Massive Savings in CO_2 Generation by Use of HBI

By Robert Hunter,
Product Application Manager
Midrex Technologies, Inc.

Carbon emissions are a growing issue on a global scale. Modern society has advanced through industrialization and that has led to better standards of living and prosperity worldwide but also contributed to increased emissions. As greater focus on CO_2 becomes more mainstream, alternative solutions and better methodology are working their way into common practice. The industrial world contributes in a significant way to CO_2 emissions and ironmaking, like agriculture and transportation, is a major culprit, but there is also room for improvement. This paper examines just one way the steel industry can lower carbon emissions through use of HBI.

IRONMAKING

From the dawn of the Iron Age, over 3,000 years ago until the early-1700's, all iron was made using charcoal as the reductant. Then, around 1710, Abraham Darby built the first blast furnace to be fueled by coke. Darby's development was revolutionary and it was one of the founding events of the Industrial Revolution. It was essential to provide the enormous quantity of iron used in modern times. Each of the past two years (2007 and 2008) the world produced approximately one billion tons of iron, an amount that would be unsustainable using charcoal, because there simply aren't enough trees in the world to make the requisite amount of charcoal year after year.

From charcoal to coke to natural gas

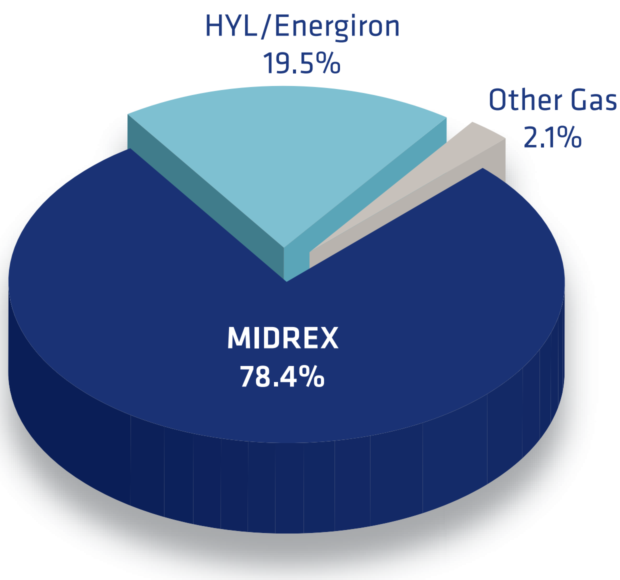
Even though it was a major innovation, ironmaking with coke took hold slowly. It did not become the dominant method of ironmaking until the mid-19th century. Today coke-fueled blast furnaces produce well over 90 percent of the world's iron. Natural gas (methane) is responsible for about five percent, coal for about two percent (primarily in rotary kilns) and only about one percent, or less, is made with charcoal. Many of the blast furnaces, especially the newer, larger ones, also employ an additional fuel other than coke (pulverized coal, oil, methane).

Ironmaking's contributiuon to the world's CO_2 generation

All of these fuels, except for natural gas, share one important characteristic. They are comprised almost totally of carbon and generate lots of carbon dioxide as a by-product. Including the processing step to make the coke from metallurgical coal, approximately 1.8 tons of CO_2 are produced for every ton of iron that is made. Different sources give figures varying from 1.6 tons of CO_2 to 2.2 ton of CO_2. The differences evolve from how one accounts for other by-products of coke making. For instance, if some of the coke oven gas is used to generate electricity, the CO_2 produced by burning that coke oven gas should not be counted against the iron. On the other hand, any coke oven gas that is burned to heat the coke battery should be accounted as being used in ironmaking.

Regardless of how one calculates it, ironmaking is clearly responsible for a massive amount of CO_2 generation. Using the 1.8 tons of CO_2 per ton of hot metal figure and multiplying by the tonnage of hot metal produced each year gives about 1.8 billion tons of CO_2 per year. Figures for the total contribution of CO_2 for all of mankind also vary, from 31 billion tons per year to 35 billion tons per year. Ironmaking is responsible for five to six percent of the entire production of CO_2 by all of civilization!

2008 World Gas-based Production by Process



Total World Production: 50.9 Mt

	2007	2008
MIDREX	76.3%	78.4%
HYL/Energiron	21.7%	19.5%
Other Gas	2.0%	2.1%

Source: Midrex Technologies, Inc.

The remainder of processing steps in steelmaking generate an additional one to two percent. Note that each one percent represents 310 million tons per year.

Using Natural Gas Direct Reduction

So, let's return to the question of how iron is reduced from the oxide into metal. In 1957 in Monterrey, Mexico, Juan Celada of Hylsamex started up the first commercial ironmaking plant using methane as the reductant. In 1969, Don Beggs of Midland-Ross commissioned the first MIDREX® Direct Reduction Plant for Gilmore Steel in Portland, Oregon. Today the heirs of these technologies make over 50 million tons per year of direct reduced iron using natural gas. In 2008, 40 million tons were made by the MIDREX® Process, almost 10 million tons by the HYL/Energiron Process and an additional one million tons by a plant in Venezuela which operates using the Finmet Process.

What is different about using methane instead of charcoal or coke? *Answer:* **the environmental effects**. Methane is a far cleaner fuel, especially when CO_2 generation is considered.

To reduce iron with coke or charcoal each atom of oxygen in the iron oxide (iron ore) requires one atom of carbon. In a blast furnace the carbon from the coke or charcoal is first partially oxidized to carbon monoxide (CO) using gaseous oxygen. This oxygen is provided by the blast air (heated air enriched with additional oxygen, then injected into the blast furnace at the tuyeres). This carbon monoxide diffuses into the highly porous ore and collects an additional oxygen atom from the iron oxide, creating metallic iron (Fe) and forming carbon dioxide. On the other hand, when methane is used, each molecule of CH4 is first reformed into one carbon monoxide molecule) and two hydrogen molecules (each is H_2). Each of these three molecules will take one oxygen atom fromeach molecule of CH4 is first reformed into one carbon monoxide molecule) and two hydrogen molecules (each is H_2). Each of these three molecules will take one oxygen atom from the iron oxide. So the products of the reduction reaction are two water molecules (H_2O) and one carbon dioxide molecule (CO_2). Only one-third as much CO_2 is generated.

Were it possible to produce the entire world's iron with natural gas direct reduction plants, over one billion tons of CO_2 could be avoided per year. While that is not likely, the CO_2 savings through use of DRI are significant. An example is the use of DRI in the blast furnace, as is done by AK Steel of Middletown, Ohio.

RESULTS: EXPERIENCE AT AK STEEL

For nearly two decades, AK Steel has been adding hot briquetted iron (HBI) to the charge mix of their blast furnace. This is quite similar to the practice of adding prepared scrap or other metallic sources of iron (used grinding balls, for instance) to a blast furnace. It greatly enhances the productivity of the furnace while simultaneously achieving vast savings of fuel (on a 'per ton of hot metal' basis). For each 10 percent of the iron burden (charge to the furnace) that is metallic, the productivity of the furnace increases by 8 percent. And, for each 10 percent metallic, the fuel consumption decreases by 7 percent.

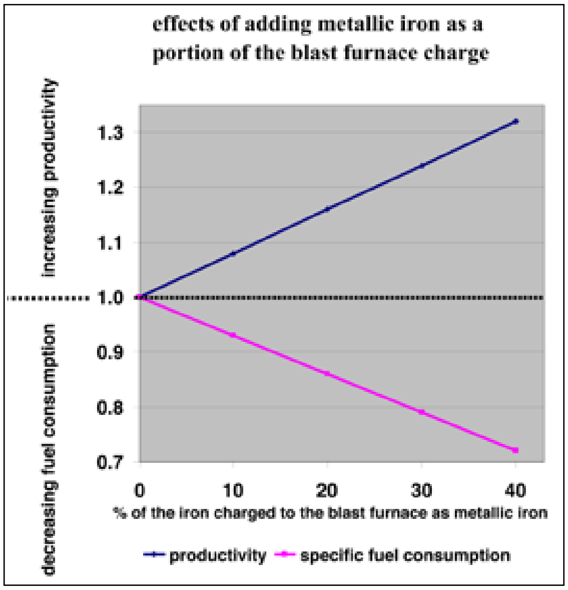
For the past few years, AK Steel has typically charged 30 percent of the burden as metal, primarily HBI from Venezuela, together with some B-scrap. The furnace productivity has averaged over four tons per day per cubic meter of working volume, the best in the world. Similarly, total fuel consumption is remarkably lowered, to about 440 kg per tonne of hot metal.

The extraordinary advantage this gives AK Steel is primarily the increase in productivity. With the blast furnace as the limiting operation of the entire steel works at Middletown (as is typical of many integrated steel works), additional tonnage from the blast furnace means additional tonnage of salable product. When profit margins are good, this has extraordinary leverage at the "bottom line." When profit margins are lower, this still allows the works to maintain a broad customer base.

Also, at AK Steel an additional advantage was available. Prior to raising the productivity of the Middletown blast furnace, AK Steel operated another blast furnace at a nearby site (about 30 miles away) in Hamilton, Ohio to supplement the hot metal output of the Middletown furnace. This was necessary to keep the steel shop running at a good rate. Once the Middletown furnace raised its production rate, the Hamilton furnace could be closed. Thomas Graham, then president of AK Steel, stated at World Steel Dynamics' 1994 Steel Survival Strategies conference that the closure of the Hamilton blast furnace saved AK $60 million dollars per year in fixed costs. (Those were 1994 dollars; today the equivalent figure would be over $80 million.)

Usage of HBI in US, Europe, and Japan blast furnaces:

Since AK Steel began using HBI on a regular basis, nearly every integrated works in the United States has also employed it as blast furnace charge. However, the others typically only use it when they need a production boost, or when one blast furnace is down in a works which has multiple furnaces. Some mills in Western Europe have also tested the concept. In each of the cases in North America and in Europe, the focus was on improving production rates. Recently, in Japan, at least two of



the major integrated steelmakers have conducted extensive tests (hundreds of thousands of tons of HBI each) with the focus being CO_2 savings. And, in China, where over half of the world's iron is made, a major feasibility study regarding CO_2 saving by the steel industry targeted blast furnace usage of HBI.

Copenhagen Climate Change Conference

For most of December the United Nations Climate Change Conference, made world headlines. It still remains to be seen to what extent the conference will have on various countries in the next few years; however, one thing is definite: the importance of DRI.

The Stockholm Environmental Institute issued a report for the conference on "Europe's share of the Climate Challenge" that states "Perhaps the most promising route [to reduce CO2] is to replace Blast Furnace Iron with Direct Reduced Iron." In addition there is very likely decisions to be made which will lead to further monetization of CO_2 emissions. With this in mind, Midrex has thoroughly examined the economics of charging HBI to a blast furnace with CO_2 penalty/bonus as an added factor. Using expected levels of CO_2 pricing from $20/t up to $80/t, and the probable extent of HBI usage,varying from 5% up to 30% metallization of the blast furnace burden, the potential CO_2 savings is a very significant factor. But, in none of the cases was CO_2 as important as the already well known factors, productivity increase, fuel savings and capital cost savings.

Nonetheless, the additional saving is such that we strongly recommend any and all integrated facilities to conduct their own economic analyses. Following Copenhagen, the economy of using HBI will have one more positive feature, massive savings of CO_2.