Japan International Cooperation Agency (JICA)
Under Secretary of Mining,
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of The Argentine Republic

THE STUDY ON THE FEASIBILITY FOR THE REACTIVATION OF HIPARSA IN THE ARGENTINE REPUBLIC

FINAL REPORT

SUMMARY

DECEMBER, 1998

International Consulting Service Co., Ltd.
in association with
KOBE STEEL, LTD.

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* Remarks Numbers of Tables, Figures, Graphs, and Attachments in this Summary Report use the same numbers as in the Final Report.

Chapter 1

PURPOSE OF THE STUDY

The problem at present in Argentina is that the expansion of the economy does not well lead to the decrease of the unemployment rate. In Buenos Aires province where the capital of Argentina, Buenos Aires, is located, about 80% of the national population and GDP is concentrated. To relax this one-point concentration of the economy through romotion of the local economy has been one imortant theme of today.

The former HIPASAM (Hierro Patagonico de Sierra Grande Sociedad Anonima Minera), located in Rio Negro Province in the southern part of Argentina, was established in 1962 as a state-owned enterprise belonging to the Department of Defense. It was planned to mine 3.5 million-t per year of iron ores from its mine and dress the iron ores to produce pellet feed and to produce 2.0 million-t per year of pellets from the pellet feed. Of the north, east and south deposit, the south deposit was developed and the facilities were began to be constructed in 1971. The construction of pelletizing plant was completed in 1979 at last.

Problem was that phosphorus content in the iron ore could not be decreased in the concentration plant to the level required at the market. In addition, various troubles occurred in the pelletizing plant and the production amount was only about 0.45 million-t per year on average. The low productivity and the corresponding deficits caused the plant to shut down the operation in May 1991. In 1993, the former HIPASAM was transferred to the management of Rio Negro province. Today, HIPARSA, established by Rio Negro Province, manages maintenance of the iron ore mines and the concentration plant and the pelletizing plant including the shipping facilities.

Rio Negro Province would like to resume operation of HIPARSA for generation of employment opportunities and effective use of the invested capital because the province has no other prosperous industries. As part of reactivation of HIPARSA, Rio Negro Province plans to produce HBI, which has a higher added value and be more suitable for export than pellets, by making good use of the domestically available natural gas.

The purpose of this study aimed at establishing the plan for reactivation of HIPARSA based on the most suitable scenario selected from the viewpoint to technology and economy. To be specific, the study made the followings.

① Review of the markets for pellets and HBI worldwide, including Argentina

② Review of the conditions of HIPARSA when it was operated and today.

③ Study of the technologies applicable to HIPARSA.

- Study of the possibility of decreasing phosphorus content of iron ores through mineral dressing test and a study of method for modifying the concentration plant
- Execution of pot grate test and study of the method for modification of the pelletizing plant
- Study of efficient mining method

④ Preparation of scenarios for reactivation of HIPARSA

⑤ Selection of the most suitable scenario from those prepared in item ④ above through their comparative study

⑥ Execution of feasibility study of the reactivation scenario selected in item ⑤ above and corresponding establishment of the plan for reactivation of HIPARSA

Chapter 2

BACKGROUND OF THE STUDY

HIPASAM (Hierro Patagonico de Sierra Grande Sociedad Anonima Minera) started operation as a state-owned company under the federal government (Ministry of Defense) in 1971 to produce iron ore pellet for the domestic iron/steel industry.

It had to stop operations in May 1991. Reasons of the stoppage include that the removal of phosphorus in the concentration process was not up to the design requirements, that the operation of the pelletizing plant was not smooth and the designed capacity of 2 million-t of pellet per year was not achieved. In August 1993 the company asset was transferred to the Rio Negro Province and HIPARSA (Hierro Patagonico Rionegrino Sociedad Anonima) established by the Provincial government is maintaining the plant. The maintenance is costing the provincial government $200,000 per month.

2.1 NATIONAL AND PROVINCIAL POLICY

2.1.1 National development plan

Some policy measures connected with the revitalization of Argentina's economy started during the previous regime such as the Austral plan. Since then the value of peso ($) gained stability against foreign exchange represented by the US$.

In the mining industry Argentina's policy is growth through attracting domestic private capital and foreign capital and technology. With the legal and tax framework including incentive measures established foreign investment started to flow into Argentina. Foreign investment in the mining industry was about US$ 6.5-billion, more than 9 times the yearly average of 1981-1990.

2.1.2 Present situation of mining and industrial policy and the legal/tax framework

2.1.2.1 Legal framework of Argentina mining

Legal framework of Argentina mining consists of several laws and regulations including following:

1 Mining Code
2 Mining Investment Law No. 24.196
3 Regulating Law of mining Investment Decree No. 2686/93
4 Mining Reorganization Law No. 24.224
5 Federal Mining Agreement Law No. 24.228
6 VAT Funding Law No. 24.402
7 Decree No. 779/95
8 Mining Updating Law No. 24.498
9 Environmental Protection for the Mining Industry Law No. 24.585

2.1.2.2 Tax framework of Argentina for mining and industrial project

(1) National Taxes

1) Income Taxes
Corporation and commercial limited partnership, in the proportion pertinent to the limited partners, organized in Argentina; 33%.

2) Value Added Tax
The general tax rate is 21%

(2) Provincial Taxes

1) Mining Tax

Rio Negro Province has a Resolution 47/96 to levy tax on mining production. Tax varies with minerals produces. For Iron Ore, the current rate is $2 per ton of ore mined. The provincial government suggests the possibility of mitigating the tax burden if the feasibility study shows the necessity.

2) Gross Income Tax

All the Provinces in Argentina levy a tax on income resulting from the various profitable production, commercialization and service activities, whose tax rates apply to the gross income accrued, the deduction of the V.A.T. being admitted.

In Rio Negro Province, production and sale of HBI is subject to 3% Gross Income Tax on the sale amount.

(3) Municipal Taxes

According to Sierra Grande Municipality, there are two categories of taxes on the municipality level; Service Tax and Hygiene /Safety Tax.

(4) Incentives by the Federal/Provincial Governments

There is no unified and comprehensive law for the development of Patagonia. There are some individual laws for promotion of Patagonia economy. The only one which may have favorable effect to the present project is the rebate system for the export from Patagonia ports. The system gives the rebate for the export amount in accordance with the following schedule (**Table-2**).

Table-2 Patagonia export rebate rate schedule

Year	Rate of rebate
1999	7% of exported value
2000	6
2001	5
2002	4
2003	3
2004	2
2005	1
2006on	nil

2.1.3 Present situation of privatization policy

Since 1991 the Government has carried out a major privatization program encompassing most major sectors of the economy; Electric Power, Airlines, Petroleum, Gas, Steel, Railroads, Telephone. This process will be virtually completed by the year 2000 with the privatization or leasing of most enterprises that remain under the control of the Federal Government.

Reactivation of HIPARSA will be entrusted to private sector through an open tender based on the framework in which the federal and provincial governments would work out to attract interest of private sector after submission of the present study and recommendations.

2.1.4 Environmental policy and regulations

Argentina is suffering from a variety of pollution problems that are more serious than one would expect in a country of its upper-middle levels of income and economic development.

Argentina's pollution problems are mainly the result of the gradual increase of the urban population and industrial development combined with an inadequate regulatory framework and a long standing deficit in sanitary and waste treatment infrastructure.

As part of the transformation of the economy and the state, the Government is making a strong effort to complete structural reforms involving the privatization of public services (including water supply, sewerage and solid waste disposal) and the decentralization of regulatory responsibilities and social programs to the Provinces and Municipalities.

2.1.4.1 Conceptual framework and regulation

The excessive pollution levels in many parts of Argentina point to the need to improve and strengthen the Government's strategy for the management of environmental pollution.

(1) Groundwater Contamination

Groundwater contamination is a major concern as a large share of households (28% in the country, but 65% in the outer ring of AMBA (Area Metropolitan de Buenos Aires) which is not connected to the water network, uses groundwater to meet its daily needs.

A second major source are industrial effluents, which are also frequently disposed of in leaching pits and septic tanks.

(2) Surface water contamination

Obras Sanitarias has estimated that 2.2 million m^3/day of raw sewage and 1.9 million m^3/day of industrial effluent flow from the AMBA in the Rio de la Plata.

(3) Air pollution

Air pollution is primarily an inner city problem. Most of the pollution in downtown areas can be attributed to vehicles and most of that in the suburbs to industrial emissions and, in some areas, the burning of garbage. However, there is very little systematic information about air pollution levels and compositions. Environmental regulation of air pollution in Argentina are shown in **Table-5**.

Table-5 Environmental regulation of air pollution in Argentina

Component	Maximum Value (μ g/m^3)	Term of Measurement
CO	40	1 h
	10	8 h
SO_2	850	1 h
	400	24 h
	80	1 year
NO_2	400	1 h
	180	24 h
	100	1 year
Pb	1.5	3 sec.
Particulate Matter	150	24 h
Fraction of Respirable	50	1 year
Ozone	235	1 h
(Photochemical oxidant)	120	8 h
SH_2	8	30 min.

(4) Hazardous Wastes

A recent study estimates that about 47,000 t/year of hazardous wastes are produced in the Province of Buenos Aires alone.

(5) Solid Waste

In most parts of the country solid waste is collected by municipal contractors and deposited in open-air dumps where some of it is burned. Local concerns focus on the coverage of collection, which is inadequate in the regular settlements which concentrate the poorer population. In the absence of collection, garbage piles up in empty lots and local streams, where they constitute a source of water contamination, and to a lesser extent, a breeding ground for disease vectors.

(6) Noise Problems

Noise pollution is caused primarily by heavy, congested traffic.

2.1.4.2 Managing industrial pollution

(1) Problem and current policies

Industrial discharges are a major source of air, water and solid waste pollution in Argentina. In principle, these discharges are regulated by the Provinces through a framework of zoning regulations and industrial operation permits.

(2) Large enterprises

For the large part most enterprises recognize the need to improve their environmental performance and the general economic benefits that this will bring. They have access to the necessary management, technical and financial resources.

(3) Hazardous Waste Management

Recently, a national Hazardous Waste Law (Law 24.051 of 8 January 1992) has become effective. SERNAH has issued regulations pertaining to this law (Decree 831/93 of 23 April 1993 and Resolution 242/93 of 24 June 1993)

(4) Environmental Policy and International Competitiveness

There are strong grounds for believing that the opening up of the Argentina economy will bring environmental benefits by accelerating the adoption of newer, cleaner technologies, the influence of foreign investors who expect their local operations to achieve higher levels of environmental and operating efficiency, and the preferences of customers in some foreign markets that suppliers should, where possible, conform to the "green" certification requirements such as those of ISO 14000 .

2.1.4.3 Impact on environment

One important feature of Argentina's institutional framework is the system of government, in which the Provinces delegate functions to the Central Government. This implies that there are as many ways of organizing the control of pollution as there are Provinces.

A second unusual feature is that the institutional structures of the Government are rapidly changing.

(1) The current institutional situation

In principle most environmental matters are the responsibility of the Provinces unless expressly delegated to the National Government.

1) National Agency

The national organization of environment policy centers around the Secretaria de Recursos Naturales y Ambiente Humano(SERNAH), a cabinet level agency reporting directly to the President and with a total staff of 359.

2) National-Provincial coordination

As a common practice, the National Government enacts laws applicable in its jurisdiction, and then invites the Provinces to adhere to such law. If the Province decides to adhere to the national law (or decree, regulation, standards, etc.), it may adopt such law in total or in part. The Province determines also the provincial authority which will implement such law or it may delegate the powers to implement the law to the Municipalities.

3) Provincial Agencies

In general, the Provincial standards are adapted from National standards.

Since in many Provinces, environmental agencies (ministries, secretariats or sub-secretariats) are still relatively new, there are still some overlapping problems between them and health agencies who used to be responsible.

(2) Steps towards a reform of environmental institutions

SERNAH is aware of many of the problems and of the necessity to streamline the problems and of environmental policy in Argentina. It is very actively working at reorganizing its institutions to establish a more transparent and ultimately more effective national environmental system.

(3) Pollution control cost and environmental impacts

The available data consistently shows that the environmental control costs are a very small component of total production costs and value-added.

(4) Use of environmental impact assessment

The Environmental Impact Assessment (EIA) is one of the critical instruments of environmental regulation, particularly for addressing major environmental impacts, cross-media issues, and projects involving resettlement of the affected population.

A promising instrument for making the EIA process more transparent and efficient is the application of social damage costs for comparing environmental damages with project benefits. One of the requirements for the EIA would be to show that the investment project is economically viable when taking its environmental and social externalities fully into account.

(5) A general Environmental Law

The critical jurisdictional issues that have constrained effective environmental management in Argentina could be clarified with a law that defines the National environmental system, i.e. the roles and responsibilities of the Federal and Provincial Governments in regards to environmental policies and management.

The law should provide a sound legal basis for the introduction of effluent fees, and other economic instruments for environmental management, by establishing the general principle that the State has the right to charge those that use the country's natural and environmental resources, i.e., the "polluter pays" principle.

2.1.4.4 Survey of the environmental conditions and regulations on site (at Sierra Grande)

(1) Mine site (Area Ⅰ)

In Area Ⅰ solid waste discharged from the mine and the concentration plant is piled up into the dumping dam, which is known as Laguna Blanca and has an area of about 4 km × 5 km by eye measurement. The area of dam has a natural surface shape like that of a basin. It was confirmed that no people live in or around the basin. All waste water from the mine site (Area Ⅰ) is collected and stored in the Laguna Blanca.

(2) Pelletizing plant site (Area Ⅱ)

The Pellet plant site (Area Ⅱ) is located separately at the seaside at a distance of about 32 km from Mine Site. No people live around the plant site. But at a distance of about 8 km in the northern direction a small health-resort (known as Baln El Salado) is located. It was confirmed that no pollution problem has happened there since the start of the pelletizing plant operation. In this survey period the weather was fine and the wind was generally light, but sometimes it was windy and dusty. We were told that district of Sierra Grande area in Rio Negro belongs to the Patagonia area and during the year the wind can be strong and blows with the velocity of typhoon occasionally.

(3) Solid waste and its utilization

Solid waste like non-magnetic ore from the pre-concentration plant and tailing ore from the concentration plant in the Area Ⅰ has been piled up at Laguna Blanca. But it was developed about ten years ago that the apatite ore is separated from magnetic ore in the concentration plant and is able to be used as a raw material of fertilizer.

In the pelletizing plant no solid waste was generated.

(4) Waste water

In Area Ⅰ, all waste water from the mine site is collected in the Laguna Blanca and a small volume of waste water is kept in there.

In Area Ⅱ, waste water from the pelletizing plant is collected in deposit ponds near to the plant and part of the overflow water from ponds after the fine solid are removed is returned to the plant and the rest flowed to the sea.

(5) Weather conditions at the site (at Sierra Grande)

1) The precipitation volume
The precipitation volume is 200 mm yearly average.

2) Wind velocity
Wind velocity is strong throughout the year.

3) The direction of a wind
Wind blows from the west to the east.

(6) Analysis of drinking water at Sierra Grande

HIPARSA maintains and supplies drinking water from two water springs to the city in which about 6,000 peoples now live. The water quality of Los Berros and La Ventaana the location of the water springs is certified that the water from both springs is able to use as drinking water.

In the environmental protection of mine activity in Argentina various standards of water quality are regulated in the Mine Law (No.24585).

(7) Environmental regulation of soil

Each regulation for agriculture and industry is different, and the regulations for industry are more generous than for agriculture.

In accordance with the results of survey at this time the application for environmental protection in the mining activity is summarized below as follows.

1) All business action connected with prospecting of ore, boring, mining, development, manufacturing, extraction, storage, and closing of mining area.

2) If a new plant for direct reduction is projected to be constructed this plant is regulated by Mine Law (No. 24585) and EIA in accordance with that a presentation has to be made to jurisdiction government office.

2.1.4.5 Measurement method and result

It was found that HIPASAM did not execute the investigation concerning the environment at all after they began to operate, and the data did not remain.

On the other hand, the state government clearly shows an environmental standard based on the mining law about the water quality. However, a clear standard is not shown about other environmental elements. The drinking water of the Sierra Grande city is in the range of an environmental standard in As, NO_3^-, and NO_2^-.

(1) Measurement method

Area Ⅰ : Plants and Environmental elements which becomes object

Conc. Plant: Waste water, Solid waste, Reutilization of solid waste
Laguna Blanca (pond): Waste water
Laguna Negro(pile): Solid waste

Area Ⅱ: Slurry transportation: Waste water
Pelletizing plant: Waste water, Particularte Matter, NOx, SOx, CO gas
HBI plant: Waste water, Particularte Matter, NOx, SOx, CO gas

(2) Results

1) Air quality
In Area Ⅰ, the Pollutant radiates chiefly an atmospheric material from the manufacturing plant, and is NOx, SOx, Oxidants, CO, and is Particulate Matter, etc.. The resolution is restricted in Provincial Level as **Attachment-3-1** (Resolution 242/97).

On the other hand, law 20284/73 is shown an Standard, Alert, Alarm, and the Emergency level in Federal Level. For instance, the case of photochemical Oxidants and NOx is indicated as **Attachment-3-2**.

2) Water quality
In Area Ⅱ, the main Pollutants is chiefly discharged drain, and is a pH, a heavy metal ion, P, Cl, and BOD, etc.. These are examined in Chapter 9.

It is necessary to investigated EIA based on these standard values.

Attachment-3-1　Resolution 242/97

SO_2	1.300 mg/Nm^3	3 h
	0.365 mg/Nm^3	24 h
CO	10.0 mg/Nm^3	9 h
	40.0 mg/Nm^3	1 h
O_3	0.235 mg/Nm^3	1 h
NO_2	0.367 mg/Nm^3	1 h
Particulate Matter (PM)	0.15 mg/Nm^3	24 h
pb	0.002 mg/Nm^3	3 month

Attachment-3-2　Law 20284/73

	Photochemical Oxidants	NOx
Standard	0.1 ppm/h	0.45 ppm/h
Alert	0.15 ppm/h	0.6 ppm/h
Alarm	0.25 ppm/h	1.2 ppm/h
Emergency	0.40 ppm/h	-

2.2 PRESENT SITUATION OF MACRO ECONOMY AND IRON ORE MINING SECTOR

2.2.1 Present situation of macro economy

Argentina is endowed with an agricultural sector in the fertile Pampas capable of producing a sizable export surplus and achieving its economic development and industrialization mainly relying on the export of grain and beef. Argentina attained one of the highest standards of living in the world by the 1920's. Because of the prolonged postwar economic stagnation after World War II however the country is now classed as one of the upper middle-income countries in terms of per capita income by the World Bank classification.

The Convertibility Plan in 1991 suppressed inflation, and the period of rapid economic growth started.

Table-17 shows the major benchmark figures of the Argentina economy during 1990～1997.

Table-17 Principal Economic Indicators of Argentina

Million Pesos at 1986 prices

	1990	1991	1992	1993	1994	1995	1996	1997
GDP	9213.1	10180	11229	11931	12948	12355	12881	13962
Growth rate (%)		10.5	10.3	6.3	8.5	-4.6	4.3	8.4
Gross Domestic Fixed Investment	1232.2	1620.8	2164.1	2510.5	3056.9	2559.9	2771.7	3524.1
Export	1181.3	1121	1144.6	1171.9	1358.3	1667	1775	1911
Import	547	960.4	1598.7	1813.3	2221.4	1964.5	2295.2	2918.8

(Source: Macroeconomic Activity Report No.4 -March 1998- Ministry of Economy and Public Works and Services)

2.2.2 The present situation of the social environment

Argentina's economy is getting back to the growth track. In this section, the most basic and important resource of a nation, population, is briefly reviewed to examine the future potential of Argentina for further economic growth.

Argentina's population in 1991 was 32.6 million, with 49% male and 51% female. The population is expected to reach 47 million in 2025 with 23,995,722 females and 23,164,604. males.

Population density is 11.7 per km^2 for all of Argentina, with 2,165 for Buenos Aires district. In the urban areas of the Federal Capital, the density is 14,827. Rio Negro, on the other hand, has a density of 2.5.

Age structure of Argentina's population shows a balanced distribution of pyramid shape, implying growth potential during future decades.

Argentina's educational level judging from the percentage of enrollment at tertiary school being 41% of the age group is one of the highest in the Latin American countries. (The World Bank, World

Development Report 1997, p.227) This would prove the higher quality of Argentina's work force although there may be other factors which affect the quality other than education such as work habits, cultural effect on work etc.

The unemployment rate almost tripled from 1988's 6.3% to 1995's 17.5%, probably due to privatization of major state owned enterprises and the slow down of economic activities caused by the Mexican crisis.

2.2.3 Present situation of the iron ore mine and iron ore mining sector

Sierra Grande (HIPARSA) is the only existing iron ore mine developed so far in Argentina. The data provided by the Undersecretariat of Mines shows that there are no significant Iron ore deposits in Argentina.

2.2.4 Development plan for the iron ore mine and iron ore mining sector

Sierra Grande (HIPARSA) is the only iron ore mine in Argentina and there is no other iron ore mine development plan. Steel companies in Argentina are importing iron ore, mainly from Brazil.

2.2.5 Present situation of investment / trade

The annual growth rate of GDP of Argentina reached 8.4% for 1996-1997, second only to China among the major world countries. Most of the factors for the economic growth such as investment, consumption, export showed growth. Among them, the investment showed a remarkable increase as a result of recovery of confidence of investors, domestic and overseas on the future of the Argentina economy. In 1997, investment grew 27.1%, contributing 44% to the growth of the total demand.

Imports grew as capital goods imports grew in line with the strong demand caused by growth of investment, resulting in renewal of production facilities and a stronger competitive position. The deficit of the balance of trade is financed by foreign investment, which is the source of the driving force for the growth of the Argentina economy.

Argentina exports are showing growth as a result of recovery of competitiveness and favorable circumstances such as the establishment of Mercosur.

Mercosur is the fourth largest economic group in the world after EU, NAFTA and APEC. Argentina is enjoying the benefit of free trade within Mercosur based on her competitiveness in agriculture and with the natural gas/petroleum advantage together with large amounts of investment and a capable work force.

2.3 GENERAL SOCIAL AND ECONOMIC CONDITIONS OF RIO NEGRO PROVINCE

2.3.1 Present situation of social and economic conditions of Rio Negro Province

Rio Negro Province's population in 1991 was about a half million (506,772), male 254,153 (50.2%) and female 252,619 (49.8%), more male proportion than the national average. Population wise, Rio Negro is only 1% of Argentina. Age wise, the population of 20-24 years old segment shows larger dent compared with the national figure, showing possibility of outflow of this segment to other part of the country.

There is no unemployment data for comparison for Rio Negro province. Since there is no significant industry in the province, unemployment rate data, even though available, may not mean much. It would suffice to consider the impact of HIPARSA creating job opportunity of at least 750 employment as a single entity in Sierra Grande.

According to the statistics, the value of mineral production of Rio Negro province was about $6-million to $18-million per year. The feasibility study by HIPARSA presumes concentrate transfer price to HBI process at $23/t. The order of magnitude of the present project would be $20-million per year. This simple and crude comparison shows the importance of HIPARSA reactivation for mining industry in Rio Negro province.

2.3.2 Development plan for Rio Negro Province

There is no official plan for development of mining and industry in Rio Negro Province. Nor there is any integrated law or plan for the development of mining and industry in Patagonia. The only actual implementation of a large industry is Aluminum Argentina in Chubut province. In Rio Negro Province, a Zona Franca project started in middle of 1998 near Punta Colorada.

There are, however, some laws and plans to assist economic activities and growth of the region. One of them is the Rebate System for Export from Patagonia Ports.

Chapter 3

IRON ORE PELLET AND HBI MARKET

3.1 ARGENTINA IRON AND STEEL MARKET

Argentina now has 4,200,000 t/year of crude steel production and they estimate it's production in 2005 at 5,000,000 t/year. Raw material, iron ore (no local production yet) has been mostly imported from Brazil, taking advantage of the Mercosur tax incentive. In 1996, the consumption of iron products were about 5,500,000 t and about 2,000,000 t were exported and about 1,600,000 t were imported.

Taking advantage of the tax incentive within the Mercosur zone, trade between Brazil/Argentina has increased steadily year by year, this has been also applied to the iron trade. In Argentina, there are four mills, that have EAF(electric arc furnace) and two mills with blast furnaces. After reactivation of HIPARSA, they will be possible customers (buyers) of HIPARSA pellet, competing with Brazilian iron ore.

* All source from CIS

3.1.1 Present situation of steel supply

Present production of crude steel is approx. 4,200,000 t/year and CIS (centro de industriales siderurgicos) estimates production in 2005 at 5,000,000 t/year.

Table-24 Production of crude steel in 1997 by company and process

(kilo-t)

Company	EAF	BOF	Total
SIDERAR		1,867	1,867
ACINDAR	1,148		1,148
SIDERCA	902		902
ACEROS ZAPLA	53	96	149
ACEROBRAG	91		91
CIF	12		12
Total	2,206	1,963	4,169

(Source:CIS 1997)

3.1.2 Present situation of steel demand

Table-28 Present situation of steel demand

(kilo-t)

	Apparent consumption	Export	Total
1990	1,461	2,585	4,046
1991	2,384	1,833	4,217
1992	3,367	1,128	4,495
1993	3,294	1,235	4,529
1994	4,152	1,351	5,503
1995	3,451	1,966	5,417

(Source:CIS 1995)

3.1.3 Scrap market

In scrap market, there are almost no quantity of import and export, as well as Brazil.

3.1.4 Present situation of foreign trade

As to iron ore, there is no supply from domestic production and almost all is imported from Brazil. Taking advantage of the import tax incentive within Mercosur, hereafter Argentina will concentrate on importing iron ore only from the Mercosur country (Brazil).

Table-30 Import of iron ore

(kilo-t)

Origin	1991	1992	1993	1994	1995
CHILE	51	- -	90	172	113
CANADA		61	--	--	--
BRAZIL	2,179	3,454	3,115	3,931	4,116
PERU	80	32	--	--	--
VENEZUELA	--	27	--	--	--
TOTAL	2,310	3,574	3,205	4,103	4,229
(US$/t)	43.17	38.81	34.35	28.66	34.62

(Source:CIS 1995)

Table-31 Tax difference (Import of Argentina)

Product	Arancel no.	From Mercosur	From out of Mercosur
Iron Ore	2601.11.000	0%	2.0%
	2601.12.000	0%	2.0%
	2601.20.000	0%	2.0%

(Source: HIPARSA)

3.1.5 Situation of main domestic mills for purchase of HIPARSA pellet

SIDERAR (TECHINT Group)

- They are interested in purchasing BF-pellet.
- An important point in quality is the phosphorus content.
- SIDERAR will study to use HIPARSA HBI for their BOF in future.
- Discharging port is San Nicolas.

ACINDAR

- They are interested in purchasing 200-300 kilo-t/year of HIPARSA HBI.
- ACINDAR made it clear that if the phosphorous content is higher than a certain level, they will not purchase.
- Discharging port is Villa Constituicion.

ZAPLA

- This company is interested in purchasing 250,000 t/year of HIPARSA HBI, which is replace of purchased scrap.
- ZAPLA has problem in production of pig iron by charcoal, because of severe limitation of the production of charcoal in ecological reason (protection of forest zone), so they will consider to replace pig iron to HBI too.
- Transportation is by vessel from Punta Colorada to Barranqueras (Provincia Chaco), from where upto Jujuy (Provincia Jujuy, where locate ZAPLA mill) by railway.

ACERBRAG (PIERO Group)

- Now purchases 10,000 t of scrap from the domestic market, competing with ACINDAR, etc.,
- They are expanding their plant and in the year 2000 will consume 250,000 t/year of scrap and/or HBI.
- However they can receive HBI/scrap only by truck (they have no discharging port facility).

3.2 MERCOSUR, AS AN EXPORT MARKET OF HIPARSA HBI

Argentina mills suggested the sales possibility of HIPARSA HBI to Mercosur (Brazil) in addition to the pellet market in Argentina, because;

- There are many mills, which have EAF facilities. They are at present consuming domestic pig iron and scrap (both well balanced and no import of HBI), but are facing difficulty to procure pig iron as ecological reason (on account of severe protection of Amazone forest, charcoal blast furnace mills are obliged to reduce pig iron production).
- Also Brazilian blast furnace mills are studying to consume HBI for getting higher productivity, which will create new demand of HBI in Brazil.
- One steel maker is operating HBI plant of 310 kilo-t/year scale for captive use only (it is said that this production cost is very expensive because using high cost of Brazilian natural gas from off-shore)
- Brazil has tax incentives and also advantageous payment terms on imports from Argentina, in comparison with from outside of Mercosur, according to the Mercosur agreement. However Venezuela could be in competition with Argentina HBI, after their participation in Mercosur, which is scheduled by the year 2000.
- Brazil has no project for HBI production because of the lack of an economic natural gas supply.
- In order to overcome ocean freight competition, HBI (not BF pellet/DRI) is the most suitable product.

There are less sales possibilities for HIPARSA HBI in the other countries in Mercosur - Uruguay, Paraguay, Chile, who are not existing users.

3.2.1 Mill list, of those that have EAF/blast furnace in Mercosur (Brazil)

In the Mercosur market, possible buyers of HBI exist only in Brazil, where the following mills have EAF, blast furnace, DR.

Table-33 Mill list, that have EAF, Blast furnace, DR in Brazil

Company name	EAF	Blast furnace	DR
ACESITA		○	
ACOMINAS		○	
SIDERURGICA ALTEROSA		○	
SIDERURGICA BARRA MANSA	○		
BELGO	○		
CIA SIDERURGICA BELGO	○	○	
COSIPA		○	
CSN		○	
DEDENI	○		
GERDAU	○	○	○
MANNESMANN		○	
METALSIDER		○	
SIDERURGICA RIOGRANDENSE	○		
SIDERURGICA SAO CRISTOVAO		○	
SIDERPA		○	
CIA SIDERURGICA DE TUBARAO		○	
USIMINAS		○	
VDL SIDERURGIA		○	
VIENA SIDERURGICA DO MARANHON		○	
VILLARES METALS	○		
ACOS VILLARES	○		

(Source: Iron and Steel Works of the World)

3.2.2 Scrap and pig iron market in Brazil

3.2.3 Import tax difference of HBI (Import into Brazil)

Table-36 Import tax difference (Import into Brazil)

Product	Arrancel no.	From Mercosur	From out of Mercosur
HBI	7203.10.000	4%	9%
	-IMPORT TAX	0%	5%
	-IPI	4%	4%

(Source: Japanese trading firm)

Argentina is able to give favourable payment terms to Brazil, in accordance with Brazilian import regulations.

from Mercosur	no limit of sight
from out of Mercosur	at sight or minimum 360 days

3.3 WORLD HBI MARKET

World steel production is forecast at 1-2% growth per year to 2010, which means 800 million-t in 2000, 850 million-t in 2005, and 900 million-t in 2010.

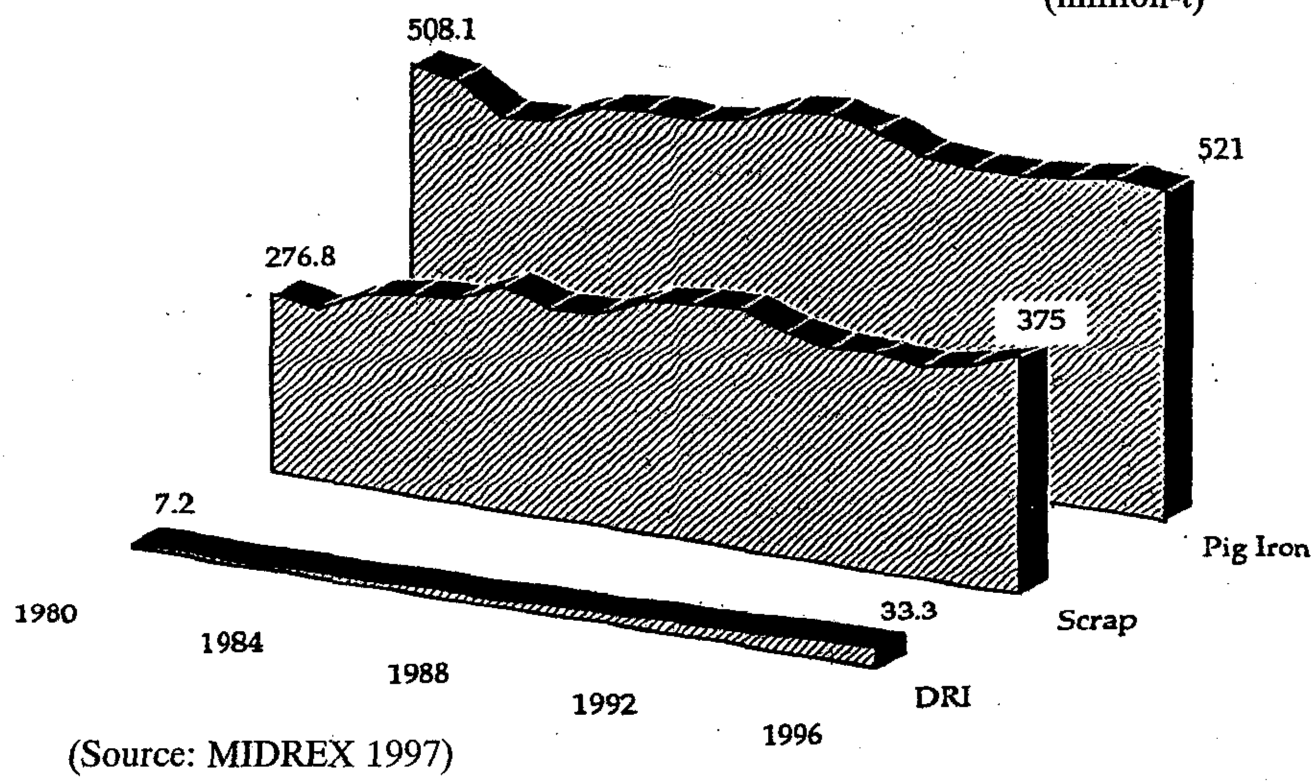
Such growth in the significant increase in steel demand and exports are expected especially in the developing countries that have low production costs.

Now that steelmaking by the EAF route is growing significantly faster than any other process.

Graph-6 shows pig iron, scrap and DRI actual consumption. It means that DRI/HBI use is increasing world wide, as EAF mills have captured a large share of steel production.

Graph-6 World metallic consumption

(million-t)



(Source: MIDREX 1997)

3.3.1 World direct reduction industry

Since 1970, world DRI production has grown tremendously. Most DRI also HBI is produced in developing countries with access to high quality iron ore and low cost natural gas.

(1) Growth in EAF steelmaking

(2) Expansion into higher quality products

(3) Increase in demand for purchased scrap

(4) Little growth in prime scrap supply

(5) Insufficient quality of purchased scrap

Worldwide scrap supply is huge -approximately 400 million-t/year consumed. However, most have high metallic residual prime (low residual) scrap supply cannot satisfy total needs of hi- quality steel producers.

3.3.2 DR production forecast

Table-39 DR production forecast

(million-t)

	1994	1995	1996	2000	2005	2010
Asia	5.8	7.1	8.1	11.0	13.3	15.2
N. America	5.7	6.2	6.7	15.3	18.6	18.9
S. America	10.3	6.6	6.8	10.2	12.9	16.6
Middle East	5.6	6.0	6.7	10.4	11.6	12.6
Oceania	0.0	0.0	0.0	3.2	4.5	4.5
Others	0.9	4.9	4.7	7.4	13.8	12.8
Total	28.3	30.8	33.0	57.5	74.7	80.6

(Source: Japanese trading firm)

3.3.3 Forecasted average HBI prices

Table-40 are forecasted average HBI pricees for 1997-2010. During this period, HBI price will be lower on account of low steel demand. But when demand increases, price of all iron, steel and HBI too will rise accordingly.

Table-40 Forecasted average HBI prices

(1997-2010 US$/t)

North America	155 delivered
Europe/Middle East	160 CIF
Asia/Oceania	165 CIF

(Source: MIDREX 1997)

3.3.4 Trade of DRI/HBI

In 1996, 6.9 million-t of DRI/HBI were shipped worldwide. However, 1997 onwards it's figure have jumped drastically (Table-42)

Table-42 World merchant HBI demand

(million-t)

	1997	1998	1999	2000	2005
North America	9.61	9.73	9.85	9.97	9.97
Western Europe	2.43	2.50	2.50	3.07	3.07
Asia/Oceania	8.95	10.26	12.25	13.65	15.48
Middle East/North Africa	1.35	1.09	1.34	1.61	1.61
Latin America	0.86	0.70	0.70	0.70	0.70
Former USSR/Eastern Europe	0.11	0.21	0.44	0.59	0.59
Africa	0.33	0.33	0.33	0.33	0.33
World Total	23.64	24.82	27.41	29.92	31.75

(Source: MIDREX 1997)

3.3.5 Rough scheme of project and demand of HBI in the world

Table-43 Constructed plant of HBI at end of 1996

(kilo-t)

Own consumption	Sale to merchant	Total
7,530	6,560	14,090

(Source: CIS)

Table-44 Demand of merchant of HBI

Year	1998	1999	2000	2005
kilo-t	24,810	27,400	29,920	31,740

(Source: MIDREX)

Table-45 Balance of demand and offer of merchant HBI

(kilo-t)

	1998	1999	2000	2005
Demand	24,810	27,400	29,920	31,740
Offer	13,450	13,450	13,450	20,000
Balance	-11,360	-13,950	-16,470	-11,740

(Source: CIS)

3.3.6 Iron ore pellet requirement for DR

Up to the year 2000, requirement of iron ore pellet for DR demand will increase significantly in N. America and during 2000-2005 in Asia and up to 2010 in S. America its requirement will rise, according to DR projects.

Table-46 Iron ore pellet requirement for DR

(million-t)

	2000	2005	2010
N. America	19.7	22.4	22.4
Asia	9.8	13.0	15.6
Middle East	14.4	16.2	17.7
S. America	9.9	13.1	17.6
Others	8.5	9.9	9.9
Total	62.3	74.6	83.2

(Source: Japanese trading firm)

3.4 TRANSPORTATION OF DRI/HBI FROM HIPARSA

3.4.1 Distribution of HIPARSA pellet

Distribution of HIPARSA pellets are realizéd by following two ways.

(1) By truck

By truck for domestic clients, who have no receiving port facility. At present, small lots of pellet are despached to domestic cement factory.

(2) By ship

By ship for domestic clients and for export from Punta Colorada, HIPARSA berth. In past, HIPASAM has shipped several lots of pellet to domestic mill SOMISA but any lot of shipment for export has not been realized. HIPARSA port conditions are stated in 3.4.3 in details.

3.4.2 Handling/Shipping

Handling and shipping of DRI/HBI transportation are manualized as IMO CODE, which to be refered to **Attachment-4**.

Attachment-4 **IMO CODE FOR HBI TRANSPORTATION**

DEFINITION

A material emanating from a densification process whereby the DRI feed material is at a temperature greater than 650℃ at time of moulding and having a density greater than 5.0 g/cm^3.

BC No.	IMO Class	MFAG Table No.	Approximate Stowage Factor m^3/t	EmS No.
016	MHB	-	** 0.35	B15

** (to be verified by shipper)

PROPERTIES

Material may slowly evolve hydrogen after contact with water. Temporary self-heating of about 30℃ may be expected after material handling in bulk.

Approximate Size : Length 90 mm to 130 mm
Width 80 mm to 100 mm
Thickness 20 mm to 50 mm
Briquette weight 0.5 kg to 2.0 kg
Fines : Up to 5% (under 4 mm)

OBSERVATIONS

Open storage is acceptable prior to loading.
Loading, including transfer from one ship to another, during rain is unacceptable.
Unloading under all weather conditions is acceptable. During discharge a fine spray of fresh water is permitted for dust control.

SEGREGATION AND STOWAGE REQUIREMENTS

Boundaries of compartments where DRI is carried should be resistant to fire and passage of water. Separated from materials of classes 2, 3, 4 and 5 and class 8 acids.

SPECIAL REQUIREMENTS

Certification

A competent person recognized by the national Administration of the country of shipment should certify to the ship's master that the DRI, at the time of loading, is suitable for shipment.
Shippers should certify that the material conforms with the requirement of this Code.

Shippers' requirements

The shipper may provide advice in amplification of this Code but not contrary thereto in respect of safety during carriage.

Precautions

1. Prior to loading :
   All cargo spaces should be clean and dry. Bilges should be sift proof and kept dry during the voyage. Wooden fixtures such as battens, etc., should be removed. Where possible, adjacent ballast tanks, other than double bottom tanks, should be kept empty. Weatherdeck closures should be inspected and tested to ensure integrity.

2. Hot moulded briquettes should not be loaded if product temperature is in excess of 65℃ (150℉).

3. Cargo spaces containing DRI material may become oxygen depleted and all due caution should be exercised upon entering such compartments.

4. Adequate surface ventilation should be provided.

5. Radar and RDF scanners should be adequately protected against dust during loading and discharging operations.

3.4.3 HIPARSA port condition

(1) Place of port

Punta Colorada (provincia Rio Negro).

(2) Operator

HIPARSA.

(3) Loading equipment and berth

This is the iron ore loading berth, which belongs to HIPARSA, although there has been no activity for the past few years (pellet shipment for old-SOMISA) loading facilities are well maintained.

This consists of a 1,500 m conveyor belt of which 1,000 m juts out seawards supported on piling. At the eastern end of the piling there are 2 pairs of mooring dolphins, one pair abreast on the north side and the other on the east side enabling a vessel to berth either on the northern or the eastern pair of dolphins. Reported depth alongside: Eastern Dolphins 45′ low water. Northern Dolphins 35′ low water. Vessels of up to 70,000 DWT have loaded.

The dolphins on either berth are set approximately 65 m apart and are fitted with 2 bollards and a capstan for the reception of backsprings. There are mooring buoys laid ahead and astern of the dolphins to take head and stern lines.

The maximum loading rate is 2,000 TPH. The conveyor belt at its extremity is fitted with a platform and an auxiliary belt, capable of rotating through 176°, moving horizontally 31 m and giving a 42 m outreach to serve either berth.

NOTE:

- These port facilities are only for loading (conveyor belt is only for out-going cargo).
  Shipping condition is "THINC" 24 hours run, except in bad weather and difference of ebb/flow is about 8 m.
- Government of Provincia Rio Negro has project to establish "Zona Franca" at Punta Colorada, including HIPARSA berth.

(4) Vessel service to Punta Colorada

It is easy to obtain space and reasonable ocean freight under charter vessel base for export and domestic (cabotaje) transportation.

Chapter 4

PAST SITUATION OF HIPASAM

HIPASAM (Hierro Patagonico de Sierra Grande Sociedad Anonima Minera) started operations as a state-owned company under the federal government (Ministry of Defense) in 1962 to produce iron ore pellet for the domestic iron/steel industry.

It had to stop operations in May 1991. Reasons of the stoppage include that the removal of phosphorus in the concentration process was not up to the design requirements, that the operation of the pelletizing plant was not smooth and the designed capacity of 2 million-t of pellet per year was not achieved. In August 1993 the company asset was transferred to the Rio Negro Province and HIPARSA (Hierro Patagonico Rionegrino Sociedad Anonima) established by the Provincial government is maintaining the plant.

In this chapter, why HIPASAM was forced to stop operation is explained.

4.1 CORPORATE MANAGEMENT

Information on the Corporate Management of the ex-HIPASAM was very scarce. According to the 1983 HIPASAM organization chart, the number of total employees was 1,177 of which the head office contained 122 and Sierra Grande plant site 1,055. The team was informed that there were actually over 400 people in the HIPASAM head office, which indicates a top-heavy organizational structure. Generally speaking, in State-owned companies, there is a tendency for over-employment and inclusion of social services within the scope of company activities.

The sale was to another state-owned steel making company in Argentina. The sales structure and the status of a State owned company may not have induced sales and marketing efforts, or incentives for quality and productivity improvement.

4.2 PRODUCTION TECHNOLOGY

4.2.1 Iron ore mines

(1) General

The full-scale development of Sierra Grande south deposit started in 1971. The mining method adopted from the beginning for the deposit was sub level stoping by truckless system suitable for the characteristics of this deposit. (deposit width: average 9m, inclination :35～50° , length :3000 m).

The Central shaft reached the 522 ML. No. 1 crusher (jaw crusher) installed at 410 ML and skip loading station installed at 480 ML. Excavated ores were placed into No.1 crusher and then hoisted by the skip to ground level where they were transported to the crushing plant at ground level (No.2 crusher) by belt conveyor.

(2) Underground structure

The development system of the south deposit is a composite development of inclined shaft and ordinary shaft.

There is a central shaft in the middle of the south deposit. Inclines (section 5.5m×5.0m) are extended to 522 ML from the central shaft.

Main level distance is 70m and a transportation drift (section 4.5m× 6.0m), a loading drift (section 4.5m×6.0m) and a drilling drift (4.0m×4.0m) are constructed and each of them are connected to the inclined spiral shaft.

Furthermore the main level is divided into a sub level each of 23 meters and each sub level has a transportation drift, loading drift and drilling drift.

The loading drifts are connected to ore loading gate at each main level by ore pass (section 2.4m×2.4m).

(3) Mining method

A scale of one ore block at sub level stoping method is 70m in height, 9m in width and 200m in length.

A sub level in an ore block is set 23m in distance. Drilling drifts and loading drifts excavated from the incline are made at each sub level.

A pass which is the first free face of stoping is made at each end of the ore block. This pass connects to each sub level. Stoping starts from the expansion of the pass. When free face is completed, charging holes are drilled for full scale stoping.

The drilling method of charging holes is fan-shaped drilling by fan-drill jumbo.

Typical drilling pattern is spacing:1.8m, drilling length : 28.8～9.6m/hole, total drilling length : 231.6 m. A sub level of which fan-shaped drilling completed are blasted one after another. Excavated ores are transported by loader and dumped to the ore pass.

(4) Transportation

As stated above, a transportation drift on the south deposit was made for a distance of 70 m. Excavated ores were dumped to the pass which connects each sub level.

Excavated ores collected in the pass were transported by the mine trucks to the ore pass which connects to the No. 1 crusher at 410 ML.

The ore crushed by No.1 crusher were dumped to the skip at 480 ML and hoisted to ground level. The ore hoisted to ground level were further crushed by the crushing plant and stocked on the stock yard by the stacker.

(5) Ventilation and water discharge

As mentioned before, the underground structure of the south deposit is a composite structure. Ventilation is basically natural ventilation, however, mechanical ventilation by electric fan is also used due to truckless mining and deepening of stoping.

Natural mine water and operation drain water are collected by water drainage at each drift and water drain pipes (ϕ 80 mm) connecting each drift are then discharged to the outside of the drift by water pumps.

4.2.2 Iron ore concentration plant

(1) Underground primary crushing

The primary crusher reduced the size of the ore from up to 1 m^3 to less than 300mm.

(2) Secondary crushing

The plus 100 mm screen oversize is reduced to minus 100 mm by two hydroset secondary crushers.

The minus 100 mm product of the secondary crushing is conveyed to a storage area where it is fed by a stacker to the pile of total 20,000 t live capacity.

(3) Preconcentration

Beneath the stockpile the ore was withdrawn and was transferred to the preconcentrator for distribution to three parallel lines.

On each line the crude ore was fed to a dry primary magnetic separator on which a concentrate was recovered and the rejects were fed to a secondary magnetic separator. The rejects of the secondary separator were collected and transported to the disposal area.

The pre-concentrate which the plus 75mm was fed to the tertiary cone crusher to reduce minus 25mm. The minus 75mm plus 25mm was fed either to the cone crusher or bypasses the crusher as grinding media for the pebble mills in the concentrator.

The crude ore averaging 46.5% iron was upgraded to the preconcentrate of 53 to 54% iron by rejecting 29 to 30% weight of waste.

(4) Concentration

1) Outline

The flow sheet at the time of start of the concentration plant is shown in **Fig.-4**. There were 3 lines of grinding, magnetic separation and flotation of which equipment were same. It is reported that the concentration plant was operated rather smoothly.

The concentration plant had sufficient capacity and it may be said that a reason of not achieving the production plan was not caused by the plant capacity. Several modifications were made to the concentration plant and the process flow at the final stage when the concentration plant was in operation was shown in **Fig.-5**. The time, purpose and effect of the modification of process were not known as there is no engineers except maintenance engineers remain in the concentration plant.

Phosphorus content in the concentrate at the start of the concentration plant was specified to less than 0.18% and actual phosphorus content has never exceeded during the operation. Seeing from Table-65, the trend of annual average phosphorus content in the concentrate was stable around 0.137%. High phosphorus content in the concentrate as compared with other sources was the subject of discussion from the beginning of the operation and various measures to reduce the phosphorus content were tried between 1980 and 1983, such as selection of flotation reagents or cyclone classification, etc.

It also confirmed when size of concentrate became finer, phosphorus content could be decreased, however, it was believed that fine grinding caused difficulty of filtration of pellet feed. When checked at the site, it seemed that the filter itself had more problem for filtration.

Figure-4 Original Flowsheet Constructed by Kurimoto

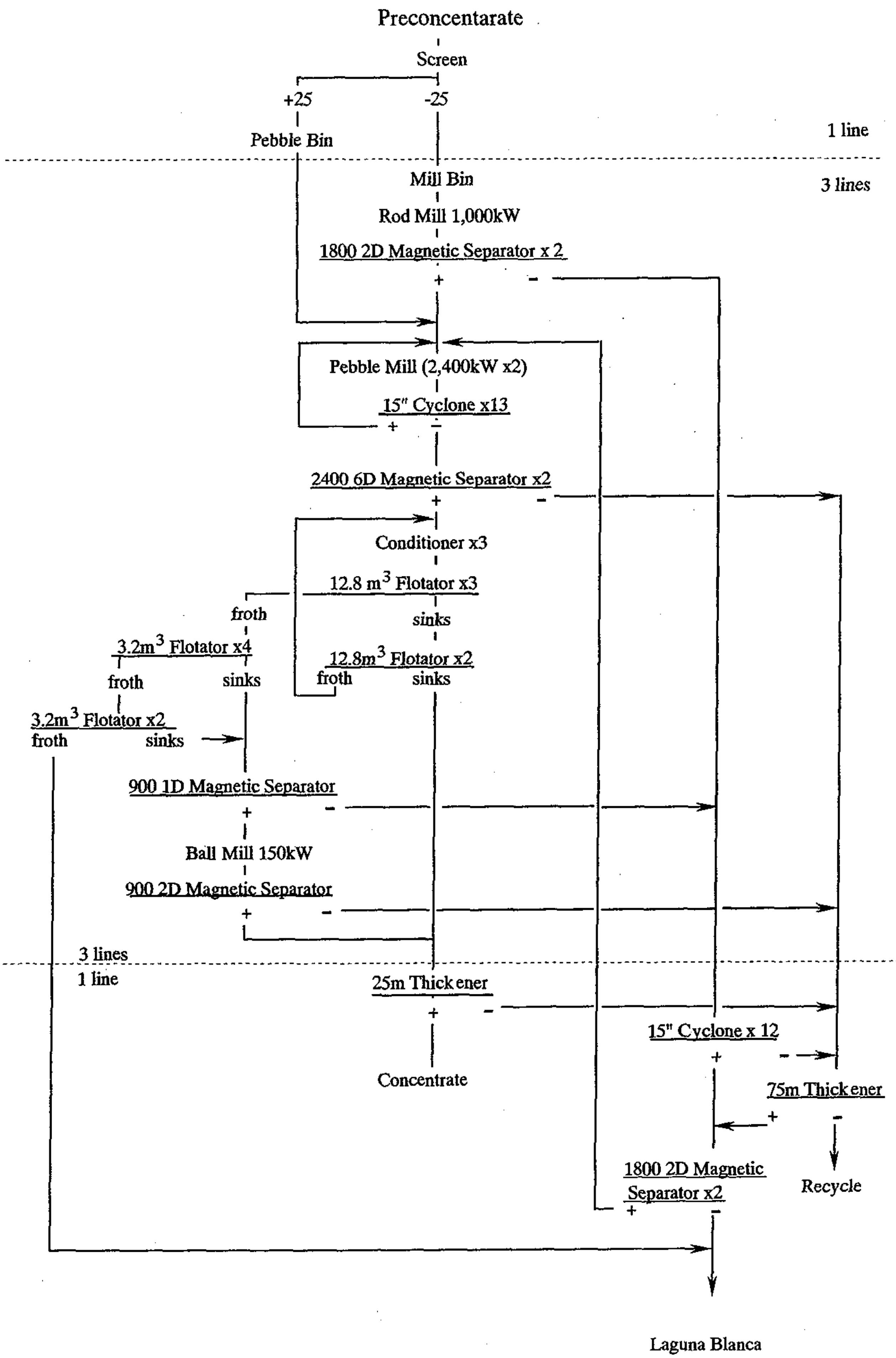
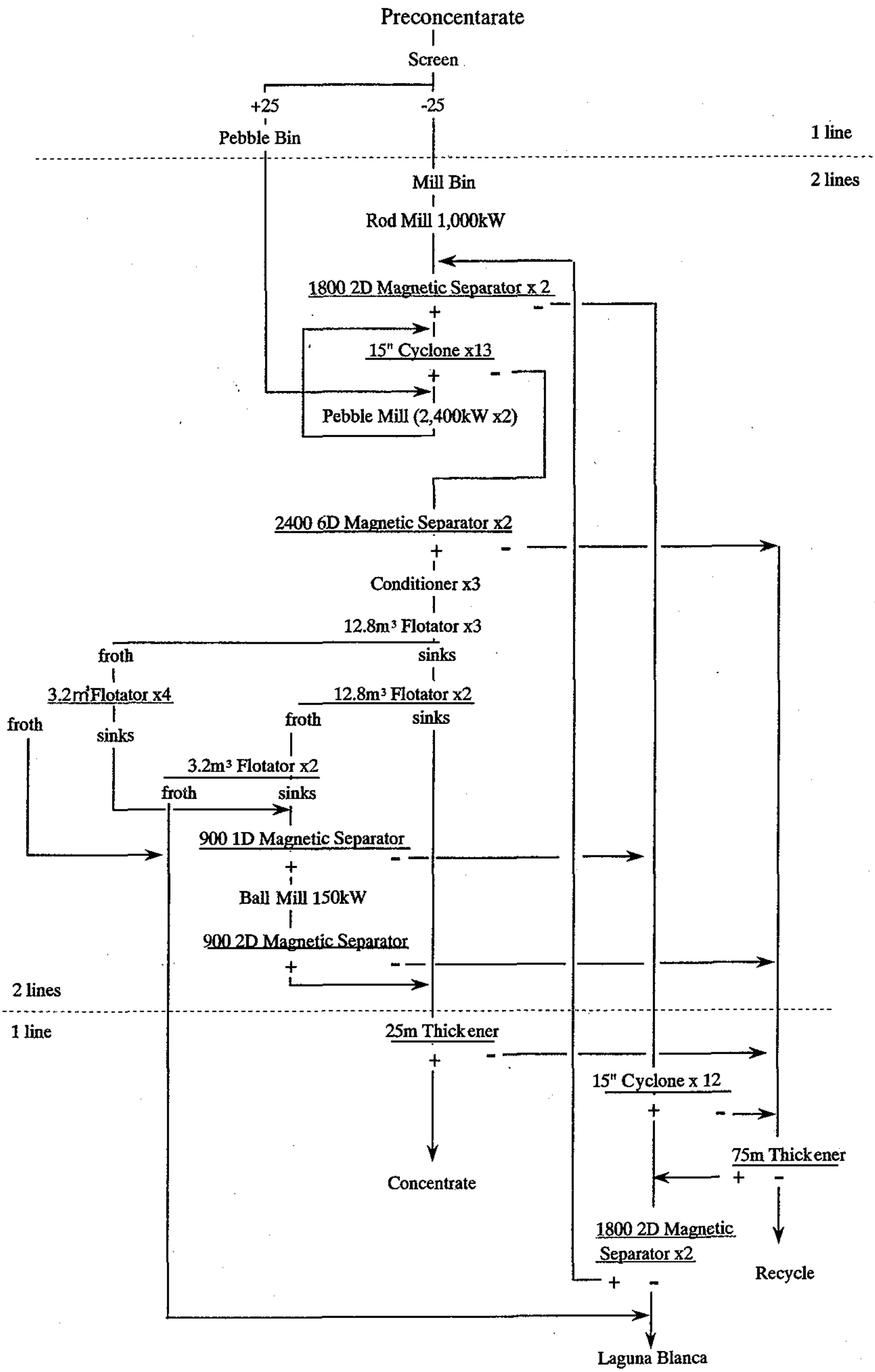


Figure-5 Flowsheet Operated by HIPASAM



2) Primary grinding and magnetic separation

Feed rate was normally 120 t/h. The rod mill ground the ore less than 1mm.

Primary magnetic separators are consisting of two two-drum separators. The preconcentrate of approximately 53% to 54% iron and 1.3% to 1.4% phosphorus was upgraded to 60 to 61% iron with 0.95 to 1% phsphorus.

3) Secondary grinding

The primary magnetic concentrate was pumped to a pump in closed circuit with the cyclone underflow recirculated to the pebble mill. Although feed rate of the pebble was not stable at all time depending on the quality of the ore, it was typically 18t/h. The product of secondary grinding was the cyclone overflow of 87～91% minus 44 microns.

4) Secondary magnetic separation

In the secondary magnetic separation, the concentrate was improved from 60～61% iron with 0.95～1% phosphorus to 67% iron with 0.45% phosphorus. The secondary magnetic concentrate was directed to the flotation circuit.

5) Floatation

To remove phosphorus, a flotation section was incorporated to float the apatite.

6) Regrinding circuit

The non-floated middlings from the cleaner cells were thin in pulp density. They were pumped to a magnetic separator. The densified magnetic materials flowed at 60～70% solids to a ball mill. The reground material was pumped to a three drum magnetic separator. The concentrate recovered on this separator joined the concentrate from flotation.

7) Concentrate thickening

The final concentrate averaging 68.57% iron with 0.137% phosphorus was fed to a 25m diameter concentrate thickener. The thickend concentrate went to the slurry pipeline system.

8) Tailing disposal

The tailing from the three control magnetic separators and the tailing of the flotation circuit were the general tailing of the concentrator that was pumped to the Laguna Blanca natural tailing pond.

(5) Concentrate transportation system

The underflow from the concnetrate thickner was transferred from the tanks to the 200mm inside diameter pipeline system in which it was pumped a total distance of 32.4 km to Punta Colorada.

There remains a supervisor of operation at concentrate transportation system from whom hearing of the actual operation could be made. Solids were withdrawn from the concentrate thickner with the density of 72～65% and diluted by water aiming 62% at the entrance of pump. Normal flow rate was 2.2 m/sec. but there was no problem of appying 1.2～2.5 m/sec..

4.2.3 Pelletizing plant

Analysis of past records are summarized as follows.

- Main reason for low annual production is low availability not low hourly production rate.
- Low quality could be attributed to rapid heating pattern with bursting.
- Many problems remained for long periods without solution as the plant could not reach final development stage because the many problems caused people an impossible task to improve the plant.

In other words, problems made new more problems.

(1) General description of the pelletizing plant

1) History of the plant

This plant was constructed from 1973 to 1978.

The guarantee test of the facilities and the performance test for capacity ware not carried out. Equipment list, technical specification, operation manual, etc. do not exist as final documents. Final construction work was completed by HIPASAM itself and production was started at the end of 1978 and continued to 1991.

2) Plant layout

a) Main production equipment

After receiving slurry, it is to be sent to 6 disc filters to be dewatered to reduce moisture to 9 to 10 %. The filter cake after being blended with bentonite and hydrated lime is charged to 4 drum-type-pelletizers to be agglomerated to green pellets.

The pellets are charged into 4 shaft pelletizing furnaces after being screened. Designed production capacity of the plant is 2.0 million-t product pellets per year (7,500 hours per year). After induration, pellets are screened for the removal of under size (under 5 mm) andthen sent to product yard.

(2) Availability

1) History of Furnaces

Basically 2 furnaces were operated except for the period when a just repaired furnace was restarted.

Two furnace operation continued to the end of project. No.3 furnace construction was completed in November, 1988. Longest operation was 18 month and average operation was about 10 months.

In **Table-50**, total operating hours and production for each year is shown.

Table-50 Production and furnace operating hours

	Production t/year	Shipping t/year	Furnace running hrs. h/year	t/h
1980	311,932	134,552	4,030	77
1981	326,303	303,184	4,842	67
1982	566,066	655,006	9,628	59
1983	520,822	596,090	9,008	58
1984	420,129	510,055	7,650	55
1985	509,429	513,749	10,369	49
1986	646,356	569,096	10,463	62
1987	464,660	438,858	9,360	50
1988	605,134	655,033	12,146	50
1989	591,899	659,117	11,722	50
1990	612,783	624,406	12,988	47

2) Analysis of stoppage

a) Cause of stoppage

In **Table-52**, cause of stoppage by month wise in 1989 is shown. Causes of big stoppage are almost the same in each of the 3 years. The followings are the major causes of stoppage.

- Trouble with belt conveyor
- Balling drum and scraper
- Trouble with shaft furnace
- Trouble with index feeder buggy
- Trouble with wiper bar
- Lack of concentrate
- Shut down by labour union
- Trouble with utilities

Table-52 Cause of stoppage by month in1989

		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
		%	%	%	%	%	%	%	%	%	%	%	%
1	Stock Tank for Concentrate	0.00	0.00	0.21	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.24	0.21
2	Thickner for Concentrate	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Slurry Pump and Piping	1.61	0.00	0.00	0.00	0.66	0.00	1.14	0.02	0.00	0.76	0.32	0.73
4	Vaccum Pump	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
5	Compressor for Disc Filter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Disc Filter	0.63	0.00	0.13	0.29	0.42	0.00	0.05	0.00	0.29	1.34	0.32	0.55
7	Dosing of Additives	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.04	0.15	0.28	0.00	0.00
8	Belt Conveyor	8.28	1.52	1.77	0.80	7.65	1.59	2.74	2.06	1.23	4.52	4.19	4.14
9	Blendig of Additives	0.50	0.00	2.19	2.47	0.00	0.00	0.12	66.05	0.16	3.94	0.00	0.12
10	Balling Bin and Feeder	0.05	0.01	0.00	0.25	0.26	0.00	0.13	0.00	0.04	0.09	0.00	0.85
11	Pelletizer and it's Scraper	1.66	1.85	0.44	0.12	2.09	0.15	0.62	0.87	0.74	8.77	2.74	0.69
12	Green Pellets Screen	10.44	0.60	1.29	2.67	4.78	4.12	2.67	0.12	8.09	14.92	5.64	1.82
13	Shaft Furnace Body (Spout and grout)	8.57	2.12	2.24	3.28	13.97	2.07	3.62	11.15	22.49	17.69	52.22	2.27
14	Charge Conveyor Buggy	17.82	3.90	2.86	3.29	17.77	3.07	4.55	2.22	2.85	8.80	2.58	4.23
15	Upper De-duster	2.90	0.96	0.06	0.00	1.05	0.00	0.00	0.38	0.74	0.12	0.14	1.30
16	Door for Dust Supression	1.85	4.51	1.30	0.72	16.79	1.67	0.00	0.48	0.20	2.90	0.42	0.03
17	Combustion Chamber	1.00	0.16	0.28	0.02	0.16	0.40	0.02	0.27	0.40	0.00	1.75	1.78
18	*Chunk Breaker*	0.88	0.20	0.00	0.00	1.29	0.05	0.15	0.00	0.00	0.55	24.81	0.21
19	Wiper Bar	9.54	2.51	6.65	2.10	19.73	2.74	7.73	0.83	2.30	11.07	2.25	1.92
20	Compressor (cooling and process)	2.18	0.08	1.02	0.59	1.85	0.13	0.09	0.03	0.00	0.12	0.44	1.78
21	Plant Air Compressor	2.41	0.01	0.00	0.03	0.00	0.03	0.00	0.04	0.00	0.39	1.48	0.28
22	Water Punp for Process and Sealing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Cooling Tower	0.00	0.00	0.04	0.09	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
24	Furnace Charge System of Fired Pellets	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.10	0.00	0.92	0.00	0.00
25	*Electrical Substation and Control Room*	0.54	0.09	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
26	Grindng System of Additives	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	Product and Shipping Screen	0.01	0.50	0.00	0.04	0.05	0.03	0.16	0.00	0.05	0.15	0.13	0.48
28	Lack of Material	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	Lack of Concentrate	27.53	29.77	68.57	58.49	7.71	83.64	39.45	15.17	60.21	0.00	0.00	24.23
30	Full of Product Yard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
31	Labour Union	0.00	48.12	10.90	24.73	0.00	0.00	36.65	0.00	0.00	22.13	0.00	51.62
32	*Troubles in Utility*	1.61	3.09	0.00	0.00	3.49	0.21	0.00	0.08	0.00	0.52	0.33	0.76
33	Others	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.04	0.06	0.00	0.00	0.00
	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

(3) Operation

1) Operation results

Average availability in 1989 was 62.3%. In September No.3 furnace was re-started after repair and best availability (83.0%) was shown in October. Average monthly production was 50 kilo-t and production in October was 73 kilo-t.

2) Operation control

a) Green pellets production control

In this plant moisture content in filter cake was too high and the water splay was impossible. This means that yield control and size control were not done with normal method and they ware adjusted by the change of balling material feed rate and additive (like as bentonite and lime hydrate) feed rate.

According to the change of concentrate property, dewatering result of disc filter would change and balling conditions would change resulting in the change of green pellets production because convinient moisture control was not possible according to the change.

b) Induration control

In this plant, there was no control measure of water spray and the change of concentrate property affected directly green pellets production. As a result, stacking level of burden in the furnace changed and the operator was adjusting the discharge rate from the furnace by changing movement of wiper bar. This means that excess or insufficient air was blown into furnace leading to excess or insufficient heat supply which generated low tumbler index, spout or bursting.

Control flow should be as shown in **Fig.-10**.

c) Heat balance (in shaft excluding cooler)

Main items of heat pattern are listed in Table-59 with comparison of other pant A.

Fig.-10 Required control flow

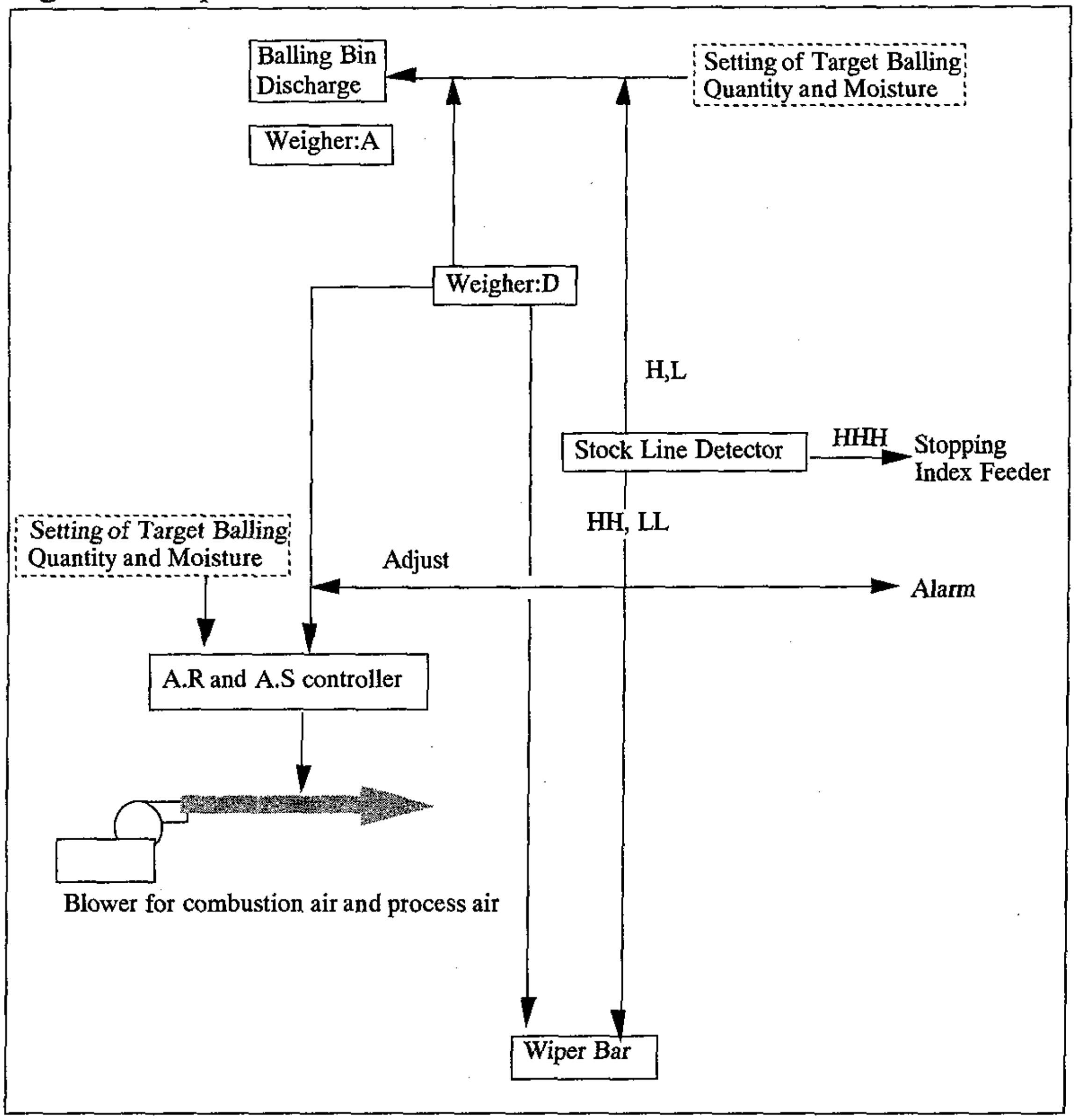


Table-59 Main index of furnace operation

Table- 59-1 Material (kg/kg-PP)

	HIPASAM	A
Concentrate	0.988	1.067
Bentonite(kg/kg-PP)	0.016	0.008
H.Lime	0.001	0.000
Dolomite	0.018	0.000
Silica	0.007	0.000
Total Material	1.029	1.075
Product Pellets	1.000	1.000
Fines	0.021	0.050
Dust	0.010	0.030
Others	0.017	0.017

Table- 59-2 Green pellets moisture

	HIPASAM	A
Moiture	11.0	9.4

Table- 59-3 Dimension of Furance

	HIPASAM	A
Width-Max(m)	2.4	2.1
Width-Min(m)	2.1	1.8
Length(m)	6.3	5.4
Area (m^2)	14.2	10.6

Table- 59-4 Heat source (kg/t-P.P.)

	HIPASAM	A
Fe3O4	865.98	933.87
N.Gas	19.29	0.00
Coal	0.00	6.00
Heavy oil	0.00	10.80

Table- 59-5 Operating condition

	HIPASAM	A
Product rate(t/h)	57.000	78.100
Air (kg-air / kg-PP)		
A.R. (kg-air / kg-PP)	1.080	0.850
A.S. (%)	41.000	30.000
A.R. (kg-air / kg-GP)	1.050	0.914

Table- 59-6 Base data for heat balance

	HIPASAM	A
Fe3O4(% in conc)	87.65	87.50
Fe3O4(%) in P.Pellets	5.10	1.66

Table- 59-7 Temp (℃)

	HIPASAM	A
Exhaust gas	280	180
Furnace out pellets	600	600
Firing temp	1370	1340?
Firing temperature level	200±50	400

Firing temp; ?=Estimation

Firing temperature level=(mm) from stacking level

Table- 59-8 Number of tuyers

	HIPASAM	A
Short side	4×2	10×2
long side	20×2	18×2

Table- 59-9 Gas balance (m^3/h)

	HIPASAM	A
Wsated(1) gas total	49152	50834
O2 partial pr in waste	13.20	14.58
Wsated(2) gas total	58170	61676
O2 partial pr in waste	11.16	12.01

Waste gas (1): excluding H2O from green pellets

Waste gas (2): inluding H2O from green pellets

Table- 59-10Heat balance (kcal /t-PP)

	HIPASAM	A
Input		
Hot gas	238761	107353
Fe3O4	102792	110850
Carbon	0	50634
Input Total	341553	268837
Out put		
Waste gas	106101	48976
Pellets	117355	113570
Cooling Water	702	702
De-composition	6291	545
Water evapolation	74491	65364
Output Total	304940	229158

Table- 54-11 Dscending of burden and ascending of waste gas(1)

	HIPASAM	A
Dscending (cm/min)	4.7	9.0*1
Ascending (cm/sec)	96.3	132.8*1
A/D	20.54	14.83*1

*1: Calcurated based the results of dscending speed, horizontal area and feed rate of furnace of HIPARSAM and feed rate and hrizontal area of furnace of A plant.

3) Quality control

a) Quality design

In the first two years after starting production fine was generated in great degree, compressive strength was low, tumbler index showed low value and Index of LTD showed low value with the blend of bentonite 7 kg/t-product pellets.

At the end of 1981, hydrated lime addition tests were done with the blending ratio 0.2 to 1.0 %.

By blending hydrated lime, compressive strength of green pellets and resistance against heat shock was increased but the requirement of increasing bentonite to 15 kg/t-product pellets occurred for keeping drop strength. But still the LTD index was low and finally the addition of quartzite and dolomite was done to improve LTD index. Pellets with blending of hydrated lime, quartzite, dolomite and bentonite was named No.219 and this pellets was produced to the end of the project.

b) Quality measurement for process

As for green pellets, moisture, drop number, compressive strength and heat resistance were measured 2 times per shift. Tumbler indexes lower than 90 % were shown frequently.

As for concentrate and product pellets, items for measurement and it's results are known from **Table-60** to **Table-62.**

c) Control method of tumbler strength

When low tumbler strength was shown, A.R. was increased for first step. When low tumbler strength was shown after the increase of A.R., then A.S. was increased.

Table-60 Quality measurement (concentrate sampled) for process

	Conc. Consump.	T.Fe	Fe++	Fe_3O_4	P	S	SiO_2	Al_2O_3	CaO	MgO	V_2O_5	TiO_2	Cr	Ni	Zn	Na_2O	K_2O
	t/month	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
1988-Ave	50,656	68.69	22.86	91.88	0.125	0.090	1.68	1.49	0.347	0.091	0.142	0.137	0.027	0.037	0.011	0.064	0.034
1989-01.	66,548	68.68	23.08	94.41	0.142	N.A	1.72	1.51	0.340	0.095	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1989-02.	33,851	68.56	23.00	94.08	0.137	N.A	1.84	1.56	0.356	0.118	0.158	N.A	0.038	0.026	0.011	0.052	0.026
1989-03.	41,774	68.59	22.86	94.00	0.134	N.A	1.83	1.54	0.345	0.109	N.A	N.A	N.A	N.A	N.A	0.066	0.041
1989-04.	35,907	68.80	22.95	94.10	0.142	N.A	1.83	1.55	0.354	0.106	N.A	N.A	N.A	N.A	N.A	0.057	0.039
1989-05.	66,943	68.50	23.16	94.68	0.145	N.A	1.72	1.57	0.336	0.098	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1989-06.	40,825	68.61	23.06	94.45	0.164	N.A	1.77	1.62	0.375	0.133	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1989-07.	42,743	68.69	23.17	95.26	0.139	N.A	1.80	1.61	0.340	0.114	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1989-08.	46,462	68.66	23.43	93.43	0.137	N.A	1.75	1.61	0.328	0.112	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1989-09.	44,306	68.62	23.19	93.19	0.128	N.A	1.75	1.63	0.337	0.1	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1989-10.	72,844	68.94	22.94	92.11	0.121	N.A	1.56	1.55	0.277	0.082	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1989-11.	48,385	68.57	22.94	91.70	0.117	N.A	1.57	1.49	0.298	0.118	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1989-12.	54,549	68.70	23.03	93.32	0.111	0.074	1.71	1.48	0.278	0.094	N.A	N.A	N.A	N.A	N.A	0.054	0.030
1989-Ave	49,595	68.67	23.07	93.67	0.134	N.A	1.72	1.56	0.326	0.104	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1990-Ave	48,160	68.88	22.70	92.72	0.131	N.A	1.59	1.55	0.314	0.096	N.A	N.A	N.A	N.A	N.A	N.A	N.A

Table-61 Quality measurement (physical property of product pellets) for process control

	Produc - tion	Tumbler Test			Comp.Streng.		Size Distribution				RDI (JIS)				LTD (ISO)			Reduction Test(JIS)			RUL (ISO)		Swelling		Porosity
	t/month	T.Ind.	A.Ind.	-6.35 mm	Ave	-80 kg	+19 mm	19-8 mm	-4.75 mm	Ave	+9.5 mm	+6.3 mm	+3.15 mm	-0.5 mm	+6.3 mm	+3.15 mm	-0.5 mm	Red. 180	CSAR	dR / dt	Red. 80	dR / dt	Swell	Red.	
		%	%	%	kg/P	%	%	%	%	mm	%	%	%	%	%	%	%	%	kg/P	%/min	%	%/min	%	%	%
1988-Ave	49,761	92.1	5.4	6.8	280	2.1	3.3	85.8	4.2	12.2	72.3	81.1	87.8	8.6	59.6	69.1	19.1	59.5	65.0	0.299	65.9	0.830	20.9	64.7	20.5
1989-01.	64,777	91.1	5.8	8.9	267	3.4	4.8	81.1	5.9	11.9	71.2	81.2	88.1	8.2	50.0	62.3	22.1	58.2	58.7	0.286	N.A	N.A	20.8	68.6	22.0
1989-02.	35,257	91.0	6.1	7.3	257	6.9	3.9	84.7	4.1	12.0	69.5	78.9	86.0	9.5	53.8	66.8	19.4	60.9	64.7	0.302	N.A	N.A	23.7	60.4	21.7
1989-03.	42,157	92.2	5.6	5.9	295	3.2	3.7	87.1	3.8	12.4	75.7	82.6	87.5	9.3	67.6	75.6	16.0	59.9	67.1	0.305	N.A	N.A	19.2	68.3	21.6
1989-04.	33,866	91.7	6.0	6.4	306	2.5	4.3	86.3	4.1	12.6	76.2	83.3	88.6	8.8	46.2	57.8	27.0	58.5	61.0	0.293	N.A	N.A	21.4	63.9	21.1
1989-05.	65,751	91.6	5.7	7.4	282	3.1	4.4	84.6	4.7	12.5	71.0	80.4	87.6	8.3	54.7	63.7	22.4	58.0	61.1	0.287	N.A	N.A	24.3	62.9	20.8
1989-06.	38,936	91.3	6.1	6.6	280	3.1	3.8	87.1	4.3	12.9	75.8	82.2	88.4	7.9	53.4	64.8	22.5	59.1	53.7	0.307	N.A	N.A	21.0	60.7	20.6
1989-07.	42,325	91.6	5.9	5.9	271	2.5	2.9	87.8	3.6	12.4	72.9	82.3	88.3	8.0	60.5	68.3	20.6	59.0	50.7	0.290	N.A	N.A	22.7	70.9	21.6
1989-08.	43,418	92.0	5.7	7.0	253	3.8	2.0	87.4	4.1	11.6	76.5	83.8	88.7	8.2	72.5	78.7	13.9	60.8	71.6	0.296	N.A	N.A	19.4	65.8	22.0
1989-09.	45,124	91.8	6.0	6.1	244	3.6	1.9	86.8	3.5	11.5	79.2	86.1	90.0	7.3	72.7	78.5	13.6	59.7	46.1	0.279	N.A	N.A	20.1	64.0	21.6
1989-10.	72,704	91.5	6.2	8.1	265	5.7	3.3	85.4	4.9	11.9	81.0	86.7	90.3	7.7	63.2	73.8	16.1	60.0	52.9	0.301	N.A	N.A	20.6	62.9	20.8
1989-11.	49,507	90.3	7.3	9.9	298	5.1	4.6	81.2	6.9	12.6	79.7	85.2	88.9	8.7	65.4	73.8	18.0	61.3	52.9	0.297	N.A	N.A	17.3	65.5	21.1
1989-12.	57,960	90.3	6.9	8.5	277	6.0	3.8	85.5	5.0	12.5	79.4	85.8	89.4	7.7	61.9	72.2	16.1	66.3	50.3	0.351	N.A	N.A	21.7	58.1	21.4
1989-Ave	49,329	91.3	6.1	7.5	274	4.1	3.0	85.2	4.7	12.2	75.8	83.4	88.6	8.2	60.2	69.8	18.8	60.2	57.1	0.300	N.A	N.A	21.0	64.3	21.3
1990-Ave	51,050	90.2	6.8	6.5	275	4.1	7.2	83.9	4.0	13.5	68.0	77.8	85.1	10.7	44.5	55.8	29.0	66.5	54.9	0.346	N.A	N.A	23.2	69.0	21.6

Table-62 Quality measurement (chemistry of product pellets) for process control

	Produc -tion	T.Fe	Fe++	P	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	S	V_2O_5	TiO_2	Cr	Ni	Zn	Basicity	
	t/month	%	%	%	kg/P	%	%	%	%	mm	%	%	%	%	%	%	Bin.	Quat.
1988-Ave	49,761	65.19	1.28	0.104	3.17	1.77	0.85	0.36	0.077	0.051	0.0054	0.155	0.121	0.031	0.040	0.010	0.268	0.245
1989-01.	64,777	65.07	1.18	0.104	3.34	1.83	0.94	0.45	0.075	0.051	0.0054	0.189					0.281	0.269
1989-02.	35,257	64.97	1.33	0.120	3.27	1.88	0.99	0.47	0.066	0.044	0.0050	0.136					0.303	0.283
1989-03.	42,157	65.14	1.21	0.116	3.24	1.81	0.87	0.44	0.075	0.057							0.269	0.259
1989-04.	33,866	65.06	1.17	0.110	3.22	1.85	0.86	0.44	0.072	0.060							0.267	0.256
1989-05.	65,751	65.08	1.13	0.115	3.15	1.82	0.87	0.40			0.0043						0.276	0.256
1989-06.	38,936	65.05	1.12	0.127	3.33	1.79	1.00	0.43			0.0029						0.300	0.279
1989-07.	42,325	65.04	1.14	0.113	3.35	1.84	0.96	0.46			0.0032						0.287	0.274
1989-08.	43,418	65.15	1.11	0.113	3.20	1.85	0.89	0.46									0.278	0.267
1989-09.	45,124	65.04	1.06	0.113	3.23	1.80	0.86	0.48			0.0040						0.266	0.266
1989-10.	72,704	65.27	1.06	0.104	3.11	1.76	0.83	0.47									0.267	0.267
1989-11.	49,507	65.20	1.21	0.104	3.17	1.69	0.84	0.51			0.0040						0.265	0.278
1989-12.	57,960	65.22	1.22	0.104	3.20	1.67	0.82	0.46	0.068	0.057	0.0080						0.256	0.263
1989-Ave	49,329	65.12	1.16	0.111	3.23	1.79	0.89	0.45	0.071	0.054	0.0046	0.163		0.035	0.029	0.011	0.276	0.267
1990-Ave	51,050	65.14	1.25	0.114	3.15	1.77	0.86	0.49	0.064	0.050	0.0043						0.273	0.274

4.3 PRODUCTION MANAGEMENT

4.3.1 Iron ore mines

Mining Division consisted of 6 departments of Production, Preparation, Services, Geology, Planning and Maintenance. Each department is further divided into 2~3 sections in accordance with contents of work.

Mining work was carried out on 3 shift basis including maintenance. The time spent at work was 8 hours per day (actual working hours; 5.8 hours) and average working days per month was 20.8 days.

4.3.2 Iron ore concentration plant

(1) Production control

Production was controlled by annual production plan.

Chemical analysis and size distribution analysis were executed at each shift day by day.

(2) Standardization

Operation manual existed, however, actual operation seemed not to coincide with the instruction described in it.

(3) Organization

Concentration plant was divided to 3 sectors, i.e., process, operation and maintenance. Operation further divided to pre-concentration, concentration and concentrate transportation pipeline. Preconcentrate and concentrate sections were operated in 3 crew 3 shift basis, where concentrate transportation pipeline section was operated in 4 crew 3 shift basis.

4.3.3 Pelletizing plant

(1) Production control

Production plan was made due to the annual consumption fore cast of ex-SOMISA, only one customer for HIPASAM.

(2) Standardization

There are no final documents of the plant and no operational manual for the plant. Chiefs from each group held morning meeting, judged pant conditions after analyzing plant conditions and made workin order in the form of documents if there was abnormal conditions to rectify it.

(3) Organization in the plant

Total persons number was 221 (209 of HIPASAM employee + 12 of contractor).

Usual repair work (excluding large scale fabrication) was done within the organization.

4.4 RECORDS OF AMOUNT

4.4.1 Iron ore mines

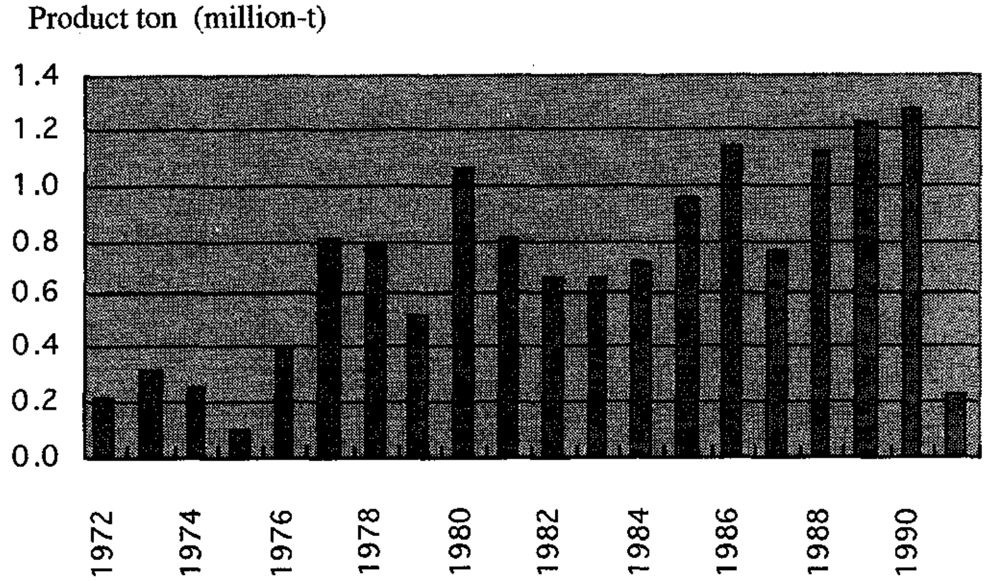
(1) Production amounts

Graph-16 shows a trend of production when HIPASAM started operation.

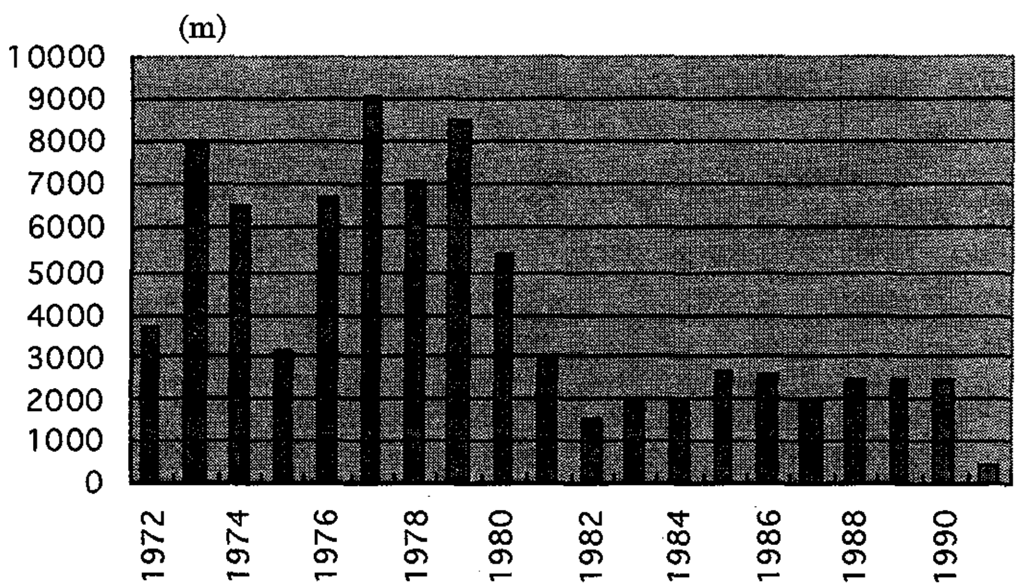
(2) Drifting

Graph-17 shows the trend of drifting length when HIPASAM started operation.

Graph-16 Trend of Production



Graph-17 Trend of Drifting



(Source:HIPARSA)

4.4.2 Iron ore concentration plant

Records on amount and quality of products of ex-HIPASM are shown in **Table-64** and **65.**

Table-64 Transition of yearly production in Preconcentration Plant

Year	Crude Ore	Preconcentrate		Waste
	t	t	Wt.%	t
1980	742,944	518,349	69.77	224,595
1981	656,574	481,900	73.4	174,674
1982	1,160,180	832,883	71.79	327,297
1983	1,138,024	776,734	68.25	361,290
1984	909,206	615,542	67.7	293,664
1985	1,041,807	732,337	70.29	309,470
1986	1,481,960	1,085,361	73.24	396,599
1987	1,061,893	759,271	71.5	302,622
1988	1,345,994	987,243	73.35	358,751
1989	1,274,420	941,266	73.86	333,154
1990	1,292,531	885,773	68.53	406,758
Total	12,105,533	8,616,659	71.18	3,488,874

Table-65 Transition of yearly production in Concentration Plant

Year	Preconcentrated Feed			Concentrate			Tails		
	t	% Fe	% P	t	% Fe	% P	t	% Fe	% P
1980	506,719	54.31	1.332	337,519	68.43	0.145	169,200	26.13	3.700
1981	478,690	53.75	1.361	296,884	68.41	0.143	181,806	29.82	3.350
1982	867,743	53.97	1.396	523,644	68.73	0.139	344,099	31.52	3.308
1983	790,941	54.16	1.355	496,652	68.52	0.136	294,289	29.93	3.411
1984	630,107	53.10	1.328	394,720	68.42	0.134	235,387	27.41	3.329
1985	740,711	53.23	1.330	463,821	68.28	0.149	276,890	28.01	3.309
1986	1,069,074	53.29	1.293	650,794	68.43	0.140	418,280	29.73	3.086
1987	772,597	53.08	1.306	450,476	68.66	0.138	322,121	31.29	2.939
1988	963,878	52.66	1.304	585,177	68.66	0.126	378,701	27.93	3.124
1989	954,082	52.62	1.342	567,539	68.65	0.135	386,543	29.09	3.115
1990	927,096	53.54	1.298	568,488	68.87	0.133	358,608	29.24	3.146
Total	8,701,638	53.37	1.329	5,335,714	68.57	0.137	3,365,924	29.27	3.218

(Both Source: HIPARSA)

4.4.3 Pelletizing Plant

Table-67 and **Table-68** show the annual shipping results 1988-1990 and monthly shipping results in 1989.

Table-67 and Table-68 張り付け

Table-67 Physical Property of pellets (for Shipping)

	Shipping	Tumbler Test		Comp.Streng.		Size Distribution						Reduction Test(JIS)			Swelling	Porosity	Moist.
		T.Ind.	A.Ind.	Ave	-80 kg	+19 mm	19-8 mm	-4.75 mm	Ave	+6.3 mm	-0.5 mm	Red.	CSAR	dR / dt	Swell		
	t/month	%	%	kg/P	%	%	%	%	mm	%	%	%	kg/P	%/min	%	%	%
1988-Ave	54586	92.4	5.4	281	2.0	3.5	86.3	5.0	12.6	81.4	9.0	59.1	68.0	0.294	19.9	20.3	2.38
1989-01.	82509	91.4	6.0	270	2.5	4.3	84.7	5.8	12.6	82.0	10.2	59.6	57.8	0.301	20.6	21.6	2.46
1989-02.	44509	92.2	5.9	270	1.3	4.5	82.6	7.0	12.2	77.2	11.7	60.6	61.9	0.299	23.0	21.6	2.29
1989-03.	70494	92.4	5.6	269	5.6	4.0	86.8	4.9	12.6	82.6	6.8	61.9	57.1	0.310	22.9	21.5	2.48
1989-04.	19170	92.5	5.5	315	3.0	6.7	84.5	6.6	13.4	84.0	10.1	59.7	55.9	0.285	21.5	19.9	2.45
1989-05.	38293	92.3	5.6	286	1.6	3.8	85.4	5.7	12.7	77.6	10.4	57.1	55.2	0.277	19.8	21.0	2.57
1989-06.	66952	92.1	5.7	282	2.6	4.4	86.8	4.7	13.1	84.6	8.0	58.5	56.1	0.287	22.9	20.9	2.38
1989-07.	53764	91.9	6.0	280	2.0	4.0	89.0	4.3	12.9	81.3	8.9	54.5	54.6	0.245	21.0	21.2	2.55
1989-08.	39840	92.9	5.0	260	3.0	3.2	88.1	4.5	12.5	87.5	5.9	61.3	50.5	0.303	21.7	20.5	2.66
1989-09.	73130	92.4	5.4	259	3.0	3.6	85.1	4.8	11.8	91.4	6.0	59.9	50.5	0.287	21.5	21.7	2.88
1989-10.	58600	92.8	5.4	270	3.4	4.0	84.4	5.9	12.0	88.6	7.4	59.7	52.5	0.300	21.8	20.7	2.58
1989-11.	56039	91.7	6.4	284	4.3	4.6	84.4	6.3	12.4	89.7	7.2	61.8	47.6	0.300	22.2	21.7	2.58
1989-12.	55823	91.7	6.2	302	2.1	3.7	83.0	7.6	12.2	83.0	8.7	64.2	52.0	0.310	21.7	20.6	2.06
1989-Ave	54927	92.1	5.8	276	3.0	4.1	85.4	5.6	12.5	84.5	8.3	60.0	54.3	0.293	21.8	21.2	2.50
1990-Ave	52034	91.2	6.4	269	2.9	5.6	83.0	6.2	13.1	76.0	11.4	65.9	53.5	0.333	22.5	21.2	2.17

Table-68 Chemistry of pellets (shipping analysis)

	Production	T.Fe	P	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	S	Basicity	
	t/month	%	%	kg/P	%	%	%	%	mm	%	Bin.	Quat.
1988-Ave	54586	65.28	0.103	3.22	1.77	0.835	0.34	0.071	0.057	0.0044	0.259	0.236
1989-01.	82509	65.08	0.107	3.20	1.89	0.874	0.44	0.068	0.044	0.0039	0.273	0.258
1989-02.	44509	65.17	0.119	3.33	1.86	0.942	0.44	0.075	0.051	0.0046	0.283	0.266
1989-03.	70494	64.91	0.116	3.28	1.82	0.903	0.44	0.074	0.055	0.0043	0.275	0.262
1989-04.	19170	64.82	0.128	3.26	1.69	0.970	0.47	0.080	0.070	0.0046	0.298	0.290
1989-05.	38293	64.91	0.112	3.20	1.78	0.865	0.38	0.073	0.057	0.0059	0.270	0.250
1989-06.	66952	65.00	0.122	3.36	1.77	0.956	0.41	0.067	0.055	0.0042	0.285	0.266
1989-07.	53764	65.00	0.124	3.25	1.83	0.943	0.46	0.071	0.047	0.0026	0.290	0.276
1989-08.	39840	65.07	0.121	3.07	1.78	0.934	0.48	0.071	0.050	0.0036	0.304	0.291
1989-09.	73130	65.01	0.116	3.17	1.86	0.888	0.46	0.074	0.049	0.0043	0.280	0.269
1989-10.	58600	65.22	0.106	3.17	1.72	0.812	0.47	0.070	0.048	0.0040	0.256	0.262
1989-11.	56039	65.18	0.109	3.09	1.74	0.818	0.48	0.068	0.047	0.0044	0.265	0.269
1989-12.	55823	65.19	0.100	3.21	1.68	0.827	0.48	0.061	0.050	0.0052	0.258	0.268
1989-Ave	54927	65.06	0.114	3.22	1.80	0.889	0.45	0.070	0.051	0.0043	0.276	0.267
1990-Ave	52034	65.13	0.114	3.11	1.75	0.861	0.48	0.067	0.048	0.0047	0.277	0.276

Chapter 5

RECENT SITUATION OF HIPARSA

Since May 1991, mine has been operating intermittently to supply iron ore to domestic cement manufacturers and iron ore dressing plant and iron ore pelletizing plant have never been operated.

However, all the equipment and facilities of the mine, iron ore dressing plant and iron ore pelletizing plant have been keeping under careful maintenance of HIPARSA maintenance people.

In this chapter, equipment and facilities condition of HIPARSA at the time of 1998 is explained.

5.1 FACILITIES AND PLANTS

5.1.1 Ore deposit

Sierra Grande iron ore deposit consists of four deposits of the south, the east, the north and the La Negra. HIPARSA has the mining right of the south and the east deposit in 1998.

Ore reserves of all four deposits are shown in **Table-70** and the ore reserve of the south deposit by depth is shown in **Table-71**.

Table-70 Ore Reserves of Deposits

(Unit : kilo-t)

Item		South	East	North	La Negra
Proved Reserves		90,535	----------	----------	N/A
Probable Reserves		38,348	----------	11,300	N/A
Possible Reserves		72,260	30,000～40,000	20,000	N/A
Total		201,143	30,000～40,000	31,300	N/A
Grade	Fe(%)	54.80	56.03	54.60	N/A
	P(%)	1.43	1.15	----------	N/A

Table-71 Ore Reserves of South Deposit

(Unit : kilo-t)

Item	Proved Reserves	Probable Reserves	Possible Reserves	Total
Surface～410ML	41,809	781	346	42,936
410ML～620ML	42,563	3,445	5,438	51,446
620ML～830ML	6,163	21,156	33,171	60,490
830ML～920ML	--------	12,966	33,305	46,271
Total	90,535	38,348	72,260	201,143

5.1.2 Iron ore mines and facilities

(1) Iron ore mines

Since stopping operation of the mines in 1991 periodical inspection by patrol has been executed until today. Rock fall or loose rock of roof or wall is properly eliminated so that drifts are well maintained. Remarkably rock falls are not observed on both the hanging and foot wall of the ore block already developed. Drifting was partially carried out to the level of 340ML and the situation of development at the time when operation of HIPARSA ceased is as follows.

200ML～270ML

When HIPARSA decided to stop operation work on this ore block was in progress. Estimated reserves of minable ore is 3,180 kilo-t. Fan-shaped drilling is completed with 2,560 kilo-t and remaining reserves of minable ore is 620 kilo-t.

270ML～340ML

When HIPARSA decided to stop operation about 82% of the preparation work was already executed. Estimated reserves of minable ore of this ore block is approximately 12,000 kilo-t. No fan-shaped drilling is carried out so far.

340ML under

Below this 340ML level there exists only incline and central shaft. Future development will be carried out from this drift.

(2) Facilities and equipment

1) Underground mobile equipment

Underground mobile equipment and their conditions presently possessed by HIPARSA are shown in **Table-72.**

Cylinders and pistons for drifter or cylinder and engine and other movable parts of oil-hydraulic systems have not been maintaining since stopping operation of HIPARSA. It means that the re-use of the jumbos would be very difficult.

Climbers used for raising of ore pass are placed at the face developed at the time of stopping operation of HIPARSA. These jumbos seemed to re-start by proper tuning up of air motor and other parts.

2) Stationary equipment

Stationary equipment of the mine is periodically maintained by the maintenance employees of HIPARSA.

Major stationary equipment is shown in **Table-73**.

Table-72 Underground Mobile Equipment in 1998

Item	Manufacture	Model	Quantity	Installation year	Condition
Jumbo	Tamrock	Paramatic, 2 Booms	2	1972, 1978	Kept under the roof
	Tamrock	Minimatic, 2 Booms	2	1978	No maintaining
	Atlas Copco	565 2Booms	1	1972	
Fan Drill Jumbo	Garader-Demler	Mark II	5	1975	Kept under the roof
	Tamrock	Twinring A605 RR	1	1988	No maintaining
	Tamrock	Duo A605 RS	1	1988	
	Atlas Copco	Promec	1	1975	
Climber	Alimak	STH-5L	3	1975	Place at the face
Front-end Loader	Caterpillar	980B, 3.4m³	2	1975	On use
	Caterpillar	980C, 3.4m³	2	1986	
	Caterpillar	950 , 3.4m³	1	1975	
LHD	GHH	LF-7.1 3.8m³	1	1979	On use
	Toro	350 BD 3.8m³	2	1985	
	Wagner	ST-6C 4.1m³	2	1970	
Truck	kiruna	K 500 40t	2	1975	On use(kiruna)
	GHH	MK V40.1 42t	4	1978	Kept under the roof No maintaining (GHH)

Table-73 Stationary equipment in 1998

Item	Specification	Quantity	Remarks
No.1 cr	Jaw Crusher, 800t/h, 300kW,	2	Crushing Plant:1 410ML:1
Skip	800t/h, 220kW Hoisting speed: 6m/sec.	1	Cycle time: 90sec.
Cage	60persons, 220kW Hoisting speed: 6m/sec.	1	
No.2 cr	Cone Crusher, 400t/h, 300kW	2	
Stacker	800t/h,	1	Stockpile capacity 90,000t

5.1.3 Iron ore concentration plant

Equipment and facilities of the iron ore concentration plant are maintained in good condition. At present there are no experienced operational staff except maintenance personel in HIPARSA and precious experiences of operational techniques and skills of the past 10 years operation are lost.

(1) Preconcentration plant

The preconcentration plant is operating intermittently for supply of iron ore preconcentrate to the cement factory. There exists operational data from February 1996. 2 lines out of 3 lines are well maintained and immediate operation could be possible.

However, 2 line only operation seems insufficient if 2,600,000t per year crude ore shall be treated and 3 line operation deems necessary. Secondary magnetic separeator, screen and cone crusher are needed maintenance at No. 1 line. There is no stock of spare parts.

(2) Concentration plant

There are 3 lines of almost the same equipment in the concentration plant. It appears that No.1 and No.2 line are well maintained except slurry pump. Problem of these 2 lines are same to the pre-concentration plant as there is no stock of spare parts and consumables. Repair of No.3 line seems not necessary as 2 line operation is sufficient to produce 1,100,000t per year of concentrate.

(3) Facilities for tailing disposal

Mechanism of tailing thickener was disassembled and maintained as it is now. There is a need of repair, maintenance and assemble work. 15 inch cyclones for primary magnetic separation tailing installed prior to the tailing thickener were removed. These shall be re-installed.

(4) Facilities for thickening and transportation pipeline of concentrate

It seemed that there will be no serious problems regarding the facilities for concentrate transportation as the maintenance condition of those facilities appears good. but there are no spare parts and consumables.

(5) Laboratory

There were problems at HIPARSA laboratory, such as shortage of laboratory equipment, etc.

5.1.4 Pelletizing plant

(1) Equipment

All facilities or equipment can be operated with usual maintenance work (such as cleaning, lubrication and centering) and do not require large repairs with the exception of the refractory in the furnace, index conveyor and product screen but there is much equipment which requires modification which should be done at the initial stage of commercial production after construction and guarantee test.

(2) Estimation of the time to re-start (without modification work)

It is reported that the required man-month total is estimated to be 300 man-month.

(3) Manpower

Only 3 engineers are working at present and almost manpower must be hired before the re-start.

5.1.5 Shipment facilities

(1) Equipment conditions

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 through Sierra Grande in Rio Negro Province.

(2) Railway

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 is in Viedma and Trelew.

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. 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%

(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.

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 unit consumption for the Pelletizing plant occupies about a half of the power unit consumption for the whole complex.

(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.

Table-80 Power demand of the second industrial area

	Actual demand of existing p.		HBI Plant (130 kWh/HBI-t)				Total	
Production	600 kt/year (MW)	1100 kt/year (MW)	600kt/year (7500h/year)		750kt/y (7500h/year)		Pellet: 1100kt/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.

The first industrial area has two gas-turbine generators (16 MW each) and three diesel- engine generators (350 kVA) for emergency power. 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.).

The water supply capacity is as low as 112 liters/sec. in total.

(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

It is US$ 0.096/m^3.

(4) Water quality

pH of both springs is 7.0, neutral.

(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.

Table-81 Water consumption in the passed five years

		1985	1986	1987	1988	1989	1990
Water consumption of each shop (m^3/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 (m^3/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

(6) Details of water consumption in the concentration plant

To save water the water for transporting slurry may be neutralized and its 70% may be used in the plant but it will be 14 liters/sec. at most.

(7) Water balance

The water quantity supplied from the springs is fairly stable at 112 liters/sec. in total. To resume operation therefore it is necessary to open up the prospect of securing the required larger quantity of industrial water.

(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.

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.

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.

(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 (Nm³/pellet ton)
	(Nm³ / concentration ton)	(Nm³ / 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.

(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. 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.

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)		2000 kilo-/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

Unit cost of natural gas is US$0.062179/$m^3$.

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

HIPARSA uses 9,700 kcal/m^3 as the calorific value. It mainly consists of 90 % CH_4 and 5% C_2H_6.

5.3 MAINTENANCE ACTIVITIES OF HIPARSA

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

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.

5.3.2 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.

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.

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.

Chapter 6

APPLICABLE TECHNOLOGY, FACILITIES AND UTILITIES FOR HIPARSA REACTIVATION

6.1 STUDY OF ECONOMICAL MINING METHODS

(1) General

Operation results showed the rather low productivity of 190 t/man-month for the mining division.

(2) Production capacity

1) General

The following four major factors are considered to be the deciding factor for production capacity by omitting external factors.

a) Number of the faces and the production capacity of each face made at each sub level.

b) Secondary transportation capacity for transportation of excavated ores from each face to No.1 crusher.

c) Production capacity of No.1 crusher which crushes excavated ores to minus 300 mm.

d) Tertiary transportation capacity to transport primary crushed ores from skip to the ground.

2) Production capacity of a face and number of faces

Generally speaking, stoping work is consists of drilling, charging and blasting, loading and transportation. The percentage of each item of work differs by the stoping method.

At HIPASAM fan-shaped drilling was carried out in advance on several sub level from the sub level where charging and blasting and loading and transportation work was being executed. Therefore production capacity was decided by the volume of excavated ore per round and loading capacity after blasting and a target volume was dependent upon the number of faces made at the ore block.

Productivity of each face was decided by the spacing distance of fan-shaped drilling and 2 spacing distances were blasted simultaneously at HIPASAM. Production volume at one blasting was as follows:

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

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

The transportation efficiency of LHD of 1,000 t/shift was employed.

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 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.

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

Average transportation capacity is estimated to be 400~500 t per shift per one truck.

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 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. 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.

(3) Underground mobile equipment

1) Fan drill jumbo

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

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.

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.

6.2 STUDY OF ECONOMICAL MINERAL DRESSING PROCESS

6.2.1 Countermeasures tried or proposed in the past

(1) Reagents for flotation

(2) Fine grinding for liberation of magnetite and apatite

(3) 10 inch cyclones instead of 15 inch cyclones

(4) Trials on magnetic separation

(5) Conversion of pebble mills to ball mills

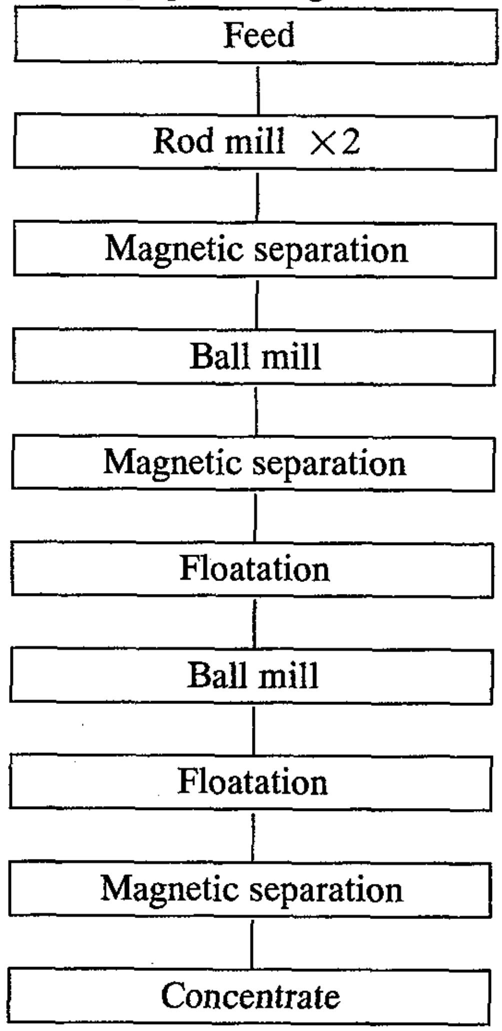
6.2.2 Other important countermeasures

(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.

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



(2) Closed circuit grinding with sieve bends

(3) De-sliming by hydraulic concentrator

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

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

(3) Too big pebble mills

6.2.4 Operation test plan for two stage processing

6.2.5 Past records of grinding mills

Estimated operation condition of the rod mill is shown in **Table-90** referring those data obtained from HIPARSA.

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 2,600,000t/year and 1,100,000t/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.

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

(2) Two stage processing at Sierra Grande

An estimated power consumption of the existing pebble mill is 2,064 kW. It is only 43% of the power installed of 4,800 kW.

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.

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

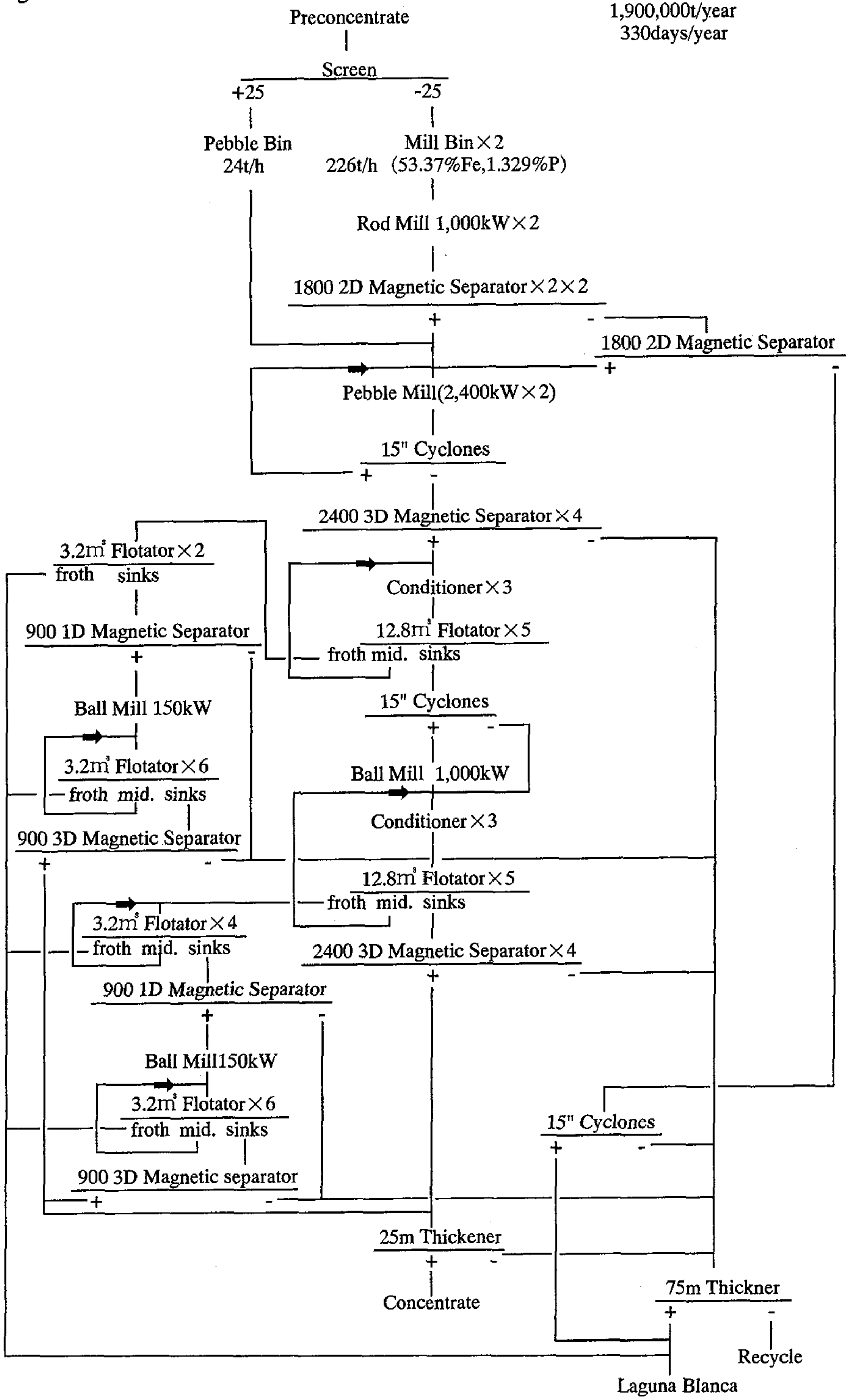


Table-92 Grinding mill performance expected

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.

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.**

INTEMIN analysis data of size distribution, phosphorus % and Fe % of final concentrate were employed for all the test.

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

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-96.**

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.

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

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.

(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 size at first stage is already too fine at two stage processing of Sierra Grandeis the problem. Test 6 is a typical two stage processingand Test 10 is a laboratory test corresponding to two stage processing of Sierra Grande. 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. 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.

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.

(2) Physical properties of concentrate

HIPASAM ore has high content of ultra fine material. It indicates low efficiency in the filtering process for dewatering. Generally the coarse grain has low oxidizing speed.

(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.

All these phenomenon cause chunk formation.

(4) Low availability

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.

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.

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.

(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
(D) fluctuation of green pellets-stock-level

3) Chunk formation

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.

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

6.3.2 Pot grate tests

Table-104 shows test results.

Conclusion is;

- 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%.

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

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. 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.

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

(2) Simulation result

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

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

3) Consideration from 2 dimensions

(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.

6.3.4 Required improvement

Required improvement can be summarized as follows.

1) Completion of rectifying equipment condition to decrease stoppage.

2) Reduction of green pellets moisture to prevent bursting and for good balling with low under size pellets and stable green pellets production to keep stock level constant.

3) Change of indurstion control to avoid bursting and chunk formation.

4) Modification of index conveyor to stack green pellets evenly for homogeneous indurating and to decrease stoppage due to the trouble of index conveyor.

5) Structure modification of hot gas duct to decrease long stoppage required for grout.

6.3.5 Forecast of operation

(1) Period of operation of furnaces

It can be assumed that 16 months could be the period for one operation, time from furnace start up to end, which will be decided by the requirement for partial brick re-lining. Whole bricks are reported to be re-lined every 7 years in other plants.

(2) Operation mode of 4 furnaces

To produce 1.1 million-t/year, 3 furnaces with 62 t/h of production rate for each are to be operated simultaneously and the other furnace is to be under stand-by. This means that it is possible to produce 1.1 million-t/year with 3 furnaces operating and 1 furnace being relined partially with brick during 4 months.

(3) Operating hour/year

Precise estimation of operation hour with a margin for the study is shown in **Table-107**.

(4) Production rate

It will be possible to produce pellets at 62 t/h.

(5) DR pellets or BF pellets

Which pellets will be produced has not been decided. Blending shown in **Table-108** will be investigated for the study and chemistry is estimated when concentrates with 68.7% Fe and 70% Fe. For the pelletizing study, unit consumption of energy is calculated with the premise that concentrate with Fe 68.7% would be used.

Table-107 Estimation of operation time for the study

Item No.	Items for time	h/year*3	%*3	h/year*5	%*5
1	Available hour for production	7509.8	85.7	6077.8	69.4
2	Stoppage due to Initial stage trouble	128.6	1.5	128.6	1.5
3	Stoppage due to Control system trouble	13.6	0.2	13.6	0.2
4	Stoppage due to peculiar cause for this plant	100.0	1.1	100.0	1.1
5	Stoppage due to the cause of "out of control"				
6	Stoppage due to special cause*4			1000.0	11.4
7	Minor scheduled shut down	288.0	3.3	576.0	6.6
8	Major scheduled shut down	480.0	5.5	480.0	5.5
9	Operating time loss for cooling down and heating before and after scheduled shut down	240.0	2.7	384.0	4.4
10	Total	8760.0	100.0	8760.0	100.0

*3: Refer to Table-101

*4: arrival delay of spare parts, delay of fabrication, etc.

*5: Time distribution for production plan in this study

Table-108 Raw material and chemistry of product pellets

	Conc Fe=68.7	Conc Fe=68.7	Conc Fe=70.0	Conc Fe=70.0
	Pellets for BF	Pellets for DR	Pellets for BF	Pellets for DR
Bentonite (kg/P)	10.0	10	10.0	10
Dolomite (kg/P)	72.0		39.0	
H.Lime (kg/P)	6.5		2.6	
T.Fe (%) in product	64.1	66.85	66.6	68.1
SiO_2 (%) in product	2.3	2.3	1.4	1.3
CaO (%) in product	2.8	0.32	1.6	0.3
MgO (%) in product	1.5	0.12	0.9	0.1
C/S	1.2	0.14	1.2	0.3

(6) Unit consumption of electric power

For the study, the unit consumption can be assumed 60kWh/t-p for producing BF pellets and 58kWh/t-p for producing DR pellets without operation of mills for additives and with reduction of mass ratio compared with BF pellets.

(7) Unit consumption of induration energy

Table-109 shows unit consumption of energy and related data. Provided that wasted gas temperature is lowered according to the heat pattern change and there is a small increase of heat loss brought out from the furnace by pellets, unit consumption is estimated.

Table-109 Unit consumption

	BF pellets in HIPASAM	New BF pellets	DR pellets
Bentonite (kg/t-p)	15.5	10.0	10.0
Dolomite (kg/t-p)	17.7	72.0	0.0
Silica (kg/t-p)	6.8	0.0	0.0
Hydrated lime (kg/t-p)	0.6	6.5	0.0
Waste gas temp (℃)	280	180	180
Heat loss by waste gas (mega cal/t-p)	99	59	55
Decomposition heat (mega cal/t-p)	6	23	0.7
Green pellets moisture(%)	11.0	9.3	9.3
Heat loss of water evaporation (mega cal/t-p)	74	65	60
N.Gas consumption (Nm^3/t-p)	27	18	15
Carbon consumption (kg/t-p)	0	6	6
Total in duration heat (mega cal/t-p)	239	220	200

6.4 STUDY OF ECONOMICAL HBI MAKING METHODS

(1) Review of iron making processes

In order to select the most suitable iron making process in 20 or more new iron making processes the following 3 points have to be considered.

1) Final product

2) Iron ore

3) Reductants

Comparison of new iron making processes on these 3 points is shown in **Table-110**. In the table, COREX, FIOR, HYL III, Iron Carbide, MIDREX and SL/RN processes are operating on commercial scale.FINMET process is under construction in north-west Australia as a modified process of FIOR.

(2) Selection of iron making processes

From the view point of reactivation of HIPARSA, the above mentioned 3 points shall be considered as follow.

1) Final product
Product must have characteristics that resists reoxidation during handling.

As a result pig iron, hot briquetted iron (HBI) and iron carbide are applicable on HIPARSA.

2) Iron ore
The fluid bed technologies require as raw material fines iron ore with a size bigger than 44 microns, but this problem was solved by means

of a micropeletization, which raised the granulometry up to 500 microns, according to the test made in Germany with the mineral of Sierra Grande in 1994.

Iron Carbide technology is operating from 1996 in Trinidad-Tobago, selling its product to Nucor Company of USA. FINMET is a modification and improvement of FIOR of Venezuela, which had been producing HBI for many years. CIRCORED have been installed in Trinidad-Tobago, but until now have not any commercial production on the world.

From the point of view of this Mission, no one of these technologies could be recommended to the reactivation of HIPARSA, because they are not proved as the process MIDREX and HYL, which are producing 63.5% and 26.4%, respectably, of the total world DR iron.

3) Reductants

Natural gas shall be able to be supplied from the existing main gas line by installing a new branch line around 47 km to Puerto Colorada.

Cost of gas is stated to be US$ 0.062179/m^3 (Calorific value : 9700 kcal/m^3 , US$ 1.6/mmBTU). Rio Turbio coal which is produced in Santa Cruz is also available and cost (cif US$ 40/t, Calorific value : 6500 kcal/kg, US$ 1.55/mmBTU) is competitive with gas.

However, volatile matter, ash content and Fixed Carbon are so much different from the specified coal which is recommended on FASTMET process that Rio Turbio coal will not be able to be used as reductant for FAST MET process.

As a result, processes what satisfy the above mentioned 3 points are MIDREX and HYL III only and in both cases the product is Hot Briquetted Iron (HBI). Typical data about final product, iron ore and reductants of MIDREX, HYL III and FASTMET are shown in **Table-111**.

Table-110 Iron Making Process

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Circofer	Circored	COMET	FASTMET	FINMET	FIOR	HYL III	MIDREX	Iron Carbide	Inmetco	SL/RN	COREX	Cleansmelt	Ifcon	Romelt	DIOS	Hi-smelt	Technored
Products																		
DRI (Sponge iron)			☆	☆			☆	☆		☆	☆							
HBI (Hot Briqutted iron)	☆	☆		☆	☆	☆	☆	☆		☆								
Molten iron												☆	☆	☆	☆	☆	☆	☆
Pig iron												☆						
Iron carbide (Fe3C)									☆									
Raw Materials																		
Pellet / Lump							☆	☆			☆	☆						
Fine (Pellet feed)*1	☆*	☆*	☆	☆						☆								
Fine (Iron carbide feed)*2									☆									
Fine (Finmet feed)*3					☆	☆												
Fine (Sinter feed)*4													☆	☆	☆	☆	☆	
Fine (Circo- feed)*5	☆	☆																
Fine (Other limitation)																		☆
Reductants																		
Natural gas		☆			☆	☆	☆	☆	☆									
Coal	☆		☆	☆						☆	☆	☆	☆	☆	☆	☆	☆	☆

Source : Midrex report and others

Note
*1 : size of ore $< 44\mu$ more than 75%
*2 : size range of ore 0.1 - 1 mm
*3 : size of ore > 6mm max15%, < 0.15mm max25%
*4 : size range of ore < 6mm
*5 : size range of ore 30μ - 1mm
☆ *: micro pellet is applicable

Table-111 Comparison of MIDREX, HYL III and FAST MET

	MIDREX	HYL III	FAST MET
Product			
Type	HBI / DRI	HBI / DRI	HBI / DRI
Total Fe (%)	90 to 94	91 to 93	86 to 92
Metallic Fe (%)	83 to 89	83 to 88	80 to 87
Metallization (%)	92 to 95	92 to 95	92 to 95
Gangue minerals (%)	2.0 to 6.0	2.0 to 6.0	4.0 to 8.0
C (%)	0.8 to 1.2	1.2	1.0 to 6.0
Iron Oxide			
Type	Pellet / Lump	Pellet / Lump	Pellet feed
Size (mm)	Pellet 9 - 16	Pellet 9 - 16	< 0.044 more than 75%
	Lump 10 - 35	Lump 10 - 35	
Operation Parameter			
Iron ore (t / t-HBI)	1.45	1.45	1.3
Nat. gas (Gcal / t-HBI)	2.6	2.8	0.6
Coal (75%FC, t / t-HBI)	—	—	0.35
Binder (kg / t-HBI)	—	—	2.6
Electricity (kWh / t-HBI)	130	90	90
Water (m^3 / t-HBI)	1.5	1.8	1.0

(Source : MIDREX report)

(3) Required utilities

Required quantity of utilities and their properties are shown in **Table-113** and **Table-114**, on the base of 750 kilo-t/year HBI will be produced at Puerto Colorada. Unit consumption of coal in FAST MET process is adjusted by FC content.

(4) Capital cost and operation cost

Comparison of typical data on capital cost and operation cost are shown in **Table-115** as a preliminary on the base of 750 module HBI plant will be constructed at Puerto Colorada and 750 kilo-t/year HBI will be produced on a standard condition.

Table-113 Required Utility (Quantity)

	MIDREX		HYL III		FAST MET		Suppliability
Product (HBI)	750kilo-t/year	7500 h/year	750kilo-t/year	7500 h/year	870 kilo-t/year	7500 h/year	
	Unit cons. (per t-HBI)	Demand (per Year)	Unit cons. (per t-HBI)	Demand (per Year)	Unit cons. (per t-HBI)	Demand (per Year)	(per Year)
Natural gas (Gcal)	2.6 Gcal	1.95 x 10^6	2.8 Gcal	2.10 x 10^6	0.6 Gcal	0.52 x 10^6	
(Nm^3 - 8800 kcal/Nm^3)	295Nm^3	221 x 10^6	318Nm^3	239 x 10^6	68Nm^3	59.2 x 10^6	
20% allowance (Nm^3)		265 x 10^6		286 x 10^6		71.0 x 10^6	
Coal (44 %FC - ton)	—	—	—	—	0.58	504,600	
20% allowance (ton)						605,520	
Water (m^3)	1.5	1,125 x 10^3	1.8	1,350 x 10^3	1.0	870 x 10^3	
20% allowance (m^3)		1,350 x 10^3		1,620 x 10^3		1,044 x 10^3	
Electricity (kWh)	130	97.5 x 10^6	90	67.5 x 10^6	90	78.3x 10^6	
20% allowance (kWh)		117 x 10^6		81.0 x 10^3		94.0 x 10^3	

Table-114 Required Utility (Quality)

Natural Gas			Coal			Water		
		Pico Truncado			Rio Turbio			Available
Gas composition (%)			Proximate analysis (%)			Characteristics		
CH_4	65.0～96.0	90.02	Ash	10	16.0	PH value		
C_2H_6	1.0～26.0	4.81	Volatile matter	15	40.0		(mg/lit)	
C_3H_8	0.04～7.0	1.91	Fixed carbon	75	44.0	Total hardness	11.9～35	128, 170
other CmHn	～2.8	1.20	Ultimate analysis (%)			Calcium hardness	11.9～30	
			C		76.6	Total alkalinity	12.6～37	124, 147
CO_2	0.02～12.0	0.17	H		6.2	Suspended solids	0.5～10.5	
N_2	0.4～17.0	1.90	N		0.8	Dissolved solids	16～50	
H_2	～0.2	0.00	S		0.9	Sulfate	1.5～3.0	66, 94
O_2	0.01～1.0	0.00	O		15.5	Total Fe	0.16～2.4	< 0.1
			Ash analysis (%)			Dissolved Fe	0.16～0.8	
Net calorific value		9,700	Fe_2O_3 / TiO_2		13.2/0.9	Silica	3.4～10.9	
(Hh kcal/Nm³)			SiO_2 / Al_2O_3		52.2/20.3	Chloride	0.5～1.3	35, 50
Gross calorific value		8,800	CaO /MgO		7.9/0.9			
(Hl kcal/Nm³)			P_2O_5 / SO_3		P/S 0.1/3.4	Temperature (℃)	max 35	
			K_2O / Na_2O		0.4/0.6	Pressure(kg/cm²G)	5～7	
			Hardgrove Index		50			
			Moisture (%)		14			
			Calorific value (kcal/kg)		6500			
			Ash Soft. temp (℃)		1280-1300			
			Melt. temp (℃)		1350-1420			

Table-115 Comparison of Capital Cost and Operation Cost (Preliminary)

	MIDREX			HYL III			FAST MET		
General Spec.									
Nominal capacity (kilo-t/year)	750			750			870		
Module size	750			750			45×2		
Operation rate (h/year)	7,500			7,500			7,500		
Capital Cost (m$)	170			175					
Operation Cost	Unit cons. (per t-HBI)	Unit price ($)	Cost ($/t-HBI)	Unit cons. (per t-HBI)	Unit price ($)	Cost ($/t-HBI)	Unit cons. (per t-HBI)	Unit price ($)	Cost ($/t-HBI)
Iron ore (Pellet-t)	1.45	30	43.5	1.45	30	43.5	—		
(Conc.-t)	—			—			1.3	20	26
Natural gas (Nm^3)	295	0.062179	18.34	318	0.062179	19.77	44	0.062179	2.74
Coal (75%FC-t)	—			—			0.58	40	23.20
Electricity (kWh)	130	0.040	5.20	90	0.040	3.60	90	0.040	3.60
Water (m^3)	0.5	0.34	0.17	1.8	0.34	0.61	1.0	0.34	0.34
N_2 gas (Nm^3)									
Binder (kg)	—			—			2.6	1.8*	4.68
Consumable									
Labor (m-h)	0.5	6	3.0	0.5	6	3.0	0.5	6	3.0
Maintenance ($)	6.0		6.0	9.0		6.0	6.0		6.0
Total			76.21			76.48			69.56

* Peridure : 1800$/t

6.5 REQUIRED UTILITIES FOR IRON ORE MINES, CONCENTRATION, PELLETIZING AND HBI MAKING PROCESS

Required utilities for mine, concentration plant, pelletizing plant and HBI plant are shown in **Table-116**.

Table-116 Required Utilities in Normal Operation

		Mine 2,600,000t/year	Conc.Plant 1,100,000t/year	Pellet Plant 1,100,000t/year	HBI Plant 750,000t/year	Others		Total
Natural Gas	Nm^3/t	-	-	15	295			
	$Nm^3/year$	-	-	16.5 x 10^6	221x 10^6			
Coal	kg/t	-	-	6	0			
	t/year	-	-	6,600	0			
Water	m^3/t	0.15	1.80	0.3	0.5			
	$m^3/year$	390 x 10^3	1,980 x 10^3	330 x 10^3	375 x 10^3			
Electricity	kWh/t	15.0	63.5	73.0	130			
	kWh/year	39.0 x 10^6	69.9 x 10^6	80.3 x 10^6	97.5 x 10^6			