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History and Prospect of Philippine Sinter Corporation†

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Abstract:

Philippine Sinter Corporation, " PSC, " started operation in 1977 and since that time it has continuously operated and has accumulated a production record of 125 million tons in 2008. During PSC's long history, enormous kinds of activities have been carried out to make progress in both operation and administrative fields. Ever since, PSC is playing the important role as a processing company supplying sintered iron ore for JFE Steel. In responding to the high steel demand recently, PSC is continuing to enhance its performance in both production and quality in order to pursue much higher productivity of JFE Steel's blast furnaces. This report will discuss substantial technical theme lately developed in the sintering plant and will summarize the 30 years history of PSC.

1. Introduction

Since Philippine Sinter Corporation (PSC) began operation in 1977, it has built a position as a key overseas raw material processing base for JFE Steel while adapting to large changes in the economic environment.

In response to rising steel demand, PSC recently expanded its equipment capacity and now has a production capacity of approximately 5.5 million tons per year.

The company's cumulative production during the 31 years since it began operation exceeds 120 million tons.

2. History of Establishment

2.1 Construction of Overseas Sinter Plant (1974–1976)

The process which led to the birth of PSC began with procurement of raw material for steelmaking between the former Kawasaki Steel and the Philippines. During the 1950s, Kawasaki Steel had imported iron ore from the Philippines (Larap Mine, southern part of Luzon Island) as raw material for the blast furnaces at its Chiba Works. Subsequently, Kawasaki Steel studied the use of pellets to improve blast furnace productivity, and as a result, established the Pellet Corporation of the Philippines (PCP) in the Philippines, which began production of pellets in 1968. However, by 1975, iron ore resources were depleted. At the time, Kawasaki Steel had studied expansion of Chiba Works, but due to constraints on land use and other issues, the company began a study of a sintering plant to be located overseas. On the other hand, the Philippine government of the time (10th President, Ferdinand Marcos) had made the development of industry on Mindanao Island an important goal and made intense efforts to attract Kawasaki Steel. Against this background, the company decided in 1973 to construct the PSC Sintering Plant (**Fig. 1**) at Phividec (Phil-

Fig. 1 Location of PSC in Philippines

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Table 1 PSC plant specification as of 2008

Process	Item	Specification
Sintering machine	Total area of strand Dimension of pallet	495 m^2 5.5 m×90 m (146 pcs)
Burnt lime kiln	Shaft type kiln (Furnace, Chisaki Corp.)	No. 1, 2 each 70 t/d No. 3 100 t/d
Yard	Number of yard Handling machine	4 yards (50 m×900 m) Product×1 Raw material×3 Reclaimer×2 Stacker×1
Berth	Sea depth 25 m×length 351 m Grab bucket unloader×2 sets (1 800 t/h)	
Vessel	Tug boat×2 sets Pusher boat and barge each 2 sets	

ippine Veterans Investment Development Corporation) in the environs of Cagayan De Oro city in the northern part of Mindanao Island, which is located on the iron ore shipping routes from Australia, Brazil, and other ore-exporting nations and enjoys favorable port conditions and weather conditions.

The superiority of this site includes the following points:

(1) Location on shipping routes to Japan for overseas iron ore resources, contributing to excellent transportation efficiency.
(2) Deep water port, enabling reduction of freight costs by use of large ships.
(3) Mild weather year-round, with virtually no typhoons or other bad weather conditions.
(4) Availability of sub-raw materials (limestone, dolomite) from nearby islands.
(5) Relationship of trust based on long history with the Philippine government.

Construction of the plant required approximately 2 and 1/2 years. Operation began in April 1977. **Table 1** shows the specifications of the PSC plant as of 2008.

2.2 Construction of Management Base (1977–2002)

With the mutual efforts of the extremely experienced Philippine staff inherited from the former pellet company (PCP) and Japanese staff, PSC successively introduced control techniques for production, quality, safety, etc. while maintaining harmony with the culture and climate of the Philippines.

1983 Assignment of first Philippine General Super intendent
1997 20th Anniversary Ceremony (Attended by 12th President of the Philippine, Fidel Ramos)
1998 Certification under ISO 9801 international standard (Quality)
1999 Construction of Nos. 1 and 2 burnt lime kiln in response to increased production
2001 Certification under ISO 14001 international standard (Environment)

2.3 Expansion of Production Capacity of JFE Steel (2003–)

As part of the global reorganization of the steel industry, in 2003, the former NKK and former Kawasaki Steel merged, creating JFE Steel. For PSC, this merger resulted in significantly higher production and quality requirements. To support higher performance, PSC began activities to expand its production capacity in order to reduce the use of comparatively expensive pellets and improve yield in transportation (reduction of fine ratio).

2002 Development and production of higher strength sintered ore
2003 Nationwide recruitment and hiring of new personnel in the Philippines
2005 Pallet width expansion (450→495 m^2) for increased production
Construction of new burnt lime kiln (No. 3) to increase production
2006 Large-scale plant modernization for improvement of equipment reliability
2007 Cumulative production reaches 120 million tons; 30th Anniversary Ceremony
2008 Introduction of waste heat gas power generation (Startup in August 2008)

Figure 2 shows the transition in annual production and shipments since the start of operation.

When PSC began operation, its annual production capacity was approximately 4 million tons. However, as a result of measures to increase production in recent years, the company now has a scale of about 5.4 mil-

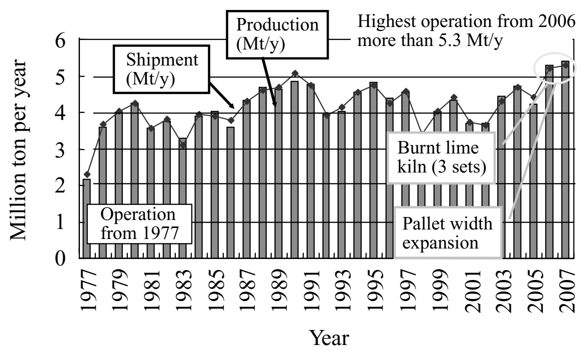

Fig. 2 Production and shipment record from 1977

lion tons. This was the result of pallet width expansion (expansion of sintering working area) and introduction of burnt lime kiln (addition of burnt lime to sinter mix), as well as other steady operational improvements. The company's current maximum capacity is approximately 5.5 million tons per year. Full production is continuing, supported by high demand.

3. Strengthening of Production System

As measures to expand its production capacity, PSC has promoted (1) Improvement of capacity utilization, (2) Expansion of the sintering working area, and (3) Improvement of raw material permeability.

For (1), improvement of capacity utilization, PSC introduced outstanding techniques from JFE Steel's steel works in connection with horizontal development of prevention of repeated trouble, thoroughgoing process control of planning and construction in order to stabilize equipment.

As a result, calendar year capacity utilization, which had been approximately 93% in the results for 2000–2003, improved to a level exceeding 95% following a series of activities.

In (2), expansion of the sintering working area, the available techniques generally include pallet width expansion, extension of the sintering strand length, and the like. At PSC, pallet width expansion was adopted in 2005 considering investment efficiency and minimization of lost production by reducing the construction time.

In (3), improvement of raw material permeability, improvement of raw material permeability by use of burnt lime (construction of burnt lime kiln) made it possible to increase the sintering bed height, thereby improving production yield.

3.1 Expansion of Sintering Working Area: Pallet Width Expansion

Figure 3 shows a cross-sectional view of a sintering machine and the condition of pallet width expansion.

In the study of pallet width expansion, design was carried out from the equipment conditions based on the existing strand rail structure, while considering the suction capability of the exhaust gas line, including the main blower of the sintering machine, and the cooling capacity of the cooler.

As a result, the pallet width was expanded from 5.0 m before improvement to 5.5 m. In March 2003, after careful advance preparations, replacement of the old pallets with new pallets (146 units) and all of the work on the sintering machine, including revamping of the material charging zone and discharging zone, were completed in a short period of approximately 1 week.

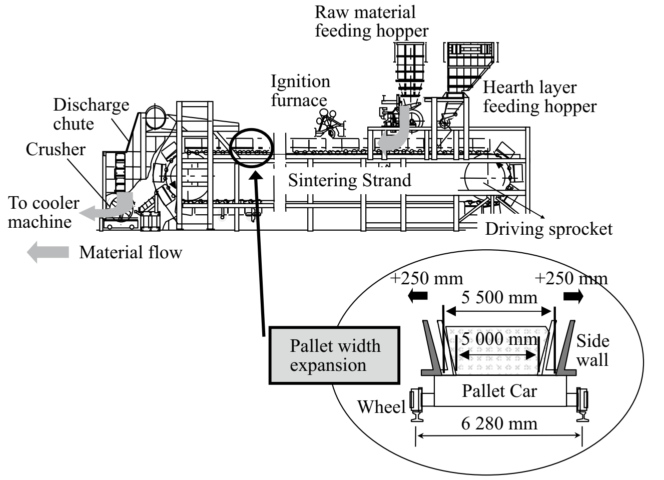

Fig. 3 Cross sectional view of sintering machine

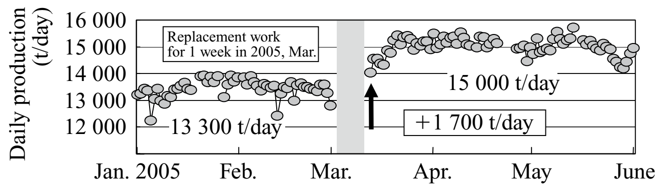

Fig. 4 Increase of production through pallet width expansion

Figure 4 shows the actual results of the production increase through pallet width expansion.

Daily production before pallet width expansion was approximately 13 000 tons. However, after pallet width expansion, production was increased to more than 15 000 tons, achieving a production increase of approximately 13%.

3.2 Improvement of Raw Material Permeability: Addition of Burnt Lime (Burnt Lime Kiln)

Burnt lime (CaO) forms hydrate limestone ($Ca(OH)_2$) as a result of hydrate reaction with water. As a binder which promotes the quasi-particle property in the sintering raw material, burnt lime is used to improve productivity.

PSC studied production of burnt lime (construction of new limestone burning furnaces) using limestone from the nearby Bohol Island. In 1999, the company introduced a rotary hearth-type shaft furnace (Chisaki Engineering Corp.; Top-shaped burnt lime furnace), which can be expected to provide high thermal efficiency.

The limestone produced on Bohol Island is geologically young, and thus is porous and has a high content of holding moisture. However, the possibility of producing high quality burnt lime using the rotary hearth-type shaft furnace was confirmed, and the actual machines were introduced.

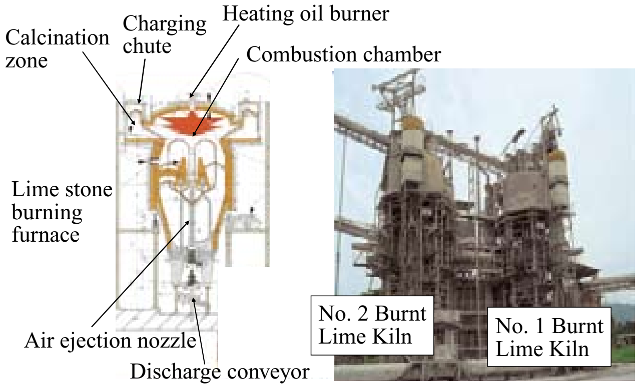

Fig. 5 Structure of burnt lime kiln

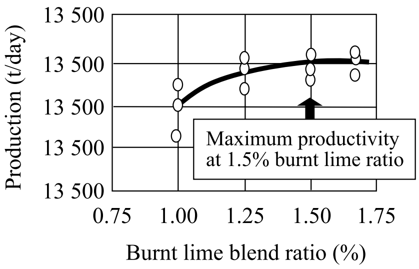

Fig. 6 Relation between sintering productivity and burnt lime ratio

Figure 5 shows the appearance of the rotary hearth-type burnt lime kiln of Chisaki Engineering Corp.

Lumpy limestone, which is charged from the peripheral direction of the furnace top, enters the furnace after evaporation of the moisture content and drying in the preheating zone.

The combustion flame from a heavy oil burner installed in the ceiling dome heats the air blow from below, and this high temperature air flow improves burning of the limestone into burnt lime. With this technique, the high temperature air circulates in the furnace, enabling continuous, high efficiency production of burnt lime.

An additional unit (No. 3 burnt lime kiln) was constructed in 2005. At present, the PSC's total burnt lime production capacity is approximately 240 tons per day.

As shown in **Fig. 6**, it can be understood that productivity is increased by addition of burnt lime.

At present, PSC is operating with a 1.5% burnt lime ratio.

3.3 Routine Operation Improvement Activities

Systematic quality control is promoted continuously in order to supply sintered ore with stable quality to the blast furnace.

One key quality item is the fine ratio (weight ratio less the 5 mm size) at the unloading port, which is an index of the degree of powdering during transportation. This information is monitored constantly and is reflected in operational actions. At the same time, in addition to the general Shatter Strength Index test method, the frequent dropping strength test was also introduced at the product conveying line at the sintering plant. This is a technique in which the fine ratio of product under 5 mm is measured after dropping destruction 50 times from a height of 2 m. As the results show a correlation with the fine ratio at unloading ports, this is also monitored constantly and reflected in operational actions as a key quality control index.

On the other hand, in order to maintain stable quality, control of raw material quality is considered a an important issue. Therefore, PSC promotes quality improvement activities (contamination prevention, etc.) in its raw material yards.

For quality control of sub-raw materials (limestone, dolomite), PSC is developing quality control activities in close cooperation with the mining company Philippine Mining Service Corporation (PMSC), subsidiary company of JFE Steel, which is located in Bohol and Cebu island in the Philippines.

4. Lump Yield Improvement during Transportation: Development of High Strength Sintered Ore

In sintered ore, minerals undergoes complex structural changes in the sintering process. Because sinter is a poly-structure material in which the original iron ore also remains in the melted structure, and sinter also has angular shape due to crushing of the product after firing, it tends to powder easily in comparison with pellets.

Accordingly, prevention of powdering of the sintered ore when transported long distances from overseas is an important issue. To date, PSC has implemented various measures, such as reduction of the drop distance of belt conveyor junctions and improvement of crushing or impulse at falling in the belt conveyer line.

On the other hand, because improvement in the strength of the sintered ore structure itself is a key problem for preventing powdering, PSC has researched the optimum structure design corresponding to the properties of the kind of blending iron ore. As a result, the company succeeded in the development of sintered ore with higher strength and reduced powdering.

As shown in **Fig. 7**, in order to improve the strength of sintered ore, it is necessary to increase the structural strength of the original iron ore and to improve the strength of the bonding portion after melting.

In addition to the chemical composition, sintered ore also has properties which differ depending on the geological formation process, producing area, and similar factors. These properties include the melting property, porosity property, wettability, etc. The optimum blend, Concept to realize higher strength sintered ore

- Increase of liquid slag bonding strength
  - · Slag volume and composition (CaO, SiO_2, etc.)
  - · Input heat amount control
- Increase of structural strength
  - · Decrease in coarser pore
  - · Enhance the strength of liquid slag

Fig. 7 Improvement concept of sintering ore strength

considering the slag design, is the key point for achieving strength.

It was discovered that optimum blending using two types of hematite iron ore with different properties is an effective method of producing high strength sintered ore while maintaining productivity. Specifically, use of the optimum combination of a type of hematite iron which has an excellent granulation property, and thus is suitable for improving productivity, and a type of hematite which has few coarse pores and a tight and hard structure has made it possible to produce high strength sintered ore with less powdering. In particular, reduction of coarse pores is one key point.

Figure 8 shows the pore size distribution of two types of sintered ore produced in pot tests. From Fig. 8, in comparison with the sintered ore (Type A sinter) produced using the conventional blending design, it can be understood that the sinter (Type B) produced using the new blending design has a reduced content of coarse pores, while retaining a basically uniform percentage of

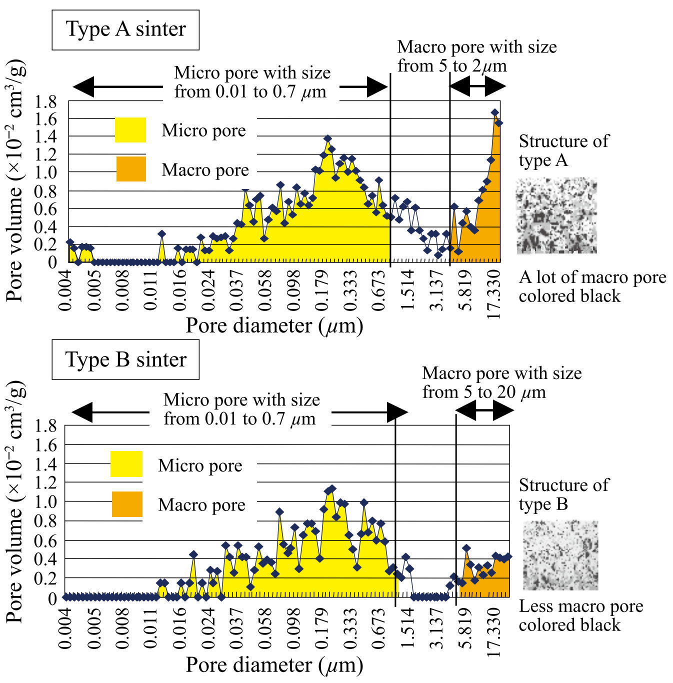

Fig. 8 Pore distribution in comparison with 2 type sintered ore

Table 2 Comparisonbetween two different type sintered ore

	Type A Sintered ore	Type B Sintered ore
Blending style of iron ore	Conventional iron ore blending	Two different type hematite by optimum blending
T.Fe (%)	58.2	60.0
SiO_2 (%)	4.7	3.0
CaO (%)	9.5	8.7
Al_2O_3(%)	1.5	0.8
Mean size (mm)	15.0	20.2
Fine size under 5 mm (%)	15.6	9.3
RI (%)*	63.0	62.5

Type A sintered ore: Conventional sintered ore
Type B sintered ore: High strength sintered ore
*Reducibility index

micro pores, and as a result, it has a tight and hard structure and high strength.

PSC began shipping the Type B sinter to JFE Steel (Chiba, Kurashiki, and Fukuyama Districts) in 2002.

Table 2 shows a comparison of the properties at the unloading port (Data averaged by 9 ships) of Type A and Type B sintered ore.

In the Type B sintered ore, the fine size under 5 mm%, which expresses the fine ratio at the unloading port, is small in comparison with Type A. From this, it can be understood that powdering is suppressed in Type B sintered ore.

5. Promotion of Energy Saving Activities

5.1 Examples of Conventional Activities

The energy used in production of sintered ore at PSC is mainly electric power and heavy oil. Electric power comprises 70% (117 MJ per ton) of total energy consumption, and heavy oil, which is used in the ignition furnace of the sintering machine and the limestone burning kilns (oil burners for generating hot blast) accounts for approximately 25% (34 MJ per ton). Reduction of consumption of these types of energy is a critical task for improving economy and protecting the environment. The following may be mentioned as examples of energy saving activities to date.

(1) Reduction of Energy Loss

Preventive activity for air leakage around the sintering machine and in the exhaust gas system

Reuse of waste hot gas after the cooler as mixed air for ignition furnace combustion

(2) Energy Saving Measures During Changes in Operational Level

Optimum combined operation of main blowers (2 units)

Optimization of number of operating crushing mills for carbon material for operation condition.

5.2 Introduction of Waste Heat Gas Power Generation System

Because Mindanao Island where PSC is located has an abundance of water resources, use of hydro power is high, at 60%. Conversely, thermal power generation using fossil fuels is low. Nevertheless, because of issues related to governmental energy policy, the unit cost of electric power remains high (approximately 3 peso per kWh) in comparison with other countries in Southeast Asia.

Against this background, PSC studied the introduction of a waste heat gas power generation system using the high temperature waste gas from the sintering machine cooler.

The system comprises a waste heat boiler, turbine, generator, and other equipment. Recovered electric power is approximately 18 MW. This is equivalent to approximately 73% of PSC's current power consumption, and thus can be expected to have large energy saving and economic effects. **Figure 9** shows the overall composition of the equipment.

In the past, the air used in cooling the high temperature sintered ore at the cooling process had been released into the atmosphere. However, with this system, the high temperature air is conveyed to the boiler, where it is used to recover steam. The recovered steam (quantity: 85 tons per hour, pressure: 2.13 MPaG) is then conveyed to the turbine, and electric power is recovered by the generator. The steam which has passed through the turbine is reused as circulating water by the condenser. **Table 3** shows the basic specification of the waste heat gas power generation system.

The waste heat gas power generation system introduced at PSC is designed and manufactured by JFE Engineering, which has an extensive record of international projects.

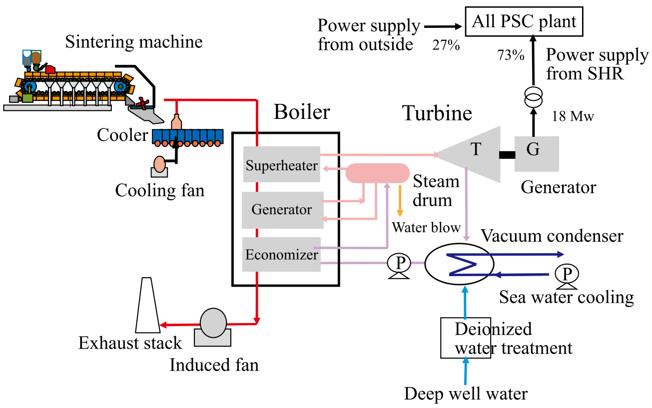

Fig. 9 Sinter heat recovery process flow

Table 3 Specification of sinter heat recover process

Equipment	Item	Specification
Boiler	Supplier Type Steam condition	JFE Engineering Forced circulation type Volume 85 t/h Temperature: 380°C Pressure: 2.13 MpaG
Turbine and generator	Supplier Type	Turbine: JFE Engineering Generator: Meidensya Corp. Condensed water type (By seawater cooling)
	Power	18.6 MW

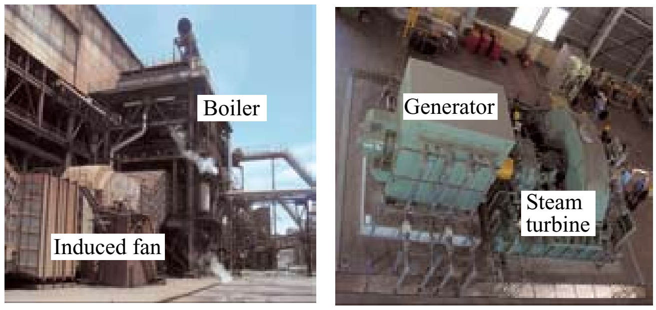

Photo 1 Boiler, turbine and generator of sinter cooler heat recovery system

Photo 1 shows the boiler, turbine, and generator of sinter cooler heat recovery system.

At the same time, this is also a bilateral Japanese-Philippine CDM (Clean Development Mechanism) project based on the Kyoto Protocol.

After approval by the Environmental Ministries of the two countries, the project was submitted to the United Nations (CDM Committee of U. N.) and was registered as a CDM project in May 2007. The target CO_2 reduction of the project is approximately 60 000 tons per year. With the start of the International Global Environment Year, PSC intends to contribute to environmental protection by effectively utilizing this system.

6. Future Issues

6.1 Energy Saving and Protection of the Global Environment

Today, the iron and steel industry is directly confronted with resource nationalism of a worldwide scope and growing global environmental problems. Philippine Sinter Corporation is no exception to these tendencies. On the other hand, accompanying the progressive mining activities of iron ore resources, an increasing trend toward lower grade ores can also be expected. Development of even more outstanding technologies which can make full use of these diversifying iron ore resources is demanded.

At the same time, protection of the global environment will be the focus of increasing attention in the future. Philippine Sinter Corporation will grapple actively with these various problems.

6.2 Improvement of Technical Base

The most critical issue for manufacturing industries is improvement of technical development capabilities.

At PSC, more than 30 years have passed since the start of operation, and the company is now facing a large change of generations as its original employees reach retirement age. From this viewpoint, PSC recognizes that hiring outstanding human resources and systematic training in the company are key management issues.

The new nationwide recruiting system in the Philippines, which PSC began in 2003, is continuing to contribute to steady improvement in the company's technical capabilities. Philippine Sinter Corporation is currently developing a variety of measures for human resource development, including improved technical education, educational guidance for young engineers by experienced personnel, and a intensive technical training program at JFE Steel's works in Japan, which began last year.

7. Conclusion

The history of PSC from its birth to development was reviewed, and examples of recent technical topics were introduced. In the future, PSC is committed to achieving further growth as a competitive, environment-friendly processing base for raw materials for steel manufacturing while continuing to respond flexibly to the various new changes in the environment which it encounters.

Finally, in the following, the authors wish to recognize the former Presidents of PSC and the engineers responsible for improvement activities related to manufacturing technology in recent years.

Past Presidents of PSC (Honorifics Omitted)

1975–1980 SAKAKI Motoi
1980–1983 UETANI Shigeru
1983–1985 SAKAKI Motoi
1985–1989 ENDO Osamu
1989–1993 TOKUNAGA Yasuyuki
1993–1996 HASEGAWA Shigeru
1996–2000 YASUNO Motozo
2000–2005 MATSUMOTO Toshiyuki (President of JFE Materials)

Filipino Superintendent and Executive of PSC (Honorifics Omitted)

1983–1996 EVANGELISTA, G.
1996–1997 MANUS, B.
1997–2002 AGUIRRE, M.
2002–2007 NOBLE, R.
2007– SAGRADO, N. (Division Manager of sinter plant)
ADIS, A. (Special Advisor for President)
SANTOS, R. (Executive of administration)

Engineers Involved in Advanced Technology and Improvement Activities in Recent Years

—Pallet Width Expansion, Burnt Lime Kiln, and Waste Heat Gas Power Generation—

MORIKAWA Yasuyuki
Staff Manager, Ironmaking Technology Sec., Ironmaking Dept., East Japan Works (Chiba), JFE Steel

HASHIMOTO Ken
Manager, Raw Materials Plant, Ironmaking Dept., West Japan Works (Fukuyama), JFE Steel

OYA Kenji
Staff Deputy Manager, Ironmaking Technical Sec., Ironmaking Dept., West Japan Works (Fukuyama), JFE Steel

TAKAHASHI Tamotsu
Staff Manager, Plant Engineering Technology Sec., Plant Engineering Dept., East Japan Works (Chiba), JFE Steel

OSADA Yasushi
Staff Manager, Ironmaking Plant Maintenance Sec., Plant Engineering Dept., East Japan Works (Keihin), JFE Steel

YOKOTSUKA Tomohito
Staff Deputy Manager, Ironmaking Plant Maintenance Sec. Ⅱ, Plant Engineering Dept., West Japan Works (Kurashiki), JFE Steel

UEKI Takayuki
Maintenance Technical Advisor, JFE Steel (Manager)

MASUMOTO Shinichi
Operational Technical Advisor, JFE Steel (Deputy Manager)

—Development of Manufacturing Process for High Strength Sintered Ore —

NUSHIRO Koichi
Senior Researcher Manager, Ironmaking Res. Dept., Steel Res. Lab., JFE Steel