DESCRIPTION OF THE IRON CARBIDE PROCESS

IRON CARBIDE HOLDINGS ^{SM} USA

November 1995

1. MAIN PROCESSES FOR STEEL MAKING

Steel makers around the world are constantly looking for new and more cost-effective sources of virgin iron units.

The ICH Process offers a unique solution. As steel making technologies continue to develop, there will be an enormous, global market for a more cost-effective and environmentally safe steel making process.

Currently, steel makers have only pig iron and other forms of direct reduced iron as sources of virgin iron. Unfortunately, pig iron often has high phosphorous and sulphur levels, which are introduced in the blast furnace along with the charge.

There are disadvantages with other types of direct reduced iron as well. Since these processes require iron ore pellets and usually produce briquettes, handling and production costs are higher.

2. OTHER DIRECT REDUCTION PROCESSES.

Because of the low operating temperature of the process and of the nature of iron carbide, no sticking or defluidisation of the material in the reactors occurs, thus eliminating a major difficulty encountered in all other fluid bed iron ore reduction processes.

The product is not pyrophoric, and therefore, does not need expensive briquetting or surface passivation treatments which are required by all other direct reduction processes.

As a result of the lower cost of the iron raw material and the lower cost of product handling, the product can be produced at a lower cost than other competing processes.

Iron carbide can be used in electric furnaces, and five leading operators have confirmed the many benefits that can be obtained. When added to scrap, iron carbide dilutes the level of non ferrous metals and tramp metal residuals, thus making it possible to produce steels that require a very low grade of residuals, such as flat-rolled sheets for deep-drawing for example in the automotive industries. Iron carbide also provides a mechanism for reducing nitrogen to unrivalled levels in electric furnace steel. Since iron carbide particles dissolve rapidly in the liquid steel, the energy gained from the oxidation of the carbon, minimises the consumption of electricity. The absence of sulphur is also an advantage, because this lowers the cost of ladle treatment for desulphurisation. Iron carbide also is easy to use and can be injected directly into the bath with nitrogen or air as carrier gas.

Iron carbide has been tested and used successfully as a substitute for scrap-iron by operators of basic oxygen furnaces.

With iron carbide, there is a decrease in the hot metal percentage of the charge per tonne of steel produced, without any decrease in productivity. Hot metal percentages of 60% are possible, which can prolong blast furnace or coke oven life by 25%.

NB: This is a feature which applies only in the case of conventional integrated steel plants.

After more than 20 years of development and research, including the successful operation of two pilot plants, the ICH Process has proven to be an effective and cost-efficient way of producing iron carbide.

Here is the basic chemical equation of the process:

$3Fe_2O_3 + 5H_2 + 2CH_4 = 2Fe_3C + 9H_2O$

This reaction is carried out in a fluidized bed reactor of unique design, with a carefully controlled five- component process gas. Since the reaction is slightly endothermic, the ore feed and the process gas are heated to temperatures slightly above the fluidised bed operating temperature of 550-600°C. The optimum size single module is designed to produce 1 000 tonnes per day. However, multiple modules can be supplied from a single gas reformer.

The reaction product in the gas phase, is water vapor. This water is removed from the gas stream by cooling and condensing it in a packed tower scrubber or chiller. The dry gas is then recirculated to the reactor, with the addition of some make-up gas to replace the hydrogen and the methane that is consumed in the reaction. The reaction product water is added to a small amount of make-up water to provide the overall process water which is needed for cooling and generation of hydrogen. Other than this water and the normal products of complete combustion, the process has no significant effluents and is therefore environmentally friendly.

Here are the necessary battery limits, materials, energy, and labor per metric tonne of iron carbide:

Iron ore	1.42 tonnes
Natural gas	13.0 G30ules
Electricity	230 Kwh
Water	1.2 m3
Labour	0.35 worker hours

These numbers are based on the following desired iron ore characteristics:

Fe(total) as Fe203	65% min.
SiO2 + Al203	4% max.
Phosphorous	<0.05%
Moisture	8% or less
Maximum particle size	1.0 mm
Minimum particle size	0.l mm
Mean particle size	0.2 mm (65 mesh)

Other types of iron-ore may be used, but they require some modification of the process conditions and may increase operating costs.

Most natural gases will work with the process, but the most cost-effective resources are those with a low sulphur content (H2S is removed in the reformer) and nitrogen contents below 1%.

The iron carbide produced naturally depends on the chemical composition of the ore for some of its characteristics. The relationship between the degree of formation of

Fe3C and the productivity of the process is well within the operator's control. The current process will typically result in a product that is 93 % converted to iron carbide.

For example, mineralogically and elementally, it would be as follows:

Mineralogical composition		Elemental composition	
Fe3C	91-96%	Fe(total)	89-93%
Fe304	5-2%	C (as Fe3C)	6-6.5%
Fe(met.)	0.5-1%	O (as Fe304)	0.5-1.5%
SiO2 + A1203	2-4%		

Iron carbide is magnetic, so if the gangue is be physically liberated, either before, during or after the process of carburation, then a dry magnetic separation can be carried out to lower the gangue content in the final product and therefore increase its iron grade.

Iron carbide does not disintegrate during the process so that the size distribution of the product is only slightly smaller than that of the feed, and is the result of the increase in specific gravity of the carbide Fe3C compared to the oxide Fe2O3.

Iron carbide is not pyrophoric, so that no special surface treatment or briquetting for shipping and storage of the product is required, except that it should be stored and shipped dry.

3. USES

Iron carbide has been tested and used successfully in both electric furnaces and basic oxygen furnaces. The advantages of iron carbide's characteristics are many:

> Because iron carbide is a chemical compound, it behaves thermodynamically and physically, in a different way than carbon which is added in the form of graphite or coke in the electric furnace. The Fe3C compound has a heat of dissolution that contributes energy to the furnace. The oxidation of the dissolved carbon from the carbide by gaseous oxygen also contributes a significant amount of energy to the process.
>
> In addition, any residual iron oxide in each particle of the product is immediately reduced to iron by the synergetic effect of intermixed carbide, which generates fine CO bubbles that sweep through the steel, absorbing nitrogen and hydrogen. Iron recovery is practically

100% complete because there is ample carbon in the product to complete the iron oxide reduction.

The expected analysis of ICH Process final product is as follows:

Fe3C	91-96%	Fe (total)	89-93%
Fe304	5-2%	C (as Fe3C)	6-6.5%
O (as Fe3O4)	0.5-1.5%		
Si02 + A1203	2-4%		

Although this analysis may vary depending on the type of ore used, there will be no significant sulphur present in any case. Phosphorous levels will depend on the type of ore used, and will be present in the product as P205. But most of the phosphorous will report to the furnace slag, not in the metal.

Most residual elements in the ore will be present in the product as oxides, but since most iron-ores have very low levels of copper, nickel, chromium, molybdenum or tin, there will be no significant amounts of these elements in the final product. As a result, iron carbide produced by the ICH Process is very clean and provides an effective method of diluting the tramp residual metals that are found in most scrap-iron charges, while avoiding the sulphur that comes with some virgin iron sources.

Iron carbide has been tested and used successfully in both electric furnaces and basic oxygen furnaces. The advantages of iron carbide's characteristics are many:

Because iron carbide is a chemical compound, the carbide acts thermodynamically and physically different than carbon added in the form of graphite or coke. The Fe 3C compound has a heat of dissolution that contributes energy to the furnace. The oxidation of the dissolved carbon from the carbide by gaseous oxygen also contributes a significant amount of energy to the process.

In addition, any residual iron oxide in each particle of the product is immediately reduced to iron by the synergistic effect of intermixed carbide, which generates fine CO bubbles that sweep through the steel absorbing nitrogen and hydrogen. Total iron recovery is virtually complete because there is ample carbon in the product to complete the reduction.

Iron carbide has been tested and used effectively by five major electric furnace steelmakers. It can be charged in bulk or charged pneumatically, using nitrogen or air as the carrier gas.

To obtain the greatest benefits, iron carbide should be injected directly into the liquid steel bath once a melt pool has been established. This can be done via lances that can carry up to 2 000 kg/min. Multiple lances can be used as well. Typical supersonic oxygen lances can keep up with this carbon input rate, adding energy to the melt via the decarbonisation reaction, with losses only to the slag FeO and to fumes. Recovery rates will be as good or better than those obtained with high quality scrap.

Nitrogen levels in the 30-40 ppm range can be achieved with as little as 5 % carbide, injected late in the heat, provided there is minimal use of the arc, following the carbide injection.

Even with 5 % iron oxide in the material, there should be no increase in electrical consumption as a result of its substitution for scrap. A reduction in electrical energy consumption may be obtained if simultaneous rapid carbon oxidation is employed. Up to 25 % carbide in the charge is considered reasonable and should result in no increase in tap-to-tap time.

The acid constituents in the material will actually help to form foaming slags by reducing the basicity, which can be lowered because there is no sulphur in the product. Therefore, lime consumption can be reduced either in the furnace or in subsequent ladle furnace treatment.

Iron carbide has been successfully tested in pilot and full-scale basic oxygen furnace (BOF) operations. Because of its inherent energy content with 6 % carbon in the form of carbide, iron carbide supplies some of the energy needed to melt and dissolve it in steel, as opposed to scrap which can only supply energy by oxidizing iron. To thermally balance the process, if iron carbide is added as a cold solid, in place of scrap-iron, it can replace scrap in a 2/1 ratio. By replacing scrap-iron with iron carbide, the charge for a BOF can be reduced from 75/25 % hot metal/scrap ratio to 60/40 % hot metal/iron carbide. If the iron carbide is preheated, even further decreases in hot metal ratio can be attained. The result is that significant reductions in the use of both hot metal and scrap-iron are obtained.

The advantages are many. For example, if BOF operators are faced with a hot metal shortage, due to a coke shortage or a cost squeeze, or if in the long-term they have to close coke oven batteries or blast furnaces because of environmental reasons, they can extend the steel production of their hot metal supply up to 25% by substituting iron carbide for scrap iron.

Because iron carbide is environmentally clean and free of sulphur, flat product producers who substitute iron carbide for hot metal and scrap-iron in the charge, can easily reduce the cost of desulphurisation per tonne of steel.

Iron carbide is an ideal material for recarbonisation in the ladle. It is economical, accurate and highly productive for steel makers who produce a low-carbon steel from their furnaces and recarbonise in the ladle to reach a more stringent carbon specification. Unlike other materials for recarbonising which introduce residual amounts of hydrogen, sulphur and nitrogen and suffer from variable recovery rates, the excellent density of iron carbide and its rapid rate of dissolution, enable injections at ladle stage in very precise amounts and with predictable and constant rates of recovery.

COMPARATIVE BENEFITS OF IRON CARBIDE

In the steel making industry, iron sources come in many forms, and each source has its own characteristics, including production costs and uses. The table below shows why there are clear benefits for using iron carbide, a revolutionary new steel making raw material, from the ICH Process.

scenario 1	**hot metal**	**premium scrap**	**iron carbide**	**total metal**
metal requirement	2250	750		3000
cost $/t	180	135	132	168.8
cost M$	405	101		506
scenario 1	**hot metal**	**premium scrap**	**iron carbide**	**total metal**
metal requirement	750	750	1500	3000
cost $/t	180	135	132	144.8
cost M$	135	101	198	434
savings				
M$				72
$/t				24.0