Production and Technology of Iron and Steel in Japan during 2014

The Technical Society, The Iron and Steel Institute of Japan

1. Overview of the Japanese Iron and Steel Industry

First, let us look at events related to the production and technology of iron and steel and science and technology which occurred during 2014. In April, Japan’s consumption tax was raised from 5% to 8%. This was the first consumption tax increase in 17 years, since the increase from 3% to 5% in 1997. Following the increase, real GDP growth rate took a sudden turn to negative, affected by the reactionary downturn caused by the consumption tax increase, and the timing of a further increase to 10%, which had been scheduled for October 2015, was postponed by 18 months to April 2017. In December, the Lower House of the Japanese Diet was dissolved and a general election was held, resulting in the inauguration of the 3rd Abe Cabinet. In science and technology, the 2014 Nobel Prize in Physics was awarded to the Japanese developers of the blue LED. The content of this award for science and technology, which is a field where Japan enjoys a superior position, was also a great encouragement to iron and steel researchers. On the other hand, the so-called “paper falsification problem” in connection with science and technology papers also became apparent in various fields, leading to a renewed recognition of the necessity of redressing issues related to the management systems of research organizations and the ethics of individual researchers. During the year, Japan also suffered various natural disasters, including a landslide disaster triggered by local torrential rains in the northern part of Hiroshima City in August and the volcanic eruption of Mt. Ontakesan in September.

Where the Japanese economy was concerned, at the end of 2012, the government implemented economic policies aimed at overcoming deflationary conditions and creating a “virtuous economic cycle.” These policies have proven successful, as the favorable trends of a weak yen rate and rising stock prices continued, and the economy recovered in a form led by domestic demand centering on personal consumption. As a result, the real GDP growth rate had increased by a cumulative 2.2% by the end of 2013. Trends of increasing revenue/increasing profit were reported in both manufacturing and non-manufacturing industries, and current profit (operating income) reached historical highs in the January–March quarter of 2014. In the first half of 2014, budgets for large-scale public works projects provided the underpinning for a favorable business climate, but personal consumption and residential investment fell sharply in the second half of 2014 due to the surge in demand before the consumption tax increase in April and the reaction that followed, while the delay in the recovery of capital investment by companies also continued. As a result, the real GDP growth rate was negative for two consecutive quarters (April–June, July–September). However, with the weak yen continued through year-end, the competitiveness of Japanese companies improved and the effect of increasing exports began to appear, and the real GDP growth rate (preliminary figures) turned positive in the October–December quarter.

Reflecting these economic conditions in Japan, crude steel production for calendar year 2014 was 110.67 million tons, thus exceeding the 110 million ton level for two consecutive years (Fig. 1). Although the prices of iron ore and metallurgical coal had risen sharply as a result of the tight supply of raw materials for steel due to increasing production in China, prices have shown a declining tendency since peaking in 2011, and were on a level one-half or less than that in the peak period during 2014. This change in the prices of raw materials for steel became a factor in rising company profits, and the business performance of steel makers generally took a favorable turn. On the other hand, equipment and operational problems at steel works were a frequent occurrence, and investigation of the causes and study of measures to prevent recurrence became an urgent matter. Overseas investment and offshoring of production also continued during 2014, particularly in the Southeast Asian countries, as Japanese makers implemented overseas development through joint ventures for the manufacture of automotive steel sheets, increased capital participation in the establishment of integrated steel works by locally-incorporated subsidiaries, etc. As conditions surrounding the iron and steel industry during 2014, the following presents an overview of trends in raw materials for iron and steel, trends in steel-consuming industries, the condition of crude steel production in Japan and worldwide, and the globalization of steel companies.

1.1. Trends in Raw Materials for Iron and Steel

Beginning in 2004, the prices of iron ore, metallurgical coal and other raw materials for iron and steel had risen sharply due to a tight supply-and-demand situation accompanying increasing iron and steel production. However, prices peaked in 2011 and have continued to decline in recent years. Iron ore supply capacity expanded as the three major iron ore producers (BHP Billiton, Rio Tinto and Vale) in Australia, Brazil, etc., carried out expansion plans targeting 2015, and new suppliers have also entered this market, while on the other hand, the price of iron ore decreased greatly in 2014 due to sluggish Chinese demand for iron ore. It has been reported that the spot price of iron ore (iron content: 62% fine ore; landed price in China) was around US$140/ton in the summer of 2013 but had fallen to the US$70 level at the end of 2014. The supply-and-demand

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equation for metallurgical coal was affected by virtually the same pattern of developments as in the case of iron ore; the major suppliers continued to increase their supply systems while the growth of steel production in China slowed, and China also increased production of domestic coal, resulting in a relaxation of supply-and-demand. It was reported that the loaded price of strongly caking coal was US$117/ton (FOB) in January–March 2015, which was the lowest price since April 2010.5)

Figure 2 shows the transition of world iron and steel production and the unit price of imported iron ore and metallurgical coal according to the World Steel Association and Japanese Ministry of Finance statistics.6)

1.2. Trends in Steel-consuming Industries

The following presents the general trends in steel-consuming industries during 2014 according to the quarterly steel supply-and-demand report of the Japan Iron and Steel Federation (JISF), etc.7) For details, please refer to the original Japanese text or the JISF website.

[Civil engineering] The first half of fiscal year 2014 saw high growth in orders received for public works civil engineering projects, buoyed by front-loading of a “15 month budget,” which combined the supplementary budget for FY 2013 and the original budget for FY 2014. In the second half, steel demand remained firm, but due to a decline in the leading indicator “deposits for contracted public works,” no increasing tone in the value of orders, like that in the first half, could be seen. As there was also a reaction from the high level of the previous year, the second half was characterized by a declining tendency.

[Construction] In residential construction, the number of new housing starts in 2013 was on the 1 million unit level due to factors such as the buying rush ahead of the consumption tax increase, etc. However, in 2014, housing starts dropped sharply, to the 800 thousand unit level, as a result of the reaction following the tax increase. In the nonresidential field, government and educational construction decreased as a result of the peel-off of the effect of the supplementary budget for FY 2013, but in spite of that decline, nonresidential construction starts (floor space) remained basically flat, at around 55 million m², supported by private-sector investment in mining and manufacturing and the commercial/service industry sectors, among others.

[Shipbuilding] After the spring of 2013, ship prices at rock bottom, coupled with a surge in demand ahead of strengthening of noise regulations, resulted in a continuing large increase in the volume of export contracts until June of 2014. Following July 2014, after strengthening of noise regulations, a reactionary downturn in new orders could be seen. However, the volume of new shipbuilding starts, which fell dramatically in FY 2012, also returned to the level of approximately 12 million gross tons.

[Automobiles] Until summer, domestic unit sales for
2014 were unpinned by the backlog of orders received before the consumption tax increase, but due to the effects of the tax increase, sales were sluggish after summer. Nevertheless, production for the year was 9.77 million units, for an increase of 1.5% from the previous year. Where exports declined by 4.5% from the previous year. Sales of fuel cell vehicles (FCV) as next-generation automobiles began at the end of 2014, resulting in a renewed focus on technological development for hydrogen filling stations and storage tanks, automotive hydrogen containers, etc.

[Industrial machinery] Production of construction machinery was firm thanks to a surge in demand for medium- and small-sized equipment in advance of strengthening of exhaust gas regulations, among other factors. There was also a firm trend in transportation machinery against the background of increased construction of distribution warehouses, etc. Electric power-related demand in the emerging economies supported production of boilers and motors. As a result, annual orders received for machinery achieved a scale of approximately ¥12 trillion, for an increase of about 10% from the previous year.

The year 2014 also saw a large change in the price of crude oil. The price of crude oil was on the level of US$100/ barrel at the start of the year, but fell to about half that, or around the US$50 level, by year end, giving rise to concerns about the effect on demand for energy development, for example, shale development in North America.

[Electrical machinery] In heavy electric machinery, the environment for orders from domestic electric power utilities remained extremely difficult. Nevertheless, the tone in this field was generally firm due to an increasing trend in capital investment against the backdrop of strong corporate profits, together with increasing demand for electric power in other countries, centering on the emerging economies. In home electrical appliances, offshoring of production continued, and there was also a feeling of reaction following the buying surge before the consumption tax increase. As a result of these and other factors, appliance production continued to decline in the second half of the year. In electronics equipment, the large decline in production of industrial electronics following the end of support for the former personal computer OS continued, and consumer electronics also remained stagnant following the sharp drop-off in production of flat-panel televisions following completion of the transition to digital terrestrial broadcasting.

1.3. Crude Steel Production

Crude steel production in Japan during calendar year 2014 was 110.67 million tons, which was an increase of 0.1% from the 110.59 million tons of 2013. This also exceeded the 110 million ton level for the second consecutive year. By furnace type, converter steel production was 84.99 million tons (0.8% decrease from 2013), while electric furnace steel production was 25.68 million tons (3.1% increase). The ratio of electric furnace steel was 23.2% (0.7 point increase) (Fig. 1).4

World crude steel production in calendar year 2014 was 1 662 million tons, which was an increase of 1.2% in comparison with the 1 642 million tons of the previous year.9 Although crude steel production continued to rise, the global increase became more gradual due to the slower growth rate of crude steel production in China. As shown in Table 1, the top 10 countries in crude steel production in 2014 were China, Japan, the United States, and so on. While all top-ranking countries enjoyed growth rates of several percent in comparison with the previous year, China’s growth rate slowed to 0.9%. According to the World Steel Association (WSA), the average operating rate of the main 65 steel-producing countries in 2014 was 76.7%,9 which was a decline of 1.7 points from the 78.4% of 2013. Focusing on production capacity, the excess production capacity in China continued to be remarkable, and exports of steel products from China increased due to the relaxation of the domestic supply-and-demand balance in that country.

According to a forecast of domestic steel demand in Japan for FY 2015 published by the Japan Iron and Steel Federation, in spite of the peel-off of the buoying effect of public works budgets, residential investment is seen as approaching bottom after the sharp drop following the consumption tax increase, and a firm trend is also foreseen in nonresidential construction and capital investment in machinery.10

Table 1. Top 10 crude steel producing countries (Source: WSA, Unit: Mt).9)

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<td>China</td>
<td>702.0</td>
<td>731.0</td>
<td>4.1</td>
<td>815.4</td>
<td>11.5</td>
<td>822.7</td>
<td>0.9</td>
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<td>107.2</td>
<td>▲0.4</td>
<td>110.6</td>
<td>3.2</td>
<td>110.7</td>
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<td>2.7</td>
<td>86.9</td>
<td>▲2.0</td>
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<td>81.3</td>
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<td>83.2</td>
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<tr>
<td>Korea</td>
<td>68.5</td>
<td>69.1</td>
<td>0.9</td>
<td>66.1</td>
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<td>71.0</td>
<td>7.4</td>
<td>71.0</td>
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<tr>
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<td>68.9</td>
<td>70.4</td>
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<td>▲2.1</td>
<td>70.7</td>
<td>2.6</td>
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<tr>
<td>Germany</td>
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<td>42.7</td>
<td>▲3.6</td>
<td>42.6</td>
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<td>42.9</td>
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<tr>
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<td>34.1</td>
<td>35.9</td>
<td>5.3</td>
<td>34.7</td>
<td>▲3.3</td>
<td>34.0</td>
<td>▲2.0</td>
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<tr>
<td>Brazil</td>
<td>35.2</td>
<td>34.5</td>
<td>▲2.0</td>
<td>34.2</td>
<td>▲0.9</td>
<td>33.9</td>
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1.4. Globalization of the Japanese Steel Industry

As in previous years, there were also reports of investment in overseas projects and other moves toward globalization in 2014 by each of Japan’s steel makers.(11) Nippon Steel & Sumitomo Metal began commercial production at a joint venture tinplate plant in China in January, began a joint venture with ArcelorMittal in the United States in February, concluded a final agreement on a joint venture for production and sales of automotive steel sheets in Indonesia in August, held the Opening Ceremony for an automotive cold-rolled steel sheet plant in India in September, concluded an agreement on supply of oil country tubular goods (OCTG) with Brunei Shell Petroleum Co. Sdn. Bhd. (BSP) in November, and also established a subsidiary to process OCTG joints in Negara Brunei Darussalam in the same month.

In September, JFE Steel discontinued a feasibility study (FS) on the construction of a steel works in Vietnam. JFE started up electric resistance welded (ERW) pipe production equipment with California Steel Industries in the United States in the same month, and in November, the company carried out a consolidation of its iron ore-related assets in Brazil.

Kobe Steel concluded an agreement to license the MIDREX® direct reduced iron manufacturing process to Paul Wurth SA of Luxembourg in March and a licensing agreement in connection with a pellet plant with FLS of India in April. Kobe also increased the capacity of its wire rod secondary processing base in China in July, established Kobelco Angang Auto Steel Co., Ltd. in China in August, and established a wire rod secondary processing base in Mexico in September.

In the special steel business, Daido Steel decided on capital participation in Sunflag Iron & Steel of India in July, and Mitsubishi Steel Manufacturing decided on 34% capital participation in PT. Jatim Taman Mfg. in Indonesia, also in July. In the casting business, Hitachi Metals agreed in August to acquire the stock of Waupaca Foundry, which is engaged the iron castings business for transportation machinery in the North American market, and make that company a subsidiary.

2. Technology and Equipment

2.1. Technical Environment of the Japanese Iron and Steel Industry

During 2014, the effects of the consumption tax increase in April were also felt in the demand environment for iron and steel. However, due to various economic measures implemented since the previous year, there was a favorable turn in economic conditions, and crude steel production in Japan exceeded 110 million tons for the second consecutive year. As a result, the blast furnace steel makers in particular operated at essentially full capacity throughout the year.(12) In these circumstances, equipment accidents due to fires and power outages occurred at multiple steel works, and this affected production. To prevent a recurrence of these problems, the causes were investigated and response measures were studied. In addition to the problem of excess iron and steel production equipment caused by expansion of production capacity in China and Korea, imports of plain carbon steel products to Japan increased due to the relaxation of the supply-and-demand situations in those countries. In particular, imports of plain carbon steel to Japan from China reached a historically high level of 600,000 tons/year, which was double the scale in the past.

Likewise, China, India and other emerging steel-producing countries continued to expand their activities in research and development on iron and steel-related technologies. For example, the number of papers submitted to “ISIJ International” have shown annual increases in recent years. In comparison with the number of papers submitted, the increase in the number of articles published is not remarkable at the present point in time, but it can be thought that those countries are achieving sure progress in ironmaking, steelmaking and other upstream processes, the environmental and energy fields, and product fields such as automotive steel sheets, among others. On the other hand, a series of large-scale leaks of technology have also come to light. The Intellectual Property Committee of Japan’s Ministry of Economy, Trade and Industry (METI) has been carrying out a study on “Prevention of technology leakage and strengthening of protection of trade secrets” since September 2014, and has spelled out the necessity of cooperative efforts by industry, academia and the government to realize the world’s highest level of protection of trade secrets in the future.(13)

Next, in 2014, continuing from the previous year, important progress was achieved in National Projects which are deeply related to the iron and steel industry. The METI project “COURSE50 (CO2 Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50)” advanced to Step 2 in 2013 and construction for installation of a test blast furnace with an inner volume of 10 m³ began at Kimitisu Works of Nippon Steel & Sumitomo Metal, with the aim of carrying out combined tests of hydrogen reduction and CO2 separation and recovery. In another METI National Project, “New Structural Systems Using Innovative New Structural Materials,” the Innovative Structural Materials Association (abbreviation: ISMA(14)) was launched in December 2013 and began full-scale technology development in 2014. The main objectives of this project are to promote technical development for achieving a radical reduction in the weight of transportation machinery, centering on automobiles, and technical development in connection with high strength, etc. of steel, aluminum and other materials which are the main structural materials of transportation machinery. Next, in the Cross-ministerial Strategic Innovation Promotion Program (abbreviation: SIP(15)) of the Cabinet Office, Japan, “Innovative Structural Materials” was taken up as one of 10 themes to be promoted in the program, and research and development began. In the Industry-Academic Collaborative R&D Programs sponsored by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Japan Science and Technology Agency (JST), “Heterogeneous Structural Control: Towards Innovative Development of Metallic Structural Materials”(16) entered its 5th year, and 3 new themes were selected for 2014. This is a long-range technology development project with a 10-year timeframe, and efforts aiming at multi-material structures for automobiles are expected.

As outlined above, amid continuing full operation in the Japanese iron and steel industry, efforts are also being made
to improve the technical level of the industry through collaboration among industry, academia and the government in order to overcome increasingly intense international competition. The following describes the main technological trends by field of iron and steel technology and introduces the technical topics of the Sustaining Member Companies of the Iron and Steel Institute of Japan.

2.2. Iron-making

Pig iron production in calendar year 2014 was 83.87 million tons, which was virtually the same level as the 83.85 million tons of 2013. Blast furnace productivity was 1.93 ton/m$^3$-day in 2014 and was essentially unchanged from 2013 (1.94 ton/m$^3$-day). A total of 27 blast furnaces were in operation at the end of 2014, which was also unchanged from the previous year. The number of blast furnaces with inner volumes of more than 5 000 m$^3$ was 14, which was an increase of 1 from the end of 2013.

At Nippon Steel & Sumitomo Metal Yawata Works, Tobata Area, No. 4 blast furnace completed its 3rd campaign of approximately 16 years and relining began. The revamped furnace was blown-in in April 2014. The inner volume was increased from 4 250 m$^3$ to 5 000 m$^3$, the charging system was changed from the bell type to a bell-less top, and No. 4BF was began its new campaign as a blast furnace with excellent operational stability and cost competitiveness.

Nippon Steel & Sumitomo Metal also improved the sintering process at Oita Works with the aim of reducing NOx in the sintering machine exhaust gas without the enormous investment required for denitrification equipment. A NOx reduction of more than 10% was realized in the actual line by devising a pretreatment method in which CaO is coated in the surface layer of coke breeze (lime coating coke).

JFE Steel developed a technology which improves the combustibility of sintering coke breeze and hydrogen-based gas by combined injection of oxygen and hydrogen-based gas into the sintering machine, and applied this technology in commercial operation at Chiba No. 4 Sinter Plant and Keihin No. 1 Sinter Plant. Application of this technology makes it possible to improve permeability during sintering, increase sintered ore strength and improve productivity.

2.3. Steelmaking

Crude steel production in calendar year 2014 was 110.67 million tons, which was a very slight increase in comparison with the 110.59 million tons of 2013. The ratio of continuous casting slabs/ingots for rolling is shown in Fig. 3. The continuous casting ratio of special steel decreased to 94.8%. It may also be noted that, beginning from January 2014, data for the “continuous casting ratio” of ordinary steel will no longer be collected.

Kobe Steel constructed a new steelmaking shop at Kakogawa Works in order to increase production capacity of low-P, low-S high grade steels such as special steel wire rod material/long products, automotive high strength steel sheets, and plates for the energy sector. Operation began in April 2014. Two units of mechanical-stirring desulfurization equipment (KR) and one dephosphorization furnace were newly constructed, enabling increased production of high grade steels and a large reduction in costs.

In December 2014, JFE Steel started operation of No. 3 BOF at Fukuyama No. 3 Steelmaking Shop and introduced a state-of-the-art hot metal pretreatment process utilizing the new converter. This process makes it possible to minimize the decrease in reaction efficiency during dephosphorization and broadly reduce lime consumption by once discharging the silica (SiO$_2$) which is generated in the desiliconization process.

2.4. Steel Products

2.4.1. Sheets

At Nippon Steel & Sumitomo Metal, Kashima Works developed a stable shape measurement technology which is free of variations in illumination intensity by using an array of high brightness LED chips to form a zigzag-shaped projection pattern on the surface of steel sheets. This technology solves the problems of measurement stability and deterioration of accuracy during the strip standing-wave phenomenon (shape change corresponding to strip movement), which were long-standing issues in measurement of the shape of steel strips while travelling.

JFE Steel developed 590–980 MPa class high elongation-stretch flangeability type high tensile strength galvannealed steel sheets (HITEN GA), which have excellent stretch flangeability in addition to elongation characteristics, as steel sheets for automotive frame parts. In the developed steel sheets, the hole expansion ratio, which is an index of stretch flangeability, is approximately 2 times higher than that of the conventional material, thereby increasing the freedom of shape design in automotive frame parts. As this material also enables positive application of HITEN GA with higher strength to automotive frame parts such as the pillar lower, etc., which have deep drawing shapes, the new
sheets are expected to make an important contribution to further weight reduction in automobiles.

2.4.2. Plates

Because the International Maritime Organization (IMO) has codified rules for corrosion prevention measures in tankers, requiring use of either an anticorrosion coating or corrosion-resistant steel, an expansion in demand for corrosion-resistant steels for shipbuilding is foreseen in the future. Nippon Steel & Sumitomo Metal’s corrosion-resistant steel for tank bottom plates has a supply record already exceeding 10,000 tons, and the company also commercialized corrosion-resistant steel for tank upper parts during 2014. In addition to reducing time and costs during tanker construction, this is expected to have a number of other benefits, including reduction of life cycle cost (LCC), lessening of environmental loads by avoiding painting, etc.

Nippon Steel & Sumitomo Metal also developed a steel plate with excellent impact resistance for use in shipbuilding. This is a new steel plate which improves ship collision safety thanks to the high ductility of the steel while also maintaining the same workability as the conventional product, and was realized by composition design and microstructural control at the crystal grain level. Because this steel plate has excellent ductility, impact energy absorption to fracture is about 3 times higher than that of conventional steels. These steel plates have excellent resistance to fracture during impact from the ship’s side, not only preventing flooding of the ship and protecting the cargo, but also preventing oil spills, which are a cause of serious environmental pollution.

JFE Steel developed a high corrosion resistance heavy steel plate for use in coal carriers. The cargo holds of coal ships are subject to severe corrosion, in which the sulfur content of the coal is a corrosion factor, and this had increased maintenance and replacement costs. JFE investigated suppression of corrosion wear loss in this coal environment, resulting in the development of steel ship plates with a combination of formability and weldability equal to that of the conventional plates. Performance was demonstrated by an exposure test in the cargo hold of an actual ship, and the new plate was adopted for the first time in a newly-constructed coal carrier during FY 2014.

JFE Steel also developed the world’s heaviest gauge 460 MPa class yield strength high arrestability steel plate. Since safety is demanded in the superstructures of ultra-large-scale container ships, extra-heavy high strength plates with excellent brittle crack propagation arrest performance (arrestability) are required. JFE developed the world’s heaviest gauge yield point (YP) 460 MPa class steel plate for ship structural use with improved arrestability by utilizing its advanced TMCP (thermo-mechanical control process) technology and unique crystal orientation control technology, and has received ship classification society approval for this product. As a result, safety design of large-scale container ships exceeding 16,000 TEU is now possible.

Kobe Steel revamped the accelerated cooling equipment at its Kakogawa Works Plate Mill in July 2014. The existing accelerated cooling equipment was improved by installing a dense array of cooling nozzles, which were also moved closer to the plate, and applying high pressure spraying of the cooling water. These improvements are suitable for uniform cooling of steel plates, and thus secure both safety and good weldability. This is expected to strengthen the company’s ability to respond to requirements for high performance steel for the energy sector, and also realize high performance in products for the shipbuilding and construction sectors.

Based on research on the relationship between the weld bead shape and paint film thickness, Kobe Steel optimized the viscosity and solidification temperature of the molten slag, which affects the bead shape in horizontal fillet welding, enabling large leg length welding of approximately 8 mm in 1 pass, and developed a flux cored welding wire which is expected to improve the efficiency of welding work and enhance paintability.

2.4.3. Steel Pipes

JFE Steel and Metal One Corporation received a joint order for 280 tons of OCTG for casing pipes for an offshore oil field development project in Brazil from that country’s national oil company, Petróleo Brasiliero S.A. This was the first order for seamless steel pipes with excellent corrosion resistance. The pipes, which have a wall thickness of 13.84 mm and an outer diameter of 9.625 inches (244.4 mm), were manufactured and shipped from JFE Steel’s Chita Works.

2.4.4. Products for Hydrogen Stations and Transportation Machinery

Nippon Steel & Sumitomo Metal developed a high strength, high nitrogen stainless steel for use with high pressure hydrogen. With practical application of fuel cell vehicles now progressing, construction of more than 1000 hydrogen filling stations, which will serve as fuel supply bases, is planned by the year 2025. Application of the developed steel, which has a combination of high strength and resistance to hydrogen embrittlement, will make it possible to reduce the cost of constructing hydrogen stations by reducing the weight of the materials used, and thus is expected to contribute to popularization of fuel cell vehicles.

Based on long years of research on hydrogen gas embrittlement, Japan Steel Works succeeded in development of high durability/high reliability steel hydrogen storage pressure vessels with a design pressure of 99 MPa. A low alloy steel, SA723 steel (NiCrMoV steel) with excellent strength and toughness was adopted as the material for these hydrogen pressure vessels, as use of this material in ultra-high pressure vessels has been confirmed in other countries. Various countermeasures were adopted to minimize the effects of hydrogen embrittlement in the processes of melting, heat treatment, processing and inspection. In particular, processing techniques that ensure excellent durability were used to suppress fatigue crack growth in a hydrogen environment, and approval as a pressure vessel with a life of up to 10⁵ fills, with no restriction on years of use, was obtained from the High Pressure Gas Safety Institute of Japan (KHK). The shape of the hydrogen storage pressure vessel makes it possible to perform inspections for internal defects by ultrasonic testing (UT) from the outside of the vessel even during use. The vessel has a straight shape which enables detailed inspection of the interior by opening the cover, and thus has a structure which can also secure reliability during operation.

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Nippon Steel & Sumitomo Metal realized low noise in railway rolling stock gear units. Accompanying higher speeds and improved comfort in railway cars, beginning with the Shinkansen superexpress, needs for noise reduction, both along rail lines and in railway cars, have also increased. Nippon Steel & Sumitomo Metal established a technology for 3-dimensional tooth flank modification of the gears of gear units. Units in which the new technology was applied were adopted in new railway cars, and the noise reduction effect was confirmed. Nippon Steel & Sumitomo Metal also set up a system for the manufacture and shipment of 150 m rails, which are the world’s longest railway rails, at Yawata Works. For shipment to customers, conventional railway rails had been cut to the standard length of 25 m or a maximum length of 50 m after rolling. However, the joints between these rails cause noise and vibration and affect the comfort of passengers, and were also a drawback from the viewpoint of railway maintenance. To improve these problems, railway companies had welded the rail joints to produce long length rails.

2.5. Measurement, Systems, and Analysis

JFE Steel developed a technology for detection of minute concavo-convex surface defects on rolls, which can be transferred to the surface of thin steel sheets as roll-generated flaws, by a magnetic flux leakage method and has applied this technology in online automatic inspection since January 2010. Kobe Steel newly constructed an automatic ultrasonic testing (UT) machine at the shear line of the Kakogawa Works Plate Mill in December 2014 for internal quality assurance of steel plates for the energy sector. Japan Steel Works established a high accuracy, high reliability quality evaluation technique by applying phased array UT technology by an automatic UT system to detection of internal defects of ultra-large-scale rotor shafts with the maximum diameter of 3 200 mm.

In analysis-related technologies, JFE Steel developed a system which enables quantitative analysis of the carbon content in iron and steel materials with the world’s highest accuracy and installed an actual device at its Steel Research Laboratory in February 2014. Although the accuracy of quantitative analysis had been limited to carbon contents on the 0.1% level with the conventional technology, this technology improves analytical accuracy to the 0.01% level, thus providing 10 times higher accuracy than the conventional device. In the theme “Development of Innovative New Steel Plates” in the National Project “New Structural Systems Using Innovative New Structural Materials,” Japan’s New Energy and Industrial Technology Development Organization (NEDO) and the Innovative Structural Materials Association (ISMA), together with JFE Steel, which is a member of ISMA, improved the carbon quantitative analysis device “FE-EPMA” (manufactured by JEOL), thereby achieving enhanced analytical accuracy. As part of the same project, JFE Steel is targeting a further improvement in accuracy and establishment of an analytical method with accuracy of 0.003% or under as a future goal.

2.6. Environment and Energy

2.6.1. Government Efforts

The 20th session of the Conference of the Parties to the UNFCCC (COP20) and the 10th session of the Conference of Parties serving as the Meeting of the Parties to the Kyoto Protocol (CMP10) was held in Lima, Peru from December 1 to 14, 2014.18) As a result of discussions in the high-level segment through working-level negotiations in the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP) and sessions of two Subsidiary Bodies, resolutions of COP and CMP were adopted, including decisions on Intended Nationally Determined Contributions (INDC) submitted by respective countries for a post-2020 framework. In addition, Japan’s Minister of the Environment, Mr. Yoshio Mochizuki, stated that “Japan reaffirms the goal to reduce emissions by 50% at the global level and by 80% in the developed world by 2050.” Minister Mochizuki also declared that Japan intends to submit its INDC as early as possible and mentioned Japan’s contribution to reduction of global emissions by utilizing its technologies.18)

2.6.2. Efforts of the Japanese Steel Industry

The Japan Iron and Steel Federation (JISF) established a “Voluntary Action Programme for the Iron and Steel Industry” and has carried out efforts with the following targets.

(1) Assuming annual crude steel production of 100 million tons, achieve a 10% reduction of energy consumption in iron and steel processes by FY 2010 compared with the baseline year, FY 1990.

(2) The above-mentioned target is to be achieved as an average value for the 5-year period from FY 2008 to FY 2012.

The JISF summarized the results of the Voluntary Action Programme in December 2013. The actual average value for the targeted 5-year period was a reduction of 10.7% and thus achieved the target of the Programme.19) Furthermore, the amount of CO₂ emissions was reduced by 10.5% in comparison with FY 1990.

A new “Low Carbon Society Action Plan” was adopted in January 2013. As a goal for the activities of domestic companies for 2020, the steel industry is making ongoing efforts to improve energy efficiency in iron and steel production process, which is already on the world’s highest level, targeting a “reduction of 5 million tons-CO₂ from the CO₂ emissions assumed for various production volumes, i.e., business-as-usual (BAU) emissions, based on the maximum use of the most advanced technologies.” As the result of efforts under this “Low Carbon Society Action Plan” in FY 2013, BAU emissions were 188.79 million tons-CO₂ against crude steel production of 108.46 million tons in FY 2013 (total production of companies participating in the Action Plan), but the CO₂ emissions corresponding to this production volume were 189.42 million tons-CO₂. Thus, the actual reduction from BAU emissions was +0.63 million tons-CO₂, or +5.63 million tons-CO₂ in comparison with the target. In spite of steady promotion of reduction by voluntary efforts, the actual results for FY 2013 exceeded BAU due to factors which could not be foreseen when the target was set. Incidentally, in FY 2013, crude steel production by the entire Japanese iron and steel industry was 111.52 million tons.

In development of innovative technologies, COURSE50 (CO₂ Ultimate Reduction in Steelmaking Process by Inno-
ative Technology for Cool Earth 50) has been underway since FY 2008 with the aim of reducing CO₂ emissions by approximately 30%, which will be achieved by reducing CO₂ emissions from the blast furnace and separation/recovery of CO₂ from blast furnace gas. Step 1 of Phase 1 was completed in FY 2012, and development under Step 2 of Phase 1 began in FY 2013 with a schedule of 5 years. The primary purpose of Step 2 is “Comprehensive development of hydrogen reduction and separation/recovery,” focusing mainly on a “mini” test blast furnace (pilot scale blast furnace). In order to establish a blast operating technology that maximizes the effect of hydrogen reduction, combined tests with a test CO₂ separation plant and the test blast furnace are scheduled.

Regarding reduction of iron by hydrogen in the blast furnace, in FY 2014, construction of a test blast furnace with a 10 m³ scale began and technical development to maximize the effect of hydrogen research was promoted. Other subjects were technical development for reduction of energy/cost in separation of CO₂ from blast furnace gas, cost reduction and verification of upscaling of the physical adsorption method, and development of a technology for utilization of unused waste heat, which is necessary in the chemical adsorption method.

As an example of application of steel slag to environmental remediation and environmental improvement, JFE Steel and the City of Yokohama carried out joint research using steel slag products in a marine area fronting Yamashita Park in Yokohama and confirmed an increase in the number of species in those waters, beginning with natural growth of eelgrass (form of seaweed). This confirmed that steel slag products function effectively as a base for adhering organisms.

In the energy field, in September 2014, Kobe Steel and Tokyo Gas concluded an agreement under which Kobe Steel will construct a gas-fired thermal power plant in Mooka City, Ibaraki Prefecture, and will supply the total output of the power plant to Tokyo Gas. In this project, Kobe Steel will construct a gas turbine combined cycle (GTCC) power plant of a total 1.2 million kW class, consisting of two 60 kW class units, aiming at startup of No. 1 unit in the second half of 2019 and No. 2 unit in the first half of 2020.

3. Technology Trade and Development

3.1. Technology Trade

Figure 4 shows the transition of the balance of technology trade in the iron and steel industry up to FY 2013. Payments received for technology exports increased by 3% from FY 2012, while payments for technology imports dropped by 66%.

3.2. Research Expenditures and Number of Researchers

The following three items were arranged using the data in Companies, etc. in Table 1 of “Statistical Survey of
Researches in Japan” published by the Statistics Bureau, Ministry of Internal Affairs and Communications. The results are shown in Figs. 5–7.21)

[Ratio of Research Expenditures to Sales]
In all industries, this item has been essentially flat for the last 3 years. On the other hand, a decreasing tendency can be seen in the steel industry. In particular, this index declined from 1.39% in FY 2009 to 1.19% in FY 2013, or a decrease of 0.2%.

[Number of Regular Researchers per 10 000 Employees]
In both all industries and the steel industry, an increasing tendency continued until FY 2011. Both showed slight drops in FY 2012, but returned to an increasing tendency in FY 2013.

[Research Expenditures per Regular Researcher]
In all industries, this index showed a slight increasing tendency in FY 2013, although it still has not recovered the level of FY 2008, i.e., before the financial crisis. The steel industry returned to the FY 2008 level in 2011, but the results for FY 2013 showed a further decrease from FY 2012.

3.3. Trends in Research and Development Utilizing Public Funds
Among iron and steel-related technical development projects, no main projects were completed in FY 2013. As new main projects started in FY 2014, “Innovative Structural Materials” (FY 2014–2018, Management Institute: Japan Science and Technology Agency (JST), budget for FY 2014: ¥3,608 billion) was launched as part of the Cross-ministerial Strategic Innovation Promotion Program (abbreviation: SIP15)) of the Cabinet Office. In research and development in this project, a system which enables sustained innovation through materials technology by utilizing new materials technologies will be constructed, assuming in particular FRP for use in aircraft fuselages and engines, power generating equipment, and large-scale structures as exits. In particular, iron- and steel-related researchers are participating in “Development of High Temperature Alloys/Intermetallic Compounds” and “Materials Integration.” Among other programs, “Development of Technology for Recovery of Iron Source from Steel Slag” (FY 2014–2016) was selected as a theme for the practical application development phase in the “Program for Strategic Innovative Energy Saving Technology” (New Energy and Industrial Technology Development Organization: NEDO).

The main continuing projects were i) “CO2 Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50 (COURSE50) Step2” (NEDO 2013 2017), and ii) “Strategic Energy Technology Innovation Program” (NEDO 2014 2016).

Table 2. Examples of research topics with public funding in iron and steel industry.

<table>
<thead>
<tr>
<th>Category</th>
<th>Subject</th>
<th>Source of funds and commission</th>
<th>Beginning fiscal year</th>
<th>Ending fiscal year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Investment Promotion of State-of-the-art Equipment to Overcome the Energy Constraint and the Appreciation of the Yen</td>
<td>METI</td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>CO2 Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50 (COURSE50) Step2</td>
<td>NEDO</td>
<td>2013</td>
<td>2017</td>
</tr>
<tr>
<td></td>
<td>Strategic Energy Technology Innovation Program</td>
<td>NEDO</td>
<td>2014</td>
<td>2016</td>
</tr>
<tr>
<td></td>
<td>Development of Technologies for Hydrogen Production, Delivery, and Storage Systems</td>
<td>NEDO</td>
<td>2010</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>Hetero-Structure-Controlled Metal Materials Project</td>
<td>JST</td>
<td>2010</td>
<td>2019</td>
</tr>
<tr>
<td></td>
<td>Development of Core Technology for Next-generation 10MW Grade Ocean Thermal Energy Conversion Plant</td>
<td>NEDO</td>
<td>2011</td>
<td>2015</td>
</tr>
<tr>
<td></td>
<td>Element Strategy Project (Research Center Creation Type) Structural Materials</td>
<td>MEXT</td>
<td>2012</td>
<td>2021</td>
</tr>
<tr>
<td></td>
<td>Zero-Emission Coal-fired Power Plant Technology Development Project</td>
<td>NEDO</td>
<td>2014</td>
<td>2017</td>
</tr>
<tr>
<td></td>
<td>Strategic Innovation Creation Program</td>
<td>Cabinet Office</td>
<td>2014</td>
<td>2018</td>
</tr>
<tr>
<td></td>
<td>New Material High Power Semiconductor for Realizing Low-Carbon Society</td>
<td>METI</td>
<td>2010</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>Development of Magnetic Materials for High Efficiency Motors for Next-generation Automobiles</td>
<td>METI</td>
<td>2012</td>
<td>2016</td>
</tr>
<tr>
<td></td>
<td>Development of Material and Member to Achieve the Advanced Energy Conservation</td>
<td>METI</td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>Development of Innovative Structural Material Technology</td>
<td>METI</td>
<td>2013</td>
<td>2022</td>
</tr>
<tr>
<td>Others</td>
<td>Mathematical Theory for Modeling Complex Systems and its Transdisciplinary Application in Science and Technology</td>
<td>JSPS</td>
<td>2010</td>
<td>2014</td>
</tr>
</tbody>
</table>

METI: Ministry of Economy, Trade and Industry
NEDO: New Energy and Industrial Technology Development Organization
JST: Japan Science and Technology Agency
MEXT: Ministry of Education, Culture, Sports, Science and Technology
JSPS: Japan Society for Promotion of Science
Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50 (COURSE50), Step 2" (FY 2013–2017), ii) Hetero-structure-controlled metal materials project" (FY 2010–2019), and iii) Technology project of advanced USC (A-USC) thermal power generation" (FY 2008–2016), etc.

The main projects on iron and steel-related research and development topics being carried out with public funds are shown in Table 2. Many of these topics are in the fields of processes, the environment and energy, materials development, etc.

4. Development of Human Resources in Technical Fields

To date, the Iron and Steel Institute of Japan (ISIJ) has conducted various types of training programs (Iron and Steel Engineering Seminars, Iron and Steel Engineering Seminar special course, Advanced Iron and Steel Seminar, Student Iron and Steel Seminar) for the purpose of cross-industry technical core human resources development. In FY 2014, as in FY 2013, the main focus was incorporation of projects to strengthen basic education in the training programs of the ISIJ. To this end, the ISIJ continued to conduct the “Introduction to Iron and Steel Engineering” seminar for master’s level graduate students and the “Experiential Seminar on Advanced Iron and Steel” for undergraduates. “Introduction to Iron and Steel Engineering” was conducted as a 3.5-day seminar featuring lectures on the fundamentals of iron and steel engineering and technical development at the site by teachers from universities and companies, together with a plant tour on the final day (in FY 2014, Nippon Steel & Sumitomo Metal’s Kimitsu Works). A total of 21 students from 10 universities participated.

The “Experiential Seminar on Advanced Iron and Steel” is a 1-day course which introduces advanced technologies related to iron and steel and the outlook for the future, and also includes a plant tour. This year, the seminar was held at four locations, JFE Steel’s East Japan Works (Keihin District), Nippon Steel & Sumitomo Metal’s Wakayama Works and Yawata Works, and Nisshin Steel’s Kure Works. These seminars are also open to students in non-materials-related fields. A total of 65 students participated in the four events.

Continuing from FY 2013, “University Special Lectures by Top Management,” featuring lectures by members of the top management of steel companies, were also held in order to stimulate interest in industry by communicating the attractions of the steel industry as a manufacturing industry. As in FY 2013, lectures were held at 11 universities. This year’s program attracted a total of approximately 1300 students. “University Special Lectures by METI,” which had been held until this year, were presented at 12 universities under the new name “Special Lectures on Iron and Steel Technology” with research laboratory director/general manager class experts newly included as lecturers. Total participation in these events was approximately 800 students.

As in the previous year, all of these seminars and lectures were extremely well received and are scheduled to be held on an ongoing basis in the coming years.

5. Technology Creation Activities in the ISIJ

The ISIJ conducts activities in which it surveys technical information related to iron and steel production technologies, identifies issues for technology development, and works to solve those issues. These activities center on the ISIJ’s Technical Committees and Interdisciplinary Technical Committees, which are part of the Technical Society.

5.1. Technical Committees

Technical Committees promote activities in respective designated fields related to iron and steel production. Regular Committee Meetings are held, where key issues at the present point in time are studied and vigorously discussed as common/important topics. During FY 2014, a total of 34 Committee Meetings (17 Spring Meetings, 17 Fall Meetings) were held, which was the same as in FY 2013. Among these, the Hot Rolled Steel Committee, Cold Rolling Committee and Heavy Sections Committee held their 100th Committee Meetings, which were commemorated by memorial programs. The total number of participants was 2,724, which was a slight increase from the total of 2,650 in FY 2013. (The number for FY 2013 includes a total of 68 university researchers and others, for an increase of 15 from FY 2013.)

Industry-academic collaboration with the ISIJ’s Academic Divisions is also firmly established, and the Technical Committees encourage exchanges through participation of university researchers in Committee Meetings and programs for training young persons, joint programs with the Academic Society, etc.

Technical Subcommittees conduct joint studies of designated technical issues on a priority basis; 19 of these Subcommittees were active during the year.

In addition to lecture meetings for young engineers and plant tours, and lecture meetings with other industries, which are continuing from earlier years, plans aiming at further activation of the Technical Subcommittees were also carried out, including a survey of overseas technologies, plant tours, etc. Technical Subcommittees also accepted requests for plant tours and holding of joint technical meetings from overseas.

5.2. Interdisciplinary Technical Committees

Interdisciplinary Technical Committees study cross-field and inter-industry technical issues. In principle, these activities are conducted within a 3-year timeframe. In FY 2014, the activities of the Interdisciplinary Committee on “Technologies for improvement of reliability of practical structural steels” entered their 3rd year and included a survey of the literature, etc. The Interdisciplinary Subcommittee on “Desirable steel materials for automobiles” conducted plant tours and submitted topics to the Society of Automotive Engineers of Japan (JSAE) while continuing to explore the proper form of a new cooperative relationship with auto makers. In the Interdisciplinary Technical Committee on “Pressure vessel materials,” the “Working Group on Study of Standards for Steel Materials” and the “Working Group on Evaluation of Hydrogen Embrittlement of Steel Materials for Chemical Plants” continued their respective activities, which included survey research, experiments, etc., and a
new “Working Group on High Strength Heat-Resistant Steels” was organized.

5.3. Research Grants and Research Groups

In “Grants for Promotion of Iron and Steel Research,” 35 new projects (including 13 by young researchers) were selected as grant recipients beginning in FY 2014. Combined with the 41 projects selected in FY 2013, this program currently supports a total of 76 projects.

During FY 2014, 19 Research Groups were active, of which seven concluded their activities during the fiscal year. During the year, seven new activities each were begun in Research Group I (“Seeds”) and Research Group II (“Needs”). For FY 2015, five new activities were selected for type I Research Groups and one new activity was selected for type II. In “Industry-originated Project Development Iron and Steel Research,” themes that were selected in FY 2012 were concluded at the end of March, and one theme which was selected in FY 2013 is currently in progress. In addition, one new proposal for FY 2015 was selected.

REFERENCES