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*The Genesis of Product Making*

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**Operating Roundup**

**Consolidated Financial and Operating Results for the First Quarter of Fiscal 2004**

Nippon Steel has released a summary of consolidated financial and operating results for the first quarter of fiscal 2004 (April 1, 2004 to June 30, 2004).

**Nippon Steel and Rio Tinto Reach Agreement on Hail Creek Joint Venture**

Nippon Steel and Rio Tinto have reached a basic agreement on creating a comprehensive alliance for the acquisition of interests in and joint development of Australian mines of iron ore.

*“A Pilgrimage: Colored Fibers Encounter Iron” (A series of works by Kei Tsuji)  
— Contribution for August 2004 —

(Works of art focused on “an alliance of iron—closely bound to both earth and man—with the arts of dyeing and weaving”)*

Born in Tokyo 1953, Kei Tsuji displays her installations, centered on dyeing and weaving, in deserts, woodlands and waterfronts the world over. Produced through a fieldwork approach, her installations represent a continuous pursuit of the connection between herself (dyed and woven cloth) and the realm of time and space (principles of the natural world).
The Genesis of Product Making

Ironmaking from Iron Ore (Three-part Series: 3)

Pig iron is derived from iron ore. Crucial to the process of extracting pig iron from iron ore is how to effectively remove (or reduce) oxygen from the ore by causing high-temperature chemical reactions between the iron ore and coke. This three-part series (issues nos. 316, 318 and 319) highlights the dynamic world of blast furnaces in which iron ore is converted into pig iron, the wellspring of the steel industry. This issue discusses Nippon Steel’s technological challenges in blast-furnace operations and predicts future technological developments in pig iron production.

Nippon Steel’s Real “Knack”—Pretreatment Technology for Blast Furnace Feedstock

The “pretreatment” processes conducted in sintering machines and coke ovens are important to determining the quality of blast furnace feedstock. The iron ore used in sintering machines consists mainly of fine powdery particles each measuring 5 mm or less in diameter. These particles are produced by blending together fine ores, which vary widely in origin and properties, in a manner that will make their mixture as homogeneous as possible. However, if these ores were to be charged into blast furnaces without further processing, they would cause the furnaces to become clogged, inhibiting the upward flow of the reducing gases. To avoid this, the ores are mixed with a small amount of lime powder and then fired and compressed into mineral agglomerates of uniform size—a task performed by sintering machines.

The function of coke when fed into the blast furnace with the sintered iron ore is to extract iron from the ore through reduction and to melt both the ore and limestone. In addition, coke must also perform the significant function of providing pathways through which the reducing gases and molten iron can pass. To make this possible, various
types of coal of varying qualities—ranging from strong coking coal to poor coking coal—are pulverized into specified particle sizes. After this, they must be adequately combined with one another and carbonized in coke ovens where they are provided with sufficient strength and appropriate particle size to prevent them from easily cracking or collapsing.

Since the late 1980s, Nippon Steel has placed an emphasis on the development of new pretreatment technologies for low-grade raw materials. Representative of such newly developed technologies is “selective pelletizing in the sintering process.” With this technology, fine ores 3 mm or less in diameter are selected by sifting. After being pelletized, these ores are mixed with the coarse ores that had been screened out and are then charged into the sintering machine. In this way, by making them uniform in shape, this method makes efficient sintering operations possible (Fig. 1).

Continuing studies were also conducted to develop pretreatment technologies for low-grade coal (or semi-soft coking coal) so that it could be
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more effectively utilized in coke ovens. Emphasis was placed on the preliminary pelletizing and agglomeration of fine coal particles for subsequent charging into coke ovens in order to produce quality coke. This technology, specifically called the dry-cleaned and agglomerated precompaction system (DAPS), was eventually established at the Oita Works.

These two technologies won the prestigious Okochi Memorial Grand Production Prize (in 1993 for the former and in 1990 for the latter) as innovative pelletizing and enhancement technologies for fine raw materials and reducing agents. Through the development of these pretreatment technologies, Nippon Steel has contributed to improvements in the quality of blast furnace feedstock that satisfy two conflicting requirements: strength and high particle porosity, as discussed in the previous issue.

In addition, these pretreatment technologies for blast furnace feedstock are highly effective in reducing energy consumption in pig iron production, a sector that accounts for about 70% of all the energy required in iron and steel production. At Nippon Steel, the contribution of these technologies is noticeable in the ratio of reducing agents (coke ratio + the ratio of pulverized coal injection)—a clear indicator of energy consumption in pig iron production. Standing at around 490 kg/t-p, this ratio is far lower than at the other major domestic steelmakers. A lower ratio of reducing agents means that a smaller amount of CO₂ is generated per ton of pig iron produced. It can be said, therefore, that Nippon Steel leads the other domestic steelmakers in offering iron and steel products with reduced environmental impact.

Nippon Steel’s Real “Knack”: In-furnace Simulation Technology

The average inner volume of the blast furnaces at Nippon Steel, together with productivity, is the largest in Japan. Next to the Kimitsu Works’ No. 4 blast furnace (5,555 m³) that was blown-in in May 2003, the world’s largest blast furnace is the No. 2 blast furnace (5,775 m³) of the Oita Works that was relined and reblow-in in May 2004. The difficulty involved in operating these mammoth blast furnaces is how to control the cohesive zone and the deadman, as discussed in the previous issue.

Nippon Steel has striven to establish advanced diagnostic technologies and a system for controlling blast-furnace operations that are based on the aforementioned successful realization of high-quality blast-furnace feedstock through pretreatment. By doing so, Nippon Steel has achieved an advanced level of highly efficient operation for mammoth blast furnaces.

Simulation and other technologies that are based on advanced mathematic models of internal blast furnace conditions, including the shape of the cohesive zone and the deadman, have enabled dramatic strides in the control of blast-furnace operations. In fact, Nippon Steel has now developed a real knack for in-furnace simulation technology.

For instance, even the internal conditions of Japan’s first “Oshima” blast furnace that was built at Kamaishi over a century ago can be recreated by this technology for analytical comparison with the
conditions in today’s most advanced blast furnaces. Since this technology permits an accurate understanding of the basic blast furnace phenomena that is unaffected either by changes in the inner volume of blast furnaces or by variations in shape and profile brought about by such changes, it has contributed to progress in blast furnace technologies, including the expansion of inner volumes (Fig. 2).

These simulations clearly show that similar phenomena occur within blast furnaces regardless of differences in the scale of their inner volumes. In order to estimate changes in the internal conditions of blast furnaces according to the charging method and the amount of raw materials and reducing agents charged, Nippon Steel utilizes a combination of models. One is called “BRIGHT” and it simulates reduction reaction, smelting and melting conditions within a furnace; the other model is called “RABBIT” and it simulates the distribution pattern of the furnace-top burden. In so doing, Nippon Steel has realized a method of precise control of blast-furnace operations that anticipates possible changes in internal-furnace conditions. Nippon Steel has also developed an expert system based on artificial intelligence (AI) methodology that capitalizes on fuzzy, neuro and other advanced theories or logic, thereby enhancing the reliability of control over the operation of mammoth blast furnaces.

The underlying strength of Nippon Steel’s blast-furnace technology lies in the fact that the company operates many blast furnaces at its five steelworks positioned around the country. Each steelworks strives to hone its own blast-furnace operating skills under different conditions, and the expertise and experience gained in this way are securely transferred to the company’s other steelworks. As blast-furnace technology has universal applicability, it can easily be shared among individual steelworks.

Overseas, Nippon Steel’s pig-iron production technology is steadily being applied in neighboring countries. Among these applications are the No. 1 blast furnace at POSCO’s Pohang steelworks (Korea) and the No. 1 blast furnace at Baoshan Iron & Steel Co. (China), both of which are based on operating technology for the No. 3 blast furnace at the Kimitsu Works of Nippon Steel.

Fig. 2 Inner Conditions of Old and Modern Blast Furnaces in Computer Simulation

“Ohashi” blast furnace

Modern blast furnace

Inner volume: 30 m³
Hearth diameter: 1.75 m

Inner volume: 3,273 m³
Hearth diameter: 12.0 m

Internal blast furnace conditions can be estimated using the excellent simulation technology of Nippon Steel. Similar phenomena occur within blast furnaces regardless of differences in the scale of their inner volumes.

(left) The internal conditions of Japan’s first “Oshima” blast furnace that was built at Kamaishi over a century ago

(right) Today’s most advanced blast furnace
Use of Pig-iron Production Technology in Creating a Recycling-oriented Society

As discussed above, blast furnaces and coke ovens not only function as pivotal reactor vessels in the ironmaking process. They also function as advanced high-temperature melting and gas-generating furnaces. The effective utilization of these functions can be the key to creating a recycling-oriented society. These units are not merely furnaces and ovens for pig iron production. With the full utilization of their functions and the energy they generate, blast furnaces and coke ovens can contribute their share to the development of society.

The energy generated by blast furnaces and coke ovens has hitherto been utilized for such purposes as power generation and the supply of gas and heat. In addition, the technologies associated with the operation of furnaces and ovens have recently come to play a very large role in the treatment of both steelworks and public by-products. For example, a technology developed at Nippon Steel’s Kimitsu Works was used in a rotary hearth furnace (RHF) to treat the dust and sludge generated at the steelworks and thereby transforms these by-products into higher value-added reduced pellet that can be reused in blast furnaces. This is a good example of how by-products can be recycled as reusable materials and contribute towards bettering the district environment (Fig. 3).

Meanwhile, a good example of the contribution of blast-furnace technology to the treatment of public waste is the direct waste-melting furnace process that Nippon Steel has offered to domestic municipal governments. In this case, a high-temperature melting technology used in blast-furnace operations is applied to waste treatment processes that burn waste in shaft furnaces similar to blast furnaces. Further, Nippon Steel was the first...
company in the world to develop and commercialize a technology that enables the addition of plastic waste generated in urban life into coke ovens as a partial substitute for coal. This technology has now been adopted at four Nippon Steel steelworks that contribute greatly to the establishment of systems for recycling urban waste in individual districts (Fig. 4).

Henceforth, the role of blast furnaces and coke ovens in the creation of a clean-energy society will increase. For instance, a project of national importance is currently studying the extraction of hydrogen for use in fuel cells from coke oven gases that contain some 50% hydrogen. Because Nippon Steel operates many coke ovens throughout the country, the company is expected to play an increasingly important role as a hydrogen supplier.

Nippon Steel was the first company in the world to develop and commercialize a technology that enables the 100% recycling of plastic waste by adding it into coke ovens as a partial substitute for coal. This technology has now been adopted at four Nippon Steel steelworks that contribute greatly to the establishment of systems for recycling urban waste in individual districts.
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Blast-furnace Technology Will Evolve towards the Future

The blast-furnace technology passed down from one generation to the next over the past 300 years will continue along the evolutionary path into the future. For instance, it is conceivable that future blast furnaces will be compact and use a large amount of oxygen. Presently, the hot air blown from the lower part of a blast furnace is usually 21% oxygen. If inexpensive oxygen in large quantities becomes available, the oxygen content of the hot air could be raised to between 30% and 50%. This would enable even compact furnaces with middle-sized inner volumes to show great productivity.

In the area of coke ovens, an innovative coke-making process is now being developed as part of a next-generation coke-making project in Japan that is known as SCOPE 21 (Super Coke Oven for Productivity and Environmental Enhancement in the 21st century). What is envisaged in this nationally important project is a compact coke oven process that will more than double productivity through advances in the hot briquetting of fine coals.

This project aims at the development of a compact coke oven process that will more than double productivity by the preliminary hot briquetting of fine coals. This next-generation coke-making project that is known as “SCOPE 21” is now being promoted in Japan as a project of national importance.
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This technology, when successfully developed, is expected to find wide use in newly installed coke production facilities (Fig. 5).

The development of new ironmaking methods to replace the blast-furnace method is proceeding worldwide. But, the blast furnace will remain the mainstay of the Japanese steel industry for some time to come. This is because the blast-furnace method not only enables the mass production of quality pig iron at low cost. It also serves as a base capable of supplying economical and highly efficient energy to plants that process steel materials and to power stations.

This may not always hold true for countries that do not have blast furnaces but plan to build their own greenfield integrated steelworks. It is asserted by some that the introduction of novel ironmaking furnaces instead of blast furnaces will be more economical in those countries. However, in advanced countries that already maintain needed production capacity with existing blast furnaces, the blast furnace method will continue to be more advantageous in terms of economy since these furnaces can serve endlessly by simply relining their interiors.

In the future, steelmakers in advanced countries will be compelled to pursue flexibility in production by actively utilizing diverse types of raw materials, reducing agents and recycled materials. This will inevitably accelerate the promotion of a “combination ironmaking process” in which the blast-furnace method exists alongside newer ironmaking methods.

(This text has been prepared under the supervision of Executive Advisor Yoshio Okuno of Nippon Steel.)
The spiraling cost of raw materials overseas and the issue of CO₂ emissions involved in global warming are becoming apparent. They pose challenges that must be met with concerted effort by the high energy-consuming ironmaking sector.

The lowest unit energy consumption in the world has already been attained in Japanese blast furnace operations through successive development of advanced raw materials processing and other technologies. In spite of this, production costs will inevitably rise even if unit energy consumption is further reduced through the enhanced recovery of low-quality energy. Further because the energy required to recover waste energy is increasing, reductions in energy use have not always followed. These facts indicate that the problems emerging with regard to raw materials cannot be solved merely by efforts made in the ironmaking process.

To cope with this situation, the recent challenges that now confront us must be solved with new and novel ideas. With regard to the raw materials of ironmaking, I think a new point of view is necessary, one in which overseas mines and the Japanese integrated steelmakers jointly examine pretreatment methods in terms of both economics and energy consumption. For example, one concept is for the oxygen and crystal water contained in iron ore to be removed at overseas mines using low-cost natural gas and coal and for the high-grade ore thus produced to be transported for feeding into blast furnaces operating in Japan. The reduction of unnecessary oxygen and crystal water from iron ore at the mines will lead to a decline in both transport volume and energy. Practices such as this are seen as an international collaboration, and I think such concepts will be necessary in an age that demands greater use of low-quality resources.

Further, pertaining to energy consumption, it is believed that biomass energy—recycled energy—will be utilized as a new energy source, while at the same research on approaches for reducing energy use is further enhanced. Because of the inherent character of recycling energy when biomass energy itself is utilized, its use does not lead to an increase in energy consumption. Accordingly, it is safe to say that the use of biomass energy will help to preserve
the global environment. Of course, certain problems remain that present significant economic obstacles to its practical application—e.g., difficulty in collecting the biomass material and the need for treatment due to high water content. Nevertheless, it is expected that concentrated efforts will be directed towards the promotion of application research that aims to reduce the use of fossil fuels and thus to mitigate global warming.

Yoshio Okuno

He assumed the position of Fellow in 1993 and took the position of Executive Advisor in 2002. He has received major prizes in the field of technology development. Among these awards are:

1974: AIME Ironmaking Conference Award of the Iron and Steel Society of AIME
1988: Nishiyama Memorial Award of the Iron and Steel Institute of Japan
1991: Distinguished Service Medal on Science and Technology, Director's Award of the Science and Technology Agency
1993: Yamaoka Award of the Iron and Steel Institute of Japan
1996: Purple Ribbon Medal (national award)
1999: Koumura Award of the Iron and Steel Institute of Japan