NIPPON STEEL TECHNICAL REPORT No. 101 NOVEMBER 2012

UDC 669 . 1

Technical Review

Program for Sustainable Development at Nippon Steel

Teruo OKAZAKI* Toru ONO

1. Introduction

In the wake of the oil crisis in the 1970s, Nippon Steel Corporation started tackling the energy-saving issue in earnest. Since then, the company has made ceaseless efforts to achieve the world's highest level of energy efficiency in its operations. At present, the company is striving to carry out a voluntary action program that is aimed at reducing its annual energy consumption during the period 2008 to 2012 by 10% from the 1990 figure. The above action program constitutes one of the important pillars in the Japanese government's plans to achieve the objectives of the Kyoto Protocol.

The techniques to save energy that Nippon Steel has employed so far can roughly be divided into: (1) process innovations, (2) maximum use of by-product gases, (3) recovery of waste heat (energy), and ... effective utilization of waste matter.

In addition, the company has been active in developing new technologies that will help revolutionize processes and build new social systems in the future.

The next-generation coke oven (SCOPE-21) that has been put to practical use after a long period of development as a new technology in advance of conventional coke oven technology is expected to replace old coke ovens which need to be renewed in the near future. Furthermore, the company is positively pressing ahead with various activities to bring about a low-carbon society and smart communities in the future, including R&D on environment-friendly steelmaking processes for a drastic reduction in CO_2 emissions and the demonstration testing of eco-towns and hydrogen towns built around steelworks.

On the other hand, in recent years, the rapid economic development of China and several other countries has brought about sharp increases in the production of steel materials, the consumption of resources/energy, and the emission of greenhouse gases. Under those conditions, improving the efficiency of steelmaking processes, especially those of developing countries, is extremely significant from the standpoint of curbing global warming, as well as coping with the energy/resources problems surrounding the steel industry. In this context, Nippon Steel has actively engaged itself in international cooperation and technology transfer in the steel sector through, for example, the "Japan-China Meeting for Interchange of Experts in Advanced Technologies for Environmental Protection/Energy Saving in the Steel Industry" and the "Asia Pacific Partnership for Clean Development and Climate" (APP).

In this technical review, in light of the above conditions pertaining to the steel industry at home and abroad, we shall describe the company's activities to save energy, curb global warming, and the company's R&D results, including the saving and recycling of resources and regeneration of the environment utilizing by-products of steelworks.

2. Overview of Domestic and Foreign Conditions affecting Japan's Steel Industry

2.1 Global warming and other problems affecting sustainable development

At the United Nations Conference on the Human Environment held in Stockholm in 1972, the Club of Rome announced the "Limits to Growth" [1], suggesting physical limits for the earth and calling for technical, cultural and institutional initiatives to prevent the "ecological footprint"—the degree of influence exerted by mankind on the environment and ecosystems—from increasing beyond the earth's capacity. It is generally said that "sustainable development" is "development whereby the present generation meet their needs without impairing the ability of the future generation to meet their needs."

In 1992, the "U.N. Conference on the Environment and Development (Earth Summit)" was held in Rio de Janeiro. There, the optimal conditions for the environment and development were discussed and "Agenda 21" embracing an action program and financial cooperation to bring about sustainable development was adopted. In addition, the "Convention on Biological Diversity" and "Framework Convention on Climate Change", etc. were signed. The Framework Convention on Climate Change came into effect in 1994. Subsequently, the Kyoto Protocol was adopted at the 3rd Conference of the Parties (COP3) (adopted in 1997 and put into effect in 2005).

The scientific aspect of the problem of climate change is as follows. The Intergovernmental Panel on Climate Change (IPCC), inaugurated in 1988, compiled scientific knowledge about the subject into reports, which were published one after another. In 2007, the IPCC's activity that led to its 4th report won a Nobel Peace Prize. (See **Fig. 1** for the contribution of Nippon Steel. At present, the 5th report is in the process of preparation.) Under the Law concerning Promotion of Measures against Global Warming (1998), the Japanese government positions global warming as an issue common to all mankind. Accordingly, it enacted several laws to ensure observance of the Kyoto Protocol and other international conventions the country has signed.

In particular, the Japanese government formulated a plan to achieve the objectives of the Kyoto Protocol (the plan was totally revised in 2005 and 2008, respectively), providing for emission control measures, etc. to be taken by the central and local governments, business entities, and nationals, respectively.

* General Manager, Global Environmental Affairs Dept., Environmental Affairs Div.
2-6-1, Marunouchi, Chiyoda-ku, Tokyo 100-8071

Fig. 1 Nippon Steel's contribution to the IPCC-AR4 (A testimonial for a contribution to the Nobel Peace Prize)

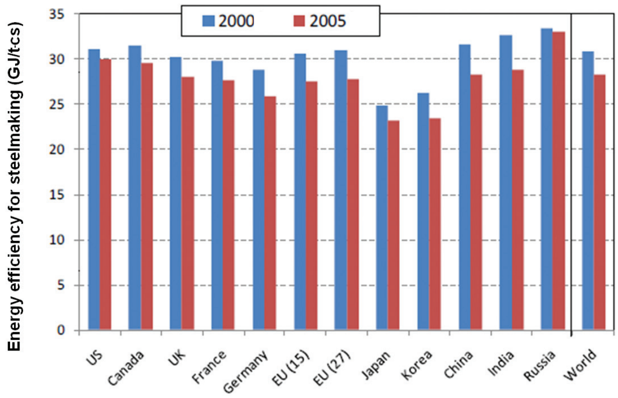

Fig. 2 International comparison of energy efficiency for integrated mills by RITE [3]

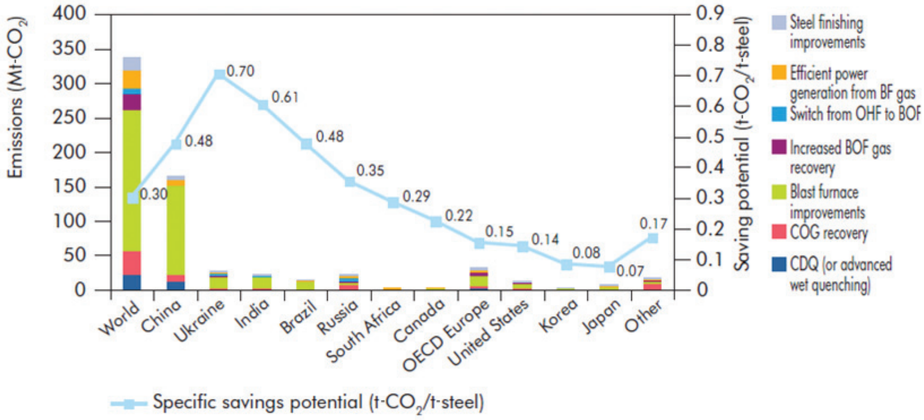

Fig. 3 Potential of CO_2 reduction in steel industry reported by IEA 2008 [4]

In the future, environment-related bills, including the Bill on Fundamentals of Measures to Curb Global Warming[2], will be discussed with an eye kept on the post-Kyoto situation. In this respect, it is necessary that domestic discussions which assure sufficient transparency as to international fairness (maintenance of fair conditions for international competition), the feasibility and effectiveness of planned measures, the burden to be shouldered by the public, etc. should be made and a consensus on every decision derived from those discussions should be reached.

Prompted by the oil crisis, etc., the Japanese steel industry has been diligently engaging itself in the development and practical application of techniques (solutions) to improve the energy efficiencies at its factories. As a result, the industry's technologies for saving energies and reducing CO_2 emissions have come to be highly evaluated by outside organizations, which suggest that the industry should be able to help reduce CO_2 emissions on a global basis through technology transfer (see **Figs. 2** [3] **and 3** [4]). Thus, the Japanese steel industry is expected to implement effective measures to curb global warming. A remarkable ability to manufacture is one of the strong points of Japan's industrial circles. Establishing domestic systems that permit making the best use of that ability is, therefore, the direction the country should take in tackling the problem of global warming in the future.

2.2 International cooperation of the steel industry—cooperative sectoral approach

2.2.1 Promotion of effective measures to curb global warming and protect the environment

The world's annual crude steel output, which had been around 800 million tons in the 1990s, increased sharply at the turn of 2000 owing to the brisk economic growth of China, etc. As shown in **Fig. 4**, it topped 1,400 million tons in 2010. The demand for steel in the world, too, is expected to continue increasing markedly until 2050 (see **Fig. 5**).

Under those conditions, it is important to use the necessary resources and energies efficiently and restrain the emission of CO_2 and other environmental loads on a global basis. On the other hand, since the technology for protecting the environment and saving energies applied by the steel industry of one country can also be

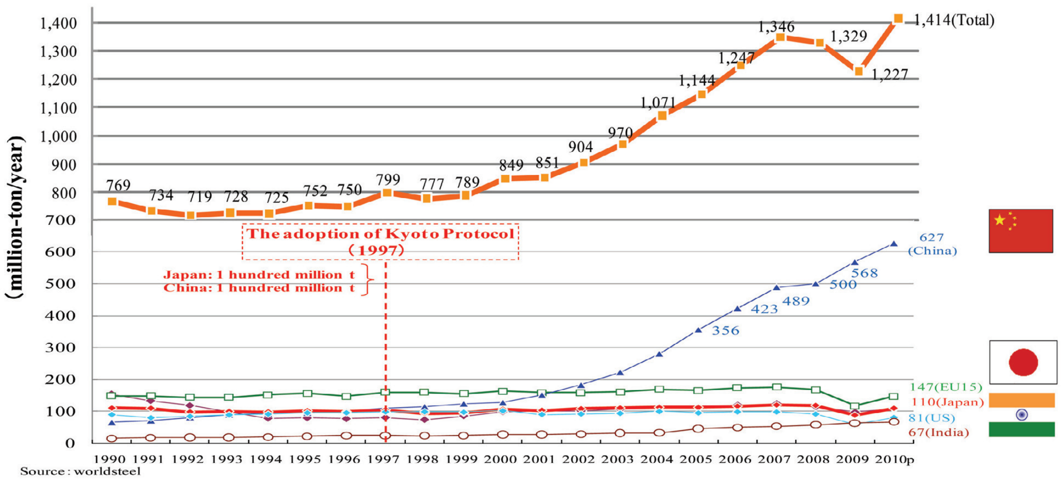

Fig. 4 Global crude steel production

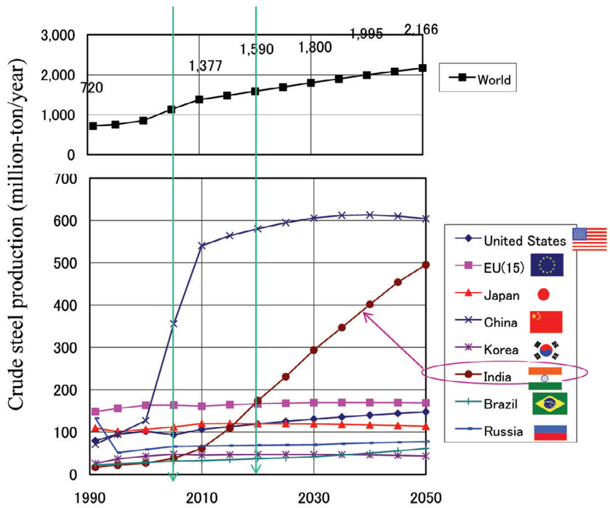

Fig. 5 Longer-term crude steel production estimated by RITE

applied by the steel industry of any other country, it is beneficial to spread such technology throughout the world. The steel industry's cooperative sectoral approach consists of: formulating common action guidelines on the problem of global warming, regional environmental problems, and problems involved in building a recycling-based society; carrying out improvement activities as required through international cooperation; and implementing specific measures to improve energy efficiencies (unit energy consumption, unit CO_2 emission) and reduce emissions of CO_2 and other environmental loads.

The first step of this cooperative sectoral approach is to share a technology list (the SOACT[5] handbook of the APP steel task force is an example of technology list) between the parties concerned, and to promote the spread of the technologies on the list through interchanges of experts, etc.

The next step is to establish a common method of calculating the overall energy efficiency of each individual steelworks (the Japanese steel industry is now working for international standardization of the calculation methodology that has been established by the World Steel Association) and create databases concerning energy efficiency, etc. on a global basis. It is expected that with the introduction of individual techniques to save energies, the overall energy efficiency will steadily improve, even though it is influenced more or less by other factors.

2.2.2 Steady expansion in international cooperation

In July 2005, the Japanese steel industry chaired the 1st Japan-China Meeting for Interchange of Advanced Technologies for Environmental Protection/Energy Saving in the Steel Industry. Since the industry leaders of the two countries signed a memorandum (in Beijing) on the interchange of technologies on a regular basis, the technology exchange meeting of experts has been held annually.

The APP[6] was started in April 2006 as a government-citizen activity of six nations—Japan, Australia, China, India, South Korea and the United States (now seven nations as Canada joined in 2007). Holding meetings twice a year, the APP has steadily produced tangible results through the sharing of technologies for environmental protection/energy savings, the establishment of common indexes of energy efficiencies, and expert diagnoses for energy savings, etc.

The effectiveness of the APP activities that form the foundation for the cooperative sectoral approach described above came to be recognized by many countries around the world. Eventually, the APP's activities were expanded from the seven Asia-Pacific nations into a global effort (Global Superior Energy Performance (GSEP) started under a meeting of the Clean Energy Ministers). In October 2007, the World Steel Association adopted a global sectoral approach, and thereby it has established an evaluation methodology commonly applicable around the world and has built a database on CO_2 emissions from the major steelworks in the world.

In 2003, the CO_2 Breakthrough Program—a program to develop technology for a drastic reduction in CO_2—was launched. Japan, too, takes part in a similar project called COURSE50 (CO_2 Ultimate Reduction in Steelmaking process by innovative technology for cool Earth 50) as shown in **Fig. 6**. Thus, since the start of Japan-China interchanges of technology, international cooperation within the steel industry has been steadily expanding, proving not only the importance but also the effectiveness of international cooperation as shown in **Fig. 7**.

2.2.3 Optimizing international cooperation in the future

The international cooperation of the steel industry that has been described so far can be divided into private-based activities, like those of Japan, China, and the World Steel Association, and government-citizen activities, like those of the APP. In any case, these activities have no legal binding force and are considered, so to speak, to be extensions of voluntary action plans. Today, their effectiveness is highly evaluated.

On the other hand, the United Nations also recognizes the importance of transferring and spreading steelmaking technology (the U.N. Framework Convention on Climate Change). For example, the Cancun Agreement (reached in December 2010) at COP16 embrace the analysis of policy problems relating to technology transfer as a "technical mechanism"; the study/recommendation of action to promote technology transfer; the promotion of cooperation, and the formulation of guidelines on cooperation; etc. Thus, the United Nations is paying closer attention to the cooperative activities of the APP, amongst others.

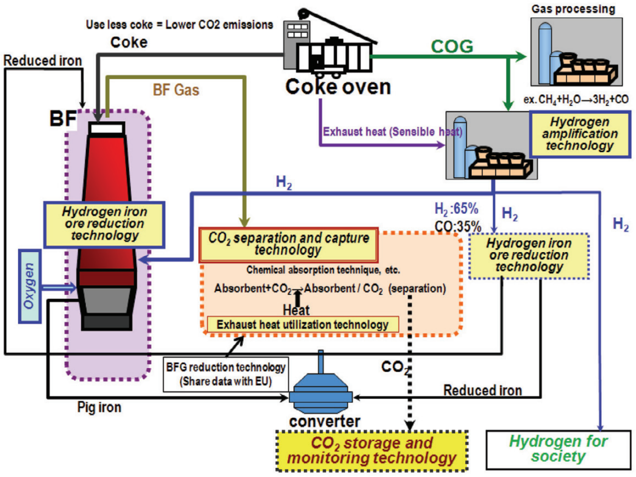

Fig. 6 New break-through technical development project in Japanese steelmaking industry

While continuing negotiations at the U.N., the Japanese government has proposed a mechanism of effective technology transfer between two countries (bilateral offset mechanism). In this respect, the Japanese steel industry is also studying specific examples.

2.3 Steel industry facilitation of a low-carbon society

2.3.1 The first commitment period under the Kyoto Protocol and the voluntary action plan of the Japan Iron and Steel Federation[7)]

(1) Activity to save energy in the steelmaking process

The steel industry has been striving to improve the energy efficiency of steelmaking processes so as to reduce annual energy consumption in the steelmaking processes for the first commitment period (fiscal 2008 - 2012) by 10% from the benchmark year (fiscal 1990). The target reduction is based on the assumption that crude steel output is 100 million tons a year. Even if the actual crude steel output exceeds that level, the industry does it best to attain the target value (this corresponds to a 9% reduction in CO_2 emissions) with the aid of the Kyoto mechanism, etc.

(2) Contribution to energy savings in Japanese society

Apart from the energy savings in the steelmaking processes, the steel industry has conducted extensive activities to save energy. These include: utilizing one million tons of waste plastic, etc. on the assumption that an efficient waste collection system is established; contributing to energy savings in our society by utilizing products/by-products; contributing to energy savings on a global scale through international technological cooperation; utilizing untapped energy in neighboring regions; helping to save energy in homes (environmental household accounts) and offices; effectively utilizing lumber from thinning; improving the efficiency of transportation of products, by-products, raw materials and fuels; etc.

Fig. 7 Cooperative sectoral approach in global steelmaking industry

(3) Activity to develop innovative technologies

The steelmakers have been co-developing innovative new technologies from a long-range viewpoint (e.g. technology to separate and recover CO_2 from blast furnace gas and technology to reduce iron ore using hydrogen obtained by reforming coke oven gas).

2.3.2 Plan to bring about a low-carbon society by 2020

The concept of Nippon Steel's action plan to help to create a low-carbon society by 2020 is shown in **Fig. 8**. This basic concept is common to the Japanese steel industry.

(1) Eco-process

By introducing the most advanced technologies into the manufacturing processes as far as possible, the company strives to further enhance energy efficiency levels that are already amongst the world's highest. Specifically, as the 2020 target, the company aims to achieve a "CO_2 reduction of about five million tons (excluding the CO_2 reduction from the BAU and from improved emission coefficients for electric power in 2020) when the most advanced technologies are introduced as widely as possible on the premise that the 2020 crude steel output is 119,660,000 tons" in the long-term energy supply-demand forecast submitted by the Advisory Committee for Natural Resources and Energy.

(2) Eco-product

Through the development of high-performance steel materials that are indispensable to bring about a low-carbon society and the supply of those steel materials to markets at home and abroad, the company contributes to the reduction of CO_2 at the stage where final products made from those steel materials are used in our society. The actual contribution in fiscal 2009 was 18,810,000 tons. For fiscal 2020, it is estimated to be 30,000,000 tons (from fiscal 2005).

(3) Eco-solutions

Through the transfer/spread of advanced energy-saving technology/equipment from the Japanese steel industry to the steel industries of foreign countries, the company contributes to the reduction of CO_2 on a global scale.

As shown in Fig. 3, the potential CO_2 reduction throughout the world if Japan's advanced energy-saving technology is transferred and disseminated internationally could reach 340 million tons (equivalent to about 25% of Japan's total CO_2 emissions). The actual contribution of this eco-solution in fiscal 2009 was 33 million tons. For fiscal 2020, it is estimated to be 70 million tons.

(4) Development of innovative technologies

The iron ore reducing process uses coal, hence the emission of CO_2 from this process is inevitable. For the period from 2030 to 2050, the company aims to dramatically reduce the CO_2 emissions by promoting the development of innovative steelmaking processes & technology under COURSE50 (reduction of iron ore using hydrogen and separation & recovery of CO_2 from blast furnace gas), etc. (see Fig. 6).

3. Activities to Save Energy and Curb Global Warming

3.1 Specific methods of saving energy

3.1.1 Implementing process innovations

The first oil crisis that occurred in November 1973 prompted the Japanese steel industry, including Nippon Steel, to carry out large-scale process innovation. Looking at the steelmaking processes, the casting and annealing processes were made continuous, which significantly improved energy efficiency and dramatically enhanced productivity. During the 1970s and 1980s, major innovations were also made in the field of system control, including hot charge rolling (HCR) in the hot rolling process, automatic combustion control (ACC) in coke ovens, etc., real-time supply-demand control of electricity, gas and steam by the energy center, and electrically powered supply-demand forecast system.

In the 1990s, a reheating furnace equipped with a regenerative burner, which is more efficient than the conventional recuperator, was developed. More and more reheating furnaces of this type have been introduced. In addition, new technologies that were designed not only to save energy, but also to permit use of inferior raw materials or improve productivity, were developed. They include coal moisture control (CMC) and the next-generation coke oven — SCOPE21 (Super Coke Oven for Productivity and Environmental enhancement toward the 21st century). In 2008, the world's first next-generation coke oven was completed at Nippon Steel Oita Works. This new coke oven has been in good operating condition. It is expected that the new technology will be applied to obsolescent coke ovens. **Fig. 9** shows the change in efficiency of energy use attributable to the above technological development at Nippon Steel. The concept behind SCOPE-21 is shown in **Fig. 10**.

3.1.2 Making the most effective use of by-product gases

In the ironmaking/steelmaking processes, by-product gases are inevitably produced. These by-product gases are first used as fuel for those processes and the remainder is utilized to generate electricity.

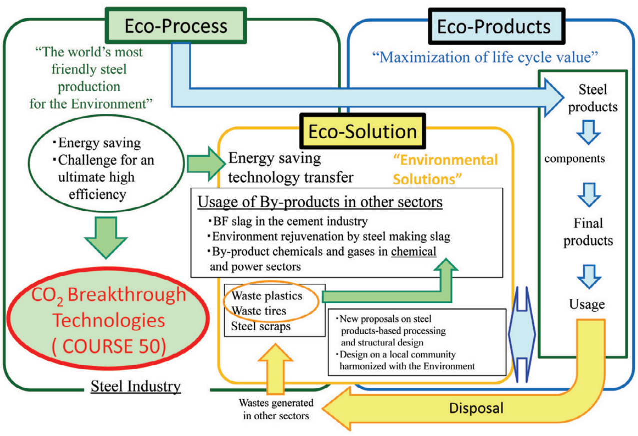

Fig. 8 Conceptual picture on Nippon Steel's Eco-activities: ECO³

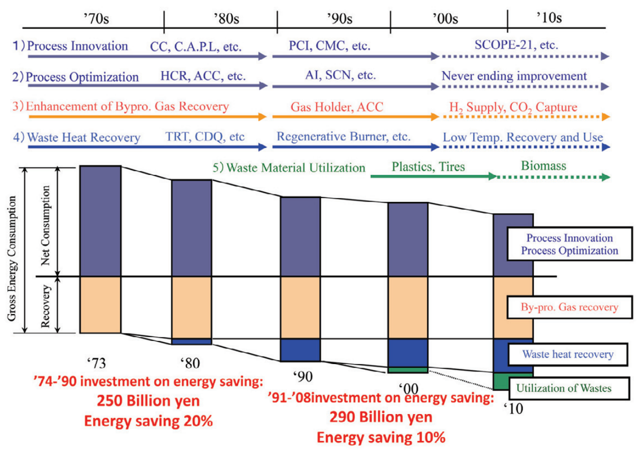

Fig. 9 Efforts for energy saving in Nippon Steel

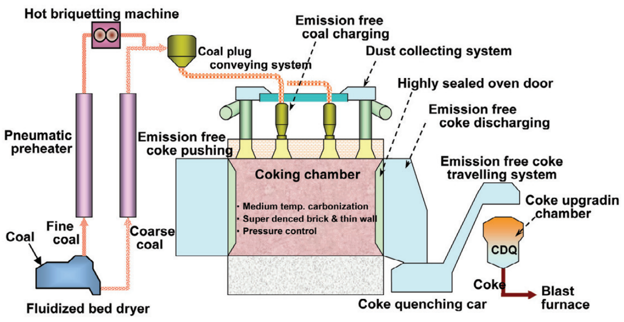

Fig. 10 Schematic view of SCOPE21 process

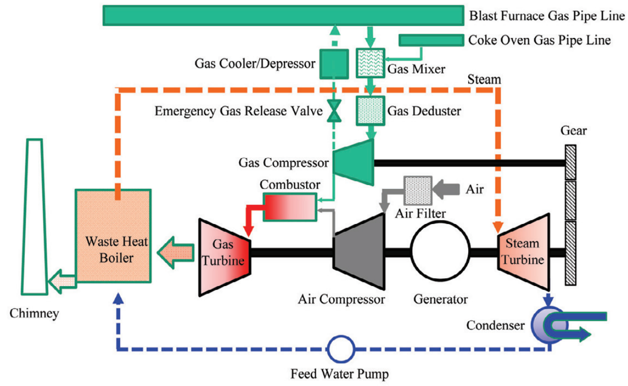

Fig. 11 Schematic view of GTCC process

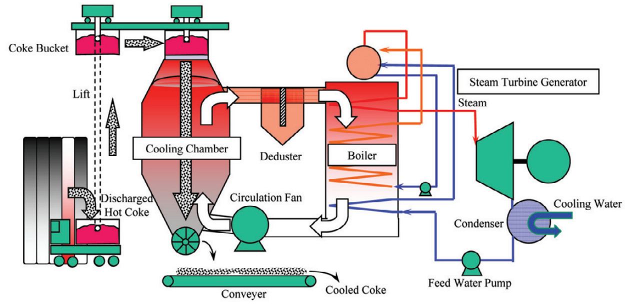

Fig. 12 Schematic view of CDQ process

As more and more energy is saved, the amounts of by-product gases utilized for electricity generation increase. At the same time, the amount of electricity required decreases. As a result, surplus electricity is produced. This surplus electricity is supplied to the neighborhood through a utility company. Incidentally, while the steelworks ordinarily operates 24 hours a day, demand for electricity is generally larger during the day than at night. Therefore, it is desirable that the amount of electricity supplied from the steelworks during the day should be more than at night. In the late 1980s, in order to permit storing coke oven gas (COG) during nighttime and using it for electricity generation during daytime, Nippon Steel constructed at its Kimitsu Works and Oita Works huge gasholders (450,000 m^3 for Kimitsu and 400,000 m^3 for Oita).

Those gasholders are the same as pumped-storage power generation or batteries in that they all store surplus energy. In terms of efficiency and construction cost, however, the gasholders are far superior.

On the other hand, from the standpoint of making the most effective use of by-product gases which have low calorific value and which are generated in huge volumes, Nippon Steel and Mitsubishi Heavy Industries, Ltd. started joint development of a gas turbine exclusively to be fired using by-product gas in the late 1970s. Today, a gas turbine combined cycle (GTCC) power plant, with a turbine inlet gas temperature of 1,300℃ and thermal efficiency of 48%, has been put to practical use. In 2004, the No. 1 300-MW GTCC fired exclusively using by-product gas was brought online at Kimitsu Cooperative Thermal Power Company within the grounds of the Kimitsu Works. **Fig. 11** shows the concept behind the GTCC fired exclusively using by-product gas.

3.1.3 Recovering waste heat

Waste heat recovery is another technology that Nippon Steel has been developing since the late 1970s. The Top-pressure Recovery Turbine (TRT) is equipment that utilizes the pressure of blast furnace gas (BFG) to generate electricity by turning a turbine installed in the BFG piping. With this equipment, it is possible to recover 40% to 50% of the BF power. Formerly, the "Soviet-type" TRT that burned some of the BFG at the turbine inlet was introduced. Eventually, the TRT efficiency was improved significantly by, for example, the co-development of "wet" and "dry" non-combustion-type TRTs by Nippon Steel and Mitsui Engineering & Shipbuilding Co., Ltd. Today, TRTs are installed at all blast furnaces operating in Japan.

Coke Dry Quenching (CDQ) is equipment which uses a non-oxidizing gas (nitrogen, CO_2, etc.) to "dry-quench" the red-hot coke discharged from the coke oven that was formerly "wet-quenched" with water and which generates steam using gas heated by the sensible heat of the coke. The steam generated can be used to generate electricity or as a power source. Since the dry-quenched coke does not contain moisture, CDQ also contributes to improved thermal efficiency of the blast furnace. Today, CDQ is installed in every coke oven at all steelworks in Japan. The concept of CDQ is shown in **Fig. 12**.

The converter gas (Linz-Donawitz Gas: LDG) sensible heat recovery equipment is an improved version of the conventional Oxygen converter Gas recovery (OG) equipment that only recovers the latent heat (chemical energy) of the LDG. It is equipped with a waste-heat boiler to recover the sensible heat (about 1,600℃) of LDG in the form of steam.

Since LDG occurs from blowing on a batch basis, the equipment is, in many cases, connected to a general process steam system via an accumulator.

3.1.4 Utilizing waste effectively

Looking at plastic as a source of energy, it has nearly the same calorific value as its principal raw material—petroleum. General waste and industrial waste contain large amounts of waste plastics. If those waste plastics can be sorted and collected properly, they can become a promising quasi-domestic source of energy. Nippon Steel has developed a technology which permits recycling waste plastics almost 100% by charging waste plastics and coking coal into the coke oven and converting them into hydrocarbon oil, coke oven gas, and coke by chemical decomposition. In the wake of complete enforcement of the Containers and Packaging Recycling Law in 2000, a social system for sorting and recovering waste plastics from general waste was established. Since then, as an effective measure to recycle resources, save energy, and reduce CO_2 emissions, the company has been positively substituting waste plastics for coking coal at all of its steelworks that have coke ovens. In addition, at Hirohata Works, waste tires are used as a raw material in the steelmaking process and are partly recycled in the form of gas or oil. Since the carbide residues and steel cords that occur at the same time can also be used as raw materials for steel products, the recovery rate is very high as in the case of substitution of waste plastics for coking coal.

3.2 Future activities

3.2.1 Development of environment-friendly steelmaking process technology

In view of the increasing influence of global warming on corporate behaviors, the five domestic integrated steelmakers, including Nippon Steel, and Nippon Steel Engineering Co., Ltd. have been developing environment-friendly steelmaking process technology (COURSE50) (see Fig. 6) to drastically reduce CO_2 emissions by around the year 2030.

The development activity involves two major technical challenges.

One is to develop technology to reduce CO_2 emissions from blast furnaces. This consists of developing a technique to control the reducing reaction of iron ore using hydrogen, etc. in order to lessen the consumption of coke in the blast furnace; the development of a technique to reform COG for hydrogen amplification using untapped waste heat from the coke oven; and the development of a technique to manufacture high-strength, high-reactivity coke for reduction by hydrogen.

The other is to develop technology to separate and recover CO_2 from BFG. For this purpose, the member companies have decided to press ahead with the development of chemical/physical adsorption processes relating to CO_2 separation & recovery from BFG and the development of technology that contributes to the reduction of energy required for CO_2 separation & recovery through expanded use of the untapped waste heat from the steelworks[8]. Nippon Steel has actively engaged in the development of a hydrogen reduction process in the blast furnace, a technique to amplify hydrogen by reforming COG using a catalyst, and a technique to separate CO_2 from BFG using the amine process.

3.2.2 Demonstration testing of an energy supply system with steelworks as the core

An integrated steelworks has an abundant supply of energy, including by-product gases, electricity, steam, and hydrogen. Therefore, it is expected to be able to serve as a base to supply energy to the neighboring area. Hydrogen, which is contained in large proportions in COG, can easily be purified using pressure swing adsorption (PSA), etc. Besides, the coke ovens, which generate COG, are widely distributed throughout the country, and hydrogen is expected to become a promising source of fuel for fuel-cell vehicles in the future. So far, demonstration testing on feeding COG-derived hydrogen to a hydrogen station has been carried out at Nippon Steel's Kimitsu Works and Nagoya Works[9, 10], respectively.

In addition, Nippon Steel's Yawata Works has already started to supply by-product hydrogen to a hydrogen station and hydrogen town in the neighboring Higashida area, thereby playing a central role in the demonstration testing of this "Hydrogen Town" [11].

Yawata Works also supplies electricity to the Higashida area, thereby supporting the demonstration testing on "Kita-Kyushu Smart Community" [12]. These activities are not intended to save energy within the steelworks, but rather to allow for efficient use of energy and meet newly emerging social needs beyond the boundaries of the steelworks.

4. Conclusion

We, at Nippon Steel, would like to continue contributing to improvements in energy efficiency, the recycling of resources, and the reduction of CO_2 emissions (curbing of global warming) by tackling the universal theme of utilizing energy and resources efficiently in the steelmaking process (eco-process, eco-solution) and by contributing to communities outside the steelworks (eco-product).

References

1) Nordhaus, W.D.: 1974 Resources as a Constraint on Growth. American Economic Review. 64, (May 1974)
2) Bill on Fundamentals of Measures to Curb Global Warming
 - 25% Reduction in Emissions (2020 Target vs. 1990)
 - Domestic Emissions Trading System
 - Taxation to Curb Global Warming
 - All Renewable Energy One-price Purchasing System
3) RITE: International Comparison of Energy Efficiency. 2008
4) IEA: Energy and Technology Perspective. 2008
5) SOACT: State-of-the-Art Clean Technology
6) APP: Asia-Pacific Partnership on Clean Development and Climate
7) Voluntary Action Plan of the Steel Industry under Voluntary Action Program of the Japan Federation of Economic Organizations (Keidanren), Not Legally Binding but Socially/Politically Binding. Pledge and Review Type Bottom-up Approach
8) Environmentally Harmonized Steelmaking Process Technology Development Homepage http://www.jisf.or.jp/course50/index.html
9) JHFC Homepage http://www.jhfc.jp/station/kanto/ekitai.html
10) JHFC Homepage http://www.jhfc.jp/station/chubu/setokita.html
11) The Research Association of Hydrogen Supply/Utilization Technology Homepage http://www.meti.go.jp/press/20110113002/20110113002-2.pdf
12) Kita-Kyushu Smart Community Homepage http://www.city.kitakyushu.lg.jp/files/000041576.pdf

Teruo OKAZAKI
General Manager
Global Environmental Affairs Dept.
Environmental Affairs Div.
2-6-1, Marunouchi, Chiyoda-ku, Tokyo 100-8071

Toru ONO
General Manager
Energy Technical Planning Dept.
Technical Administration & Planning Div.