IN THIS ISSUE

EAF Steelmaking – Past, Present and Future

Carbon in DRI – Friend or Foe?

Optimizing Metallization and Carbon at IMEXSA
Commentary

Hot, High Carbon DRI – The Energy of the Future

As Greg Hughes described in his commentary in the 2nd Quarter issue of Direct from Midrex, Midrex has reaffirmed its commitment to technology development with the establishment of the Business Development Group. My responsibilities toward this effort are to enhance the use and applications of MIDREX® DRI and MIDREX® HBI and also to promote better integration of DRI and steelmaking/melting. One way to do this is by sponsoring educational programs for the metals community, the first of which, “DRI/HBI Use in the EAF: An Idea Whose Time Has Come” was held from April 30 through May 2, 2000 in Tuscaloosa, Alabama. Led by Midrex and co-sponsored by Corus Tuscaloosa, Corus Mobile and American Iron Reduction, the seminar included technical papers, round table sessions, a steel mill visit and a panel discussion. Ample time was provided to discuss meltshop operational specifics and controversial subjects. Eighty people attended, including steel mill and foundry personnel, academics, consultants and DRI producers from around the world. The seminar will be an annual event and in the future will include sessions on DRI use in integrated steel mills and foundries.

Due to the importance of this topic, we have devoted this entire issue of Direct from Midrex to the seminar, including abstracts from three of the sixteen papers presented. Following are some of the conclusions from the seminar:

• The Value-in-Use (VIU) of DRI/HBI is site specific, even within an individual country, due to the costs and availability of inputs and steel mill cost accounting practices.
• A survey of operating parameters found no correlation between percent DRI use and meltshop productivity.
• Hot charging DRI and the use of high carbon DRI/HBI will significantly reduce meltshop electricity consumption. Essar Steel decreased electricity consumption by 124 to 145 kWh/T by using 600° C HBI. IMEXSA saw a 34.6 kWh/T savings for an additional 0.52 percent C. DR plant productivity is not compromised by producing high carbon DRI.
• Use of 50 percent hot metal in the EAF is expected to reduce power input on the order of 300 kWh/T.
• When using more than 20 percent DRI, it should be continuously charged.
• DRI shipping, storage and handling are not a major concern provided proper guidelines are followed.
• Offgas system capacity is a major consideration with increased oxygen use.
• Numerous steel mills have EAF optimization programs based on data acquisition and operating parameter analysis, but in general, insufficient manpower is dedicated to full analysis and implementation of optimization strategies.
• Exciting developments in EAF technology will continue. The model for the future will be a hybrid EAF/BOF fed with scrap; hot, high C DRI/HBI; pig iron and hot metal. It will use bottom blown oxygen and waste heat recovery. Electricity consumption may be lowered to 250 kWh per ton, with tap to tap times under 30 minutes.

MISSION STATEMENT

Midrex Direct Reduction Corporation will lead in the ironmaking technology industry by supplying superior quality services that provide good value for our clients. We will meet or exceed performance expectations, execute projects on time, enhance existing product lines, and develop or acquire new technologies. Our employees are the key to our success, and we are committed to encouraging them to grow professionally and personally.
The Beginning
Siemens started it all – Sir William, that is. He demonstrated in 1878-79 that an electric arc struck between carbon electrodes could melt steel. Unfortunately, the cost of electricity was prohibitive and the idea remained dormant. The first commercial US steelmaking arc furnace (now on display at Station Square in Pittsburgh) was installed at Halcomb Steel Company in 1906. It melted four tons and had two square electrodes.

Since electricity was still expensive, arc furnaces were reserved for the production of specialty steels, and in the early days displaced the crucible steel furnaces. US electric furnace output did not exceed one million net tons (NT) per year until 1939.

The Electric Furnace Comes of Age
When the big mills fell on hard times in the late 1970s and early 1980s, entrepreneurs saw the combination of an EAF, a continuous caster, and a long product rolling mill as a way to enter the steel industry at low capital cost. The latest so-called “mini-mills” are leading the technical revolution in steelmaking. Table I shows the process developments that fueled EAF growth.

It is instructive to trace the changes in EAF performance over the years, as shown in Table II.

The theoretical energy required to heat one net ton of scrap to 3000°F, plus that needed for slag production, is about 400 EkWh, total electrical and/or equivalent chemical energy input. Significant heat losses incurred during heating and melting of the charge increase this significantly. For example, for an EAF circa 1980, the total energy requirement was about 700 EkWh/NT. With a tap to tap time of two hours, 300 EkWh of heat was lost. Figure 1 compares EAF energy requirements for 1980, 1990 and 2000. The slopes of the lines represent average electrical and chemical power input (energy/unit time = power).

In the 1980s, emphasis was placed on increasing the total power to the EAF by supplementing electrical with controlled chemical energy. Burners, increased oxygen usage, more charge carbon, and designed post combustion all helped to reduce power-on time. But the biggest change was in transformer rating, increasing active power supplied to furnaces. Water-cooled panels and roofs, coupled with protective foamy slag, enabled adoption of the long arc practice, and various equipment developments improved electrical efficiency. Sulfur refining and temperature control were moved from the EAF to the ladle furnace, thus minimizing tap to tap times.

In the 1990s came the next assault, reducing the intrinsic 400 EkWh/NT associated with the charge by realizing the dream of fourth hole, hot waste gas capture for scrap preheating. Maintenance is an issue, and there is a limit to the heat that can be absorbed by the scrap as both heat times and gas volumes diminish. However, the energy recovered is free. Another approach is continuously charging hot DRI. A third option is to reduce iron oxide fines with coal; however, since the resulting DRI contains ash and sulfur, it is necessary to pre-melt the product. These developments have resulted in reducing the 400 EkWh/NT to 250-300 EkWh/NT.

<table>
<thead>
<tr>
<th>Transformer rating</th>
<th>1980</th>
<th>1990</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap to tap time (minutes)</td>
<td>120</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Electrical input (EkWh/NT)</td>
<td>550</td>
<td>450</td>
<td>342</td>
</tr>
<tr>
<td>Chemical input (EkWh/NT)</td>
<td>150</td>
<td>200</td>
<td>133</td>
</tr>
<tr>
<td>Total energy input (EkWh/NT)</td>
<td>700</td>
<td>650</td>
<td>475</td>
</tr>
</tbody>
</table>

Table I. EAF Process Developments

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Table II. EAF Performance</th>
<th>Chemical</th>
<th>Electrical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ladle furnaces</td>
<td>Larger transformers</td>
<td>Increased oxygen use</td>
<td></td>
</tr>
<tr>
<td>Water-cooled roofs</td>
<td>Current conducting electrode arms</td>
<td>Increased charge</td>
<td></td>
</tr>
<tr>
<td>and panels</td>
<td>Long arc practice</td>
<td>carbon</td>
<td></td>
</tr>
<tr>
<td>Eccentric bottom tapping</td>
<td>Foamy slag</td>
<td>Burners</td>
<td></td>
</tr>
<tr>
<td>Automation</td>
<td>DC furnaces</td>
<td>Post combustion</td>
<td></td>
</tr>
<tr>
<td>Capture of offgas heat</td>
<td>High impedance</td>
<td>DRI charging</td>
<td></td>
</tr>
<tr>
<td>Continuous scrap/ DRI charging</td>
<td>AC furnaces</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*By Dr. John Stubbles
Steel Industry Consultant*
The Future
How much further can we go? I worry about heat losses and all the cold air being pulled into the EAFs to maintain a negative pressure. By comparison, the basic oxygen furnace (BOF) uses a one bucket scrap charge and heat losses are minimal. Its chemically active power input is equivalent to some of the most productive EAFs in the world at about 0.6 MW/NT. But the EAF has more heat losses and most of the chemical energy is needed to satisfy that. Thus, the final frontier is a furnace design to minimize heat losses. Perhaps a hybrid EAF/BOF is the answer, using electricity, large amounts of oxygen and waste heat recovery.

I have implied that the primary justification for producing molten iron or hot DRI is productivity. Equally important is the ability to control raw material costs, especially low residual scrap. As we look into the future, several projections seem reasonable:

1. US population will increase about one percent annually, maintaining domestic steel demand at 130 million NT. Steel imports should moderate, if the world economy is healthy, to hover around 20 million NT.

2. BOF production will decline, but at least 43 million NT of first class integrated capacity will remain.

3. There will be additional EAF capacity, with a consequent shortage of prime scrap. Therefore, I predict good times for alternative iron (AI) producers.

4. The economics of domestic AI production remain company and site specific. The US steel industry energy usage trend has been downward for some time. This will bottom out as more energy intensive AI use partially offsets the reduction in fuel consumption by the elimination of obsolete blast furnaces.

Following are my views regarding other issues:

- Steel chemistry – we cannot expect the chemical removal of copper, nickel, tin, or molybdenum by any economic process. Product design, scrap beneficiating, and dilution remain the best options to meet steel specifications.

- Nitrogen – most originates from scrap rather than being picked up from the atmosphere. The only method of removal seems to be an active boil; therefore, AI should help.

- Automation – further automation of the EAFs is inevitable, but we need better sensors and more physically uniform charges.

- Power off-time – 10 to 15 minutes is best practice today. One bucket scrap charging and continuous DRI feeding will help reduce this.

Conclusions
The EAF will be the dominant US steel-making process by 2010. Demand for AI units will increase, particularly if the world economy remains healthy. Even in bad times, the mini-mills will remain more competitive than the integrated mills due to low man-hours per ton and flexibility in raw material selection and productivity.

Furnace designs to enhance continuous charging of uniformly-sized iron units, to minimize ingress of air, and to capture off-gas sensible heat are still needed.

We are on the threshold of perhaps the most exciting technical era the steel industry has ever known. The process options are mind-boggling; the potential furnace and mill designs imaginative. New products are waiting to happen. Can I sell my soul like Faust to the devil and return in 100 years?

Figure 1. EAF Energy Requirements
CARBON IN DRI – Friend or Foe?

By Louis Giguère
General Manager Primary Operations and General Services
Ispat Sidbec Inc.

INTRODUCTION
The subject of carbon in DRI and how it affects steelmaking operations is an emerging debate. This paper describes past and present experience with carbon in DRI in the EAF operations at Ispat Sidbec Inc. (ISI), shown in Figure 1. The ISI Contrecoeur Works includes two MIDREX® DRI Modules of 1.5 million metric tons (T) combined capacity. The steel plant includes two 140 T AC EAFs, two ladle furnaces, one single strand slab caster and one six strand billet caster for a combined current capacity of 1.7 million T.

ISI has been making and melting DRI since 1973, with input to the EAFs varying from 20 percent to 100 percent.

When discussing carbon in DRI, it is assumed that direct reduced iron (DRI) and hot briquetted iron (HBI) are well known and accepted by steelmakers as alternative iron unit (AIU) sources. These assumptions, in my experience, are wrong even with current worldwide usage at 35+ million T.

Many steelmakers forget that iron from reduced ore always has been THE iron unit source and scrap became the alternative thousands of years later.

The principal reduction reactions converting iron ore to DRI are:

$\text{Fe}_2\text{O}_3 + 3\text{CO} = 3\text{CO}_2 + 2\text{Fe} + \text{Q (heat)}$

$\text{Fe}_2\text{O}_3 + 3\text{H}_2 \rightarrow 3 \text{H}_2\text{O} + 2\text{Fe} - \text{Q (heat)}$

- Total carbon (CT%) is the carbon content of the direct reduction product.
- About two thirds of the carbon is present as iron carbide and the balance is deposited as carbon black or free carbon.

Excess carbon (CE%) is the fraction of carbon net of the stoichiometric requirement to reduce the remaining portion of iron oxide in the product. This notion is represented by the following formula:

$$\text{CE\%} = \text{CT} - \text{C_f(O_f/FeO)}$$

In reality, not all the iron oxide will be reduced as a percentage of FeO always exists in the furnace slag.

Combustible carbon (CC%) is the portion of total carbon available for combustion with injected oxygen. This carbon is the net of total carbon (CT%) and the portion of the stoichiometric carbon actually used for FeO reduction. Obviously, slag equilibrium FeO analysis will influence the non-reacted DRI carbon. This is shown in Table I below, for a given set of conditions.

The combustible carbon reacts with injected oxygen, releasing chemical energy to the steel bath and contributing to slag foaming.

Metallization (Met%) is the percent ratio of reduced (or metallic) iron to the total iron (FeT) in the DRI where FeT is the sum of the metallic (reduced) iron and the iron content of the FeO remaining in the DRI.

Gangue (G%) is the remaining portion of the DRI, excluding all the above, expressed as a percentage of the total weight.

### Combustible Carbon: $\text{C}_\% = \text{C}_\% - \text{C_f (FeO_DRI - FeO_Slag)}$

<table>
<thead>
<tr>
<th>Suppose:</th>
<th>DRI Input</th>
<th>Carbon &amp; Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat size = 140 T</td>
<td>Total iron = 91.7%</td>
<td>Reduced FeO = 4.4 T</td>
</tr>
<tr>
<td>Melt yield = 89%</td>
<td>Metallization = 95%</td>
<td>Reacted oxygen = 0.98 T</td>
</tr>
<tr>
<td>100% DRI = 157 T</td>
<td>Metallic iron = 87.1%</td>
<td>Reacted carbon = 0.73 T</td>
</tr>
<tr>
<td>Slag volume = 12.5%</td>
<td>Iron as FeO = 4.6%</td>
<td>Carbon in charge = 3.14 T</td>
</tr>
<tr>
<td>Slag weight = 19.6 T</td>
<td>FeO in DRI = 5.9%</td>
<td>Available C = 2.41 T (1.53%)</td>
</tr>
<tr>
<td>FeO in slag = 25%</td>
<td>Carbon in DRI = 2%</td>
<td>Lance efficiency = 80%</td>
</tr>
<tr>
<td>Weight of FeO = 4.9 T</td>
<td>Weight of FeO = 9.3 T</td>
<td>Required oxygen = 4.01 T</td>
</tr>
<tr>
<td>Specific volume = 21.2 m³/T</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table I Reacted C, FeO and C available for lancing
Figure 2 shows the relationship between Met%, C_e% and FeO for two DRI total carbon levels and Figure 3 the evolution of C_e% as a function of slag FeO% for two metallization levels and total carbon at 2 percent, both figures using 91.7 percent FeT.

A review of ISI’s 27-year historical plant experience with DRI production and use will help readers understand our evolutionary positive opinion about DRI carbon.

HISTORIC PLANT EXPERIENCE

The First Decade

In 1973, ISI (then Sidbec Dosco) started to make DRI in Module I and melt it in two 120 T, 18 ft. diameter, 52 MVA (38 MW) UHP AC, refractory-lined EAFs. Two new 135 T EAFs (“C” & “D”) were installed in 1978 and, in the mid ‘80s, “B” was converted to a ladle furnace. Consumable pipe robotic O2/C lances were installed in the slag doors of both these EAFs, leaving “A” without O2 injection.

“C” and “D”, then powered by 90 MVA (70 MW) transformers, had water-cooled walls and roof and EBT tapping. With a 55 percent DRI charge, the shop was melting 1 million T/year.

Providing the correct DRI for two different melting systems was not an easy task. The ‘85 to ‘95 decade was marked by compromises, the common thread being the low C melt down practice demanded by the overall product mix. “A” was typically pooled with “D” to feed the slab caster. Seventy-five percent of the Contrecœur steel was less than 0.2 percent C. Most medium carbon billet grades were made at the Montreal works (shut down in 1991).

While reverse efforts were made to increase C_e to greater than two percent to benefit from the chemical energy potential of the new lances, “A,” still fitted with continuous feed of oxide pellets to burn out carbon, was limping along at high operating costs. Not properly dosing these pellets would lead to wild furnace boils. Tap to tap times were in the three-hour range and any priority conflict for service of cranes or maintenance penalized this low productivity equipment. With massive doses of iron oxide, FeO slag could be greater than 40 percent. Slag viscosity was such that foaming could not be sustained, regardless of “V” ratio, resulting in furnace refractory life of 85 heats.

In parallel, “C” and “D” were provided with a melt assist model that would take into account Met%, C_e% and intended oxygen use and compute direct feed charge carbon rate, while also considering carbon from the robotic foamy slag injection. Plant oxygen availability was limited to an equivalent use of only 14 Nm3O2/T. During this period, the preferred DRI had 1.8 to 2 C_e%, 92.5 to 93 Met% and C_T% not much exceeding 0.4 percent, although ten times higher than before.

Needless to say, erratic DRI quality would put the system’s equilibrium in jeopardy. The melt model accuracy was imperative also in view of the large variation in EAF DRI feed – 20 percent DRI with three scrap charges to 100 percent DRI, depending on intended steel grade and the economics of DRI and scrap use.
This resulted in several versions of the fusion model being developed that can be selected for specific scrap/DRI practices.

“\textit{A}” was shut down in 1993. Transformer refits for “\textit{C}” and “\textit{D}” (130 MVA), coupled with a ladle and crane upgrade program in 1994, led to 140 T standardized heat sizes. However, oxygen was still limited to 14 Nm3/T.

For the melters to operate these super powered furnaces was like stepping out of an MGB and into a Formula One. The margin of error on slag chemistry, slag foaming oxygen injection, etc. became zero. On several occasions, we dissolved 6,000 kg of bench material in one heat due to excessively hot, flat and fluid (FeO rich) unfoamable slag. Rapidly improving slag chemistry control became mandatory and led to 94 Met% DRI which reduced the chemical potential of the FeO liquifier.

A new struggle arose with $C_e$ in the 0.8 percent range. A happy compromise was struck: bustle gas methane enrichment was lowered in the DRI plant, thus reducing endothermic reactions, providing higher bustle gas temperatures and favoring higher Met% at similar productivity levels.

\textbf{The Past Four Years}

The DRI plant has raised Met% to 95 percent (while maintaining or increasing production) which yields direct energy, refractory consumption and metallic yield benefits to the melt shop. Since 1994, production has increased from 1.2 to 1.7 million T by improving raw materials, increasing transformer size and reducing OME delays.

Increasing the Met% increased the combustible carbon; with 95 percent Met%, 91.7 percent FeT, 2 C\textsubscript{T}% C\textsubscript{E}% is now 1.1 and C\textsubscript{E}% is 1.64 percent (Fig 3) which, depending on oxygen availability and total percent DRI charged, may be good or bad. Considering 60 percent oxygen efficiency for consumable lances; 70 to 100 percent DRI heats would need 17 to 23 m$^3$/O$_2$/T. Foamy slag requirements would be additional. With the continued 14 Nm$^3$/O$_2$/T limit, our issue became “refining” delays, a problem uncommon to most high percent DRI melters.

Once more, specifically in 1998 and 1999, carbon in DRI was a foe. Continuously fed charge carbon was reduced to virtually nil as foamy slag carbon could not be backed off.

\textbf{Since Y2K}

In December 1999, one water-cooled C/O$_2$ lance was added to EAFs “\textit{C}” and “\textit{D}”, additional to the original robotic consumable slag door lances, mandating a new O$_2$ plant.

During melter training and commissioning of new lances, it became obvious the fume extraction system coped much better when charging higher proportions of the highly metallized and carbon rich DRI.

It is felt that a portion of charge carbon (fines) is lost to the fourth hole draft. Additionally, larger carbon particles may not fully dissolve in the slag or react with slag FeO and are flushed out with foaming slag. Thus chemical energy input to the steel bath from continuously fed charge carbon is erratic. When feeding more than 500 kg of charge carbon, ample evidence exists of combustion continuing past the water-cooled portion of the ductwork. This is causing high temperature sensors to initiate “peak shaving” (water mist cooling of exhaust gas). The alternative is activation of the primary dilution damper with loss of all bag house suction to the affected furnace.

Our goal is to double the oxygen input from 14 Nm$^3$/T to 28 Nm$^3$/T which would require \textasciitilde4400 kg carbon/heat; \textasciitilde1000 kg/heat injected via the two carbon lances, the remaining 3400 kg/heat would, for a 70 percent DRI charge, require 2.9 C\textsubscript{T}% DRI. This is not unreasonable considering the latest developments at IMEXSA’s MIDREX MEGAMOD®. Ideally, continuous feed of charge carbon would be eliminated.

\textbf{Effect on Exhaust System}

The extra 14 Nm$^3$/T of oxygen generates the same amount of CO in the furnace and requires the same amount of fourth hole gap air infiltration to post combust this CO before the baghouse. This in turn implies the infiltration of four parts of nitrogen to the one part of oxygen or 70 Nm$^3$/T of room temperature gas more than before. At 650°C this becomes 220 m$^3$/T or some 31,000 m$^3$, and, as the melt rate is about one hour, this becomes the added specific burden. This represents a greater than 12 percent surcharge on the effective fourth hole draft at Ispat Sidbec Inc.

Furthermore, during peak lancing periods, peak shaving water is 250/300 liters per minute. The water evaporates, putting an additional charge of some 50,000 m$^3$/hr at 650°C, much more than the effect of the extra oxygen consumption. We are now left with the need to resolve the problem of the burning gases in the non-water-cooled portion of the ductwork.

Certainly, high carbon DRI provides more efficient carbon combustion in the steel bath than anthracite which partially combusts in/on the slag, or in the ductwork.

\textbf{Conclusions}

- For moderate or low DRI users, carbon in DRI is an economic source of carbon as it provides combustion energy to the steel bath to the limit of tap carbon.
- A good portion of DRI carbon is in the form of iron carbide and thus generates more chemical energy when oxidized.
- For extensive DRI users, carbon in DRI is a friend IF an adequate oxygen supply exists at the EAF shop.
- Carbon in DRI is of value to replace charge carbon and negate/reduce fines floating and burning on the slag blanket, thus limiting the fourth hole exhaust system loading.
Introduction
Ispat Mexicana CV (IMEXSA) is located in Lazaro Cardenas, Mexico, on Mexico’s West Coast (see Figure 1). The plant includes a MIDREX MEGAMOD® with a rated capacity of 1.2 million metric tons (T)/year (producing more than 1.5 million T/year), two HYL III modules rated at 2 million T/year, a meltshop with four NKK AC EAFs, two NKK ladle furnaces (LFs) and a slab caster. The predicted 2000 steel production is 3.9 million T, primarily high-quality slabs for export. IMEXSA charges the EAFs with 98 percent DRI.

MEGAMOD Operations Changes
The MEGAMOD has been instrumental in meeting the needs of the meltshop by optimizing DRI quality and composition. Soon after start-up of the MEGAMOD in August 1997, the target for product metallization was raised from 88 to 93 percent. In 1998, the metallization level was raised again to 95 percent and it has been maintained at this level since then. The product carbon content was increased as well, from 1.2-1.5 percent to 1.8-2.0 percent.

At the end of 1999, IMEXSA required additional DRI productivity. Also with the installation of post combustion lances in the EAF, it was beneficial to experiment with even higher DRI carbon levels. The primary means of controlling product carbon is increasing transition zone natural gas flow. As methane in the natural gas cracks to form carbon, hydrogen is released which adds to the reductant volume. Producing carbon by this “waste heat” approach always results in higher productivity and, since IMEXSA routinely operates with furnace bed temperatures of 900°C (a large amount of waste heat) in the MEGAMOD, both needs could be satisfied.

Due to the beneficial effects of higher carbon levels in the EAFs, IMEXSA has been routinely operating at production rates of 210-220 T/h with 95 percent metallization and 2.5 percent carbon since February 2000.

Meltshop Effects
Even when operating with high DRI carbon levels, the carbon is not deposited as soot or free carbon on the surface of the pellets but is deposited and bound inside. IMEXSA carefully evaluated the results of higher carbon DRI in the meltshop in January and February 2000. Generally, the chemical energy available from the additional DRI carbon and oxygen lancing not only increased productivity but also reduced electrical power requirements. Table I summarizes the operational benefits per T of liquid steel (Tls), comparing November-December 1999 with January-February 2000.

### Table I: IMEXSA Meltshop Operating Results for 2.08% C and 2.6% C DRI

<table>
<thead>
<tr>
<th></th>
<th>Nov. 1 – Dec. 31 1999, 2.08% C DRI, 2702 Heats</th>
<th>Jan. 15 – Feb. 29 2000, 2.6% C DRI, 1730 Heats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCRAP (T)</strong></td>
<td><strong>DRI (T)</strong></td>
<td><strong>LIME (T)</strong></td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>25.2</td>
<td>393.0</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>8.8</td>
<td>150.0</td>
</tr>
<tr>
<td><strong>Avg</strong></td>
<td>16.8</td>
<td>253.2</td>
</tr>
<tr>
<td><strong>Max</strong></td>
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<tr>
<td><strong>Avg</strong></td>
<td>16.8</td>
<td>253.2</td>
</tr>
</tbody>
</table>

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**Table 1** IMEXSA Meltshop Operating Results for 2.08% C and 2.6% C DRI
Following is a summary of the meltshop operations and benefits for high carbon DRI:

1. Energy consumption: oxygen was injected early in the heat to combust the DRI carbon, adding chemical energy to the bath. This resulted in a higher DRI continuous feeding rate, better slag foaming, lower energy losses and a lowering of electrical energy consumption from 586 kWh/Tls to 551 kWh/Tls.

2. Power on time: better slag foaming, higher oxygen consumption and higher DRI feed rate (250 kg/minute) decreased power on-time from 66 minutes to 62 minutes.

3. Productivity: shorter power on-time, decreased internal and external delays and increased oxygen use increased productivity from 163 T/h to 172 T/h per EAF.

4. Electrode consumption: electrode consumption dropped from 1.38 kg/Tls to 1.33 kg/Tls due to the shorter power on-time, vigorous foamy slag formation, higher productivity and shorter power off-time, thus reducing electrode side oxidation.

5. Slag FeO: the DRI carbon reacts immediately with the prior heat’s excess FeO, promoting vigorous CO and foamy slag formation. This reduced the slag FeO from 39.1 percent to 37.7 percent with better oxygen injection control.

6. Coke consumption: high %C DRI reduces other carbon charges, including nut coke, added early in the heat to promote foamy slag, and graphite injection. Total C use was reduced from 1.3 to 0.2 kg/Tls.

7. Oxygen addition: higher %C DRI promotes earlier oxygen injection and CO formation, resulting in quicker optimum foamy slag practice. The extended period of oxygen use, and better oxygen control, negates undesirable carbon boils at the back end of melt down. Oxygen use has increased with high %C DRI and the advent of post combustion lances, from 16.7 Nm3/Tls to 19.1 Nm3/Tls.

8. Tap oxygen: better bath carbon control, better oxygen and carbon injection and slag foaming practices have lowered tap oxygen contents from 1016 to 956 ppm.

9. Refractory cost: better foamy slag protection of the lining and lower FeO, shorter power on-time, higher productivity and better oxygen and graphite injection control have decreased refractory consumption from 7.5 to 6.8 kg/Tls. This resulted in a cost reduction from $3.34 to $3.00/Tls.

The results of the high %C DRI tests have been technically and economically favorable to IMEXSA, which would like to increase the carbon level even higher. In April 2000, IMEXSA tested the ability of the DRI plant to produce 3.1% C DRI. Due to current lack of meltshop oxygen, DRI carbon is being maintained at 2.5 percent.

**Future Plans for 3.5% C DRI**

IMEXSA has explored the possibility of preheating the transition zone natural gas to achieve carbon levels up to 3.5% C. This approach cannot be implemented until meltshop oxygen availability is significantly increased.
EMCI Wins Contracts From Ispat Inland Bar Products and Nucor Steel

Midrex Direct Reduction Corporation’s sister company, EMC International, Inc., has been awarded two new contracts. EMCI will supply a cold DRI storage and conveying system at Ispat Inland Bar Products’ electric arc furnace mill in East Chicago, Indiana. The facility, to be delivered in October 2000, will be capable of receiving 40 truckloads of DRI per day and storing 20,000 cubic feet of material. Designed with multiple conveyors, the system will be able to deliver DRI from the receiving hopper at variable feed rates directly to the EAF or to a storage silo for later use. The system will give Ispat Inland the capability of automatically controlling the DRI feed rate. Ispat International, owner of Ispat Inland, operates MIDREX® Direct Reduction Plants in Trinidad, Mexico, Germany and Canada.

Nucor Steel has selected EMCI to supply a ladle furnace at its Crawfordsville, Indiana, mill. The furnace will have a capacity of 120 net tons and is scheduled for delivery in November 2000. It will be an integral part of Nucor’s new Strip Casting Mill (Project M).

Third MIDREX® Direct Reduction Plant at ANSDK in Full Production

The third MIDREX® Direct Reduction Module supplied to Alexandria National Iron & Steel Co. S.A.E. (ANSDK) in Egypt is currently in full operation and has been producing direct reduced iron (DRI) at its guaranteed rate.

ANSDK awarded Kobe Steel, Ltd. and Tomen Corporation an order in December 1997 to build a MIDREX Direct Reduction Module at its El-Dikheila steelworks near Alexandria. The plant, with an annual capacity of 800,000 metric tons of DRI, was completed on schedule in February 2000.

In the five months of operation from March to July, the plant was in full production. Over the same period, it produced DRI with a metallization of 94.2 percent.

Kobe Steel also supplied the first two MIDREX Modules, with production capacities of 716,000 and 800,000 tons per year. Module I was completed in 1986 and Module II in 1997. In 1999, the two units combined to produce 1.67 million tons of DRI.

When operations began in 1986, ANSDK produced bar and wire rod for the construction industry. The second MIDREX Module contributed to increasing the capacity of these product lines. With steel demand growth in Egypt, ANSDK is now expanding into flat products. The third MIDREX Module is a key part of that endeavor, since the production of high-quality steel sheet from electric arc furnaces requires a clean source of iron.

Kobe Steel was awarded a separate order in October 1998 to expand a mineral jetty near the ANSDK steelworks. The expansion will facilitate raw materials handling from an ore yard at the jetty to the third MIDREX Module. The project consists of adding a stacker/reclaimer, conveyors and junction towers. Kobe Steel will provide supervisory services to oversee the start of operations. The project is expected to be completed in September 2000.
FASTMET® Plant Is an Important Step in Kobe Steel Zero Emissions Program

Kobe Steel, Ltd. will convert the FASTMET demonstration plant at its Kakogawa Works in Japan into an iron-bearing solid waste recycling facility. This is part of a plan to turn Kakogawa into a zero emissions facility by the end of 2001, an industry first.

The FASTMET Plant will reclaim zinc-rich iron oxide dust from blast furnace and steelmaking operations, with a treatment capacity of 14,000 tons per year. The facility will use waste oil as the primary fuel source. It is anticipated to go into operation in spring 2001. The demonstration plant will be modified to process blast furnace and steel-making dust, including upgrading the offgas cleaning unit to recover high zinc content dust.

At Kakogawa, the FASTMET Plant will use pellets made of blast furnace and steelmaking dust. The pellets are fed to a rotary hearth furnace and heated to a high temperature. The carbon in the waste acts as a reductant and reacts with the oxygen in the iron oxide in a relatively short time, leaving direct reduced iron (DRI) with a high iron content. The DRI will be used in steelmaking operations. Plans call for zinc recovered from the offgas to be sold.

The Kakogawa Plant will be the second commercial facility using the FASTMET Process. The world’s first commercial FASTMET Plant has started up successfully at Nippon Steel’s Hirohata Works in Japan. The plant is designed to process 190,000 tons per year of steel mill waste into highly metallized DRI. The DRI is being hot charged into Hirohata’s steelmaking shop along with scrap and pig iron to produce steel.

Sponge Iron Manufacturers’ Association Holds Eighth General Meeting

The Sponge Iron Manufacturers’ Association (SIMA) was established in 1992 and has its headquarters in New Delhi. The organization consists of 17 Indian direct reduced iron producers and its Director is Mr. S. S. Bhatnagar. The MIDREX® Direct Reduction Plants at Essar Steel and Ispat Industries are member companies. Its mission is to ensure the continued development and growth of the Indian Sponge Iron industry through the compilation of data, facilitation of information exchange and contact with government agencies. On July 17, 2000, SIMA held its eighth annual general meeting. The meeting was inaugurated by Shri Braja Kishore Tripathy, the Honorable Union Minister of State for Steel, Government of India. The meeting was attended by various sections of the industry, government officials, and the press. Mr. Naveen Jindal, Vice Chairman and Managing Director of Jindal Steel and Power Ltd. and Mr. Vinod Gary, Director in Charge of Ispat Industries Ltd., were re-elected as Chairman and Vice Chairman of SIMA for the 2000-2001 year.