Direct from Midrex

4th Quarter 2002

Using OXY+® to Make Reducing Gas in the MIDREX® Direct Reduction Process

Market Forces in the Direct Reduction Industry: What Drives the Market?

Industrial Recovery Systems: Environmental Remediation

www.midrex.com
Commentary

EVOLUTIONARY…..NOT REVOLUTIONARY:
From Process Technology to Practice

Evolution is natural for an age-old industry like iron and steel. Most of the gains of the past 50 years in productivity, efficiency, and reliability have not come from revolutionary leaps forward, but rather have come from evolutionary changes made at the operating facilities. These operational changes, as well as small, practical innovations have been field tested by experienced plant operators and supervisors and incorporated into the standard designs for next-generation plants through cooperation with technology suppliers and plant-builders.

These small advances and improvements, when incorporated into the next generation steel mill, can provide results that equal or exceed the hoped-for benefits of things that claim to be revolutionary without the risks and pain of extended start-ups, cost overruns, lower shareholder values, or in the worst of cases, bankruptcy.

Consider the evolutionary progress of continuous slab casters from their introduction in the 1960s to today’s high speed, multiple-point bending and unbending slab-casters that utilize hydraulically driven dynamic mold oscillators with sticker detection and on-line width change capability, quick-change segments, top-fed dummy-bars, tighter roll spacings, advanced spray cooling, electromagnetic stirring, etc. Operational improvements also have been made in sequence casting, tundish changes, mold powders, submerged entry nozzles, casting speeds, grade-changes, width changes, etc. None of these improvements was revolutionary. Each was an evolutionary, practical innovation, and in many cases, the risks of implementation were borne by the technology or equipment suppliers. Today, conventional slab casters can produce as much as 2.5 – 3.0 million tons per year on a twin-strand machine…and with excellent quality.

The MIDREX® Direct Reduction Process has evolved from the first commercial plant in 1969 based on 150,000 metric tons per year (t/y) modules to the current 1.60 –1.80 million t/y module. For the MIDREX Process, the evolution continues with a concept design for a 3.0 million t/y module, which will rival the blast furnace.

ITmk3®, FASTMELT®, and FASTEEL™ can be considered process technologies that are more than evolutionary but less than revolutionary. Kobe Steel and Midrex have proven that rotary hearth direct reduction can be a profitable investment. These technologies build upon the rotary hearth furnace (RHF) success of the FASTMET® Process embodied in pilot-scale facilities, demonstration units, and two commercially proven operating units, which have showcased the dependability, efficiency, and profitability of the technology.

FASTMELT uses the hot high carbon DRI of FASTMET and feeds it to a proven operating unit (the electric melter), which has been customized into an ironmaking furnace rather than a steelmaking furnace. Thus the name, Electric Ironmaking Furnace (EIF®).

ITmk3 simply enhances the FASTMET RHF to convert the hot DRI into pig iron nuggets by separating the slag from the iron at higher temperatures. This phenomenon has been proven to be repeatable and controllable at a pilot scale and will be taken to the next level by the Mesabi Nugget project in mid-2003, when the demonstration facility is started up and operated.

What we have witnessed over the past 10 years in the iron & steel industry is the result of many factors. Far too many companies thought they had the ability and strength to commercialize something that held the promise of being revolutionary…and failed. As a result, capital investment in emerging technology is nearly impossible to find.

The issue that faces the steelmaker today is, “Does my company have the capability and strength to commercialize revolutionary technology or can it achieve an even higher rate of return from evolutionary advances?”

One thing is very clear, global steel consumption will continue to increase over the long-term. Efficiency gains will continue through evolutionary improvements to operations and equipment, and older, inefficient capacity will be eliminated from the supply-side. Barring continued government intervention and protection, new steel mills will be constructed, which are more efficient, more environmentally friendly, and in locations where operating costs are the lowest. Why? Because the global economy will demand it.
The use of oxygen in a MIDREX® Direct Reduction Plant or other process plant can significantly increase productivity. The MIDREX OXY+® system is the next generation of oxygen injection, employing a partial oxidation system to provide greater operating flexibility and economic benefits. This article examines the economic benefits of generating a portion of a DR plant’s hot reducing gas with the MIDREX OXY+ partial oxidation system.

REDUCING GAS GENERATION

A hot reducing gas, consisting mainly of gaseous reductants, H₂ and CO, and small amounts of methane (CH₄) and oxidants (H₂O and CO₂), is used to convert iron oxide to metallic iron inside the reduction furnace. Generation of this hot reducing gas at temperatures sufficient to reduce iron oxide is accomplished in 3 ways:

1. MIDREX® Reformer: Typically reducing gas is generated in the natural gas reformer by reacting methane (CH₄) with water (H₂O) and recycled carbon dioxide (CO₂). Hot H₂ & CO (reductants) are formed, with the balance of the gas being unreacted H₂O, CO₂ and CH₄. The reformed gas quality has a typical ratio of reductants-to-oxidants of 10 and a temperature up to 950°C.

2. In-Situ Reforming: Reformed gas (see 1 above) is then enriched with additional methane. The enriched gas, now called bustle gas, enters the MIDREX® Shaft Furnace at temperatures up to 920°C (typical — without O₂ injection). The metallic iron acts as a catalyst for reforming the unreacted methane with oxidants present. This method is called in-situ reforming. When using simple O₂ injection to achieve higher bustle gas temperatures, energy is added to the bustle gas to accelerate in-situ reactions and reduction reaction rates. However, O₂ injection consumes reductants.

3. Partial Oxidation with OXY+: An ideal method of making additional reducing gas would be one that produce the gas externally and delivers excess thermal energy to the reduction furnace without exceeding localized temperature limits of the ore or consuming valuable reductants. The third method of generating reducing gas is to utilize an external partial oxidation reactor. The patented OXY+ system produces reducing gases as a cost-effective supplement to the MIDREX Reformer and acts to counter the detrimental endothermic effects of in-situ and reduction reactions by delivering thermal energy. In OXY+, a partial oxidation reactor combusts methane with oxygen at sub-stoichiometric, ratios which are producing large amounts of H₂ and CO with excess energy. With methane as the principal fuel, the overall OXY+ partial oxidation reaction is:

\[ \text{CH}_4 + \frac{1}{2} \text{O}_2 \rightarrow \text{CO} + 2 \text{H}_2 \]

OXY+ Partial Oxidation vs. Oxygen Injection: Many MIDREX Plants are currently using simple oxygen injection to maximize the thermal energy being delivered to their reduction furnaces. This consumes valuable reductants. However, the net effect of O₂ injection is favorable. In other words, higher reduction kinetics outweigh the negative impact of the reductant consumption. OXY+ partial oxidation relies on fresh, unreacted methane as its fuel to generate additional H₂ and CO without consuming reductants. OXY+ generates new reductants, as well as thermal energy, both of which contribute to higher productivity inside the reduction furnace.

This article considers two cases in which OXY+ partial oxidation is applied in direct comparison to a comparably sized MIDREX Reformer.

Case 1: Retrofit of an existing MIDREX Plant
Case 2: Optimization of a new MIDREX Plant design

Both cases assume that partial oxidation gases are combined with the main stream of reducing gas generated by the MIDREX Reformer, prior to entering the MIDREX Shaft Furnace. However, use of OXY+ is not limited to this application. OXY+ gases can be used independently and injected into the center of the furnace. The benefits of OXY+ for center injection (patent pending) are not discussed here.

CASE 1: OXY+ PARTIAL OXIDATION REACTORS FOR AN EXISTING PLANT

Case 1 compares two options for an existing MIDREX Plant. It has been assumed that the plant has already reached a bustle gas temperature limit via O₂ injection. This implies that gas utiliza-
tion and furnace productivity have been optimized. In order to increase capacity further, the plant needs to improve bustle gas quality and increase the flow of reductants and/or total thermal energy per unit of time.

Two options are available for the existing plant:

- Option 1-1: expand the size of the existing reformer by 1-bay (30 tubes)
- Option 1-2: add an OXY+ partial oxidation system

If we hold constant many other variables, we can establish an effective comparison between these options. A process simulation was performed to compare them. Option 1-1 is assumed to generate an additional 18,000 Nm³/h of reformed gas. Option 1-2 considers two OXY+ reactors to make approximately 18,000 Nm³/h of partial oxidation gas. Each option increases plant capacity by 14 t/h.

Table I shows the effect on the plant operations for each option. As expected, partial oxidation consumes large amounts of oxygen (produced with electrical power). When comparing natural gas consumptions, not much difference is noticed. However, OXY+ has a higher natural gas efficiency because the reducing gas generated is delivered directly to the reduction furnace, thus avoiding the heat losses incurred in the reformer.

Table II shows the marginal costs applied to Table I. Each option is compared to the base tons produced. These marginal costs are calculated assuming unit costs typical of a Trinidad site. These unit costs result in slightly lower energy costs for option 1-2 and slightly higher for option 1-1.

Other Costs: Operating cost changes, while important, are insignificant when compared to the other cost considerations. Other factors in need of consideration are:

- The cost of lost production during plant modifications.
- Capital costs for each option.

All of the above factors should be considered when deciding which option to pursue. Most factors are site-specific. However, the following site conditions would favor the OXY+ partial oxidation option:

- Low oxygen and electric power costs
- High value of lost production
- Capital money for plant modifications is scarce or very expensive
- No space available for a reformer expansion

**CASE 2: OPTIMIZATION OF A NEW MIDREX PLANT DESIGN**

Case 2 examines the scenario of a new MIDREX Plant design. The selection of reformed gas generation equipment could be optimized if oxygen is available. Thus, we compared the following 2 options:

- Option 2-1: A New Plant with a full MIDREX Reformer and simple O₂ injection
- Option 2-2: A New Plant with one less reformer bay and OXY+ partial oxidation

Again, if we hold constant many other variables, we can establish an effective comparison between these options. A process simulation was performed to compare them. It has been assumed that all oxygen can be supplied by an on-site cryogenic oxygen plant.
The cost of oxygen has two parts: (1) the electrical power for oxygen generation, and (2) a $0.021 per Nm³ charge to cover all other costs associated with the oxygen plant.

Both options are assumed to produce 220 t/h of DRI at maximum capacity. The full reformer option (2-1) considers a DR plant with a 15-bay reformer and simple O₂ injection. The partial oxidation option (2-2) considers a DR plant with a 14-bay reformer and two OXY+ partial oxidation reactors.

Table III shows the effect upon the plant operations for each option. As expected, the OXY+ option consumes large amounts of oxygen. Comparing natural gas consumptions, not much difference is noticed. The OXY+ option has a higher natural gas efficiency, as stated previously in Case 1. However, this option shows an increased specific consumption of oxygen over O₂ injection. Table III also provides a comparison of costs for each ton of DRI produced based upon Trinidad costs. These unit costs show that gas cost plus electricity cost for the partial oxidation option is $0.53 per ton higher than for the full reformer option.

The question that must be addressed is, "Is the capital cost savings of OXY+ enough to justify a higher operating cost?" The answer can only be determined after evaluating all costs.

### PROJECT AND LOST PRODUCTION COSTS

Proper evaluation of each case also must take into account the capital costs, and in the case of existing plant expansions, the cost of lost production due to the plant downtime associated with each option.

#### Existing Plant Retrofit (Case 1):

Review of the operating cost differences only (as done in Table II above) appears to favor the implementation of the highly efficient MIDREX Reformer combined with a simple oxygen injection system. However, for an existing MIDREX Plant owner, other very important considerations must be taken into account such as the availability of oxygen or the shutdown requirements to implement the expansion.

Space availability or other critical process plant bottlenecks may also be a factor. An examination of just the two major cost differences between the case 1 options is detailed in Table IV. As clearly demonstrated by these figures, the net investment cost difference from just these two major project cost considerations amounts to nearly US$ 5.0 million. When amortized at an assumed total weighted average cost of capital equal to 12 percent, the advantage is US$ 5.28 per ton in favor of OXY+ (option 1-2).

### Payback (Case 1):

Table V shows a simple calculation of the relevant payback periods for each option. Given the large difference in total costs of implementation and considering operating cost differences, the OXY+ option results in a payback period which is 75 percent quicker than a reformer expansion.

<table>
<thead>
<tr>
<th>Major Cost Considerations Only</th>
<th>Base Case (before retrofit)</th>
<th>Per Additional Ton Only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reformer (Option 1-1)</td>
<td>OXY+ (Option 1-2)</td>
</tr>
<tr>
<td><strong>Project Cost of Retrofit:</strong></td>
<td></td>
<td></td>
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<tr>
<td>Production Rate (t/hr.)</td>
<td>220</td>
<td>14</td>
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<td>Annual Production (t/yr.)</td>
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<td>Retrofit Costs (US$)</td>
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<tr>
<td>Specific Capital Cost (US$/annual t)</td>
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<td>$31.25</td>
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<tr>
<td>Resulting Capital Charge</td>
<td>(US$/t) at 12% WACC*</td>
<td>$0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$0.00</td>
</tr>
<tr>
<td><strong>Lost Production Cost of Retrofit:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirement for add’l shutdown time</td>
<td>1 month</td>
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<tr>
<td>One-time Production Loss (t)</td>
<td>146.67</td>
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<td>Contribution Value of Lost DRI vs.</td>
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<tr>
<td>Purchased DRI (US$)</td>
<td>$20</td>
<td>$20</td>
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<tr>
<td>Cost due to lost production (US$)</td>
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<tr>
<td>Specific Capital Cost (US$/annual t)</td>
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<td>Resulting Capital Charge</td>
<td>(US$/ton) at 12% WACC*</td>
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<tr>
<td></td>
<td></td>
<td>none</td>
</tr>
<tr>
<td><strong>Total Capital Charge (US$/ton):</strong></td>
<td>$0.00</td>
<td>none</td>
</tr>
</tbody>
</table>

Table IV Capital and Other Cost Considerations for CASE 1 (Existing Plant Retrofit)
New Plant Comparison (Case 2): When analyzing the capital cost differences between OXY+ and a full reformer, the lost production factor does not exist, as there is negligible construction time difference. The only capital cost difference is related to the difference in plant costs, which amounts to approximately US$ 2.0 million, which corresponds to a specific capital cost advantage of just US$1.14 in favor of OXY+ partial oxidation. Using a WACC of 12 percent, the net benefit of this project cost advantage is just US$ 0.14 per ton (see Table VI below).

PARTIAL OXIDATION VERSUS IN-SITU REFORMING

OXY+ partial oxidation efficiently applies the heat of combustion in the 2nd stage of the reactor to reform methane with the products of combustion resulting from the 1st stage. In-situ reforming takes place only after gases enter the metallic bed of iron inside the furnace. Therefore, reliance on the metallic bed to equilibrate the oxidants and methane means that the bustle gas is temperature limited. OXY+ uses more oxygen to impart energy to fresh methane rather than consuming reductants and also results in a bustle gas that is closer to equilibrium, thus much lower in temperature than an equivalent O2 injection system can produce. Said in reverse, for a given bustle gas temperature limit, productivity from OXY+ is much higher than reliance upon O2 injection and in-situ reforming due to greater flow of reductants, higher quality of reducing gas and associated greater total energy delivery rate.

SUMMARY / CONCLUSIONS

An OXY+ partial oxidation system provides the most benefit to an existing DR plant that is running at full capacity yet still desires additional DRI production; i.e., one that has already maximized production with O2 injection but has more oxygen available. Although O2 injection should be the first step in maximizing production with oxygen, partial oxidation with OXY+ will allow the use of significantly more oxygen and/or lower bustle gas temperatures to achieve greater DRI production rates.

Existing Plant Summary: For an existing plant, the benefits of OXY+ versus a reformer expansion project are: more economical use of capital and less downtime/lost production. The disadvantage of OXY+ is higher operating cost; however, the net benefit favors OXY+ when considering both cost factors. Payback for OXY+ is 75 percent quicker than that of adding a reformer bay.

New Plant Summary: For a new plant, the higher operating cost of OXY+ partial oxidation needs to be offset by a greater capital cost savings, as compared to a larger reformer. The difference is just US$ 0.39 per ton in favor of the larger reformer when considering both operating and capital cost. If electricity or oxygen costs are lower or the cost of capital is higher than 12 percent, then perhaps the difference would be reduced. This analysis confirms the efficiency and cost-effectiveness of the MIDREX Reformer as the most optimum for a new plant.

OXY+ for Center Injection (patent pending): Although conventional delivery of reducing gases from OXY+ are beneficial, the unique features of OXY+ permit the targeted use of these gases where they are most needed. This innovation from Midrex will provide MIDREX Plants with additional capabilities to improve productivity and product consistency.

REFERENCES


Table VI: Project Cost Impact for Case 2 - New Plant

<table>
<thead>
<tr>
<th>Per Ton</th>
<th>15-Bay Reformer</th>
<th>14-Bay and OXY+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Rate (t/hr.)</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>Annual Production (t/yr.)</td>
<td>1,760,000</td>
<td>1,760,000</td>
</tr>
<tr>
<td>Capital Cost Difference (US$)</td>
<td>base case</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>Specific Capital Cost (US$/annual t)</td>
<td>base case</td>
<td>-$1.14</td>
</tr>
<tr>
<td>Specific Capital Charge (US$/t) 12% WACC*</td>
<td>base case</td>
<td>-$0.14</td>
</tr>
</tbody>
</table>

* WACC - Weighted Average Cost of Capital

Table VII: Summary for Case 1 — Existing Plant Retrofit

<table>
<thead>
<tr>
<th>Per Additional Ton Only</th>
<th>15-Bay Reformer</th>
<th>14-Bay Reformer &amp; OXY+</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-Bay Reformer (Opt. 1-1)*</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>Annual Production (t/yr.)</td>
<td>1,760,000</td>
<td>1,760,000</td>
</tr>
<tr>
<td>Specific Energy Operating Costs (US$/t)</td>
<td>base case</td>
<td>+$0.53</td>
</tr>
<tr>
<td>Specific Capital Cost (US$/t) 2% WACC</td>
<td>base case</td>
<td>-$0.14</td>
</tr>
<tr>
<td>Total Cost Difference (US$/t)</td>
<td>base case</td>
<td>+$0.39</td>
</tr>
</tbody>
</table>

Table VIII Summary for Case 2 — New Plant
Market Forces in the Direct Reduction Industry

What Drives the Market?

Part One: The Value of the Product - Market Price

[Editor's Note:] This is the first in a series of articles describing the factors that move the direct reduction market to build or not build additional capacity.

By Robert Hunter, Midrex Technologies, Inc.

There are several driving forces behind the need for more DRI. Some of the more important factors are: EAFs producing low residual long products (wire rod — including tire cord, special bar quality, forging quality, EAFs producing flat products (typically using thin slab casters), and blast furnaces needing to operate at increased productivity. Underlying everything are cost and price. This article will discuss the price history of cold iron units used in steelmaking.

Cost is the most fundamental factor and varies widely according to location. However, certain principles hold true almost everywhere. Iron ore and energy are by far the greater portion of total costs. A location where either of these can be obtained for a relatively low amount is an advantageous site for iron reduction. The third cost parameter is capital/financial. All other costs, combined, are minor compared to these three.

Price is the next most important factor and will be the subject of this article. Over the long term, price (after adjustment for inflation) varies by more than 6:1, but over the past twenty years (again, after adjusting for inflation) price has maintained a range only a little broader than 2:1. This will be discussed in greater detail.

Finally, success or failure of individual markets where DRI and HBI are used create a greater, or lesser, demand for the product. The main markets are (in steelmaking):

1. Production of the more malleable and ductile long products (wire rod, SBQ, forging steels, etc.) via the EAF route
2. Production of flat products using the EAF route (especially with EAFs linked to thin slab casters), and, in ironmaking, blast furnaces that need to operate at increased productivity (for instance, when another blast furnace at the same site is idled for maintenance or reline).

PRICE OF METALLICS FOR USE IN STEELMAKING

Historically, the metallics used in steelmaking were scrap steel and some small amount of pig iron and beach iron (hot metal poured to ground). More recently, it has come to include DRI and HBI and in the United States, a much larger portion of pig iron. For the past few years, six to seven million tons per year of DRI/HBI and cold pig iron have been used in U.S. steelmaking, or approximately 10 percent of the total cold charge (cold charge to BOFs plus the charge to EAFs). The different grades of scrap, pig iron, and DRI/HBI tend to be priced in parallel, so for the sake of simplicity, we will look only at the price of the 'bellweather' grade, #1 heavy melting scrap (#1 HMS). Please refer to Figure 1. Here we see the average monthly price ($/GT, delivered, 3-city composite) of #1 HMS, as reported by American Metal Market and by Iron Age since January 1955. However, it
should be remembered that inflation has radically altered the value of the dollar over this period.

Figure 2 shows the same data adjusted for inflation using the Consumer Price Index for All Urban Consumers (CPI-U), as reported by the Bureau of Labor Statistics. The inverse of the CPI-U is generally referred to as 'the value of the dollar'. Now, the data begins to show some order. There are two dramatic peaks, one in the late-1950s and the other centered on the summer of 1974. In today's dollars, the price of #1 HMS at these two times soared to remarkably high levels, over $400/GT. More recently, since 1982, prices have been much more stable.

From 1982 until present, the price has varied back and forth between what one might refer to as a 'floor price' and a 'ceiling price', although most recently, prices have been below the 'floor'. During this 20-year period, prices have spent approximately one-third of the time in the 'ceiling' range, one-third of the time in, or below, the 'floor' range, and the other third moving back and forth between the ranges.

Now, let's look at scrap prices over an even longer period of time. Figure 3 shows yearly averages since 1913. (The data since 1955 is the same as described above. The data for 1935-1955 is from American Metal Market. The data prior to 1935 is according to the Institute of Scrap Recycling Industries, ISRI.) Here we see that the peaks experienced in 1956 and in 1974 were not so unusual. Rather, they were just the two most recent of a number of high peaks; all of which attained similar heights. One can be seen during the aftermath of World War I and then three are evident following World War II; the last one being the 1956 peak shown in the earlier graph.

These latter three (after WW II) may be attributed to the era of the Open-Hearth (Siemens-Martin) furnaces. An Open Hearth was capable of accepting any charge from 100 percent hot metal and 0% cold charge through 0 percent hot metal and 100% cold charge. So, when demand for steel rose to high levels (above the capacity of the blast furnaces to produce hot metal) the Open Hearths would simply call for greater and greater quantities of scrap, thereby aggressively escalating the price.

It is interesting to note that the very low level of scrap prices seen in 2001 are even lower than those seen during the very heart of the Great Depression, 1933.

Will prices again reach the very high levels seen five times in seven decades (1910s to 1970s, inclusive)? Within the foreseeable future, probably not. Over the past few decades, the scrap collection and processing industry in most of the industrialized world has not only achieved a far higher level of technology than enjoyed before, but it has also developed systems for collection, trading, transport and processing scrap that are quite robust. It would take an extraordinarily large economic upheaval to so overtax these systems.

Will prices again return to the 'ceiling' price levels seen three times since 1982? This answer is almost certainly yes. Routine economic swings may be expected to repeatedly move prices back and forth between the 'floor' and 'ceiling' levels for a number of decades to come.
The article, “Market Forces in the Direct Reduction Industry,” uses terminology that is peculiar to the iron and steel industry. For those who are not directly involved in the industry, it might be difficult to read and understand. Therefore, to help our readers navigate through the maze of acronyms, ‘buzz-words,’ jargon and other special nomenclature, the following glossary was prepared:

#1 Heavy Melting Scrap — A common grade of steel scrap in the United States. Because it is traded in most steel scrap markets and in large volumes, it is used as a ‘bellweatherv for pricing. The official definition, as provided by the Institute of Scrap Recycling Industries, is “Wrought iron and/or steel scrap ½-inch and over in thickness, with individual pieces not over 60 x 24 inches (charging box size) prepared in a manner to insure compact charging.” Notice that this definition makes no reference to the chemistry of the scrap, only to the physical sizing and the need for density in bulk.

HMS — Acronym for #1 Heavy Melting Scrap.

S/GT — Dollars per Gross Ton — The Gross Ton is an archaic unit still used in the United States for some applications. It refers to a ton of 2240 pounds, which is approximately 1.01605t.

3-city composite — American Metal Market averages the #1 HMS price for Chicago, Pittsburgh, and Philadelphia. This average is referred to as the 3-city composite.

Beach iron — When hot metal is produced in excess (or to an unacceptable quality) and can not be cast into pigs, it must be poured out onto the ground to prevent it from solidifying in its container where it would be an unmanageably large, heavy piece. After pouring, usually to a sand or slag covered location, and after solidification, it is referred to as ‘beach iron’. The sand onto which it is poured is called the ‘beach’.

Blast furnace — A shaft furnace in which fuel is burned with an air blast to smelt ore in a continuous operation. The ore is combined with solid fuel (coke) and flux (lime) and is charged to the top of the furnace. The air blast is normally preheated and enriched with additional oxygen and blown into the furnace near the bottom. Additional gaseous, liquid, or powdered fuels (natural gas, oils, pulverized coal, etc.) may be blown into the furnace at approximately the same location as the blast. The blast partially oxidizes the fuels to form carbon monoxide, which in turn reduces the oxygen from the ore. Heat formed from the partial oxidation of the fuel then melts the metal.

BOF — Acronym for ‘Basic Oxygen Furnace’. A steelmaking furnace in which oxygen is forced at supersonic speed through a top-mounted, retractable, water-cooled lance. The oxygen accelerates the burning off of unwanted elements in a charge of molten iron and scrap.

Cold charge — Hot metal contains more energy than is needed for it to be refined into liquid steel. This excess energy can be consumed by using it to melt steel scrap and/or other sources of iron such as DRI or HBI. This steel scrap (and/or other iron sources) is referred to as the ‘cold charge’ to the steelmaking furnace.

Delivered — Delivered to the consuming steel works, which includes haulage and materials handling expenses.

Ductile — Capable of considerable deformation, especially stretching, without breaking (~ iron and/or steel).

Flat products — Steel mill products having a high ratio of width to thickness. For instance, 2-meter sheet, with a thickness of 4 mm has a width-to-thickness ratio of 500.

Hot metal — High-carbon iron typically made by reduction of iron ore in the blast furnace (Editor’s note: the FASTMELT® Process also produces hot metal). The term ‘hot metal’ generally refers to the liquid form of this metal. See ‘pig iron’.

Long products — Steel mill products having a low width-to-thickness ratio. For instance, reinforcing bar, which has a width-to-thickness ratio of 1.

Malleable — Capable of being extended or shaped by beating with a hammer. Gold, for instance, is extremely malleable because it can be hammered into extraordinarily thin sheet without tearing.

Open Hearth — A reverberatory furnace, having a shallow hearth and a low roof, used for making steel. A flame passes over the charge and heats it. Reflected and radiated heat from the furnace roof and sidewalls also contributes to the heating of the charge.

SBQ — Acronym for Special Bar Quality steel products. Bar steels with consistently higher performance in end use (or in fabrication) than standard merchant bar. SBQ will typically have fewer inclusions than merchant bar. Applications might include mechanical components, drawn tubing or drawn wire.

Siemens-Martin — The term used in Europe for the Open Hearth furnace. This term honors the co-developers of this steelmaking process. Siemens’ primary contribution was the employment of heat recuperation (regeneration), so this term excludes any Open Hearth that does not include regeneration.

Thin slab casters — Devices for the continuous casting of liquid steel into slabs of great length and having a thickness of about 50 mm.

Tire cord — The wire used for steel-belted tires. Tire cord has a particularly stringent combination of specifications for strength and ductility.

Wire rod — Hot-rolled coil stock that is cold-drawn into wire.
[Editor’s Note] In April 2002 Midrex Enterprises, Inc. signed a business development agreement with Charlotte, NC-based Industrial Recovery Systems International, Inc. (IR Systems). This article briefly reviews the IR Systems technology, which is providing Midrex an opportunity to expand beyond its traditional steel industry focus.

Industrial Recovery Systems is a Charlotte, NC-based waste management and recycling firm that offers an environmentally friendly and scientifically sound solution for the remediation of contaminated solids. The Matrix Constituent Separator (MCS) is based on proven low temperature thermal desorption technology that has been extensively field-tested throughout the United States and around the globe. The MCS has successfully treated solid and semi-solid materials impacted by a wide range of chemical contaminants such as petroleum, mercury, PCPs, PCBs, dioxins, volatile organic compounds (VOCs), and pesticides. Since May 2002, Midrex and its sister company, Professional Services International Inc. (PSI), have provided engineering, procurement, and marketing support.

IR Systems has been awarded a major contract to provide soil remediation services for a US government installation on Johnston Atoll, which is located about 700 miles from Hawaii. Midrex and PSI are assisting with the contract by preparing an engineering package for the MCS units and arranging the fabrication and shipping of multiple units to the site. The site remediation work will be performed in 2003.
The MCS is a patented process designed specifically to remove volatile and semi-volatile organic compounds from contaminated matrices (soils and process wastes). It is known as a low temperature thermal desorption (LTTD) process, although it can operate at temperatures common to high temperature thermal desorption (HTTD) systems. The MCS is a static tray, batch process that heats the contaminated material with infrared radiation, draws hot air through it, and separates the contaminants under vacuum. Decreasing the pressure in the treatment chamber reduces the boiling points of the contaminants. They undergo a phase change from liquid or solid to vapors, which are transported out of the treatment chamber, then condensed back into a liquid in the air emission control system. Figure 1 shows a typical MCS unit.

Materials for treatment in the MCS system include the contaminants, water and the matrix. The contaminants are typically present in the parts per million range (ppm), the water in concentrations ranging from 10–20 percent, and the remaining 80-90 percent is the matrix.

The six primary operating principles the MCS uses to desorb contaminants from a matrix are as follows:

**INFRARED HEATING**
Propane or another fuel is fired inside tubular heaters. The flame heats the tubes, which emit infrared radiation. This heats the bottom few inches of the matrix and creates a temperature gradient.

**CONVECTIVE HEAT TRANSFER**
Without convective heat transfer, the bottom layer of the matrix would heat up while the top layer would stay cool. Other thermal technologies must use mechanical mixing to expose the matrix to the heat source. However, the unique design of the MCS draws the heat upward through the static bed of contaminated material and simultaneously produces a vacuum in the system.

**CONDUCTIVE HEATING**
This process transfers the energy from higher temperature matrix particles to those at lower temperatures by direct contact.

**BOILING POINT REDUCTION**
The boiling point of a liquid is the temperature at which the partial pressure of the substance is equal to the system pressure. There is a direct relationship between the final treatment temperature and the system operating pressure. Therefore, by reducing the system pressure, the treatment temperature required for removal of compounds by volatilization is significantly reduced. The MCS system is capable of reducing system pressure from atmospheric to as low as 21" Hg.

**AIR STRIPPING**
The desorption process is facilitated by air stripping; i.e., passing air as a carrier gas through the matrix to transport the volatilized chemicals into the recovery unit. The rate at which a chemical is stripped from the matrix depends on its vapor pressure and stability in water. Desorption of each chemical takes place throughout the entire process, not just when the boiling point of each of the chemicals is reached.

**CHEMICAL VOLATILIZATION**
Chemical volatilization is a two step process. First, the temperature of the chemical is increased until the boiling point is reached. The amount of energy required to raise the chemical to the boiling point depends on the heat capacity (for the liquid phase) and the quantity of the chemical. In the second step, the temperature remains constant while the liquid is vaporized. The heat of vaporization is the amount of energy required to produce a phase change from the liquid to the gaseous phase.

The MCS system has proven in field service to be a cost-effective alternative to traditional thermal treatment methods. The technology has been used to treat over 500,000 tons of impacted materials in the US, Taiwan, Malaysia, Mexico and Australia. A diverse range of sites has been treated including major US Navy and Army depots, industrial manufacturing and commercial facilities, agricultural parcels and oil exploration companies.

For more information or to request a budgetary estimate, contact Thaddeus Kuzniar of IR Systems at tjkuzniar@industrialrecovery.com or (704) 552-6230.
IR Systems Receives New Product Award of Excellence

Charlotte based Industrial Recovery Systems International, Inc. (IR Systems) has received the 2002 National Society of Professional Engineers’ (NSPE) New Product Award of Excellence for the company’s Matrix Constituent Separator (MCS) technology. The National Society of Professional Engineers is the only engineering society that represents individual engineering professionals and licensed engineers (PEs) across all disciplines.

The MCS was selected in August by the US Air Force and the US Environmental Protection Agency (EPA) to treat soil on Johnston Atoll in the Pacific Ocean contaminated with dioxins and other chemicals. Midrex Technologies, Inc. and Professional Services International Inc. (PSI), are supporting IR Systems in the Johnston Atoll project (See Feature on Page 10).

IR Systems’ MCS is a proven, low-temperature, treatment system that uses infrared heat and vacuum to remove organic substances and mercury from contaminated soils and process wastes. Worldwide, over 50 sites have been successfully treated using MCS technology are in current use worldwide in countries such as Taiwan, Malaysia, Mexico and Australia, in addition to numerous sites across the United States.

According to the NSPE, the MCS is modular and highly portable. It can be quickly mobilized to the treatment site or it can be operated at a central location to treat materials from multiple sites. The MCS is energy efficient, simple to operate, and does not release hazardous emissions into the atmosphere. It can be effective at sites ranging from 1,000 to 100,000 tons and can treat the widest range of chemical contaminants in the soil remediation industry.

Industrial Recovery Systems International is a Charlotte, NC-based waste management and recycling firm that offers an environmentally friendly yet scientifically sound solution for the remediation of contaminated land and solids. For soil remediation projects, IR Systems practices low temperature thermal desorption with its unique, patented Matrix Constituent Separator (MCS) system, IR Systems’ “solution” is a proven technology that has been extensively field-tested throughout the United States and around the globe.

COMSIGUA Plant Operates at Nearly 120% Capacity in First 4 Years, Produces 4.6 Million Tons of HBI

Despite a period of historically low metallics prices, Complejo Siderurgico de Guayana, C.A. (COMSIGUA), Puerto Ordaz, Venezuela, has produced nearly 4.6 million metric tons of hot briquetted iron (HBI) with its MIDREX® Direct Reduction Plant since operations began in October 1998. The COMSIGUA plant is the world's largest DR module for the production of HBI, and averaging nearly 120 percent of production capacity during its first four years of operation and 130 percent over the past 12 months.

A History of Achievements

COMSIGUA’s plant began operations on October 1, 1998, with a rated capacity of 1.0 million metric tons/year of HBI, and passed its performance test within 30 days. Each year since operations began, production levels have increased. COMSIGUA greatly exceeded rated production capacity in 2001, which was filled with obstacles; i.e., record low steel prices, record low metallics prices, and general unrest in Venezuela. Of all recently constructed HBI plants in Venezuela, COMSIGUA is the only plant to have sustained regular performance, with availability of over 8000 hours in year 2000 and 7600 hours with a 25-day scheduled bi-annual shutdown in 2001. In the past 12 months, COMSIGUA has achieved over 130 percent of its annual rated capacity.

While recent HBI price levels have improved, they are still well below historical averages. In addition to capacity records, COMSIGUA continues to exceed HBI product quality targets with 93.5 percent metallization and 1.0 - 12 percent Carbon content.

Unlike some MIDREX modules, COMSIGUA has not yet implemented the process advantages of oxygen injection to achieve these results. They are performing extremely well, still have room for improvement. COMSIGUA is, and will continue to be, the lowest total cost producer of HBI in the world.
Midrex held its 2002 Operations Seminar for MIDREX Process Licensees October 4-7 in Manama, Bahrain. More than 40 Process Licensees and invited guests from around the world came to take part in the 4-day seminar that examined technical issues and discussed technological innovations related to the MIDREX® Direct Reduction Process. This year’s topics included oxygen injection and an advanced process control system known as SIMPAX. This new process automation system, which was co-developed with Siemens Industrial Solutions and Services Group of Germany, is a suite of control software for MIDREX Plants that provides enhanced optimization and equipment protection.