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RESEARCH AND DEVELOPMENT PROJECT**

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QUARTERLY TECHNICAL PROGRESS REPORT
PHASE II CALDERON PROCESS TO PRODUCE DIRECT REDUCED IRON
RESEARCH AND DEVELOPMENT PROJECT

CALDERON ENERGY COMPANY
COOPERATIVE AGREEMENT NO. DE-FC22-95PC92638

Reporting Period: 7-01-04 to 9-30-04

Date of Report: 10-28-04;

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Total Project: \$ 14,732,316.00 Total DOE Share This Action: \$6,457,000.00

Contracting Officer's Representative (COR): John Stipanovich;

Project Director: Albert Calderon

Assistant Project Director: Reina Calderon

Abstract

This project was initially targeted to the making of coke for blast furnaces by using proprietary technology of Calderon in a phased approach, and Phase I was successfully completed. The project was then re-directed to the making of iron units. In 2000, U.S. Steel teamed up with Calderon for a joint effort which will last 42 months to produce directly reduced iron with the potential of converting it into molten iron or steel consistent with the Roadmap recommendations of 1998 prepared by the Steel Industry in cooperation with the Department of Energy by using iron ore concentrate and coal as raw materials, both materials being appreciably lower in cost than using iron pellets and coke.

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Executive Summary

The commercialization path of the Calderon technology for making a feedstock for steelmaking with assistance from DOE initially focused on making coke and work was done which proved that the Calderon technology is capable of making good coke for hard driving blast furnaces. U.S. Steel which participated in such demonstration felt that the Calderon technology would be more meaningful in lowering the costs of making steel by adapting it to the making of iron - thus obviating the need for coke.

U.S. Steel and Calderon teamed up to jointly work together to demonstrate that the Calderon technology will produce in a closed system iron units from iron concentrate (ore) and coal competitively by eliminating pelletizing, sintering, coking, blast furnace operation. If such process steps could be eliminated, a huge reduction in polluting emissions and greenhouse gases (including CO₂) relating to steelmaking would ensue. Such reduction will restructure the steel industry away from the very energy-intensive steelmaking steps currently practiced and drastically reduce costs of making steel.

The development of a technology to lower U.S. steelmaking costs and become globally competitive is a priority of major importance. Therefore, the development work which Calderon is conducting presently under this Agreement with the U.S. Department of Energy becomes more crucial than ever.

On August 17, 2004, representatives from Calderon met with John Stipanovich, the current DOE project manager who replaced Carl Maronde, to discuss the status of Calderon's request for a one year extension to the present cooperative agreement without additional funding from the U.S. Government, with Calderon increasing its cost sharing percentage during that year to enable the continuation of the developmental work. Mr. Stipanovich notified

Calderon that such an extension was in the works, but he would like to see the work directed towards the integration of the process to demonstrate that iron can be made without coke rather than the making of a reduced product per se. Subsequent to this meeting, Calderon received the official notice of the one year extension. From August 23rd to the end of the quarter five tests were conducted, of which three were operated as integrated tests producing molten iron which was poured into pigs for comparison with merchant pig iron.

Experimental

During the 3rd Quarter of 2004 which this report covers, ten experiments were conducted; they numbered from Test Run #152 through Test Run #161. The table that follows gives the dates, the length in hours, the number of pushes, the ore weight, the coal weight and the total weight of ore and coal charged in each test run.

Test Run	Date From To	No. of Hours	No. of Pushes	Ore Wt.	Coal Wt.	Total Wt. Charged
#152	7-12 to 7-15	80:00	896	1,848	1,848	3,696
#153	7-20 to 7-22	56:00	570	1,176	1,176	2,352
#154	7-26 to 7-29	94:30	1,016	2,096	2,096	4,192
#155	8-05	17:40	167	344	344	688
#156	8-09 to 8-12	73:30	747	1,541	1,541	3,082
#157	8-23 to 8-25	55:20	575	1,186	1,186	2,372
#158	9-07 to 9-09	52:46	535	1,103	1,103	2,206
#159	9-14 to 9-16	54:06	581	1,198	1,198	2,396
#160	9-21 to 9-22	30:23	296	610	610	1,220
#161	9-27 to 9-29	54:15	577	1,190	1,190	2,380
TOTALS		568:5	5,960	12,292	12,292	24,584

These tests aggregated to 568.5 hours of operation consisting of 5,960 pushes and consuming 12,292 lbs of ore and 12,292 lbs. of coal. The first five tests (Runs #152 through 156 inclusive) were conducted with the objective of operating 72 hours each at a reasonably continuous steady state mode, based on two daily shifts of 12 hours each. Tests 152, 154 and 156 exceeded 72 hours. Tests 155 and 160 were aborted. Tests 153, 157, 158, 159 and 161 were conducted on two days of two-12 hour shifts with 6 hours added for furnace integration.

Other experimental work included changes to lance practice to cut down re-oxidation of the reduced material that builds-up at the discharge end of the reactor, and experiments in hot charging the reduced material to homogenize it, slag it and produce iron pigs comparable to merchant pigs.

Results and Discussion

During the quarter it was found that the operation of the unit based on 12-hour shifts for three or more consecutive days per test-run imposed a fatigue factor on the manpower, especially since the men had to swing from day shift to night shift every week. One solution was to increase the size of the crew, but because of maintaining the cost of the operation at a minimum, it was decided to limit temporarily the runs to two consecutive days for each run. The men agreed to this arrangement without overtime pay.

By using the charging procedure of slices into the reactor as covered in the previous report, the pushing pressures applied to cause the material to move have become manageable as long as the build-up is prevented from occurring within the reactor. To mitigate such build-up within the reactor, the penetration into the charge by the horizontal lance was reduced and a pause of ten seconds introduced to its movement as it travels in and out of the reactor. Build-up on the apron at the discharge still persisted, but such build-up was scraped every four hours. Such scraping is shown in photographs 1 and 2, the over-oxidized material that is collected after dislodgement being shown in photograph 3. There are indications that this over-oxidized material may be recycled rather than wasted.

The reduced material using the slice charging procedure is shown in photograph 4. It is to be noted that coke is sandwiched between metal slices. To determine the quality of the

metal, grinding tests were conducted as shown by photographs 5 and 6. In order to homogenize the product, a basket equipped with a 1/4" screen was fabricated that can be supported in the collection drum, wherein the fines would drop to the bottom of the drum for recycling. It was discovered that the amount of fines was excessive; (however, it was later learned that the fines can be included in the charge to the Homogenizer, as discussed below). It was decided to cover the screen with a plate with the intention of homogenizing all the material dropped into the basket as the slide gate opened. Photograph 7 shows the disengagement of the drum from the sliding gate housing and photograph 8 shows a view of the basket within the drum with hot iron/carbon material in it. It is to be noted that two handles were provided to the basket as lifting lugs.

In the homogenization step, the basket was lifted from the drum manually, using special heat resistant gloves and placed on a scale to obtain the net weight of the hot reduced material within the basket (see photograph 9), the weight of the empty basket taken into account. Next the contents of the basket were dumped into the Homogenizer (photograph 10) where a heel of molten metal had been prepared by melting ingot pigs from a previous run. Immediately following the basket dump the metal in the furnace rimmed as shown by photograph 11 but shortly thereafter it subsided (photograph 12) aided by the high carbon content in the charge. The addition of a flux followed (photograph 13). The Homogenizer (furnace) was equipped with a porous plug at its bottom where nitrogen was injected to keep the bath stirred and produce uniform iron. The hot material dumped into the furnace surprisingly got into solution quite rapidly by virtue of its temperature, the stirring action, and assistance from the dunking action provided by a graphitic paddle (photograph 14). The reduced, partially reduced, unreduced, and over-reduced (re-oxidized) material was

homogenized producing a uniform molten metal that was quiescent by virtue of being fully killed with carbon from the coke; the excess coke provided a blanket as a layer on top of a layer of neutralized slag (photograph 15).

Initially the practice was to remove both coke and slag as a dross from the top of the molten bath with a graphite scoop and discharge it onto a metallic surface placed on the floor by the side of the Homogenizer (photographs 16 and 17). Upon cooling it was discovered that the solidified dross (photograph 18) had iron laced with coke mingled with the slag, a material unfit for recycling. The practice was then altered by carefully removing the coke-laced-iron from above the slag first and depositing it on the plate on the floor (photographs 19 and 20); next the slag was skimmed from the molten bath (photographs 21, 22 and 23) and deposited away from the recovered coke-laced iron. Having selectively removed the coke-laced-iron, and then the slag, the heat was tapped (photographs 24 and 25) producing homogenized molten iron directly from ore concentrate and coal. The cooled coke-laced-iron (now a useful revert) was spread on the floor and crushed (photograph 26) for recycling into the reactor with the charge of ore concentrate and coal.

The activities shown by photographs 1 through 26 originate from Test Run 161 conducted during September 27th, 28th and part of the 29th, a test lasting 54 hours and 15 minutes during in which (roughly) the last five hours of the Run, the hot reduced material was homogenized into hot metal and poured into molds forming pigs of iron. The logs show the following:

1. Five (5) cold pigs from previous Calderon heats made from ore concentrate and coal and weighing an aggregate of 81 lbs. were charged into the Homogenizer. Power was

turned on at the Homogenizer at 5:00 a.m. on the morning of the 29th of September and a molten heel from the cold pigs was formed by 5:57 a.m. having a temperature of 2935°F.

2. At 6:00 a.m. basket #1 was dumped into the Homogenizer discharging 19 lbs of hot reduced iron/carbon material.

At 7:00 a.m. basket #2 followed, discharging 13 lbs of hot reduced iron/carbon material.

At 8:00 a.m. basket #3 followed, discharging 11-1/2 lbs of hot reduced iron/carbon material.

At 8:30 a.m. basket #4 followed, discharging 10 lbs of hot reduced iron/carbon material.

At 9:00 a.m. basket #5 followed, discharging 14 lbs of hot reduced iron/carbon material.

At 9:30 a.m. basket #6 followed, discharging 10 lbs of hot reduced iron/carbon material.

At 10:00 a.m. basket #7 followed, discharging 15 lbs of hot reduced iron/carbon material. The total iron/carbon material charged in four hours aggregated to 92.5 lbs.

3. During the homogenization, 12.3 lbs of flux were added.

4. Coke-laced-iron removed from top of Homogenizer was 27 lbs.

5. Slag removed from Homogenizer was 10.5 lbs.

6. Temperature of the molten iron bath at tap time was 2805°F.

7. Homogenizer was tapped at 10:40 a.m.

It is to be noted that initially the charging of hot reduced iron/carbon material was hourly, but the Homogenizer was so efficient in converting the material to molten iron, that it was idling about three-fourths of the time while waiting for another charge. The procedure was then changed for the iron/carbon material from the reactor to be charged on the half hour, beginning at 8:30 a.m.

Results - Rough Mass Balance

A. Total materials charged into Homogenizer

(i)	Cold pigs for heel formation	81.0 lbs
(ii)	Hot reduced iron-carbon material	92.5 lbs
(iii)	Fluxes	<u>12.3 lbs</u>
	Total	185.8 lbs

B. Total materials discharged from Homogenizer in exclusion of heat of molten metal

(i)	Coke-laced-iron recovered for recycling	27.0 lbs
(ii)	Slag removed disposal	<u>10.5 lbs</u>
	Sub-total	<u>37.5 lbs</u>
	Weight of inputs less Sub-total	<u>148.3 lbs</u>

Weight of heat tapped as cold pigs: 122.5 lbs.

Net yield in % $(122.5 \text{ lbs} \times 100) \div 148.3 \text{ lbs} = 82.6\%$.

It is to be mentioned that the above Balance is preliminary in nature by virtue that the iron content in the coke-laced-iron was not credited, as an analysis of this recyclable revert was not performed because of Calderon's limited capabilities to perform such analysis.

The results obtained in the last quarter are positive by virtue that the problems relating to stalling the push of material through the reactor appear to have been overcome; also, surprisingly, the Homogenizer is very efficient in rapidly converting hot non-uniform iron/carbon product made via the Calderon ironmaking process into hot metal by using induction.

This indicates that in the commercial application of the Calderon technology, a proven channel furnace of large capacity (2,200 metric tons) receiving hot iron/carbon product from a battery of Calderon reactors can serve as a Homogenizer and contribute many steelmaking

benefits including “high metal circulation”; see “BENEFITS” reported by Nippon Steel at end of Exhibit 1 attached. Such a large capacity channel furnace, known as a “Superheater” has been furnished by Ajax Magnethermic to Nippon Steel.

Conclusion

During the next quarter, work will continue in the integration of processing ore plus coal to iron pigs, and will include data input covering ore concentrate and coal charged, the material stuck to the apron from the discharge of the reactor, the coke-laced-iron, and losses such as dust collected. The above plus the final pigs will be sent to U.S. Steel for an in-depth analysis and preparation of a more accurate mass balance than the one furnished above.

Submitted by:

Albert Calderon
Project Director

References - Not Applicable

The work performed in this quarter which the report covers, was original work. No reference material was relied upon for the work

1. Material stuck to apron
being dislodged from the
bottom

Dislodging
device

2. Dislodged material being
swept

Broom

3. Dislodged material
collected

Over-oxidized
dislodged
material

4. Material reduced using the slice charging practice

5. Grinding test indicating a high degree of metallization

6. Grinding test indicating a low degree of metallization

7. Collection drum being disengaged from slide gate housing

Slide gate housing

Sealing surface of housing

Sealing surface of drum

Collection drum

8. Top view of basket within collection drum containing hot, metallized material

Basket

Lifting lug

Hot metallized material

Lifting lug

9. Basket with hot metallized material being weighed

Special high temperature glove

10. Hot metallized material being dumped into induction homogenizer (melting furnace)

Molten Heel

11. Top of furnace activity immediately following dumping of hot metallized material from basket

12. Top of furnace activity subsiding rapidly following dumping by virtue of excess carbon contained in the dump

13. Flux addition following the dump

14. Working the heat by dunking the material into the bath using a graphite paddle and aided by the stirring action from a nitrogen injected bottom plug

15. Killed heat covered with excess coke (carbon) floating above the slag & metal bath

Coke layer

16. Removal of floating coke & slag with graphite scoop as a dross

17. Discharging of excess coke and slag scooped from furnace

18. Mixture of coke, reduced material & slag after cool-down scooped from furnace

Reduced iron

Slag

19. Removal of coke from top of molten bath separately from the slag

20. Coke laced with some metal scooped from the furnace being cooled

21. Removal of slag after removal of coke

Glassy slag

22. Graphite paddle

Glassy slag

23. Tapping slag from heat by tilting the furnace

Shimming slag with rabble

Furnace Spout

Slag

24. Furnace being tilted to tap heat of molten iron

Turntable with molds

25. Tapping heat of molten iron into molds

26. Crushing of coke laced with metallized iron for recycling into metallization reactor with the ore & coal

FEATURE

Channel Induction Melt/Hold Technology at Nippon Steel Corp.

T. Burke, R. Osiniak and M. Li
Ajax Magnethermic Corp.

Nippon Steel Corp., the world's largest steel producer, explored methods to increase production while avoiding the high cost of relining its two blast furnaces at the Yawata Steelworks in Fukuoka, Japan. While visiting an ISCOR Steel Corp. plant near Johannesburg, South Africa, Nippon officials discovered a possible solution to their problem: a 1,500 metric ton, 13.5 megawatt, large capacity, channel induction furnace used for holding blast furnace iron and melting scrap iron and steel. The furnace was designed and engineered by Ajax Magnethermic Corp., Warren, OH.

Nippon officials concluded that similar induction technologies, though on a larger scale and capacity than that of the ISCOR facility, could be used at its Yawata facility as a melt and hold furnace that would supply molten iron to fulfill the plant's needs.

A single channel induction superheater seemed to present a solution to Nippon's primary considerations. The

After exploring methods to increase production of its blast furnaces at the Yawata facility, Nippon Steel contracted Ajax Magnethermic to design a superheater. Since installation in 1998, the superheater has, among other things, increased steel production levels.

superheater could eliminate the millions of dollars in the cost of relining the refractory of its existing blast furnaces. The superheater could also offset the variation in metal supply and heat loss experienced when transporting molten metal in railway containers over a distance of several kilometers, provide the ability to melt large quantities of scrap metal, possibly eliminate the need of additional on-line blast furnaces and provide the ability to maintain, or even increase, levels of steel production.

Nippon contracted Ajax Magnethermic Co. Ltd., Tokyo, Japan, a subsidiary of Ajax Magnethermic U.S.A., to launch

studies to determine the melt rate, efficiency and economics of the proposed project. Resulting studies indicated that a drum-type channel furnace superheater would accomplish Nippon's objectives of melt rate and efficiency at a fraction of the cost to reline the refractory of its existing blast furnaces.

EFFICIENCIES

Nippon researched different furnace configurations to resolve the mismatch between the existing blast furnaces and production capacity for continuous casting after the converter. In addition, the company hoped to reduce energy consumption and costs for the converter.

Nippon reviewed both the superheater concepts, which were named the iron resolving barrel (IRB), and arc furnace configurations to determine the various advantages of each system (Table I).

Based on the overall efficiency ratings of the compared configurations, Nippon selected the channel furnace superheater configuration for power source capacity and overall efficiency of the unit.

The channel furnace superheater concept would realize additional use of surplus power generated from the Yawata facility's waste mill gas.

Table I Comparison of IRB and Arc Furnaces 1 and 2

	Superheater (IRB)	Arc Furnace 1	Arc Furnace 2
Melt rate	60 tons/hour		
Power source capacity	30 MVA		
Overall efficiency	85 percent		

EXPERIENCE COUNTS

In addition to the superheater at ISCOR, Ajax Magnethermic also designed and engineered other systems worldwide for metal mixing furnaces and cupola operations based on induction technologies for superheating. Most recently, DaimlerChrysler in the United States has started up two 180-ton Ajax Magnethermic holding furnaces at its Indianapolis, IN, foundry. These duplex-style furnaces are thought to be the largest of their kind in the world.

In January 1997, Nippon contracted with Ajax Magnethermic to design a holding furnace for its Yawata facility. During 1997, Ajax Magnethermic engineers from the company's channel engineering and research and development groups worked in a collaborative effort with Ajax Magnethermic (Japan) to design the Nippon superheater and its inductors.

SUPERHEATER DESIGN

The induction channel furnace superheater design needed to satisfy many considerations of Nippon. The resulting furnace for the Yawata facility was designed to have a capacity of 2,200 metric tons, which is the largest furnace of its kind in the world.

The superheater is a refractory-lined horizontal cylindrical vessel similar in appearance to a conventional hot metal mixer. This furnace has two series of high capacity Ajax Magnethermic jet flow inductors attached to the underside of the vessel (Figure 1). Each inductor operates on a single-phase line-current frequency to meet the 27 megawatt design requirement (Figure 2, Table II).

The Ajax Magnethermic-designed twin-loop jet flow inductors minimize

recirculation of molten metal within the induction channel. In the jet flow inductor, molten metal flows from the main pool down through a center channel and returns up through two exit channels. This permits stirring of the main pool (Figure 3).

PROJECT MANAGEMENT

The size and complexity of the Nippon superheater furnace required that it be fabricated in Japan, based on the Ajax Magnethermic design. Both Ajax locations

Figure 1 The line drawing shows the end view of a furnace with inductors.

Figure 2 Inductor artwork is shown.

supplied the furnace engineering drawings, inductors, inductor technology, electrical power supplies, switchgear and also furnace startup. An aggressive schedule was set for the design and construction of the superheater. The superheater was commissioned as planned in October 1998.

VESSEL CONSTRUCTION

To satisfy the melt capacity requirement, the vessel was designed to accommodate six jet flow inductors rated at 4,500 kW each. The inductors were designed to be capable of 6,000 kW, making them the largest in the world. The design called for three inductors per side to be attached to the underside of the vessel at 45 degrees from center. Steel plates were welded to compose five rings that

Table II Electrical

Inductors	Six Ajax jet flow 4,500 kW nominal rating
Power supply	Three-phase, phase-balanced transformer
Primary voltage	27,500 V
Power control	19 tap, on-load primary tap switch
Leads per inductor	6 water-cooled leads each

Figure 3 The furnace/inductor cross-section, displaying the jet flow concept, is shown.

together form the furnace outer shell with two domed ends. The resulting vessel is 9 m (29.25 feet) in diameter and 20 m (65 feet) long (Figure 4).

The vessel geometry and placement of the inductors required that four pedestals accommodate a total foundation load of 3,880 metric tons.

DRIVE

To permit rotation of the vessel for charging and pouring, the furnace is equipped with a series of drive gears and motors at either end of the furnace. The motors were 110 kW each, inverter driven (Table III).

OPERATION

At Nippon's Yawata facility, the holding furnace will play an important role in the steelmaking process. From the blast furnace, molten metal will be transported via railway transfer car and moved by ladle through desulfurizing and degassing processes before being ladled into the superheater. Steel scrap will be dumped into the back of the holding furnace into one of the three charge doors. Alternating between charge doors was found to even the wear on the refractory.

The holding furnace was designed to superheat blast furnace iron to between 1,300 and 1350°C at the rate of 360 metric tons/hour. The design also permitted 57 metric tons/hour of steel scrap to be melted to 1,350°C.

As an example of the operation, a superheater powered at 36 MW can superheat 14,000 metric tons of hot metal/day

by 220°C. A few basic oxygen furnace (BOF) shops process as much as 14,000 metric tons of hot metal/day. However, instead of superheating blast furnace iron, a 36 MW unit can produce 1,900 metric tons/day of synthetic hot metal (at 1,530°C) by melting low priced steel scrap with added carbon, manganese and silicon. Superheater capacity in tons of hot metal and installed kW can be whatever meets the requirements of individual BOF shops. Retrofitting existing hot metal mixers with high capacity jet flow inductors is also possible.

REFRACTORY

Nippon decided to follow its traditional refractory design for the hearth refractory for the Yawata Steelworks superheater holding furnace by using magnesium oxide (MgO) brick, which Nippon believed was the most economical alternative for the 800-mm-thick hearth (Figure 5). Because MgO bricks expand much more than alumina bricks, traditionally used in the United States, expansion joints were installed between the bricks to maintain stress in the shell at reasonable levels.

As firing procedures were reviewed, Nippon officials realized that once the vessel was under fire and the expansion points compressed, it could not be cooled without collapsing the lining. The

six inductors were eventually mounted with a 900°C furnace, and Nippon's refractory system worked well.

CONTROLS

Programmable logic controllers (PLCs) were installed, and computer interfaces were used for displaying and trending of the superheater data, including water flow and temperatures for the six inductors and throat flanges. More than 70 furnace shell thermocouples were returned for data logging. The PLCs also monitor all inductor power and conductance data.

Sintering, using six thermocouples for each inductor, permitted the prescribed heat-up schedule to be followed.

Nine jet flow inductor assemblies, including six operating and three spares, were completed in December 1997, followed by a demonstration of the inductor lining by Allied Mineral Products in early 1998 for Nippon at the Ajax Magnethermic facility in Warren, OH. The demonstration was videotaped for Nippon personnel. The furnace was installed in June 1998, and inductors were lined three months later. The six inductors were fired on schedule in October and acceptance testing occurred in November.

POWER SUPPLY AND STARTUP FIRING

Ajax Magnethermic (Japan) designed the power supply for the Yawata superheater.

Figure 4 An isometric view of vessel with supports and dimensions is shown.

Table III Mechanical

Diameter	9 m
Length	20 m
Total foundation load	3,880 metric tons
Refractory thickness	800 mm
Main hearth refractory type	MgO brick
Inductor refractory	MgO dri-vibe
Rotation power	220 kW
Rotating mechanism	2× rack and pinion
Number of scrap charge doors	3
Number of ladle charge doors	1
Total molten metal capacity	2,200 metric tons
Total usable capacity	1,500 metric tons

Figure 5 A refractory cutaway is shown.

It consists of a three-phase, phase-balanced system with an on-load primary tap changer for power control.

An eight-hour period was required to mount each inductor because of their large sizes. This included capping the MgO dri-vibe, firing the capping, rigging the inductors and mounting them about 17 meters above the mill floor. Water, power and thermocouple connections were then made.

As the 4,500 kW inductors were mounted on the hot furnace, they were energized. The refractory sinter began when all inductors were on, followed by an average sinter cycle of about 70°C/hour. Several holding periods were used as the prime temperature of 1,150°C was reached. Two ladles provided 600 metric tons of priming metal.

Two gas burners in the ends of the vessel fired the main furnace hearth. These burners also supplemented the furnace hearth by thermocouple control to keep the slag in a molten state and supply above melt line thermal losses. Ajax Magnethermic (Japan) executed the well-run October 1998 startup, made possible to a large extent

by Nippon, through its commitment to a clean and thoughtful installation.

FULL POWER PRODUCTION

During the second half of 1999, in preparation for full power production in 2000, three of the six inductors were changed to gain experience with the procedure and to study the first-year wear. Inductor electrical data indicated that no buildup or erosion was evident in the inductor channels. Physical inspection confirmed that the inductors did not need to be changed.

The final overall operating efficiency of the superheater had been specified by Nippon to be a minimum of 80 percent. The efficiency of the inductors was tested before shipping, and Ajax Magnethermic found that the electrical loss at full power was about 130 kW for coils, 70 kW for bushings and 100 kW for the case. This put the inductor efficiency at 94 percent. Electrical transmission efficiency was measured at about 96 percent. Given the power consumption for steel scrap melting at 340 kWh/metric ton, superheating iron at 4.6 kWh/metric ton and 1,400 kW of loss from the

furnace body, the calculated overall efficiencies were around 81 to 83 percent.

After startup and operation, testing confirmed that operational efficiency was about 85 percent, including furnace radiation loss and all other losses. Cold steel melting rate was about 1 ton/minute at rated power.

STEELMAKING BENEFITS

The superheater technology has proven to be beneficial to Nippon's Yawata Steelworks. Some benefits that can be applied to the steel industry include the following:

- ◆ Steel scrap melting uses excess scrap metal and increases hot metal production.
- ◆ It provides the ability of increasing the temperature of molten metal for transported iron in the steelmaking process.
- ◆ A more continuous flow of metal to the basic oxygen furnace is realized.
- ◆ Surplus electrical energy is better used.
- ◆ It is possible to adjust metallurgy.
- ◆ High metal circulation is provided.