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Hot Charging DRI for Lower Cost and Higher Productivity

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As 1999 draws to a close, I would like to recognize a noteworthy milestone. This year marks the 30th anniversary of the start-up of the first MIDREX® Direct Reduction Plant at Oregon Steel Mills, the beginning of the commercial success of the MIDREX® Direct Reduction Process. There are a few of us left at Midrex who participated in that start-up, including me, and it is rewarding to look back upon the ensuing 30 years and know that we played some part in that effort. Bruce Kelley, our Vice President of Engineering and Technology, and Dave Meissner, Manager of R & D, are veterans as well. Chuck Sanzenbacher, another pioneer, passed away recently, as noted in the 3rd Quarter issue of Direct From Midrex.

Many of the innovations and solutions we developed in the early days of the MIDREX Process are still used in MIDREX Plants today. During the three decades since start-up at Portland, the MIDREX Process has become the world’s most successful direct reduction technology, accounting for more than 60 percent of world DRI production each year since 1987. To date, a total of 53 MIDREX Modules have been built on five continents, in 18 countries, representing over 30 Mt of capacity.

It is interesting to reflect upon the direct reduction industry. In the early 1980s, there was a flurry of interest in direct reduction, and many processes were proposed and developed. Of 16 processes we tracked then, only four have enjoyed commercial success. This shakeout is typical in an industry with many more aspirants than ultimate contenders. This process ensures that only those processes and equipment with the best technological features and economics win out, which benefits us all. The crucible of competition ensures survival of the fittest.

We are now going through a similar shakeout situation due to the strong steel market and high scrap prices from 1993 until 1998. By my count, there are about two dozen direct reduction processes that are being offered commercially. Undoubtedly, most of these will not be ultimately successful.

We continue to enhance the state-of-the-art for MIDREX™ Technology with innovations such as HOTLINK™ (see article on page 3), our system for transferring hot DRI directly to an EAF. Other developments to be featured in future issues of Direct From Midrex include high carbon DRI (up to 3.5 percent), and OXY+™, our system for producing additional reformed gas using partial oxidation of natural gas. We also are pleased that the first commercial FASTMET® Plant is now under construction in Japan, with start-up scheduled for April 2000 (see News & Views). We are staking our future upon continued innovation for the MIDREX Process and the successful commercialization of FASTMET and FASTMELT®.

It has been a fascinating journey with the MIDREX Process since 1969. Thirty years from now, it will be very interesting to look back at the DR industry and see what evolution has occurred.
INTRODUCTION

There have been many modifications in Electric Arc Furnace (EAF) design, driven by strong pressure within the industry to reduce costs. Now, steel producers are looking at upstream process designs that can further improve efficiency. Hot charging is one such improvement that can reduce operating cost and increase EAF productivity. Various scrap-preheating technologies are now available, however, preheating of direct reduced iron (DRI) cannot be accomplished applying conventional off-gas preheating systems.

A variety of systems have been designed to convey hot DRI (HDRI) from a Direct Reduction (DR) furnace to an EAF. These systems include mechanical conveyors (apron type or drag chain), transport vessels (by rail or truck) and pneumatics. These systems, although functional, have inherent maintenance and reliability problems and typically require significant capital investment.

Midrex Direct Reduction Corporation has designed a system to transport HDRI to an EAF or similar melter using gravity. This system, called HOTLINK™, is primarily intended for greenfield sites and takes advantage of lower power and electrode consumption as well as higher EAF productivity which can be realized by hot charging.

ADVANTAGES OF HOT CHARGING

The concept of hot charging is not new. In fact, several MIDREX facilities have successfully charged HDRI into an EAF and realized significant savings. Hot charging is an effective means of lowering the cost per metric ton (tonne) of liquid steel because of the reduction in power and electrode consumption (Figures 1 and 2). As a rule of thumb, power consumption can be reduced about 20 kWh/tonne of liquid steel for each 100°C increase in the composite charge temperature. Electrode consumption is also reduced due to its linear relationship with power consumption (about 0.004 kg/kWh). The composite charge may consist of a mixture of HDRI, cold DRI or cold scrap.

In addition to the power and electrode savings, hot charging will increase EAF productivity for a meltshop designed to charge cold DRI. For a greenfield site, significant capital cost savings can be realized by downsizing the EAF electrical system in order to take advantage of this increase in productivity.

WHAT IS HOTLINK?

There are several methods of transporting HDRI from a Direct Reduction (DR) furnace to an EAF. HDRI can be conveyed pneumatically, carried by hot transport vehicles, transported by a variety of mechanical conveyors, or simply charged by gravity via a direct connection from a DR furnace to an EAF. Of all these options, gravity is the simplest, most reliable, least maintenance-intensive and is the basis for the HOTLINK system.

HOTLINK is suitable for greenfield facilities planning to use high percentages of DRI to make liquid steel or hot metal. It is the most efficient way to charge HDRI to an EAF or similar melting furnace because
there will be:
• minimal temperature loss since the distance conveyed is short
• minimal HDRI degradation since material velocities are low
• no re-oxidation of material since the system is sealed
• low maintenance and high reliability since the system uses gravity for transport and is based on existing technology.

The incorporation of MIDREX™ Technology into the integrated steel mill is a natural fit. The MIDREX MEGAMOD™, first introduced in 1994, has consistently proven to achieve capacities of 1,000,000 tons/year to nearly 1,600,000 tons/year from a single DR furnace. A single MEGAMOD is the perfect match to “HOTLINK” with a single EAF to produce liquid steel or hot metal.

MIDREX has worked closely with SMS Demag to develop several system layouts to connect the DR furnace with the EAF. A variety of arrangements are possible and should be evaluated on a project-by-project basis.

HOTLINK DESIGN FEATURES
It is critical that the transport method from the DR furnace to the EAF be capable of delivering HDRI without adversely affecting product quality while providing maximum operational flexibility. Additionally, the transport system must be reliable, maintenance-friendly and easy to operate. The HOTLINK system is designed for these key requirements. Figure 3 shows a schematic representation of the material handling system for a typical HOTLINK arrangement.

Maintaining Product Quality
MIDREX can design a DR facility to produce up to 1,600,000 tons/year of hot and/or cold DRI. The plant is capable of providing DRI or HDRI up to 95 percent metallization with carbon from 0.5 to 3.5 percent.

HDRI Temperature
HDRI will be delivered to the inlet of the EAF at more than 700°C. Since the DR furnace is located close to the EAF and because the HDRI is transported by gravity, there will be minimal temperature loss of the HDRI from the discharge of the furnace to the inlet of the EAF (<20°C). Making HDRI is not new to MIDREX. For more than 15 years, our HBI plants have been routinely briquetting HDRI at 700°C. These same plants have never attempted to maximize HDRI temperature because higher temperatures could damage the briquetting equipment. With DR furnace bed temperatures approaching 900°C in many plants, HDRI temperatures to the EAF would be maximized and could exceed 700°C.

Product Degradation
Gravity transport allows equipment to be sized for low material velocities. This is important because material velocity directly affects product degradation, not to mention the wear rate of the equipment. Low material velocities minimize unnecessary fines generation and promote longer equipment life. There will be minimal degradation of HDRI during transport from the DR furnace to the EAF.

Re-oxidation
From the discharge of the DR furnace to the inlet of the EAF, the HDRI is maintained in an inert atmosphere. The design philosophy is similar to the design of the briquetter feed legs of an HBI plant where inert gas, from the products of combustion...
in the reformer, provide the seal. There will be no re-oxidation or loss in metallization of the HDRI during transport to the EAF.

Operational Flexibility
Midrex recognizes the difficulty of matching a continuous process (the DR plant) with a batch process (the EAF). A HDRI surge bin, located between the DR furnace and the EAF, acts as a buffer to account for the difference in instantaneous throughputs of the two plants. Typically, there is also a significant difference in the availability of the DR plant (8,000 hours/year) and the EAF (7,200 hours/year) due to operational and maintenance schedules. A DRI cooler, also gravity fed, is incorporated into the design to provide maximum availability of both the DR furnace and the EAF. This allows the DR plant to maintain production (making cold DRI) when the EAF is down. Conversely, the EAF can also maintain production using cold DRI from storage when the DR plant is down.

Simultaneous Production of DRI and HDRI
Both DRI and HDRI can be produced simultaneously. In fact, any combination of cold DRI or HDRI can be discharged on demand (i.e., from virtually 100 percent cold DRI or HDRI can be discharged simultaneously. In fact, any combination of cold DRI or HDRI can be discharged on demand (i.e., from virtually 100 percent cold DRI to 100 percent HDRI). The plant can instantaneously switch from producing DRI to HDRI, or vice versa, without stopping production.

Product Size Variation
HOTLINK can operate with large variations in product size and is designed to convey all product less than 200 mm diameter to the EAF.

Provisions for Cold DRI Usage
The material handling system has several provisions for cold DRI usage. These options are very important to ensure that EAF availability and productivity are maximized. The integrated plant has the ability to do any one or all of the following:
- Charge cold DRI directly to the EAF
- Mix cold DRI with HDRI during charging the EAF
- Send cold DRI back to the DR furnace to be reheated
- Produce cold DRI for sale

If the DR plant is shut down while the meltpshop is in operation, then cold DRI can be charged directly to the EAF through the cold DRI surge bin. If the plant would like to reduce cold DRI storage while the DR plant is on-line, then cold DRI from the surge bin can be blended with HDRI and charged to the EAF. This option will lower the composite charge temperature, thus reducing the savings in power and electrode consumption. Alternatively, a significant amount of cold DRI (up to 10% of furnace discharge) can be added back into the DR furnace for re-heating to avoid lowering the charge temperature. Since the cold DRI is already reduced, it will not consume much reductant. This effectively means the discharge rate of the DR furnace can be increased by almost the same amount of cold DRI that is being reheated. Certainly more energy is required to heat the additional throughputs, but nearly the same quantity of oxide can be reduced.

Equipment Description
The HOTLINK concept is based on simple philosophy and solid principles. Utilizing gravity for transport reduces material handling requirements to the simplest possible form. Like gravity, the design of all ancillary equipment must be simple and reliable. Almost all equipment is currently being used at existing MIDREX™ Plants, which provides a low-risk, reliable and low-maintenance solution for hot charging.

DR Furnace
The DR furnace design is similar to that used at existing HBI Plants. The DR furnace has been raised about 15 m relative to a typical HBI MEGAMOD™. The discharge of the DR furnace is designed so that mass flow can be maintained in the reduction zone whether discharging hot, cold, or both. A “pant leg”, located at the discharge of the DR furnace, directs product to the EAF and to the DRI cooler.

DRI Cooler
The DRI cooler is similar in design to the cooling zone of cold discharge furnaces. The cooler is designed to operate over a wide range of DRI flow rates, from minimal discharge up to the maximum output of the DR furnace. There is a dynamic seal leg located at the discharge of the cooler, and below that, a vibrating feeder controls the DRI discharge rate.

HDRI Surge Bin
Between the DR furnace and the EA F, a surge bin is used to stage the HDRI for EA F charging cycles. The HDRI surge bin is sized to accommodate marrying the continuous DR process with the batch EAF process. Dynamic seal legs are used to separate the surge bin from the DR furnace and seal the top of the DR furnace and the bottom of the DRI cooler. This seal leg allows material to pass while preventing the escape of combustible gases from the DR furnace into the bin.

The HDRI surge bin has more than enough capacity to completely charge one EAF furnace heat. A vertical screwfeeder, similar to the briquetter feed screw at HBI plants, is used to control the rate at which material is fed to the bin. A horizontal screwfeeder, remotely controlled from the EAF pulpit, discharges material from the bin to the EAF. Isolation valves are located at the inlet and outlet of the HDRI surge bin so that periodic maintenance can be conducted safely.

Cold DRI Surge Bin
Located within the DR furnace structure, the cold DRI surge bin gives the ability to feed cold DRI to the EAF when required. Sized to supply more than one EAF furnace heat, this bin can feed cold DRI directly to the EAF, even if the DR plant were shut down. If the DR plant is on-line, the cold DRI surge bin can still be used to blend cold DRI with HDRI before entering the EAF. This option can be particularly important to limit the size of DRI storage. The discharge rate of the cold DRI surge bin is controlled from the EAF pulpit.

MELTSHOP DESIGN FEATURES
Demag has developed a variety of meltpshop arrangements to accommodate the HOTLINK system. At the steameakers’ discretion, the Demag EBT furnace can be oriented so either the slag door, transformer or fourth hole are facing the DR furnace. Given this flexibility, the appropriate arrangement can be selected on a project-by-project basis.

Figure 4 shows a basic HOTLINK arrangement connecting to a Demag EBT furnace with the transformer positioned underneath the DR furnace structure. The tap hole and slag door are opposite one another and are located perpendicular to the flow of HDRI. The pulpit, attached to the other bay wall, is positioned opposite the furnace to facilitate visual control of the
operation. The alloy storage bins are incorporated in the meltshop bay columns next to the DR plant.

The horizontal screwfeeder below the HDRI surge bin is remotely controlled from the EAF pulpit. The flow of cold DRI is also controlled from the EAF pulpit, using a separate feeder. From the HDRI and the cold DRI surge bins, material flows through a feed leg to the EAF. A small amount of inert gas is used to continually purge the feed leg to prevent product reoxidation. The feed leg extends through the EAF roof near the furnace center. This feed leg is fabricated of high-quality steel and is water-cooled. After being hydraulically lifted, the feed leg can be swung out of the feeding position when tilting the furnace for tapping.

There will be minimal degradation of the HDRI because of the relatively low material velocity and the short distance material is conveyed. Nevertheless, the HDRI will contain some small quantity of fines generated during the reduction process (depending largely on the quality and type of oxide feed). For this reason, the EAF feed leg has been designed to ensure conveyance of product fines into the liquid bath. This will increase HDRI yield and prevent problems in the off-gas system.

COST COMPARISON

To establish a base case for cost comparison, consider a stand-alone cold discharge MEGAMOD located adjacent to a meltshop with one EAF, ladle furnace and slab caster. In the base case, all EAF charge materials would be at ambient conditions (25°C).

The HOTLINK system would be designed to produce any combination of DRI from 100 percent hot to 100 percent cold. The meltshop would be designed to handle composite charges containing blends of HDRI, cold DRI and additional scrap (or return scrap) if required. The ladle furnace and slab caster would be the same as the base case. Following are the relative capital and operating cost comparisons.

Capital Cost

In the DR plant, extra equipment and additional structures are required for HOTLINK. Obviously, these items represent an increase in capital cost relative to a cold discharge facility. In the meltshop, however, capital cost is actually reduced.
Similarly, Figure 6 shows the estimated electrode savings per tonne of liquid steel for an electricity cost of $0.035/kWh. For a plant producing 1.2 million tons of slabs per year, this would represent a saving of $7.2 million.

CONCLUSIONS

Hot charging is a viable means to reduce the operating cost of producing liquid steel or hot metal. Intended primarily for greenfield facilities, HOTLINK is the most efficient way to charge HDRI to an EAF or similar melter because gravity is used for transport. The concept is based on simple design philosophy and proven equipment, which provides low risk and high reliability.

HOTLINK is capable of producing any combination of HDRI and DRI (from 100 percent hot to 100 percent cold). The system is designed so that:

- HDRI is conveyed to the EAF at more than 700°C with minimal temperature loss during transport
- There will be no re-oxidation or loss of metallization
- DRI degradation during transport is prevented
- Operational flexibility is maximized

The capital cost of an integrated HOTLINK facility making slabs is about 3 percent higher than that of an equivalent facility equipped to charge cold DRI. The operating cost savings generated by charging 100 percent HDRI at 700°C would be between 3 percent to 4 percent based on electricity cost of $0.035/kWh. For a mill producing 1.2 million tons per year of slabs, this would represent a saving of $7.2 million per year resulting in a payback of less than two years.

The preceding paper was originally presented at the Iron & Steel Society’s 57th Electric furnace Conference held in Pittsburgh, PA, Nov. 14-16, 1999.
FINES TO SLABS IN WESTERN AUSTRALIA
A Case Study of the Integrated Mini-mill

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Australian Commercial Management
Perth, WA, Australia

Introduction

Western Australia is very well known for its large iron ore reserves, supplying more than 143 Mt of iron ore products to East Asia and Europe in 1998.

Western Australia, with its strong political and economic ties to Southeast Asian countries such as Taiwan, China, Japan, Korea, Malaysia, etc., is well-positioned to become a long-term, high-quality supplier of steel products to this growing region. Furthermore, the WA government has long supported the concept of value-added iron ore sales, and is ready to act.

The final piece of the puzzle has now fallen into place, as energy prices in WA have reached levels competitive with other industrialized countries. In fact, WA has two key ingredients necessary to make it a very cost-competitive supplier of steel to the Asian markets: abundant iron ore and natural gas.

While pellet plants have long been built in multi-million ton sizes, only recently have iron ore direct reduction plants reached a similar scale. Only the MIDREX® Direct Reduction Process has been proven to achieve capacities of 1.6 million tons per year (Mt/y) or more in a single module, pushing capital cost well below US$140 per annual ton. These economies of scale are detailed in the following case study of a mini-integrated slab-making facility built in WA using iron ore fines as the feed material. The location is Oakajee, WA, and it is adjacent to the industrial estate and port facility being proposed by the WA government.

The concept has been promoted by several parties, including Kingstream Steel, Austeel and more recently by the Oakajee Steel project being developed by North West Shelf Gas, and the iron ore owner Mt. Gibson Iron NL.

Plant Concept

The process plant concept is as follows. Direct reduction grade fine iron ore concentrate (pellet feed) is delivered to the plant by way of slurry pipeline or dedicated rail system. The concentrate is delivered to the pellet plant ready for mixing, balling and induration. The iron ore pellets are fed to the MIDREX MEGAMOD™ Shaft Furnace, and reduced using natural gas to produce DRI. The DR plant concept also includes the state-of-the-art HOTLINK™ hot DRI delivery system, in which hot DRI is fed directly to the EAF at 700°C. Liquid steel is processed by the ladle furnaces and delivered to the twin-strand conventional thickness slab caster. Slabs will be delivered on board ocean-going vessels for transport (FOB). Thus, using fine iron ore concentrate as the input and slabs as the product, we have the following plant configuration:

1) Pellet Plant (3.9 Mt/y)
2) MIDREX DRI Plant with HOTLINK (2.8 Mt/y)
3) Slab-making Facility (2.4 Mt/y)
4) Interplant Services (as required)

Capital Cost and Financing

An approximate capital cost breakdown is shown below. It is envisaged that the plant will be funded with a 70:30 ratio of debt to equity. Debt is financed at 8 percent interest, and the exchange rate is assumed steady at 0.65 US$/A$ for the life of the project. All interest during construction is included in the pre-operational costs below. A detailed but basic financial model was generated using these assumptions, as well as the following considerations for selling price and operating costs.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pellet Plant</td>
<td>US$ 210 Million</td>
</tr>
<tr>
<td>MIDREX Plant w/HOTLINK</td>
<td>$ 410 Million</td>
</tr>
<tr>
<td>Meltshop &amp; CCM</td>
<td>$ 330 Million</td>
</tr>
<tr>
<td>Interplant</td>
<td>$ 90 Million</td>
</tr>
<tr>
<td>Total EPC Cost</td>
<td>US$ 1,040 Million</td>
</tr>
<tr>
<td>Pre-Operational Costs</td>
<td>$ 160 Million</td>
</tr>
<tr>
<td>Total Project Cost</td>
<td>US$ 1,200 Million</td>
</tr>
</tbody>
</table>

Slab Selling Price

In 1998, approximately 24 million tons of slabs were exported throughout the world.
It is unfortunate that the most recent trough of steel prices was experienced at the same time as the Asian crisis, causing prices to fall much further than any historical lows (see Figure 1). FOB prices for merchant slabs are expected to average US$225 per ton (A$346 per ton) over the next 11 years.

Operating Cost Detail
Before we can establish operating costs for the mini-integrated steel mill facility, we must first establish the input costs which can be assumed for a Western Australian plant. The unit costs assumed for this plant are outlined in Table I.

Pellet Plant Operating Costs
We have assumed a pelletizing plant capable of producing approximately 3.90 Mty of iron oxide pellets of approximately 67.5 percent Fe. The iron ore concentrate is high-quality magnetite (Fe3O4) with an iron content of approximately 70 percent Fe. The pellet plant converts the iron ore concentrate into hematite pellets (Fe2O3) for approximately A$10 (US$6.50) per ton, plus the cost of concentrate. Recycled dust, fines and sludges from the DR plant are utilized to minimize waste.

DR Plant Operating Costs
We have assumed a MIDREX™ Direct Reduction Plant capable of producing 2.80 Mty of DRI with 93 percent metallization and 15 percent carbon produced from two MIDREX MEGAMODS at 1.40 Mty each. The DR plant converts the oxide pellets into hot DRI which is then transferred to the EAF via the HOTLINK system.

Continuous Caster Operating Costs
We have assumed a traditional thick slab caster capable of producing 2.40 Mty of slabs. The processing cost per ton of slabs is approximately A$23 (US$15) plus the cost of liquid steel from the LF.

Operating Cost Summary
Table III on the following page shows the operating costs broken down by process. Concentrate costs are the single largest expense at US$35 per ton of slabs (25.2%), followed by the EAF costs and DR plant costs.

Financial Results
Using the above financial inputs, and slab selling price of US$225 per ton as the base case for the model, we calculate an IRR for the equity investor of 18.9 percent after tax, after 20 years of operation and using a 70:30 debt-to-equity ratio. Assuming the project was completely funded by equity, the total
project IRR is 12.2% after tax. The equity investor achieves payback of its investment after only 4.8 years of operation, and payback of the entire investment of US$1.20 billion occurs after 6.5 years of operation. The summary is shown in Table IV.

One of the biggest concerns of companies contemplating an investment of this magnitude is capital cost overruns. The BHP HBI plant at Port Hedland, and its abnormally large price tag, has made many investors wary of Western Australian construction conditions. While the specific construction costs are definitively higher than many other regions of the world, the capital cost specified in this study is also higher than would be expected elsewhere. In fact, these figures compare favorably with those recently proposed for the Kingstream project in Western Australia, which was bid on a fully competitive basis for a turnkey project.

**Conclusions**

A greenfield steelmaking plant is not only viable in Western Australia, it is very profitable for the equity investor. The combination of huge quantities of iron ore, low-cost energy, and politically stable government should be very attractive to foreign investors as well as domestic mining companies looking toward value-added projects.

It is unfortunate that recent steel prices have dipped well below all expectations, due largely to the Aisan financial crisis, and its coinciding with a steel industry downturn. Recovery is already occurring, and by the time this project starts up, prices should have already peaked.

What is most promising for WA is that this plant has one of the lowest operating costs in the world for slabmaking, and should be profitable even in the worst market downturns. The MIDREX™ Direct Reduction Technology is well suited to the use of fine iron ore as the combination of pellet plant and MIDREX Plant result in a very cost-competitive plant, both from a capital cost and operating cost basis. The economies of scale provided by two MIDREX MEGAMODS, and their very good match with pellet plant, EAF, LF and CCM capacities, provide the owner with proven processes with little risk.

The after-tax IRR of 18.9 percent should prove very attractive to the steel industry investor, as should the project IRR of 12.2 percent.

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**Midrex News & Views**

**EMCI Enters Agreement with Flohe GmbH & Co.**

On October 25, 1999, EMCI International, Inc. of Pittsburgh, Pennsylvania, announced that they have entered an exclusive License Agreement with Flohe GmbH & Co. of Castrop-Rauxel, Germany, for the sale and manufacture of Current Conducting Electrode Arms. EMCI has become the exclusive representative of Flohe in the North American Free Trade Zone (United States, Mexico, and Canada).

The agreement covers Flohe-designed equipment, including:
- Copper Clad Steel and Aluminum Arm Body Designs
- Low Loss Electrode Column Heads
- Integral Electrode Holders
- DC EAF Current Conductive Furnace Bottom Assemblies

Flohe GmbH & Co. has over 60 years of high current engineering experience and has developed the premier state-of-the-art technology.

**Two MIDREX Plants Reach One Million Ton Milestone**

In September, the COMSIGUA HBI Plant in Matanzas, Venezuela, produced its one millionth ton of HBI, reaching its full rated capacity within the first year of operations.


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**Table III Operating cost summary breakdown by process**

<table>
<thead>
<tr>
<th>PLANT</th>
<th>Annual Cost (x 000's)</th>
<th>Specific Cost per ton slabs</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A$</td>
<td>US$</td>
<td>A$</td>
</tr>
<tr>
<td>Concentrate</td>
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<td>84,033</td>
<td>53.87</td>
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<tr>
<td>Pellet Plant</td>
<td>39,141</td>
<td>25,442</td>
<td>16.31</td>
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<tr>
<td>DR Plant</td>
<td>98,812</td>
<td>64,228</td>
<td>41.17</td>
</tr>
<tr>
<td>EAF</td>
<td>129,605</td>
<td>84,243</td>
<td>54.00</td>
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<tr>
<td>LF</td>
<td>35,266</td>
<td>22,923</td>
<td>14.69</td>
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<tr>
<td>CCM</td>
<td>54,897</td>
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<tr>
<td>Sub-Total</td>
<td>A$ 487,002</td>
<td>US$ 316,551</td>
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<tr>
<td>Gen'I &amp; Admin.</td>
<td>7,800</td>
<td>5,070</td>
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<tr>
<td>Port Fees</td>
<td>19,200</td>
<td>12,480</td>
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<tr>
<td>Total Costs</td>
<td>A$ 514,002</td>
<td>US$ 334,101</td>
<td>A$ 214.17</td>
</tr>
</tbody>
</table>

**Table IV Financial results**

- **IRR Equity Investor, after tax:**
  - After 10 yrs. Operation: 13.4%
  - After 15 yrs. Operation: 17.4%
  - After 20 yrs. Operation: 18.9%

- **IRR Overall Project, after tax:**
  - After 10 yrs. Operation: 7.3%
  - After 15 yrs. Operation: 10.8%
  - After 20 yrs. Operation: 12.2%

- **Overall Project Payback Period:** 6.5 years operation

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**Exchange Rate:** 0.65 US$/A$
Kobe Steel Signs Contract With Nippon Steel for First FAST-MET Plant

Kobe Steel, Ltd. has announced that the world’s first commercial-scale iron-bearing waste recycling plant using the FASTMET® Process will begin operation in the second quarter of 2000 at Nippon Steel Corporation’s Hirohata Works in Himeji, Hyogo Prefecture, Japan.

Kobe Steel is responsible for designing, fabricating and constructing the waste treatment plant, which will have a nominal capacity to process 190,000 metric tons per year of iron-bearing waste. The 140,000 metric tons of DRI produced by the facility will be charged hot to the BOF at the Hirohata Works.

In this application of the FASTMET Process, steel mill waste in the form of iron oxide dust from steelmaking operations and mill scale is collected and formed into pellets. The pellets are fed to a rotary hearth furnace, which reduces the pellets using coal as the reducing agent. The high-purity reduced iron is then recycled for use in steelmaking. The new plant will enable Nippon Steel to produce direct reduced iron (DRI) with a metallization of over 90 percent. Recycling the dust is an efficient use of steel by-products and enables Nippon Steel to greatly reduce iron-bearing wastes.

The FASTMET Process offers an attractive alternative technology to produce DRI, a premium quality raw material or supplement in EAF steelmaking, blast furnace steelmaking and foundry operations.