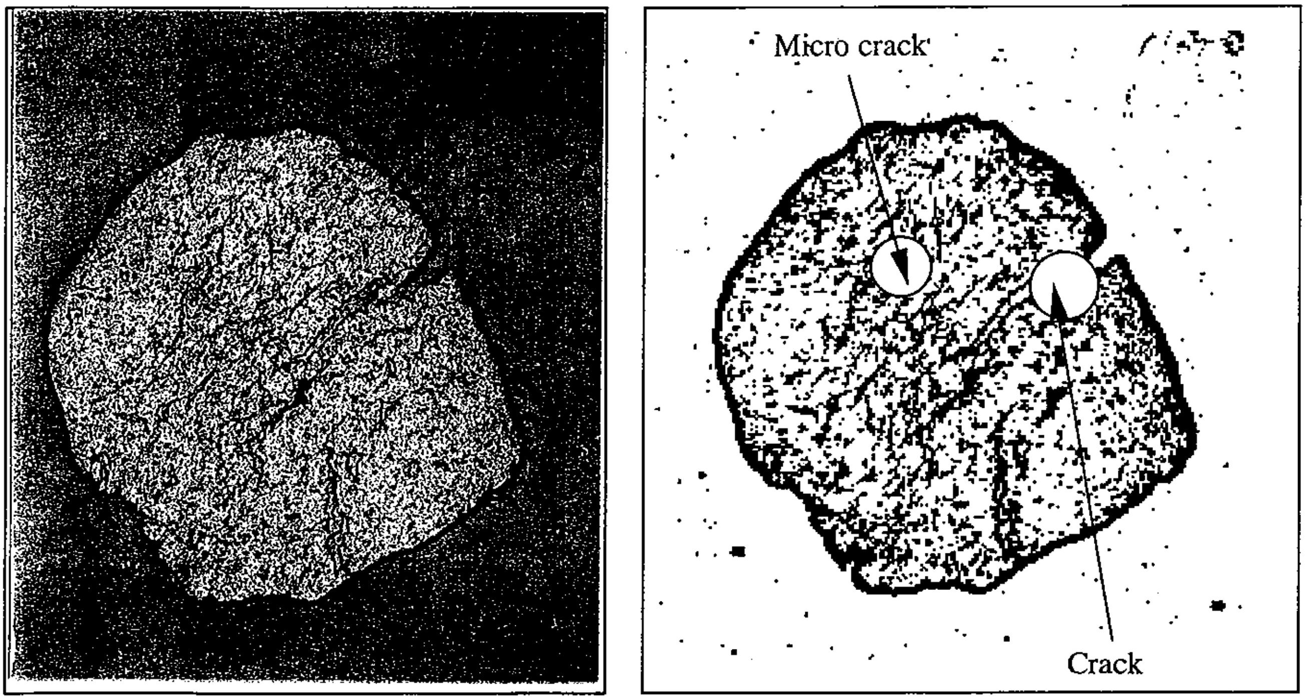


Photo-1 Section of pellet particle

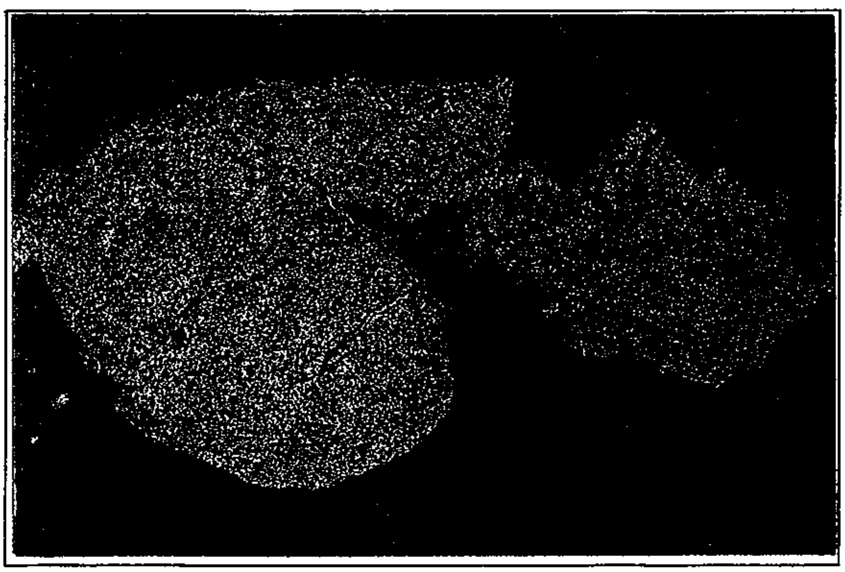


Photo-2 Part of chunk (Pellet particle and filling up material)

Filling up material between pellet particles
Chips and fines are bonded and they are adhering to pellets.
This bonding part sample analyzed as Chunk bond in **Table -102.**

3) Oxidization speed

Test condition

Balling material: HIPASAM conc 99%+Bentonite1%

Dried green ball (11 to 13mm)

Gas composition O_2(10.5%)+N_2(89.5%)

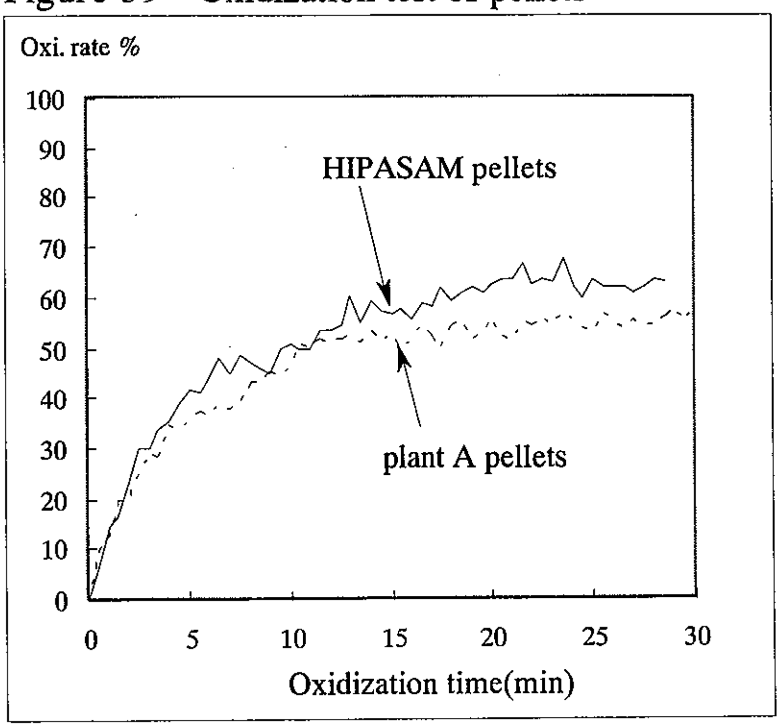
Temperature:600℃

Test result

As shown **Fig.-39**, dried green pellets made from HIPASAM concentration has higher oxidization speed compared with green pellets made from plant A concentration.

In other words, HIPASAM pellets generated more oxidization heat than plant A pellets at upper part of furnace. This leads to the conclusion that exhausted gas temperature was higher and firing level in furnace (maximum temperature level) was shallower in HIPASAM compared with in plant A.

Figure-39 Oxidization test of pellets

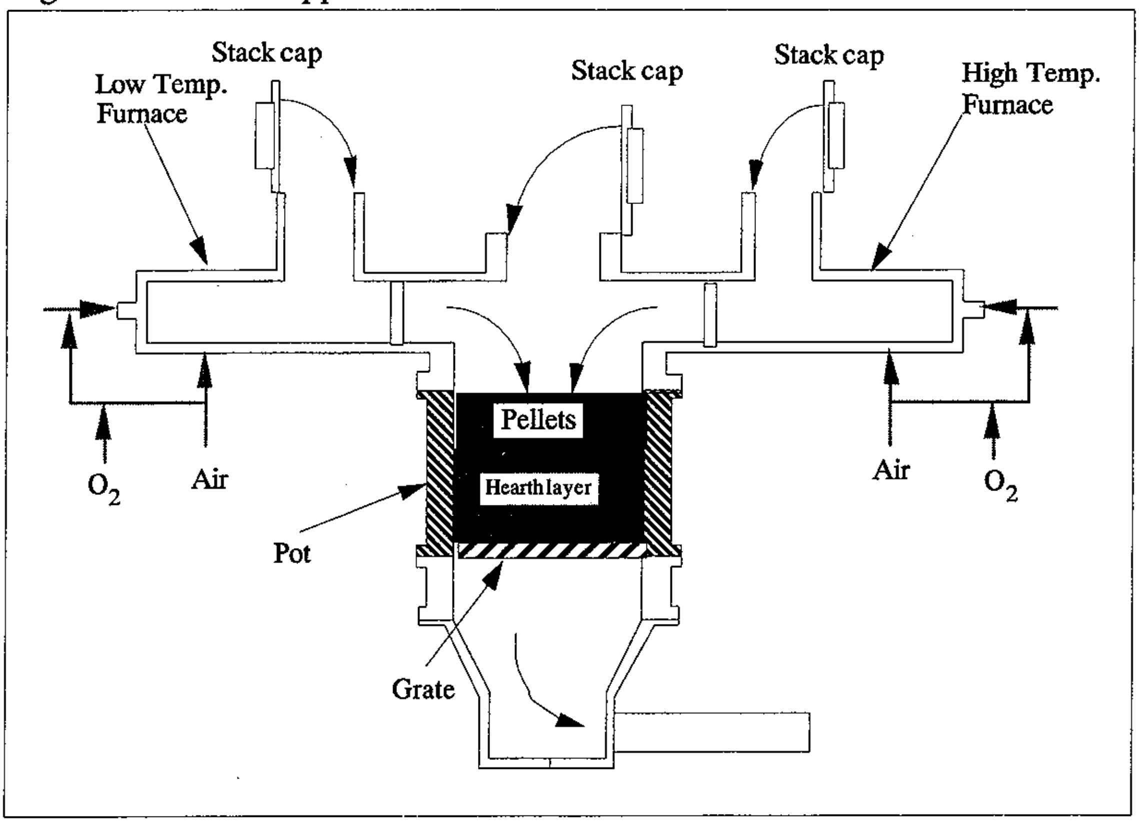


(2) Concept of the pot test

1) Purpose of pot test

By simulating furnace conditions, it is possible to know the quality of pellets and phenomenon of furnace. Conceptional figure of pot test apparatus is shown in **Fig.-40**.

Fig.-40 Pot test apparatus



2) Procedure of the test

After charging green pellets on to Hearth layer (which is charged in to protect grate from high temperature gas and is generally aluminum ball), hot gas is blown into pot from low temperature furnace by opening valve. After a while, the valve of low temperature furnace is closed and the valve of high temperature furnace and high temperature gas is blown into pot. Usually three furnaces, low temperature, middle temperature and high temperature furnace are used for pot test.

(3) Pot test

1) Bursting detection

Five pot tests were conducted at the laboratory of KOBE STEEL,LTD. for finding out the phenomenon where bursting happens and the border line conditions.

The result showed that the temperature 1.5 minute after heating start should not exceed 400 deg C to prevent bursting.

* KSL-0

Pot condition

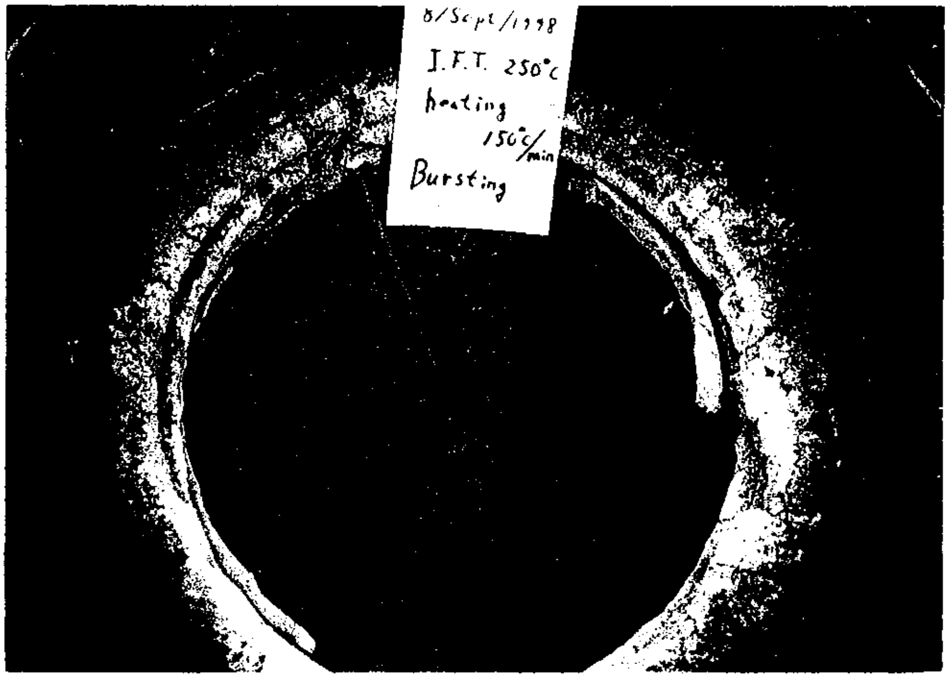
- Thickness of green pellets layer =10.5 cm
  Pellets is stacked layer by layer in shaft furnace and thickness of one layer is about 10cm.
- Heating pattern (same as KSL-1 shown in **Fig.-41**)
  This pattern simulates the heating pattern which was reported at site investigation.
- Green pellets moisture 8.6%

Result

Serious bursting was found at upper part of pellets layer as shown in **Photo-3.** Bursting zone thickness was estimated 2 cm from surface.

Photo-3

Except sphere ones, all material is chips generated by bursting



*KSL-1 to 4

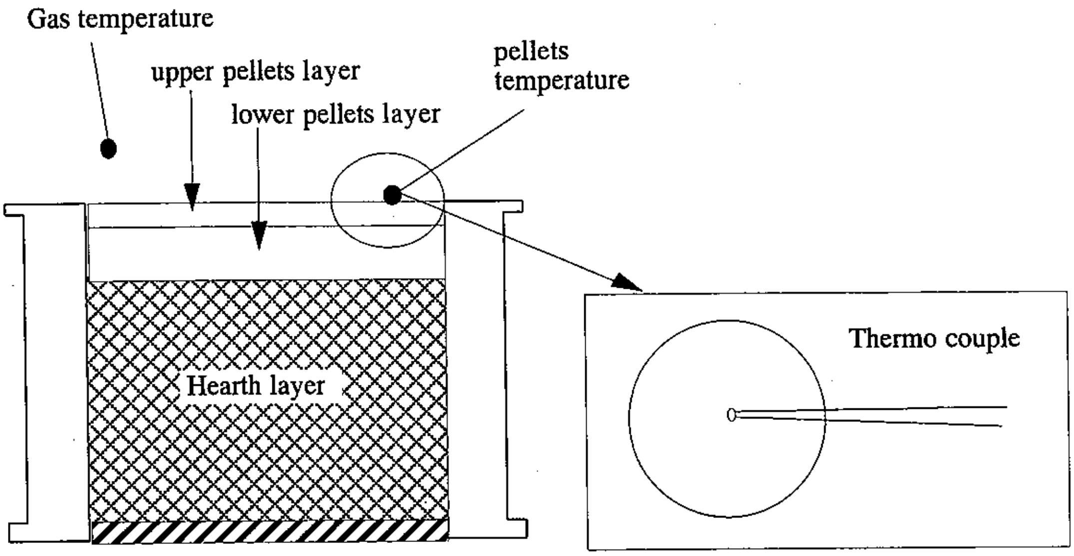
<u>Pot condition</u>

- Pellets is charged as shown in **Fig.-42.**

Wire net with aperture 5mm is inserted between upper pellets layer and lower pellets layer to recover upper layer pellets and chips when bursting happens.

One pellet is placed on the top of upper pellets layer. Thermo couple is inserted into this pellet to detect the bursting temperature and heating time. If busting happens and pellet is broken to pieces, thermocouple is exposed directly to hot gas and temperature measured by thisthermo couples will escalate rapidly.

Fig.-42 Pellet charging



Thickness of each layers

upper pellets layer	2.0 cm
lower pellets layer	8.5 cm
hearth layer	69.5 cm

- Heating pattern

  The patterns are shown in **Fig.-41-1**. Gas temperature is the one which is measured just above the pellets layer.

  KSL-1: which simulates the pattern of HIPASAM operation

  KSL-2: which is made with the assumption the level of firing is deepened from 35 cm to 50 cm.

  KSL-3: the level of firing is deepened to 46 cm.

  KSL-4: the level of firing is deepened to 49 cm.

- Heating speed is lowered as following

  KSL-2→KSL-3→KSL-4→ KSL-1

<u>Results</u>

Bursting was found in the case of KSL-1 and was not found in other cases.

As shown in KSL-1 in **Fig.-41-3**, sudden increase of pellet temperature was found and went up to the gas temperature. This indicates that bursting happened at this time and temperature.

Heating pattern of other cases do not show sudden increase of temperature as shown in **Fig.-41-2**. After heating, upper layer pellets and chips were recovered and they were separated by sieving with 10mm and particles over 10mm were separated to two categories by visual checking as shown in **Table-103**.

Fig.-43 shows the 1.5 minute-temperature vs. spherical pellets content after heating. It can be concluded that bursting will not happen when 1.5 minute-temperature is kept under 400℃.

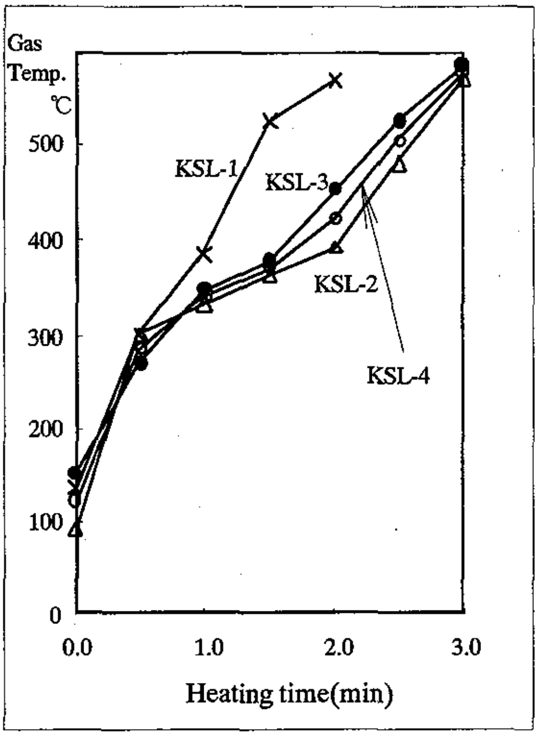


Fig.-41-1

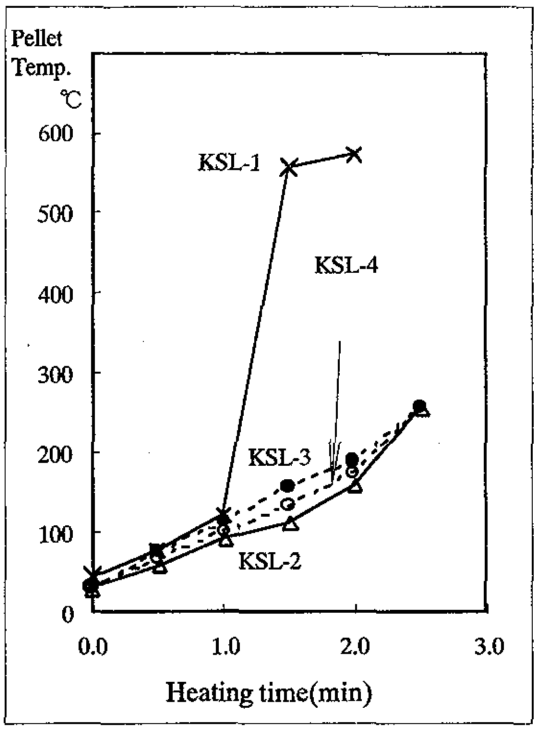


Fig.-41-2

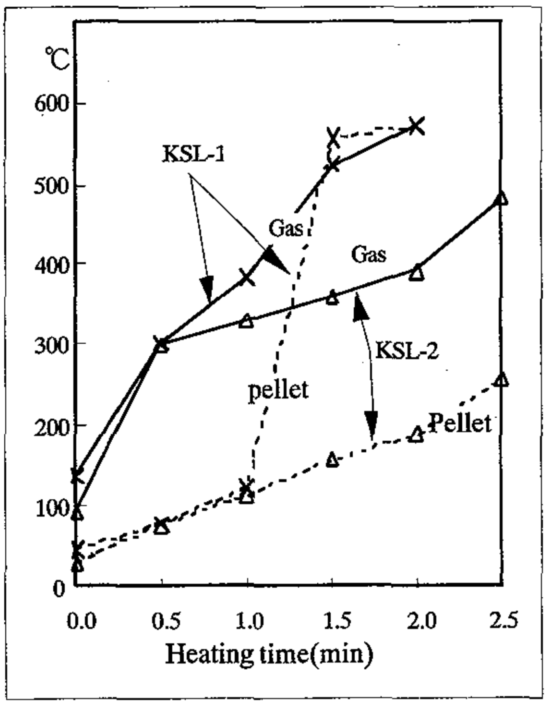


Fig.-41-3

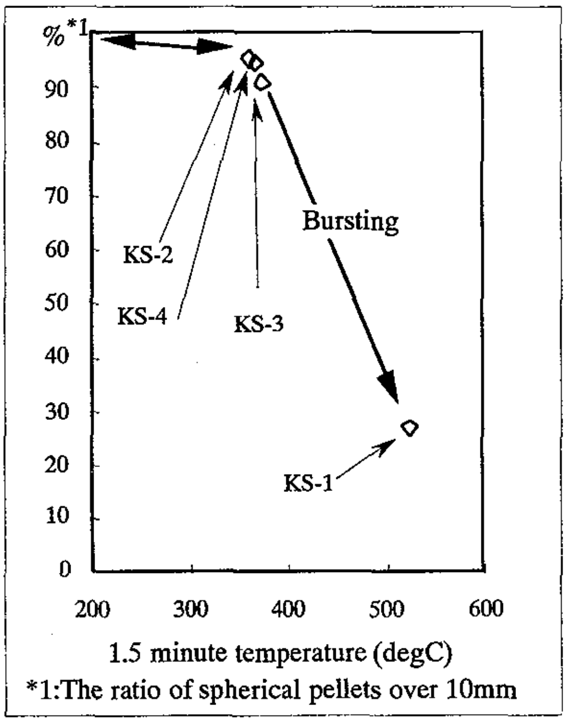


Fig.-43

Table-103 Bursting detection

		KSL-1	KSL-2	KSL-3	KSL-4
Green ball charge	(dry-kg)	3.88	3.52	3.79	4.39
Non recovery*1	(dry-kg)	1.33	0.02	0.09	0.04
Spherical pellets*2	(dry-kg)	1.05	3.36	3.44	4.15
Pellets with defect*3	(dry-kg)	0.90	0.09	0.15	0.15
Chips*4	(dry-kg)	0.60	0.05	0.11	0.05
Non recovery*1	%	34.28	0.57	2.37	0.91
Spherical pellets*2	%	27.04	95.56	90.74	94.52
Pellets with defect*3	%	23.22	2.45	3.98	3.43
Chips*4	%	15.46	1.42	2.90	1.14
1.5 minutes temperature	℃	525	360	375	368

*1:Non recovery=Charged green pellets-recovered quantity and this weight loss is due to the emission to lower part through 5mm apperture wire net

*2:Spherical pellets=pellets over 10mm and without crack and broken part

*3:Pellets with defect:pellets over 10mm but with crack or broken part

*4:Chips=under 10mm, decrepitaed pieces and fines

2) Burn through pot test

Eleven pot tests were conducted at the laboratories of KOBE STEEL,LTD. and Maumee Research & Engineering, Incorporated.

Table-104 shows test results. Test cases with the word PGF were conducted at the laboratory of Maumee Research and Test cases with the word of KSL were conducted at the laboratory of KOBE STEEL,LTD. Basic procedure of tests are almost same. In test series of PGF, retention time at firing temperature is kept for 15 minutes, same in all cases. In test series of KSL, higher temperature was used for short retention time to observe phenomenon in the case of excess high temperature firing indicated by HIPASAM operation.

Table-104 Burn through result

		PGF-026	PGF-027	PGF-028	PGF-029	PGF-030	PGF-031	PGF-032	PGF-033	PGF-034	KSL-24	KSL-25		Fore cast	Spec
Bentonite blend	%	1.6	1.6	1.6	1.6	1.6	1.6	1.6	0.8	0.8	1.0	1.0		1.0	-
Limestone blend	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0		0.0	-
Moisture of green ball	%	9.2	10.3	10.3	9.1	10.3	10.0	9.5	9.3	9.8	8.6	9.6		9.6	-
Drop number	-	13.8	16.7	16.7	over 20	over 20	over 20	over 20	7.8	9.9	3.7	6.0		6.0	-
Dry compression	kg/P	11.3	10.8	10.8	7.5	14.7	14.7	14.7	6.1	5.2	1.4	1.4		1.4	-
Wet compression	kg/P														
Firing temperature	℃	1177	1232	1288	1288	1288	1288	1288	1288	1288	1365	1439		1288	-
Retention time at F.T	min	15	15	15	15	15	15	15	15	15	6	3		15	-
Retention time over 1280℃	min			15	15	15	15	15	15	15	7	7		15	-
heating rate(0-5min)	℃/min	235	243	259	215	216	240	259	217	215	153	144		144	-
Temp. after 1.5 min heating	℃	329	328	317	314	328	316	315	318	321	375	323		350	-
Chemistry of fired pellet															
T.Fe	%											67.11		67.11	66>
FeO	%											6.15		6.15	-
P	%											0.05		0.05	0.03>
SiO_2	%											2.12		2.12	3.0>
Al_2O_3	%											1.62		1.62	1.8>
CaO	%											0.32		0.32	-
MgO	%											0.10		0.10	-
K_2O	%											0.037		0.037	-
Na_2O	%											0.063		0.063	-
S	%											0.00		0.001	>0.025
V_2O_5	%											0.19		0.19	-
Porosity	%											27.70		26.00	-
Cold comp. strength	kg/P	113	137	174	134	157	124	128	266	305	149	193		250	150>
Tumbler															
+1/4	%	96.9	97.1	97.6	95.8	97.8	92.9	82.8	96.9	96.3	87.5	93.0		96.4	95>
1-6.3mm	%										5.9	2.4		1.2	-
1-0.5mm	%										0.1	0.1		0.1	-
-0.5mm	%	2.7	2.5	1.9	1.6	1.5	1.5	2.1	2.2	2.3	6.5	4.5		2.3	4.0>
Linder test	%														
+1/4	%									98.6		99.1		99.1	>97
1/4 to 6M(6.35 to 2.36 mm)	%									0.2		0		0	-
6M to 32M(2.36 to 0.495 mm)	%									0.5		0.1		0.1	-
-32M	%									0.7		0.7		0.7	-
Reduction ratio	%									92.2*1			93.3*1	93	-
Metallization	%											92.2*2	90.2*1	92	>92
Static bed reduction															
Reduction ratio	%									96.4*1			95.7*1	93	-
Comp. strength after reduction	kg/P											53.6		>50	>50
Metallization	%									94.6*1		98.1*2	93.7*1	92	>92
Reduction test under load															
Cluster strength*3	%												39.6*1	30	<30
Reduction ratio	%												98.4*1	95	
Metallization	%											97.5*2	97.7*1	93	>92

*1: Calculated from weight loss *2: Calculated from analytical result *3: Cumulative % of residual as cluster during 20 times shutter

Results

A) PGF-026 to 034, KSL-24 and KSL-25 were conducted within the non-bursting temperature zone (Temperature after 1.5 minute heating is lower than 400℃.)
From visual checking, bursting did not happen though moisture content of green ball was changed 9.6% to 10.3%.

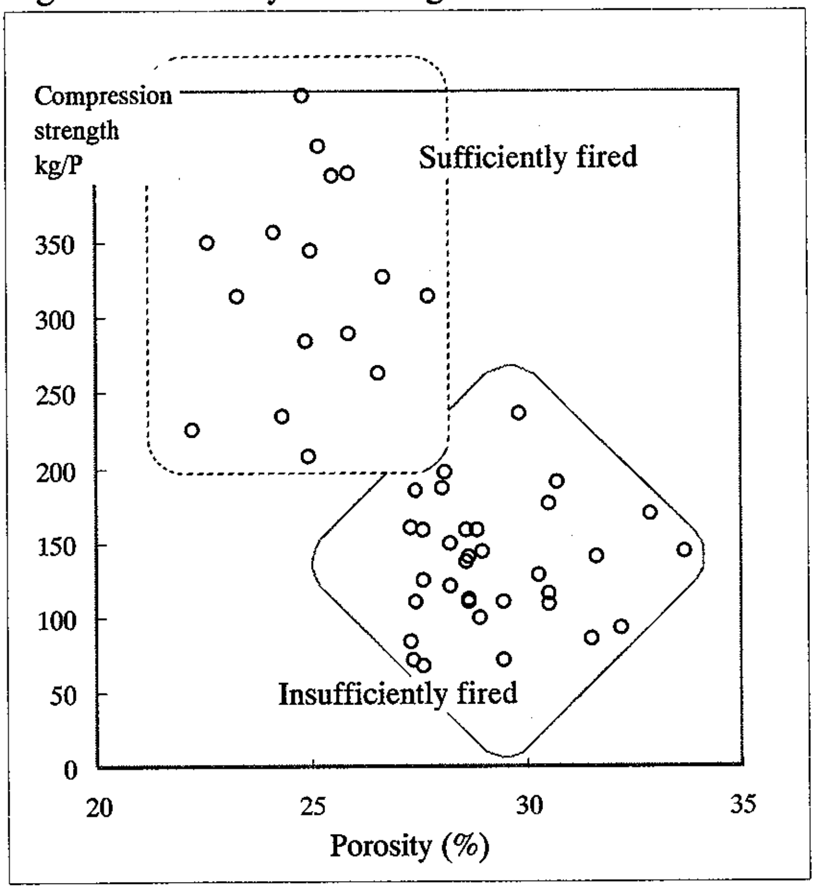
B) High bentonite blend and high moisture made green ball very elastic as shown in high drop number.

C) It is possible to produce fired pellets with high compression strength. (PGF-033, PGF-034, KSL-25)
It is indicated that excess bentonite suppress the generation of hematite bond and generates brittle phase of SiO_2-FeO-Al_2O_3. (PGF-026 to PGF-031)

D) For producing pellets with strength required for DR grade, it is required to use firing temperature at 1288℃ for 15 minutes retention time. (PGF-33 and PGF-034)

E) By utilizing higher temperature than 1288℃ and shorter retention time at firing temperature, it is possible to produce pellets with strength just higher than limitation of quality specification. (KSL-25) Firing with Short retention time generated the big variance of strength and lowered average strength. (refer to **Fig.-44**) Retention time at firing temperature is longer in commercial plant. Even if high temperature is used for firing, it is possible to keep enough retention time. High temperature firing did not show abnormal phenomenon like as cluster generation. This means that chunk formation did not occur due to high temperature firing in HIPASAM plant.

Fig.-44 Porosity vs Strength



F) By adding limestone, strength was improved.(PGF-034) This has been proven through long period pelletizing history and it was true in this case. It is thought that calcium ferrite was generated and it gave strong bond to ore particles leading to high pellet strength.

G) Linder test showed satisfying result. This test for DR grade pellets is almost equivalent to LTD for BF grade test. From the LTD result of HIPASAM pellets, property measured by Linder test is feared to be inferior. From the result of PGF-034, it can be concluded that good quality about this aspect can be produced with proper blend of bentonite and moisture content.

3) Conclusion

- High blend of bentonite does not give good effect to compression strength. High moisture does not give good effect.
- It is possible to produce DR grade pellets with bentonite around 1.0%.
- Moisture should be less than 10%.

6.3.3 Simulation on fluid and thermal transition in the shaft furnace

In order to have basic information on the heat pattern of pellets in the shaft furnace, simulation was conducted at Mechanical Engineering Research Laboratories of KOBE STEEL,LTD. A conventional single dimension simulation model was operated taking into consideration with,

① heat transferance between gas and pellets
② oxidation of magnetite
③ condensation and evaporation of water
as variable factors
Ⅰ-heat transference efficiency between pellets and gas
Ⅱ-feed rate of pellets and gas

(1) Concept of simulation model

1) Outline of calculation model

For simplifying shaft furnace, this model used the vertical column which has unit area and temperature, where chemical composition and so on are homogeneous within one horizontal plane. It is premised that green pellet is supplied from the top of furnace, hot gas are supplied into column at the middle part of column and cooling gas is supplied from the bottom as shown in **Fig.-45**. In this furnace (column), chemical reaction and heat flow is to be calculated.

2) Chemical reaction and phase change

This model will take following chemical reaction and phase change into consideration.

- Water evaporation
- Water condensation
- Oxidization of magnetite

Based on the above, conceptional figure will be expressed as shown in **Fig.-46** and **Fig.-47**.

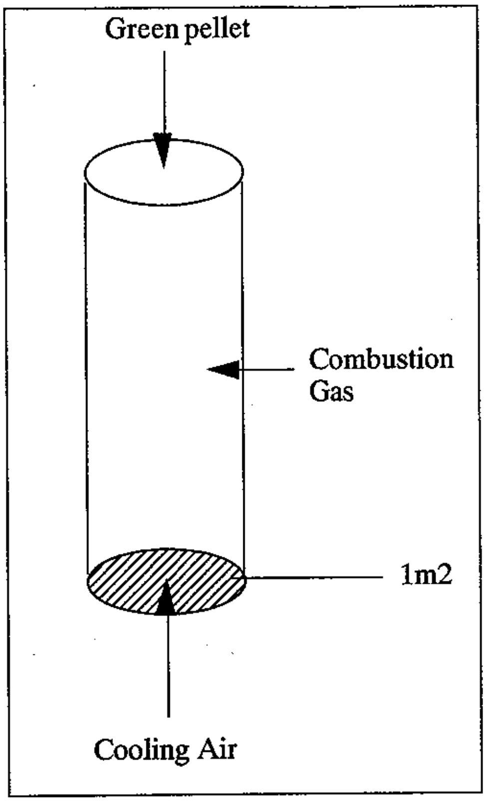


Figure-45 Simlified shaft furnace

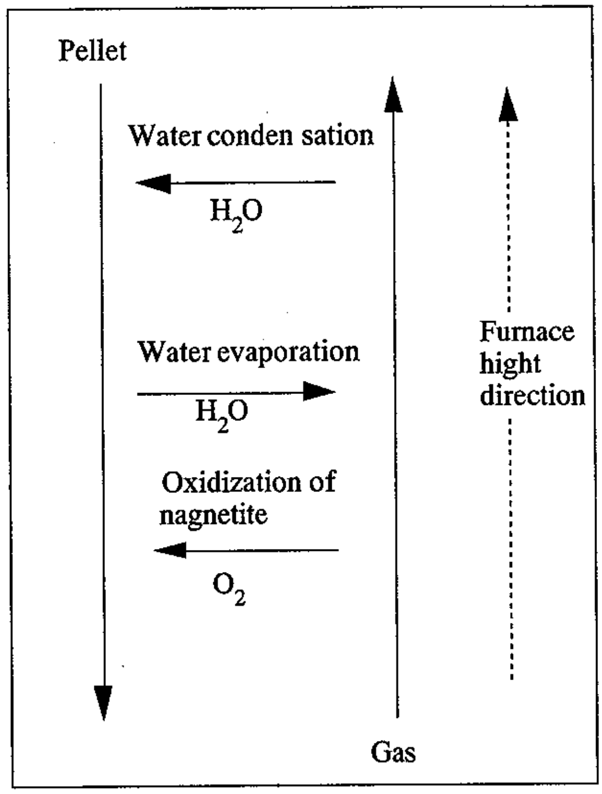


Figure-46 Material movement between Gas and solid

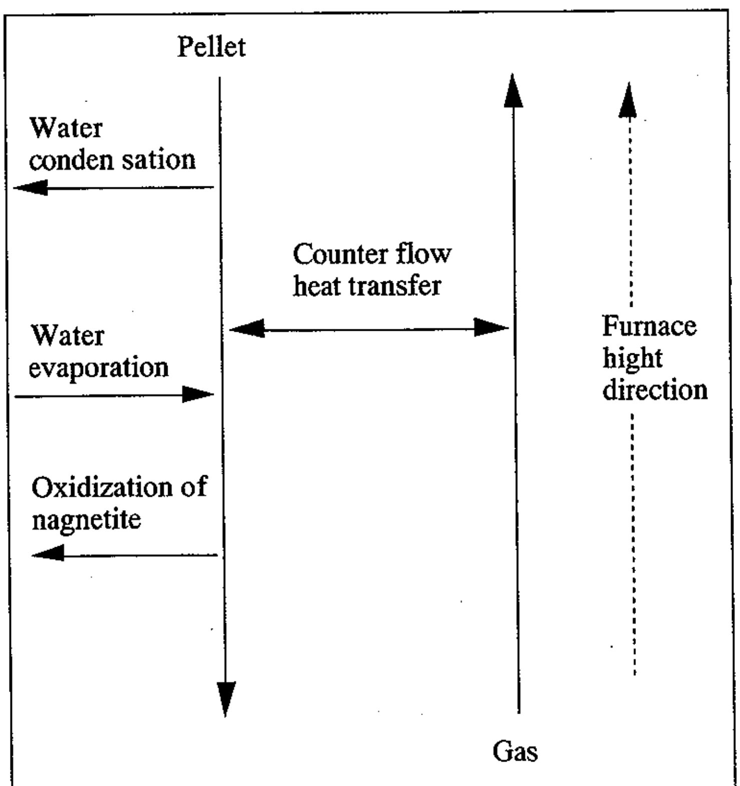


Figure-47 Concept of heat transfer

(2) Simulation result

1) Heat pattern with good heat exchange efficiency through the depth

If pellets can contact with gas without any disturbance, then heat can be exchanged efficiently and heating speed is not so steep as shown in **Fig.-48-1**. Namely, if heat transference efficiency were constant through the column, heating up speed of green pellet would be not so rapid but moderate. Shoulder of heating curve will exist just above the level of tuyer. Solid lines in the figure mean base conditions and dotted lines mean the conditions with 20% less gas volume. By decreasing gas volume, temperature of gas and pellet(solid) is lowered with great degree at upper part of column. Pellets in this condition is imagined as shown in **Fig.-48-2.** Pellets can keep spherical shape from top to bottom, gas and pellet flow rate will be homogeneous through the column and heat transferance efficiency will be kept constant.

2) Heat pattern with good heat exchange efficiency at only upper level

If pellet is deformed to flat shaped ball as shown in **Fig.-49-2** or the gap between pellet particles choked with fines and chips and contact area with gas is reduced, gas flow rate is lowered and heat exchange efficiency is lowered. High temperature gas goes up to upper part of furnaces without being cooled by descending pellets.

If there is very thin layer with good shape ball without deformation at upper part of furnace, gas will exchange heat with solid rapidly and heat pattern becomes steep. If there is not the layer, hot gas will be exhausted from the top of furnace. Namely, due to deforming and breaking of green pellet, heat transference efficiency will be lowered and hot gas, which keep high temperature up to upper part of furnace, contacts with green pellet at the top of furnace and causes rapid heating up of green pellet. By decreasing gas volume, heating pattern is moderated a little. The heating pattern shown in the figure is easy to make imagine from the plant operation view point. The condition of charged pellets reflects the actual conditions.

3) Consideration from 2 dimensions

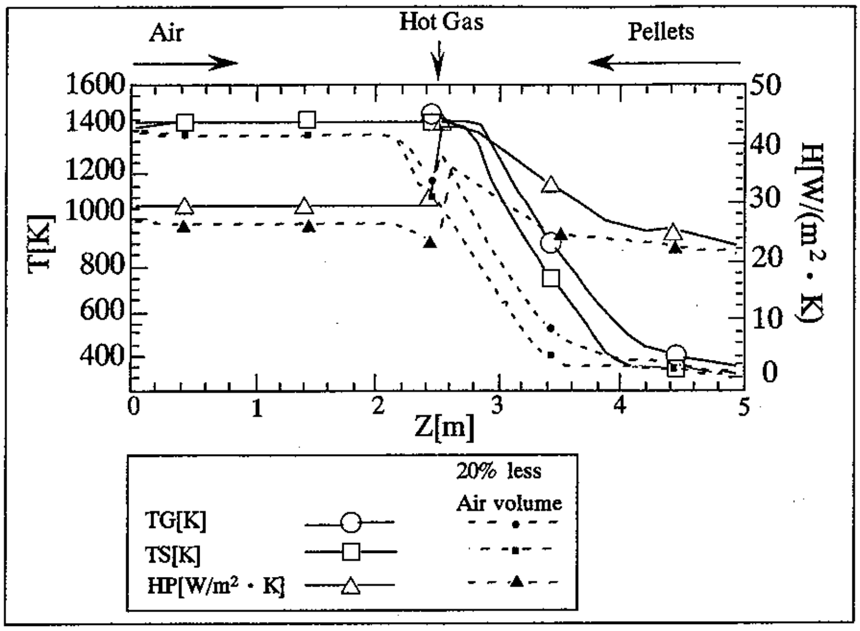
It has been reported that heat pattern in shaft furnace shown in **Fig.-49-1** is representative but different pattern as shown in **Fig.-50-1** and **2**. were observed at the plant A. This indicates that pattern in **1)** and **2)** happens by turns and this makes the understanding of shaft-furnace-operation-analysis difficult. It has been recognized that it is very difficult to lower the vast plane of bulky material homogeneously even in blast furnace equipped with many tuyers in circle. If descending speed of pellets is different on horizontal plane, permeability will change and heat pattern will change at many places on horizontal plane in shaft furnace. In big shaft furnaces, pattern in **2)** has possibility to happen easily. From the view point of suppression of typical pattern **2)** and controllability of descending speed evenly, small dimension of furnace is easy to operate.

(3) Conclusion

In order to avoid rapid heating up of green pellet, it is important to keep heat transference efficiency good and homogeneous through the column.The reason of lower heat transference efficiency in the bottom of column is estimated that deformation and/or breaking of green pellet will suppress gas flow.

Accordingly, it is important;

- to produce green pellets strong against deformation.
- to reduce gas volume for making steep-heating moderate.



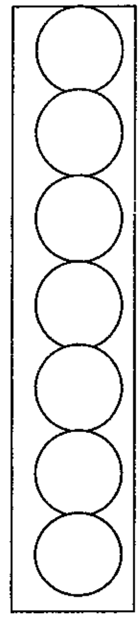
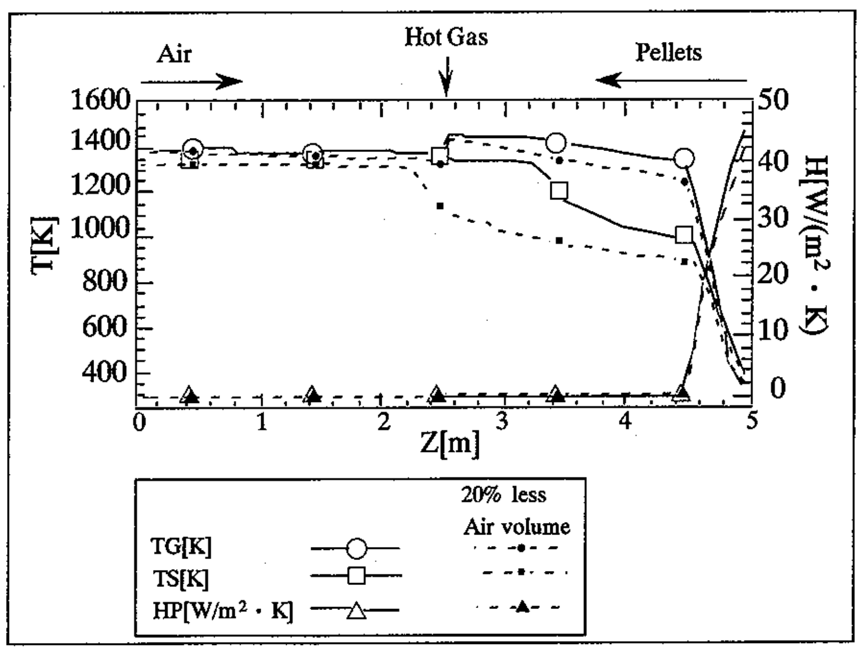


Figure-48-1 Heat pattern with high heat exchange efficiency through the depth

Figure-48-2 Image of the status in shaft



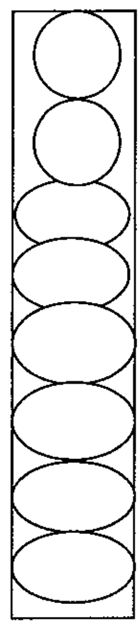


Figure-49-1 Heat pattern with high heat exchange efficiency at only upper level

Figure-49-2 Image of the status in shaft

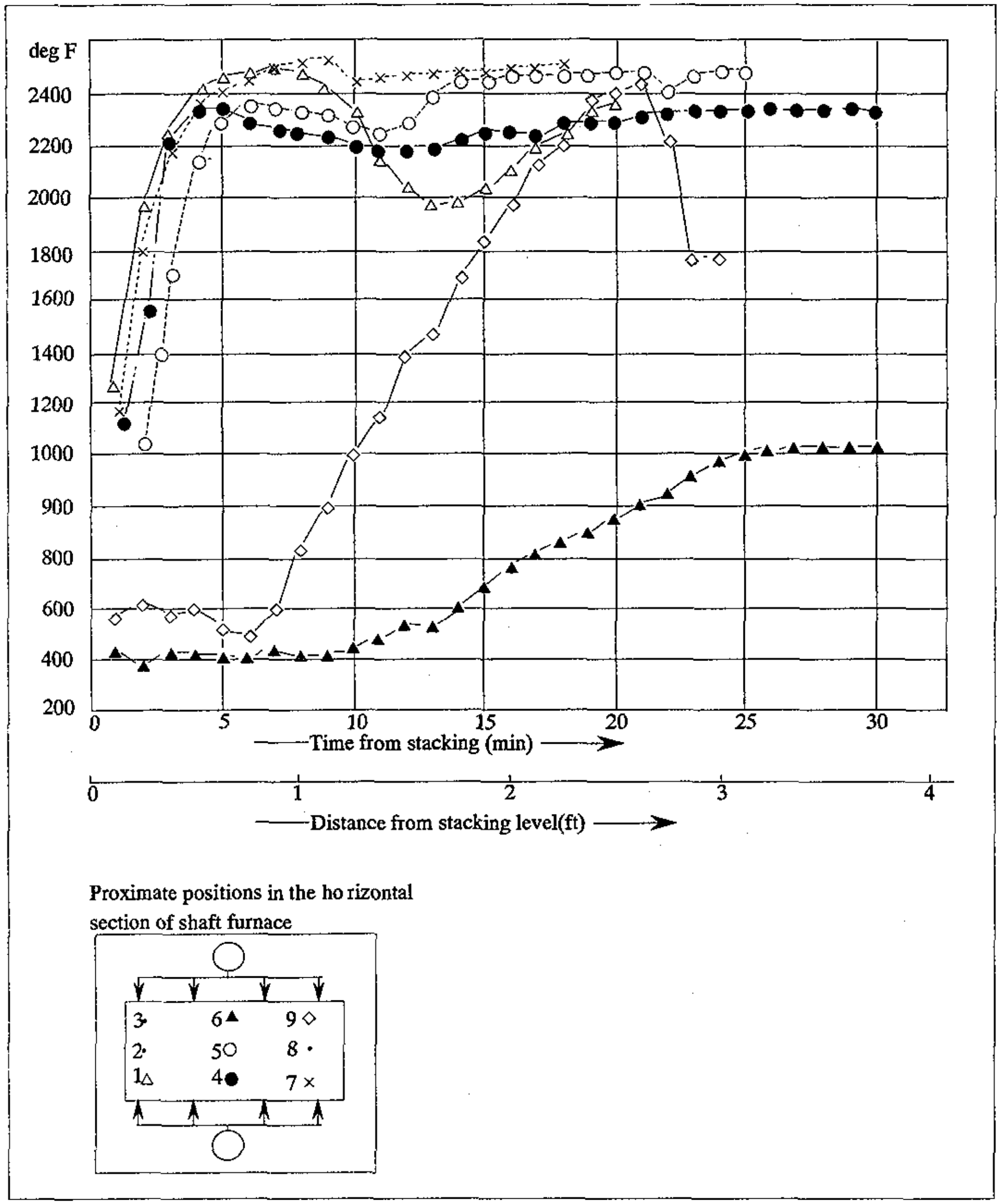


Figure-50-1 Heating pattern in shaft furnace (plant A)

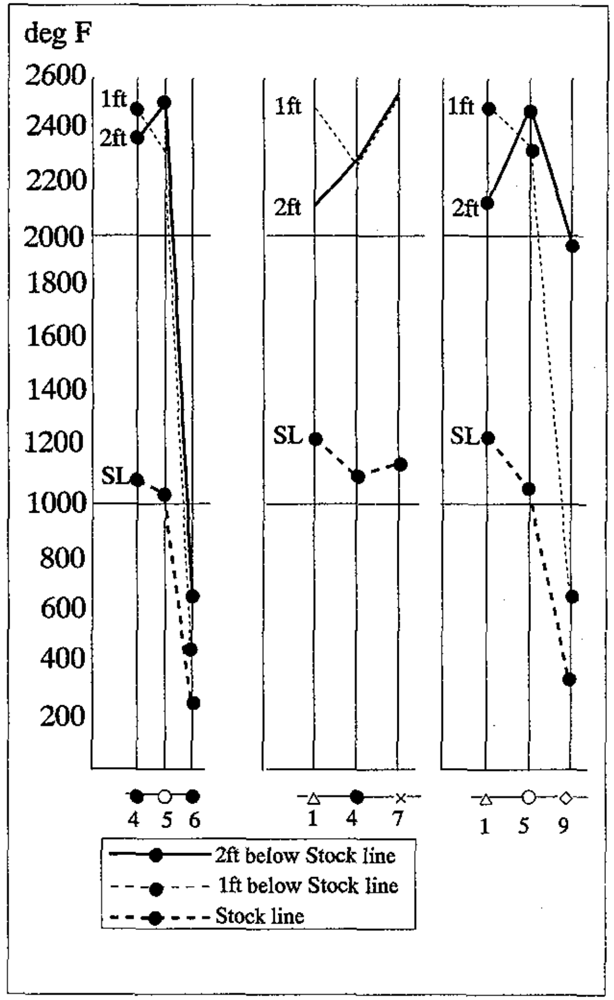


Figure-50-2 Temperature in 3 holizontal planes