2014 OSTC Study Tour — JAPAN

24 October 2014 — Nippon Steel & Sumitomo Metal Corp. – Kimitsu Works

The AIST Oxygen Steelmaking Technology Committee (OSTC) has been a frequent ambassador to the international steelmaking community. On 19–25 October 2014, the OSTC conducted its fifth international oxygen steelmaking study tour with a visit to Japan. Twenty-one delegates from eight countries visited five elite steelmaking facilities and an equipment manufacturer during the six-day study tour.

The OSTC conducted its fifth international study tour on 19–25 October 2014 in Japan.

The delegates met in Osaka, Japan, on 19 October 2014 to begin the tour. On 20 October, the delegates visited the Nippon Steel & Sumitomo Metal Corp. (NSSMC) – Wakayama Works. Mr. Hiroaki Yamazoe, general manager steelmaking; Mr. Kiyohito Fujiwara, vice head of works; Mr. Masatoshi Otsuka, senior manager — technology; and Dr. Takashi Sawai, general manager — steelmaking technology division, head office, greeted the delegation and provided an overview of the manufacturing process at the facility. The Wakayama Works first began operation of its oxygen steelmaking facility in 1961. Originally, the facility had two steelmaking operations, each producing 160-ton heats via two RH degassers and four casters. In 1999, the two steelmaking facilities were replaced by a single facility producing 250-ton heats sent to two RH degassers and three continuous casters. The improvement in the operations came through the relationship of the casters to the steelmaking vessels. The layout of the facility has the steelmaking vessels in the center of a compass rose. The hot metal and scrap come from the south, the slab caster is in the west, the bloom caster is in the east and the round caster is in the north. The round caster is in line with the seamless pipe and tubemaking plant. Currently, the facility produces 4.5 million tons per year via two blast furnaces, the steelmaking facility, three casters and the rolling facilities. Sixty-three percent of its production is slab and sheet products, 26% is seamless tube, 6% is special bar quality (SBQ), and the remainder is stainless and high alloy produced via a separate facility containing an electric arc furnace (EAF) and argon oxygen decarburization (AOD).

Because of the high phosphorous content of the iron ore, the blast furnace iron must first be dephosphorized prior to being decarburized. Prior to dephosphorization,

20 October 2014 — Nippon Steel & Sumitomo Metal Corp. – Wakayama Works


21 October 2014 — Kobe Steel Ltd. – Kakogawa Works

the blast furnace iron is desiliconized in the blast furnace runner. Torpedo cars then deliver the hot metal to the steelmaking facility. A separate basic oxygen furnace (BOF) vessel is used to dephosphorize the metal. It is tapped and transferred to the second BOF vessel to be decarburized. In the decarburization BOF, the heat is blown for only 9 minutes, at which time a sublance tests the heat for proper temperature and carbon content, and then the heat is tapped into the waiting steel ladle. The steel ladle is sent to one of the two RH degassers for 18 minutes of treatment and, depending on the grade to be produced, to the proper casting stream for solidification. Steel produced on the round caster is sent directly to the seamless pipemaking facility, which includes the piercing mill, the mandrel mill, and then the sizing and saw mill. The steel from the slab caster can either be rolled via hot mill and cold mill to coil or sent to the breakdown and universal mill to be rolled out to either H-shape or sheet pile. The blooms are rolled to billets and further processed for structural steel.

Following a question and answer session with the representatives from the NSSMC – Wakayama Works, the delegation traveled to Himeji, Japan, where they were greeted by Mr. Terutoshi Umeda, section manager overseas marketing department, and his assistant, Mr. Yuta Tsukui. Nippon Steel & Sumikin Engineering Co. Ltd. They presented the delegation with their technologies on BOF suspension systems and a new material for BOF vessels, SEV295-Mod. The BOF suspension system utilizes cotter keys and brackets to support the vessel to the trunnion ring. The SEV295-Mod steel was developed to resist heat-induced creep in BOF vessels, thereby reducing deformation and cracking in the vessel shell and extending the vessel life beyond 20 years.

On 21 October 2014, the delegation traveled to the Kakogawa Works of Kobe Steel Ltd., where they were met by Dr. Sei Kimura, manager — steelmaking development section, and Mr. Takashi Miyake, senior researcher, and were provided an overview of the steelmaking operations and a description of the equipment involved. The location in Kakogawa produces 6 million tons

20 October 2014 — Nippon Steel and Sumikin Engineering Co. Ltd. – Terutoshi Umeda (left) and Jamie Lash (right)

of steel per year. Iron ore and coal are sourced in Australia and Brazil and converted to iron via two coke ovens, a sinter plant and two blast furnaces. The waste gas from the coke and ironmaking operations is collected in a gas accumulator and used for generating almost 700 MW of power, which is used by the Kakogawa plant and local community. The hot metal is dephosphorized and desulfurized in the torpedo car and then sent to the BOF facility for steel production. Since April 2014, 40% of the metal has been routed to a newly built dephosphorization facility to facilitate iron dephosphorization before being sent to the steelmaking facility for decarburizing.

The current steelmaking operation began production in 1970 and produces sheet, plate and wire. The steelmaking facility has three BOFs, three RH degassers, a ladle furnace, four continuous casters and a bottom-poured ingot facility. The facility produces 250-ton heats. Sheet production includes advanced high-strength steels, which are further processed at the Kobe Steel-U. S. Steel Corp. joint venture, PRO-TEC, in Liepsic, Ohio, USA. Plate produced by Kobe Steel is residual stress-controlled steel plate used for shipbuilding and high-pressure containment vessels. Steel produced for wire rod is high-strength steel used for bolted connections in automotive applications and for automotive springs, resulting in 40% and 20% lighter components (respectively) than conventional steels.

That evening, the delegation traveled to Kurashiki, Japan, to prepare for their next visit. The evening activities were sponsored by Berry Metal Co. and Lhoist Group. Berry Metal Co. supplies oxygen lances for BOF steelmaking, among other products. Lhoist Group supplies lime and alloys for steel production.

The delegation visited JFE Steel Corp. on 22–23 October 2014. The first visit was to JFE Steel Corp. – West Japan Works (Kurashiki) on 22 October. The delegation was greeted by Mr. Tomomichi Terabatake, manager of steelmaking technology, and the steelmaking staff of JFE Steel, and was given an overview of the facility and its history. The West Japan Works is made up of two facilities, Fukuyama and Kurashiki, which are 30 km apart. Kurashiki produces

21 October 2014 — Kobe Steel Ltd. – Kakogawa Works

21 October 2014 — Kobe Steel Ltd. – Kakogawa Works — Left to right: Jamie Lash, Nenad Radoja, Hiroyuki Takeuchi, Sei Kimura, Shinya Otani and Takashi Miyake

10 million tons per year and represents 70% of the West Japan Works' steel production. Raw materials come from Australia, Brazil and India. Iron ore is sintered and pelletized at the sinter plant before being reduced to molten iron in one of four blast furnaces located at Kurashiki.

The Kurashiki steelmaking operations produce 10 million tons of steel per year via two separate BOF facilities: No. 1 steelmaking and No. 2 steelmaking. All hot metal is dephosphorized in the torpedo car prior to being sent to either steelmaking facility. No. 1 steelmaking produces 3 million tons per year, mainly electrical steel, structural steel and billets for tube and wire. No. 1 utilizes two of the three BOFs at the facility (one vessel undergoes maintenance while the other two are in production), two RH degassers, two casters and ingot production for manufacturing large cross-section plate and forgings. Of the total Kurashiki production, 11% goes through 2CC, 16% through 3CC and about 1% of the steel is manufacturing via ingot production. No. 2 steelmaking produces 7 million tons per year of steel strip and steel plate. The visit at Kurashiki focused on No. 2 steelmaking due to its unique process and equipment. Kurashiki No. 2 steelmaking has three K-BOP converters and utilizes them in a manner similar to the No. 1 facility: two vessels are in operation while the third vessel undergoes maintenance or is on standby. The K-BOP converter utilizes a top lance for oxygen injection at 900 Nm^3/minute and six bottom tuyeres injecting oxygen as well as argon and carbon monoxide to produce the 310-ton heat. The facility can produce 60 heats per day via the two operating vessels, utilizing concurrent blowing practices and having a separate offgas collection system for each vessel.

Steel produced at No. 2 steelmaking is sent to one of two RH-KTB degassers before going to either No. 4CC or No. 6CC. The No. 4CC is a conventional slab caster 220 mm thick having widths from 850 to 1,920 mm. The vertical height is 8 m before the slab is bent horizontal for the runout table. The primary product of the No. 4 CC is automotive-grade ultralow-carbon (ULC) steel. No. 6CC is primarily used for plate production for sour gas applications in the oil and gas industry. To meet the stringent quality requirements for those applications, No. 6CC casts a slab up to 310 mm thick and 2,450 mm wide. No. 6CC has an 18.6-m vertical section to allow as much inclusion flotation as possible prior to bending.

Following the visit to Kurashiki, the delegation boarded a bullet train, Japan's high-speed train, on the Shinkansen to travel from Okayama to the Tokyo region for the balance of the study tour. Upon arrival in Tokyo, they were transported via

22 October 2014 — JFE Steel Corp. – West Japan Works (Kurashiki)

23 October 2014 — JFE Steel Corp. – East Japan Works (Chiba) — Left to right: Yohei Kaneko, Jamie Lash, Hirohide Uehara, Kimiharu Aida, Masohiro Naka and Masaki Koizumi

bus to the Chiba area, which is located in the Keiyo Industrial Zone east of Tokyo city. The Chiba Works, the site for the 23 October visit, and the Keihin Works represent the East Japan Works of JFE Steel Corp. Mr. Mitsuru Ogawa, managing director, and Hirohide Uehara, general manager — steelmaking at JFE Steel, welcomed the delegation to the Chiba Works and presented the equipment and processes used at Chiba to produce 4.4 million tons of steel per year.

Originally built in 1951 as Kawasaki Steel, the Chiba facility was the first integrated steelmaking facility to be built in Japan following World War II. No. 1 steelmaking began production in 1951 as an open hearth operation. Oxygen-based steelmaking began in 1962 at No. 2 steelmaking as production around the world shifted away from open hearth technology. By 1971, No. 1 steelmaking had closed the inefficient open hearths and converted the operations to 100% oxygen-based production. In 1977, the Chiba Works started up a third oxygen steelmaking facility at No. 3 steelmaking, which utilized a QBOP-style converter. In 1994, both No. 1 and No. 2 steelmaking shops were closed, and carbon-based steelmaking was consolidated at No. 3 steelmaking. A stainless steelmaking facility began operation adjacent to the carbon steelmaking facility.

Today, JFE Steel Corp. – East Japan Works (Chiba) iron- and steelmaking operations consist of a single blast furnace, a sinter plant, the QBOP stream, the stainless steelmaking stream and rolling facilities that produce flat rolled sheet, coated sheet, stainless sheet and special steels such as high-alloy, heat-resistant steels. At Chiba, hot metal is desiliconized and dephosphorized in the torpedo car. Upon arrival at the steelmaking shop, the hot metal is poured into an iron transfer ladle and desulfurized prior to being charged into the QBOP. In the QBOP, oxygen is injected at the rate of 600–700 Nm^3/minute (depending on the time of the blow) into the bottom of the vessel to decarburize the hot metal into steel. During the blowing process, an oxygen lance is lowered into the top of the vessel, where 400 Nm^3/minute is injected to provide post-combustion.

After 17 minutes, 322 tons of steel are tapped into a ladle and sent to the RH-KTB station for refinement and degassing. The Kawasaki top blown (KTB) process allows the QBOP to tap steel at a higher carbon content (i.e., shorter process time and lower tap temperature). At the RH, the KTB lance blows oxygen during the degassing process to lower the carbon content to 30 ppm or less in a process time that is shorter than a conventional RH. Solidification of the sheet products is completed via the No. 3 continuous caster. No. 3 CC is connected to the hot mill facility and can hot-charge slabs directly to the hot strip mill. The hot strip mill has the unique ability to join the coils between the roughing stands and the finishing stands to keep the finishing stands running at full speed.

23 October 2014 — JFE Steel Corp. – East Japan Works (Chiba) — Question and answer session

Members of the Oxygen Steelmaking Committee from the Iron and Steel Institute of Japan (ISIJ) and the OSTC study tour delegation met at ISIJ headquarters in Tokyo for an afternoon of technical exchange on 23 October. Mr. Wakimoto, ISIJ executive director, welcomed everyone and encouraged open discussion for the benefit of all in attendance. Dr. Makoto Tanaka, chairman of the ISIJ Steelmaking Committee, provided the opening remarks. Dr. Takashi Sawai, secretary of the ISIJ Steelmaking Committee, chaired the first session. Mr. James Lash, chair of the OSTC, chaired the second session. Mr. Nenad Radoja, vice chair of the OSTC, provided the closing remarks for the event. The presentations of the day included:

- Steelmaking Models in the United States Steel Corporation Process
  Yun Li, senior research consultant, United States Steel Corporation
- ThyssenKrupp CSA — Four Years of Practice and Results
  Humberto Marin, director — steelmaking operations, ThyssenKrupp CSA

23 October 20214 — A technical exchange was held between AIST and ISIJ on BOF technologies.

24 October 2014 — Nippon Steel & Sumitomo Metal Corp. – Kimitsu Works — Jamie Lash (right) and Kenji Tomita (left)

- Investigation of Bath Oscillation in Q-BOP With Water Model Experiment
  Futoshi Ogasawara, senior researcher, JFE Steel Corp.

- Utilization of Sound Signals to Evaluate the Risk of Slopping at Ternium Siderar BOF
  Jorgelina Perez, steelmaking and continuous casting process manager, Ternium Siderar

- LD Automation and Process Control Landscape at voestalpine Stahl
  Martin Egger, process engineer BOF, voestalpine Stahl Linz GmbH

- Heat Loss Reduction at Wakayama Steel Works
  Shuji Uehara, steelmaking technology section, Nippon Steel & Sumitomo Metal Corp.

- Automation Systems in North American BOF Facilities
  Neal Pyke, steelmaking reliability coach, ArcelorMittal Dofasco Inc.

- Addressing the Phosphorus Problem — Experience of Tata Steel
  Chaitanya Bhanu, chief LD3 and TSCR, Tata Steel – Jamshedpur

- Development of Dephosphorization Technique on High-Carbon Steel at LD-OTB
  Atsushi Tazuke, steelmaking technology section, Kobe Steel Ltd.

At the conclusion of the exchange, a social dinner was hosted by ISIJ. During the dinner, Dr. Sawai and Mr. Lash again thanked everyone for attending the exchange. Dr. Sawai commented on the need for international discussions to further the development and optimization of steelmaking technology worldwide. Mr. Lash supported Dr. Sawai's comments and invited the ISIJ steelmakers to visit North America next year to continue the relationship between the two committees.

The final steel facility tour for the delegates took place on Friday, 24 October. The group traveled to Nippon Steel & Sumitomo Corp. – Kimitsu Works, located on the southeastern shore of Tokyo Bay on an area of land reclaimed from the sea. The facility is a fully integrated steel mill producing 10 million tons of steel per year for sheet, plate, wide-flange beams, wire rod, tire cord, as well as seamless and electric resistance welded (ERW) pipe. The delegates were greeted once again by Dr. Sawai, who was accompanied by Mr. Tomita, GM steelmaking, steelmaking planner, refining technology, and steel quality for interstitial-free (IF) and pipemaking. Dr. Sawai and Mr. Tomita provided a brief overview of the production capabilities and equipment of the two steelmaking facilities on-site. No. 1 BOF focuses its entire production on long products, utilizing three BOFs, two injection stations for low-sulfur steels and two bloom casters. No. 2 BOF has three LD-OB converters (converters utilizing bottom stirring elements injecting oxygen, LPG, CO_2 and nitrogen), three RH degassers, two injection stations, a vacuum injection station and three casters. No. 2 and No. 3 casters produce IF steel, while the No. 6 caster produces only plate grades. In line with the No. 6 caster is the vacuum powder injection station, which couples the vacuum process with powder injection to reduce the sulfur content of the finished steel grade to less than 5 ppm, which is required for the ultralow sulfur and low hydrogen chemistries needed in sour gas line pipe. The overview was followed by a visit to the LD-OB, the RH degasser and the No. 3 casting facility.

On Friday, 24 October 2014, a dinner hosted by Toshiba Mitsubishi-Electric Industrial Systems Corp. (TMEIC) was held for the delegation. Mr. Naotada Sawada, director and vice president, and Mr. Masashi Yamamoto, senior manager, welcomed the group and thanked them for making the effort to visit Japan and the TMEIC manufacturing facility in Fuchu, Japan. Mr. Radoja thanked TMEIC for its support and presented Mr. Sawada with a plaque of appreciation. Special recognition was given to Mr. Ippei Shibata, TMEIC International Sales, for his individual efforts and participation through the week to ensure the delegation's visit to Japan was without concern.

On Saturday, 25 October, Mr. Shibata and the delegation traveled to Fuchu, Japan, to visit the TMEIC manufacturing facility. The state-of-the-art Fuchu facility manufacturers low- and medium-voltage variable frequency drives. These drives perform efficient and reliable speed control for small to large mill motors, which are used in rolling mills and process lines in the metals industry as well as many other heavy industries, such as oil and gas exploration and power generation. Mr. Katsutoshi Kutsuwada, quality assurance specialist for drive systems, welcomed the delegates at the facility and provided the tour of the Fuchu Drive Manufacturing Department. The study tour concluded with this visit to TMEIC.

The working culture is driven to excellence. It isn't about getting something working. It is about getting it working perfectly. As a result, you see very good efficiencies in all the equipment they are running. Huge opportunities for "Western" mills to learn and apply.

The Japanese steelmakers do things because they are the right thing to do. Not for financial reasons only. As a result, the financials eventually figure themselves out and the overall cost is reduced.

Neal Pyke, steelmaking reliability coach, ArcelorMittal Dofasco Inc.

AIST's Oxygen Steelmaking Technology Committee regularly provides its members with opportunities to grow their knowledge of the oxygen steelmaking process, the latest technology and procedures and to network with knowledgeable people.

25 October 2014 — TMEIC — Left to right: Bimal Saha, Thomas Daum, Randall Stone, Mike Strelbisky, Katsutoshi Kutsuwada, Chaitanya Bhanu and Ippei Shibata

2014 OSTC Study Tour — Japan

ITEMS LEARNED AND OBSERVED

Raw Material Quality

Because most of the iron ore in Japan is sourced from Australia, India or Brazil, the phosphorous content in the resulting hot metal is around 0.150%. The high hot metal phosphorous requires the Japanese steelmakers to dephosphorize their hot metal prior to decarburizing it in the converters. From this visit, the delegation saw five different methods for dephosphorization:

1. Two-converter process in which the hot metal is desiliconized at the blast furnace, desulfurized in the iron ladle, charged into a dephosphorization converter, tapped, then charged into a decarburization converter to be processed and tapped as steel (NSSMC – Wakayama Works).

2. Single-converter operation in which the hot metal is desiliconized at the blast furnace trough, dephosphorized in the torpedo car, desulfurized in the hot metal ladle and decarburized in the converter (JFE, Kobe Steel).

3. Single-converter operation but a combination of the first two methods, in which the hot metal is taken to a separate building to be desulfurized in an iron ladle then charged into a dephosphorization converter. The metal tapped out of the dephosphorization converter is then sent to the BOF facility to be decarburized in the decarburization vessel (new facility in Kobe Steel).

4. Single-converter deslag and reblow in which the hot metal is desulfurized in the iron ladle and charged into the vessel. The vessel is blown to dephosphorize the heat, then the vessel is tilted to remove the vessel slag and reblown to decarburize the heat (NSSMC – Kimitsu Works).

5. Single-converter double tap: similar to the previous method, but after dephosphorization, the heat is tapped into an iron ladle, the vessel slag is dumped out, the heat is recharged back into the same vessel and then decarburized (NSSMC – Kimitsu Works).

Companies are currently conducting studies in Japan to evaluate the efficiency of these processes. The general consensus is that the double converter process, in which the dephosphorization and decarburization are conducted in two separate BOF vessels, seems to be the most efficient.

Desulfurization

To improve the desulfurization process in the hot metal ladle, the Japanese steelmakers utilize the Kanbara Reactor (KR) process. The KR process of desulfurization utilizes a lance with a refractory impeller at the bottom. During desulfurization, lime reactant is injected into the ladle via the lance while the lance rotates at approximately 90–120 rpm to improve mixing of the reagent with the hot metal. By utilizing the KR process, treatment time at desulfurization takes only 12 minutes instead of 20 minutes utilizing the conventional lance process.

Environmental Programs

Because of the conscious effort of the steel companies to conserve and reduce steelmaking byproducts, each of the steel facilities visited used similar techniques to reduce, recycle and reuse steelmaking byproducts:

1. Offgases were collected and utilized to generate power for the mill and surrounding community.

2. Steelmaking dusts were recycled to further beneficiate the iron units in the dust.

3. Slag from the iron- and steelmaking processes was either reused or processed for use in road building, cement production or rock wool production.

4. Plastic bottles such as water bottles were shredded and used as an injectant in the blast furnaces.

Through its conscious efforts toward energy conservation, Japan leads many of the industrialized nations in energy efficiency in steel production, according to a Japan Iron and Steel Federation study from 2010. ✦

A Nippon Steel & Sumitomo Metal Corp. (NSSMC) – Wakayama Works
B Kobe Steel Ltd. – Kakogawa Works
C JFE Steel Corp. – West Japan Works (Kurashiki)
D JFE Steel Corp. – East Japan Works (Chiba)
E Iron and Steel Institute of Japan (ISIJ)
F Nippon Steel & Sumitomo Corp. – Kimitsu Works
G Toshiba Mitsubishi-Electric Industrial Systems Corp. (TMEIC)
JAPAN
Kakogawa
Kurashiki
Osaka
Wakayama
Nagoya
Tokyo
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Kimitsu