CHEMICAL ECONOMICS - GAS, IRON AND STEEL

In a previous article I discussed the production of steel from coal and iron ore by the blast-furnace route, which accounts for the major portion of the world's steel production of 1,650Mt/y. This route has good economies of scale and is now practiced in facilities producing volumes of about 1 million tonnes of iron per year or more. Steel production is seen by many countries as a strategic necessity and for many countries (such as New Zealand) production of steel on this scale is not warranted. This develops the opportunity for smaller scale technologies many of which are grouped as Directly Reduced Iron (DRI).

DRI has been commercialised for over 100 years. In essence there are two approaches, one uses coal and other uses natural gas. Of the approximately 75Mt/y of DRI produced about 80% is produced from gas. The coal based DRI technologies are generally all different being developed to process particular ores and coals. In recent times new facilities have been built which use coal as coke oven gas or coal gasification to provide the reducing gas.

For gas based technologies, a shaft based system developed and promoted by the Midrex Corporation (www.midrex.com) has achieved a high level of take-up. In this process iron ore lumps (>6.3mm) are loaded into the top of the shaft-furnace and are reduced by an upward flowing stream of reducing gas, a mixture of hydrogen and carbon monoxide.

The reducing gas is produced in a steam reforming unit from the natural gas. Relative to other steam reformers which produce synthesis gas for ammonia or methanol production, reducing gas reformers operate at high temperature and low pressures which maximises hydrogen and carbon monoxide concentrations.

As the iron ore is reduced, water and carbon dioxide are produced which could reverse the reaction if the concentration becomes too high. To prevent this, excess reducing gas is fed to the furnace and recycled after water and carbon dioxide has been removed. Reduced iron is separated from the ash. As produced, DRI is pyrophoric and is passivated by a briquetting process prior to shipment.

Because of the demand for lump ore for this technology (and its benefits to blast furnace operations) there is a significant price premium for lump ore over fines, typically 20%. Fines can be used but require pelletizing at additional cost prior to use. Because of this price differential, there have been attempts to use iron ore fines in the direct reduction process.

In the 1970s, Esso succeed in the Fine Iron Ore Reduction (FIOR) process on a semi-commercial plant in Texas. The technology required the fines to be fluidised in an ascending stream of reducing gas. Four sequential reactors were required with fresh ore charge to the first reactor and passing progressively to other reactors which completed the reduction process. However attempts to transfer the technology at full scale to ore reduction in the Orinoco region of Venezuela failed because the ore used, on partial reduction, became sticky, aggregated and clogged the reactors.

The technology was improved by Voestalpine (an Austrian steel conglomerate) who managed to get the technology to work and marketed this as the FINMET process.

In the late 1980s, BHP decided to use the FINMET process rather than the more proven Midrex process for a very large scale DRI operation at Boodarie in WA known. This was known as the BHP HBI (hot-briquetted iron) plant. It ran intermittently for several years but seems to have suffered from the same problems as the original Esso FIOR plant, sticky partly reduced ore, which adversely impacted on production rates. A fatal accident at the site persuaded the company not to persevere with the process and the facility was demolished in 2005.

Prior to steel making, the DRI is melted in an electric arc furnace (EAF) which separates impurities from the iron as a slag. Unlike the blast furnace, an EAF has limited ability to handle slag and this limits the level impurities in the feed. The main feed competitor to DRI for EAF operations is scrap steel for which there is a large and extensive international market - especially good quality scrap containing few tramp metals produced by the scrapping of ships, particularly the oil tanker fleet which has a high turnover rate.

Despite BHP's experience, the large reserves of natural gas and iron ore in Western Australia will always attract DRI type operations. The figure illustrates some of the key economic issues for the cost of DRI production. The figure plots the production costs for an HBI operation in WA and a conventional DRI facility in Texas against the prevailing gas price. The salient data is given in the table for the two facilities of similar scale. The HBI data has been escalated from published BHP SEC filings (capital cost $A2.6 billion in 1999) and the Texas DRI from Midrex/Voestalpine publications for an export DRI operation based near Corpus Christie. This has just been completed. For comparison the cost of good quality scrap (US market, May 2016) is $250/t.

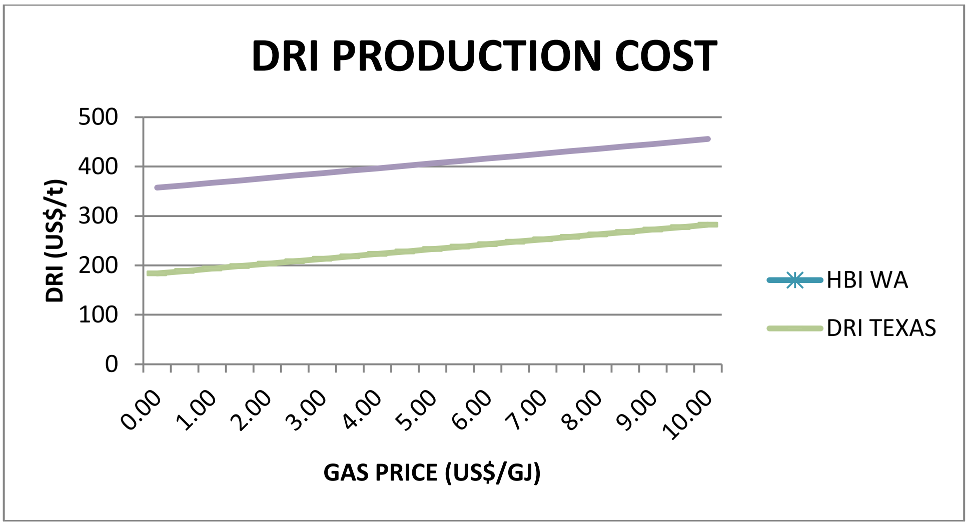

Figure 1: Comparison of DRI production costs in WA and Texas.

Table 1: Data for DRI operations

		DRI Texas	HBI WA
Capacity	kt/y	2000	2000
Capital (late 2015)	US$ million	770	2875
Iron ore	type	lump	Fines
Iron ore pricing basis	FOB fines = US$55/t	FOB fines + 20%	Run on mine cost
Iron ore price	US$/tonne	66	35
Gas Usage	PJ/y	19.7	19.7

FOB = free on board

The main difference clearly evident is that despite low gas prices (<US$5/GJ) and lower iron ore cost (run of the mine cost), the very high capital cost for operations in Australia makes DRI production in Australia non viable. This is in contrast to the US Gulf area where both low capital costs and low gas costs (typically $3/GJ) can deliver DRI well below the cost of scrap. This makes export of DRI from the US to Europe viable.

DRI operations are of interest because of their relatively lower emissions of carbon dioxide. Other methods which have been tried have included the CSIRO/Rio Tinto HiSmelt process which reduced ore with powdered coal in a molten metal bath. This project has now been abandoned in Australia and the technology transferred to India for further development.

A fully "renewable" route would be to use wood charcoal for the reduction. This has been practiced in the past (prior to the coal age) and is still found in some countries such as India. The problem is that blast furnaces are restricted in size and require enormous quantities of biomass (wood) for the operation.

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SOME PHOTOS BELOW

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BHP HBI FACILITY

RIO TINTO HiSMELT FACILITY