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The US metallics market has seen remarkable changes in the last ten years. In 1988, US EAF steel production was 33.4 million metric tons (Mt); last year, it was about 44 Mt. From 1995 to 2000 alone, there was over 19 Mt of new electric furnace capacity brought on-line in the US. Given that electric furnaces need about 1.1 tons of cold charge materials for each ton of steel produced, this translates into an increase of over 20 Mt in charge material requirements. In addition, much of the new EAF capacity was designed to produce steel with low residual (copper, chrome, tin) contents, necessitating the use of low residual charge materials (prime scrap and virgin iron), not "ordinary" common grade scrap.

How was this increase in charge requirements met? By a number of sources: domestic scrap, imported scrap, imported and domestic merchant pig iron, imported DRI/HBI (made from pellets/lump or fines, by a number of processes in various locations), and domestically produced DRI. Last year was truly remarkable in that for the first time in history, the US was a net importer of metallics! Throughout most of the 1980s, the US was a net exporter of 8-10 Mt/y of metallics.

This is a great situation for electric furnace producers, because it expands the number and type of materials they can use, thus increasing their options and flexibility. Whereas in the past, they relied almost entirely on home scrap and purchased scrap, now they have a number of alternatives, including large amounts of high quality virgin iron products. This can only help to make mini-mills more competitive in the future.

Midrex is making a concerted effort to assess the needs of the steelmaking industry and provide technologies and products to meet those needs. Traditionally, we have focused on the production of DRI, and the MIDREX® Direct Reduction Process has become the dominant technology. Now, with the formation of our new Steelmaking Department, we are increasing our attention on applications and melting of DRI.

As part of this effort, we will be working with steelmakers to ascertain the DRI product requirements necessary for various applications. An example is carbon content. Most MIDREX™ Direct Reduction Plants produce product with one to two percent carbon, which has met the needs of the industry. Today, there is a growing desire from mini-mills for a higher carbon product to provide energy and productivity benefits. MIDREX Plants have the capability to produce higher carbon levels and many are responding.

Midrex will continue to explore the raw material needs of the steel industry, develop technologies to meet those needs, and work with direct reduction plants to provide the best products possible.

Feedback from steelmakers is crucial to the success of this effort. Please talk to us.
Utilization of Sponge Iron in Electric Arc Furnaces

By: Nabil Daoud Takla
Qatar Steel Company Ltd. (QASCO)

This paper was originally presented at the AISU’s 2nd Electric Furnace Symposium in Damascus, Syria, October 18-20, 1998.

Various process routes are applied to produce steel. These routes can be divided into two categories “from ore to steel” and “from scrap to steel.” There is no doubt that as far as energy consumption is concerned, the route “from scrap to steel” is more advantageous, because only melting energy is needed. Therefore, this method of steel making has been successfully applied for more than a century. In coming years, there will be a tremendous increase in EAF steel production of higher value steel. These higher value steels require lower residuals and, in many cases, lower nitrogen levels than steels normally produced in the EAF. Also, the rapid developments of Ultra High Powered Electric Arc Furnaces have contributed to the vast interest in DRI for producing the required quality of steel. Normally two steel grades (High Tensile and Mild Steel) are produced. QASCO’s EAFs operate using a 95 percent DRI charge, which is one of the highest ratios in the steel-producing world. This paper presents a detailed description of the major equipment and the practice for producing steel by utilizing a high percentage of DRI. Several activities have been adopted to increase productivity in the EAF, mainly the reduction of tap-to-tap time. Moreover, within two years QASCO will have also used HBI as a part of the EAF charge.

Introduction
Historical Data
QASCO is the first integrated steel plant in the Gulf region, and was established in 1974 by three shareholders:
• Government of the State of Qatar: 70%
• Kobe Steel Ltd., Japan: 20%
• Tokyo Boeki Ltd., Japan: 10%
The operation was started in March 1978, with the prime objective to produce steel reinforcing bars to meet the domestic demand, as well as the demand of surrounding countries. Since its start-up, the plant has made undaunted progress towards full utilization of all its production units with the required standards of quality and efficiency. At present QASCO is considered as one of the best and most reliable quality steel producers in the region.

In 1998 Qatar took over the management from the Japanese and in 1997 the government of Qatar purchased the Japanese shares, thus establishing itself as a wholly nationalized company.
Main Facilities

Table I shows the present facilities with design capacities and established production figures.

The production in all the shops has increased gradually over the years as a result of continuous modifications and reduction of delay time.

New Projects

As a part of QASCO’s commitment to cater to the ever increasing demand, QASCO has envisaged various projects with systematic approaches for productivity improvement in all the related shops. Projects currently under implementation are:

a) High-speed finishing bar mill which is under commissioning now. The line was installed by M/s Mannesmann Demag to increase rolling mill capacity by 150,000 tons/year and introduce D8 as a new product.

b) New UHP-EBT Electric Arc Furnace supplied by Mannesmann Demag is now under erection and expected to be completed by March 1999. Annual capacity is around 450,000 tons.

c) New 4 strand CC machine curved type to produce billet with 130 and 150 mm square with length 3.5-12 m. Machine is under erection and is expected to be completed by May 1999. The machine is supplied by M/s Mitsubishi, Japan.

d) New HBI Plant, which was contracted with M/s Lurgi/Midrex to produce two million tons/year of HBI from two MIDREX MEGA MODS™. The project will be completed by the beginning of the year 2001. QASCO is the main partner of this project and is responsible for its management. Feasibility studies for other projects are under progress and will be executed according to the desired schedule.

Sponge Iron/Hot Briquetted Iron

SPI/HBI Raw Material for the EAF

Scrap was considered as the main raw material for EA Fs for a long time, but the importance of Sponge Iron (SPI) or HBI as a partial substitute for scrap is being increased every day. Sponge Iron or HBI has its advantages and disadvantages compared with scrap. These points will be discussed based on actual available data from QASCO’s experience in the relative field.

Storage of SPI/HBI

The storage of SPI for long periods of time is affecting its metallization partially due to surface deoxidation. The sponge iron will lose about 1 percent from its metallization after six months of storage in the open yard. Table II shows the relation between time and metallization.

This problem will not occur in the case of HBI storage where its reoxidation rate is very slow due to less porosity.

Handling of SPI/HBI

Handling of SPI/HBI inside the plant was easy where a magnet or shovel loader can handle it, and be stacked, reclaimed and transferred by using belt conveyors. During handling, some dust will be created causing minor pollution. In the case of HBI, a small percentage will be chipped off or broken but without affecting its performance.

Usage of Sponge Iron in QASCO’s Electric Arc Furnaces

QASCO was the first steel plant in the region to adopt the DR-EAF steel making route. The success achieved by QASCO with the DR-EAF route, especially with higher sponge iron blending ratio of 90-95 percent, is recognized internationally and has set very high standards not only for Arab countries, but also for the rest of the world.

Charging of Raw Material

QASCO has established its own standards to feed the EA Fs with different percentages of SPI. Most of the sponge iron is fed to the furnace by a continuous feeding system through the bucket elevator and the balance is charged with the scrap in the basket to produce a quick liquid bath in the furnace.

In the case of 90 percent sponge blending ratio (SBR), 9 tons of scrap are charged in the basket with 26 tons sponge, and 51 tons of sponge are fed by continuous feeding through the conveyor. In the case of 95 percent sponge blending ratio (SBR), 9 tons of scrap are charged in the basket with 26 tons sponge, and 51 tons of sponge are fed by continuous feeding through the conveyor.
percent SBR, 4 tons of scrap are charged in the basket with 31 tons of sponge and the remaining 51 tons of sponge is fed through the conveyor.

**Operation Pattern**

The operation pattern for different SBR has been standardized at QASCO. In Figure 1 the operation pattern for 85-95 percent SBR is shown. In this pattern, no oxygen lancing or ladle furnace is considered. With the above pattern, the tap-to-tap time is around 110-115 minutes without oxygen lancing or the use of LF (tapping temperature is around 1630° C).

**DRI Quality and Its Effect on EAF Parameters**

As a result of the high percentage of DRI used in QASCO’s EAF, its operating parameters are directly proportional to the DRI quality. QASCO aims to produce high quality sponge iron in order to improve operating parameters in the EAF. The typical quality of sponge produced from the MIDREX Plant at QASCO:

- Metallization 95.00%
- Metallic Fe 87.90%
- Total Fe 92.50%
- Carbon 1.54%
- Gangue 4.70%
- Sulfur (max) 0.015%
- Phosphorus (max) 0.035%
Effect of DRI Quality on EAF Parameters

In the following we will show the effect of DRI quality on EAF parameters, mainly yield and power consumption, which have a direct influence on tap-to-tap time. We will consider the metallization of sponge iron as a good indication of sponge quality.

In Figure 2 it is clear that EF yield changes proportionally with variation in metallization. Also, apart from metallization, the actual range of metallic Fe and total Fe contribute directly to the EF yield. Whenever the metallization goes below 94 percent all the parameters change drastically with negative effect.

Figure 3 shows that for every 1 percent change in metallization, power consumption increases by 8-10 kWh/ton.

Effect of SBR on Operational Parameters

Sponge blending ratio (SBR) has some unique effects on EAF operation parameters (considering stable sponge properties). In the following we will show the effect of sponge blending ratio (SBR) on the following parameters:

1. Electric power consumption
2. Electrode consumption
3. EF Yield
4. Tap-to-tap time

Figure 4 shows for every 10 percent increase of SBR, power consumption increases by 15 KWh/t. This increase is mainly due to the higher gangue quantity obtained from DRI. For every increase of 10 percent SBR, electrode consumption increases by 0.19 kg/t as shown in Figure 5. For every increase of 10 percent SBR, yield decreases by 0.40 percent as shown in Figure 6. For every increase of 10 percent SBR, the tap-to-tap time increases 2.5 minutes as shown in Figure 7. This increase is mainly due to the higher power required for melting DRI.

Advantage/ Disadvantage of DRI Compared with Scrap

From the previous information we can summarize the advantages and disadvantages of DRI compared with scrap as a raw material for EAFs.

Advantages of DRI

a) Lower cost compared to scrap, especially in countries having natural gas resources with lower cost.
b) Fixed chemical composition which improves working efficiency in EAF.
c) Low percentage of impurities such as sulfur and phosphorus.
d) Almost non-existence of harmful elements such as lead and copper.
e) Advantages in case of production of high quality steel.
f) Easy handling and storage.
g) High density for fixed volume.
h) Possibilities of feeding without opening the furnace roof by continuous feeding system through 5th hole in the roof.
i) Stable steel bath surface which reduces the possibility of electrode breakage.

Disadvantages of DRI

a) Higher consumption of electric power and accordingly the graphite electrode consumption.
b) Increased tap-to-tap time.
c) EF wall and roof exposure to arc in absence of scrap during the initial power on time.

c) Low percentage of impurities such as sulfur and phosphorus.
d) Almost non-existence of harmful elements such as lead and copper.
e) Advantages in case of production of high quality steel.
f) Easy handling and storage.
g) High density for fixed volume.
h) Possibilities of feeding without opening the furnace roof by continuous feeding system through 5th hole in the roof.
i) Stable steel bath surface which reduces the possibility of electrode breakage.

Conclusion

From the above, taking into consideration the economical effect of each mentioned parameter, it is highly recommendable to use DRI in EAFs, especially in the Arabian countries where natural gas is available at a moderate price and there is an acute shortage of high-quality scrap.
By Greg D. Hughes
Director - Technology
Midrex Direct Reduction Corporation

Partial Oxidation to Generate Reducing Gas
There are two methods of using oxygen in combination with natural gas to produce reducing gas of sufficient temperature and gas quality to be used directly as a bustle gas source for the MIDREX® Direct Reduction Process. Each of these methods is discussed in detail. One method is based on the objective of boosting the plant capacity with a parallel partial oxidation gas generator. This method is called reformer augmentation. The second method is more germane to new plants and involves the removal of the reformer from the flowsheet. This method is referred to as reformer replacement.

Partial Oxidation for Reforming Augmentation
The use of partial oxidation to provide additional reducing gas to the MIDREX Process, referred to as reformer augmentation, is based on the same system of reactions as that for reformer replacement. In the reformer augmentation flowsheet, the partial oxidation system is installed in parallel to the existing reformer to provide a supplemental amount of high temperature, good quality reducing gas. A diagram showing the flowsheet for reformer augmentation is provided in Figure 4.

The partial oxidation system operates by burning natural gas with oxygen in a very fuel-rich mixture. The mixture of natural gas and oxygen burns to an equilibrium of the system of chemical equations listed below:

Reforming Reactions:

**Figure 4**  MIDREX® Direct Reduction Process (partial oxidation for reformer augmentation)
very fuel-rich mixture. The mixture of natural gas and oxygen burns to an equilibration of the system of chemical equations listed below:

Reforming Reactions:
- \( CH_4 + H_2O \leftrightarrow CO + 3 H_2 \)
- \( CH_4 + CO_2 \leftrightarrow 2 CO + 2 H_2 \)
- \( 2 CH_4 + O_2 \leftrightarrow 2 CO + 4 H_2 \)

Cracking Reaction:
- \( CH_4 \leftrightarrow C(s) + 2 H_2 \)

Water-Gas Shift Reaction:
- \( CO + H_2O \leftrightarrow CO_2 + H_2 \)

The gas quality and temperature provided by varying the fuel-to-oxygen mixture are shown in Figures 5 and 6.

The relatively high temperature of the partial oxidation reducing gas (1000 – 1400°C) functions much like the use of direct oxygen injection to boost bustle temperature. The mixture of the partial oxidation reducing gas and conventionally produced reformed gas (900 – 950°C) results in an elevated bustle gas temperature. This additional thermal energy in the bustle gas can be used to boost the reduction kinetics in the shaft furnace or it can be used to heat enrich the natural gas or cooling zone bleed gas and offset the endothermic load of in-situ reforming within the shaft furnace. The most significant difference between this reformer augmentation method and that of simple oxygen injection is that not only is there a temperature boost to the bustle gas, but additional reductant is generated in the process, which further increases plant capacity.

The reformer augmentation method of increasing plant capacity, as well as the oxygen injection method, are not without limitations. The most obvious of these is the limitation due to the potential for generating export fuel. This limitation is inherent with any capacity increase that involves the introduction of an externally generated reducing gas to the flowsheet. Since the reducing gas is being added to a closed system, the top gas created by this additional bustle gas must be vented in the fuel system to maintain the mass balance. Most plants today have improved their heat recovery systems to maximize the amount of heat recovered from the flue gas and minimize the amount of natural gas required in the main burner system. These plants would very rapidly reach an export fuel situation if this method of increasing capacity were employed. The economics of each plant will be different as the price of oxygen, natural gas, and the ability to utilize the export fuel, etc. vary from site-to-site. To assist the reader in examining his particular situation, it requires approximately 210 Nm³ of O₂ at 99.5 percent purity and 315 Nm³ of natural gas to generate 1,000 Nm³ of reformed gas of a quality of approximately 11.2.

Partial Oxidation for Reformer Replacement

The use of a partial oxidation system as the sole source of reducing gas to the MIDREX process is called reformer replacement. The reaction system and theory are the same as described in the previous section. The flowsheet consists of removing the reformer and heat recovery systems from the conventional MIDREX process flowsheet and replacing them with a CO₂ removal system, recycle gas reheater, and partial oxidation system. A diagram of the reformer replacement flowsheet is shown Figure 7.

The top gas from this flowsheet is recycled to a CO₂ removal system where the CO₂ and H₂O are removed. The resulting high quality gas is then reheated to a specified temperature dictated by the bustle gas setpoint temperature. In other words, the recycle gas is used to temper the partial oxidation reducing gas down to the desired bustle gas temperature.

The ability to maximize the production in this flowsheet is highly depen-
dent on the nitrogen content in the oxygen supply and the natural gas supply. This method of reducing gas generation is thermally efficient. The high thermal efficiency is due to the fact that all of the heat released by the partial oxidation reactions is absorbed by the reducing gas, thereby increasing its exit temperature. There are no flue gases evolved to the atmosphere from a burner system as in the case of a reformer. The recycle gas reheater does contain a burner system and evolves flue gases, but this is a much smaller heat load than a reformer, and therefore a much smaller heat loss. This overall high thermal efficiency translates into a small requirement for fuel in the reheater burner system.

To ensure that the system does not become an export fuel generator, it is necessary to recycle as much of the top gas as possible back to the CO₂ removal system. The amount of recycle gas that can be tolerated will be governed by the rate at which the nitrogen concentration in the recirculating gases builds up, depending on the CO₂ removal technology chosen. High oxygen purity and low natural gas nitrogen levels can have a large impact on the economics of this system.

This method of reducing gas generation has the advantage of not being adversely affected by sulfur or heavy hydrocarbons in the natural gas since there is no catalyst to poison. However, care must be taken in the design of the partial oxidation system to avoid soot (solid carbon) formation or to handle it (if it is formed) in such a way so as to maintain operational availability. One potential disadvantage to this system is realized when operating with high sulfur-liberating iron ores. The sulfur liberated by the ore is totally removed from the recycle gas by the CO₂ removal system. This concentrates the sulfur in the vent gas from the CO₂ removal system and it still exists as H₂S. This gas must at the very least be burned to oxidize the sulfur to SO₂ before it is released to the atmosphere. The vent gas itself is of such a low heating value as to be unburnable without the addition of some amount of a higher heating value fuel. If the concentration of sulfur in the vent gas should rise above that allowed by environmental regulations in the plant area, a sulfur scrubbing system would have to be added to the flowsheet for the vent gas.

**Conclusion**

The economics of using this type of a plant versus a plant based on the standard MIDREX Process flowsheet is variable on a case-by-case basis. Each site needs to be examined individually since variances in oxygen price, availability and purity, as well as natural gas composition, electricity price, etc. have a very large impact on the final return on investment for the plant owner. Once the cost and availability of these factors have been evaluated, Midrex can provide the right flowsheet to fit your situation.
**Ken Matthews Retires, Jim Simmons Named President of EMC International (EMCI)**

Mr. Winston L. Tennies, President of Midrex Enterprises, Inc. (MEI), has announced the retirement of Mr. Kenneth D. Matthews, President of EMC International, Inc. (EMCI). Mr. Matthews was one of the original founders of Electric Metallurgy Corporation (the predecessor of EMCI) and served as president of both EMCI and EMCI since 1987. EMCI is a supplier of electric arc furnaces, ladle furnaces, and other systems, equipment, and services to the steel industry.

In announcing Mr. Matthews’ retirement to the assembled EMCI employees at their suburban Pittsburgh office, Mr. Tennies wished Mr. Matthews well, saying, “I want to wish Ken the very best as he begins his retirement years. I want to recognize Ken for his many years of service to EMCI and the steel industry and thank him for making EMCI a profitable and successful company during the eight years EMCI has been part of the Midrex family of companies.”

Mr. Tennies also named James C. Simmons as Mr. Matthews’ successor, effective March 1, 1999, and announced Mr. Simmons’ election to EMCI’s Board of Directors. In accepting his new position, Mr. Simmons said, “I intend to encourage the Company to continue its growth by building on the experience and ability of our people.”

Mr. Simmons has more than 33 years of steel industry experience, including research and development, project management, marketing, sales, and senior management.

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**MIDREX - Gold Prize Winner of the Tamiya Prize**

Midrex Direct Reduction Corporation was named as the Gold Prize winner of the prestigious Tamiya Prize. The Tamiya Prize is named for the fifth President of Kobe Steel, Mr. Kaemon Tamiya, and has been awarded since 1960 to the companies of Kobe Group whose activities contribute to society and to the profit of the company.

The selection of one Gold Prize, one Silver Prize, and five Bronze Prizes were made at the Kobe board meeting on March 16, 1999. Mr. Winston Tennies, President of Midrex, attended the awards ceremony in Kobe, Japan to accept the award on behalf of Midrex. Mr. F. Yamashita, President of Kobe Engineering Company, accepted the award for his company.

Upon presenting the award, Mr. Koshi Mizukoshi, President of Kobe Steel, Ltd., commented, “The board decided to award the gold prize to the Midrex group and members of the Kobe Steel, Ltd. Engineering Company for achieving the top score in all of the examined categories... Due to the discovery that the expansion of the furnace diameter improved the output of the product, we were able to gain a competitive edge in the direct reduced technology field. As a result, we have acquired over 60 percent of the share of direct reduced iron production in the world and are the undisputed leader in the field. Midrex’s achievements working with foreign companies and blending new technology with the realization of high profits was a major determinant in the award of the gold prize.”

Since its inception in 1960, this is the first time the Tamiya Prize has been awarded to a non-Japanese branch of Kobe Steel.

Other winners included:
- **Silver Prize:** Kobe Metal Products
- **Bronze Prize:** Shinko Pantecc
- **Bronze Prize:** Shinko Electric
- **Bronze Prize:** Shinko Wire Company
- **Bronze Prize:** NABCO
- **Bronze Prize:** Yutani Heavy Industries
Two MIDREX™ Plant Start-Ups in May

With their start-ups planned within one month of each other, you might consider MIDREX™ Plants at Carribean Ispat, Ltd. (CIL) and Saldanha Steel, twins. However, one look at the two MIDREX Plants and it is easy to see they are very different. CIL is a 1.36 Mt/y DRI plant which will utilize the largest natural gas reformer ever built. At press time, the burners had been lit and refractory dry-out was underway. First product is expected from CIL by the end of May, with the plant ready for full operation by the end of June. Also going through start-up procedures in May is the MIDREX Plant at Saldanha Steel. This module will use the offgas from a COREX® C-2000 Plant, and therefore requires no reformer. First production is expected by the end of May, with the plant ready for full operation by the end of June.

New President to Head Kobe Steel

Kobe Steel, Ltd. announced that Vice President Koshi Mizukoshi was appointed President, Chief Executive Officer, and Representative Director, effective April 1, 1999. Former President Masahiro Kumamuto was appointed Chairman of Kobe Steel.

Mr. Mizukoshi joined Kobe Steel in 1961 after graduating from the University of Tokyo from the Faculty of Economics. In January 1978, he became Assistant to the President. In June 1989, Mr. Mizukoshi was appointed a Director of Kobe Steel and concurrently was the General Manager of the Iron and Steel Division’s Planning and Administration Department. In June 1991, he rose to the position of Managing Director. In June 1993, he was appointed Senior Managing Director and was General Manager of the Technology Administration Department in the Iron and Steel Division. In June 1996, Mr. Mizukoshi became Executive Vice President and Representative Director of Kobe Steel, Ltd.

Kobe Steel, Ltd. Moves Offices

Kobe Steel’s Tokyo offices in the Tekko Building in Chiyoda-ku and the Kobelco Building in Koto-ku have moved. Effective Monday, May 1, 1999, the new address for Kobe Steel Headquarters is: 9-12 Kita-Shinagawa 5-chome Shinagawa-ku, Tokyo 141-8688 JAPAN Tel: 81(3) 539-6000

MIDREX® Plant Production Data (Mt)

Note: 1999 data contains estimates for plants whose data is unavailable at time of publication.