HYL NEWS

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The experience gained in the last decade of implementation of high capacity plants allows us to offer to the market the best DRI and HBI products and the best performances, while we have completely debugged the plant equipment design and optimized the process, teaming-up with operators and vendors. As a result, Energiron plants have demonstrated and proved a better learning curve: the world record start-up period of EZZ Energiron plant, i.e. 29 days from first DRI to full production, is an undisputable performance success, as well as the 98-99% plant availability demonstrated by actual plant operations like LebGOK HBI plant and Ternium Monterrey and Puebla plants among others.

These results have been accomplished by keeping our focus on four pillars.

**Innovation:** our capacity of exploring new horizons while doing better what we are doing now. We provide our customers the possibility to anticipate the nature and the speed of change, outperforming among their competitors. We improve process efficiency and product quality through enhanced automation and equipment digitalization.

**Reliability:** our constant and dedicated effort and attention to details, with outstanding service attitude, make our products made to last and make our people deliver what we promised. We have shown our commitment to providing zero latency in learning by a few possible mistakes that may result from incremental innovation.

**Sustainability:** our solutions envision a better future for our children, while providing at the same time the highest value to all stakeholders and allowing everyone who works in the DRI industry to live it with passion.

**Safety:** Nothing is more important than safety! We ensure that the technologies and solutions we develop make the surrounding environment safer.

We know that we will continue to face tough challenges in a moment characterized by volatility and uncertainty, but the actions we have implemented on these four pillars make HYL and Energiron ready for the challenges of today being designed for the future.
The continued tightness in the direct reduction-grade pellet market is being felt by HBI and DRI production plants worldwide. The Samarco dam catastrophe is still a recent memory and it will certainly be some time before the supply of iron ore pellets is resumed/replaced.

Iran, which took over the first place position from India as leading producer of DRI and HBI will not be able to help much in this regard. In addition to continuing complications in dealing with Iran, the desirability of using exported pellet feed from Iran is limited since most iron ore sources there tend to be quite high in sulfur and silica and thus less productive in direct reduction furnaces.

What we have been seeing, in the past with Energiron DR plants based on their high raw materials flexibility, and now with nearly all DRI and HBI plants, is the use of blast furnace pellet feed mixed with available DR-grade pellet. The attractiveness of this option is that it helps reduced overall iron feed costs to the DRI plant, although it produces a somewhat lower grade DR product.

The flexibility of the Energiron technology again becomes apparent in that it is able to adapt to temporary market conditions, either by changing the iron feedstock quality or the reducing gas input among other factors. The article in this issue touches on the topic of using hydrogen as a reducing agent for DRI production, yet another flexibility to be considered and developed.

We hope you find the articles in this issue to be informative and we welcome your comments and observations. You can always find additional information through our websites at www.tenova.com and www.energiron.com.
IMPROVING PERFORMANCE AND DECREASING CO$_2$ EMISSIONS IN BLAST FURNACE INSTALLATIONS USING HIGH-CARBON DRI/HBI

by Jorge Martínez - Technical Proposals Manager & Pablo Duarte - Commercial VP

INTRODUCTION

Environmental impact and its associated regulations are becoming a necessity in contemporary civilizations, not only because of the effect of Global Warming-Greenhouse Gases (GHG) but also because of the effect on quality of life and overall sustainability. The steel and iron making sectors are not the exception, as the industry is currently being required to comply with the strictest environmental policies. Historically, the steelmaking industry has been characterized by an intensive use of fossil fuels, which leads to a significant impact on the environment through GHG emissions, mainly in the form of CO$_2$. The traditional BF-BOF route uses coal as the main energy source for iron oxides reduction while the DR-EAF route can use as sources of reducing gas not only natural gas, but also syngas from coal gasification, coke oven gas (COG) and hydrogen (H$_2$) can be used. For this reason, the DR-EAF route emits 40% to 60% less CO$_2$ as compared with BF-BOF route, depending on the source of power generation at specific plant location. If the power is considered CO$_2$-neutral, as may be the case whenever the electricity is generated from renewable sources, the aforesaid range of CO$_2$ values will be decreased even more.

The use of traditional DRI/HBI in the blast furnace as a pre-reduced material feed, has been explored since long ago as a possible way to increase furnace productivity and/or to reduce the coal (PCI)/coke consumption while decreasing CO$_2$ emissions. As a general rule and applicable to typical DRI/HBI, for each 10% of burden metallization in the charge, the coke rate can be decreased 6% to 7% while the productivity can be increased by 7% to 8%. As a result of lower coke rate, also other potential contaminants associated with the coke oven batteries can be reduced too.

An exclusive feature of the ENERGIRON Zero Reformer (ZR) Technology is the ability to produce High-Carbon DRI/HBI. Due to the nature of the ZR process itself and the prevailing conditions inside the shaft, high-C DRI can be produced having >90% of the total carbon in the form of cementite (or iron carbide, Fe$_3$C). Since the High-C DRI/HBI has higher energy content as compared to standard DRI/HBI, further coke/PCI savings and further productivity increase are expected in the Blast Furnace. In this paper, the further CO$_2$ emissions reduction due to the use of High-C DRI/HBI in the BF is analyzed.
The ENERGIRON Process (Figure 1), based on the ZR scheme, is a major step in reducing the size and improving the efficiency of direct reduction plants. Reducing gases are generated by in-situ reforming of the hydrocarbons of the natural gas (NG) within the reduction reactor, feeding NG as make-up to the reducing gas circuit and injecting oxygen at the inlet of the reactor. Prevailing operating conditions of the ENERGIRON ZR process, characterized by high temperature (>1050°C), presence of water (H₂O) and carbon dioxide (CO₂) as oxidants produced by partial combustion of the reducing gas with oxygen (O₂) injection, promote the in-situ reforming of the hydrocarbons. Once hydrogen (H₂) and carbon monoxide (CO) are generated, simultaneous reduction of the iron ore and subsequent carburization of the DRI, take place inside the reactor, making this process scheme the most efficient in terms of energy utilization and overall energy consumption.

The basic ZR scheme allows the direct use of natural gas. ENERGIRON plants can also use conventional steam-natural gas reforming equipment as an external source of reducing gases, which has long characterized the process. Other reducing agents such as H₂, syngas produced from coal gasification systems, pet coke and similar fossil fuels, and coke-oven gas, among others, are also potential sources of reducing gas, depending on the particular situation and availability. In any case, the same basic process scheme is used regardless of the reducing gas source.

The current configuration of this technology employs a continuous shaft furnace-based process, with both the product quality and process efficiency having been significantly optimized over the years. The ENERGIRON ZR technology is currently the most flexible option for producing DRI based on its uniquely simple process configuration and its wide flexibility for using different energy sources and available raw materials.

The ZR scheme is also characterized by high operating pressure (6-8 bar A at top gas). The elevated pressure allows a high productivity of about 10 t/h x m² and low reducing gas velocities of about 2 m/sec (as compared to lower operating pressure processes for which the gas velocities are >5 m/sec), thus promoting a homogenous gas distribution through the solids bed while minimizing dust losses through top gas carry-over. This assures a very low standard deviation of the premium DRI quality and lowers the overall iron ore consumption, which in turn lowers the overall operating costs. A distinct advantage of this process scheme, without an integrated/external reformer, is the wider flexibility for DRI carburization.

A unique feature of the ZR DR Technology is the ability to produce controlled high carbon levels in the DRI in the form of iron carbide (Fe₃C). DRI carbon levels up to 5% can be obtained, due to the prevailing conditions in the reduction zone of the reactor, of high CH₄ concentration (~20%) along with the H₂ and CO, and the high temperature of the bed (>860°C), which favors the diffusion of carbon into the Iron matrix and the precipitation of iron carbide (Fe₃C).
**Product Quality**

For the purposes of this analysis and to differentiate the High-C DRI from the traditional DRI, the High-C DRI stands for a DRI with carbon content \( \geq 3.5\% \) of which \( >90\% \) is in the form of iron carbide \((\text{Fe}_3\text{C})\).

**USE OF HIGH-C DRI/HBI IN BLAST FURNACE**

DRI/HBI can be used in the Blast Furnaces as pre-reduced material, partially replacing the traditional ferrous feed consisting of lump ore, sinter and oxide pellets.

By feeding DRI/HBI into the BF, there are two possibilities, which will improve the BF operation in terms of productivity and/or coke input requirements:

1. Same liquid steel production rate is kept while environmental impact is reduced due to a decrease of specific coal (coke/PCI) consumption and consequently reduction on \( \text{CO}_2 \) emissions.
2. To increase the BF productivity, decreasing not only specific consumption figure, but also achieving savings in production costs.

For purpose of this paper, the first possibility will be only analyzed.

In an integrated steel works, the excess of coke oven gases (COG), converter gases (BOFG) and blast furnace top gases (BFG) are sent to a power plant to generate electric energy for the in-plant users and there is always an excess which is exported. Figure 2 presents an overall schematic of a typical integrated steelworks.

The \( \text{CO}_2 \) emissions evaluation, for this reference case, is based on a typical material and energy balance of an integrated steel mill, including thin slab casting and rolling for the production of hot rolled coils.

The following basis has been considered for the analysis:

- \( \text{CO}_2 \) emissions related to iron ore mining / pelletizing plant including transport, are not taken into account.
- Import power is \( \text{CO}_2 \)-neutral on the basis that the import power is coming from renewable energy sources.
- Power required for oxygen production is also \( \text{CO}_2 \)-neutral.
- Export power credit does not represent credit for \( \text{CO}_2 \) emissions.
As can be noted in Figure 2, for this BF/BOF route, the CO₂ emissions are about 1,810 kg of CO₂ per ton of liquid steel, assuming that no CO₂ credit is taken into account for the export power.

The use of direct reduced iron (DRI) or hot briquetted iron (HBI) as metallic charge to BF allows a significant reduction of fossil fuels specific consumption. Several steelworks have already used DRI/HBI in the BF during the last decades and have reported the results. Please refer to Figure 3 for the reported values of decrease of coke consumption and increase of productivity as function of metallized burden in the feed charge.

As per Figure 3, for each 10% of burden metallization in the mix charge, the coke rate can be decreased to 6% to 7% while the productivity can be increased by 7% to 8%. All the reported results in Figure 3 are based on the use of traditional DRI/HBI which implies carbon levels not higher than 2.0%C.

![Figure 2](image1) Overall carbon balance for typical integrated steelworks

![Figure 3](image2) Coke rate decrease and production increase in function of burden metallization as per reported results by existing integrated steelworks.
A further decrease of the PCI/coke consumption and increase of the BF productivity can be reached whenever High-C DRI/HBI (~4.0% C) is used instead of standard DRI/HBI (<2.0% C). As mentioned, more than 90% of the carbon contained in the High-C DRI is in the form of iron carbide (Fe₃C). For this analysis, the DRI/HBI charge is 362 kg/tLS (equivalent to 35% burden metallization).

In this respect, the following additional benefits are expected when using High-C DRI/HBI to the BF:

The secondary reduction of the remaining wustite (FeO) in DRI with the carbon. This reduction reaction generates CO gas which can also reduce the iron ore around the DRI, improving furnace efficiency and decreasing PCI/coke requirements. This effect is limited with the traditional DRI/HBI with lower carbon content. Refer to Figure 4 for the effect of the High-C DRI in the BF.

The additional energy provided by the excess of carbon in the DRI.

According to this analysis, the PCI/coke rate can be decreased down to 8% to 9% while the productivity can be increased up to 9% to 10% for each 10% of metallized burden in the feed charge if using High-C DRI/HBI. Figure 5 represents the effect of the High-C DRI use, in terms of coke savings and productivity increase.

In this regard, there are other similar analysis related to use of High-C DRI in BF, which indicates a higher impact of this material as metallized burden in connection to further PCI/coke reduction and productivity increase due to not only the secondary reduction of FeO but also to more optimized BF operation.

A natural gas-based Zero Reformer DR Plant is considered to produce High-C DRI/HBI, since this is the only proven and reliable DR technology for producing High-C DRI in any range of 2.0% – 5.5%. Figure 6 corresponds to the schematic configuration of the integration of the DR plant with the BF/BOF installation. High-C DRI/HBI is specified as 94% Mtz avg and 3.5% C avg.

The CO₂ emissions generated in the DR Plant by the natural gas are taken into account while
the import power is considered CO₂-neutral as established in previous paragraphs. The effect of the use of High-C DRI/HBI will result in a specific coking coal consumption of 410 kg/tLS (or coke rate of 337 kg coke / tHM) while the PCI will not be needed at all. The DRI/HBI charge will be 362 kg/tLS (equivalent to 35% burden metallization).

Depending on DR Plant location (abroad or on-site), the associated CO₂ emissions generated in the DR Plant can or cannot be counting for environmental impact. Therefore, the overall BF-BOF CO₂ emissions can be decreased from 1,810 kg CO₂ / tLS to:

- 1,334 kg CO₂ / tLS if the DRP is located abroad i.e. CO₂ emissions from DRP are not considered, or
- 1,492 kg CO₂ / tLS if the DRP is located in the integrated steelworks i.e. CO₂ emissions from DRP are considered.

Then, the use of High-C DRI reduces the CO₂ Emissions in 26.3% or 17.6% respectively, depending on DRP location.

The expected CO₂ emissions, using standard DRI/HBI, will be reduced only 20.6% or 10.8%, clearly showing that the effect of the high carbon content in the metallized product is significant in terms of lower use of PCI/coke.
USE OF HYDROGEN AS REDUCING AGENT

Nowadays, important research work is being conducted worldwide to economically produce hydrogen by means of water electrolysis through Polymer Electrolyte Membranes (PEM’s) and other high-efficiency electrolyzers, based on the consideration that the required electricity for this application is generated from renewable energy sources like eolic or solar PV.

In the steel and ironmaking industries, the hydrogen will replace carbon as energy source for the iron ore reduction process. For the case of gas-based Direct Reduction, the hydrogen will replace natural gas. The ENERGION ZR scheme is already prepared to use any amount of hydrogen in replacement of natural gas with no major equipment adjustments. In fact, for the ENERGIRON ZR scheme, the use of hydrogen will be reflected in a more “relaxed” operation and productivity increase since the equivalent “in-situ” reforming of natural gas will be lower.

Use of hydrogen concentrations as high as 70% at the inlet of reduction shaft is already well proven in the existing ENERGIRON-III plants, which involves a steam reformer to produce the reducing gases ($H_2$ and CO).

The use of $H_2$, replacing NG as energy input, implies a decrease of %C in the DRI as the CH composition is diluted in the reducing gas. However, due to the flexible process scheme configuration of the ZR scheme in terms of make-up distribution to the reduction circuit and to fuel utilization, it is possible to keep the 3.5%C even at 35% energy input as $H_2$ (or about 64% as volume-Nm$^3$/tDRI). For 70% $H_2$ as energy (~88% as volume-Nm$^3$/tDRI), the expected C in DRI will be <2.0%.

Figure 8 indicates the effect CO$_2$ emissions reduction in the DR Plant and in the BF-BOF steelworks as function of the $H_2$ usage in the DR Plant. For all cases, potential CO$_2$ off-taking from the DR Plant has not been considered.
Selective CO₂ elimination through an amine-based absorption unit is an inherent system of the ENERGIRON ZR technology to optimize the reducing potential of the recycling system. The removed CO₂ can be commercialized for different uses.

The CO₂ removal unit mainly consists of the CO₂ absorption column and one stripping column, plus auxiliary equipment. The recycled reduction gas, with high CO₂ concentration, is fed to the CO₂ removal system at the bottom of the absorption column.

This is a packed bed tower where the gas is decarbonated by counter-current contact with cold lean absorbing solution coming from the stripping section. The absorbent is an amine-based solution. Decarbonated gas exits at the top of the absorption column with a lower CO₂ content and then routed back to the reducing gas circuit. Rich solution exits from the bottom of the CO₂ absorption column, and it is heated up in the rich/lean solution heat exchanger by transferring the heat from the hot lean solution coming from the stripping column. Then, it is sent to the top of the same stripping column.

The CO₂ is stripped off from the rich solution in the stripping column. Low pressure steam is used as heating media for CO₂ release. The required steam is generated by the sensible heat of the top gas through heat recuperator, achieving an overall energy integrated system. The CO₂ rich vapour stream is lastly cooled.

Figure 8
CO₂ Emissions Reduction Plot as function of Hydrogen use as Energy in the DR Plant. Primary axis (red line): CO₂ reduction in the DR Plant only. Secondary axis (blue line): CO₂ reduction in the BF/BOF steelworks + DR Plant.

FURTHER REDUCTION OF CO₂ EMISSIONS BY MEANS CO₂ OFF-TAKING
down and at this point, the rich CO₂ gas stream is ready for commercialization or further treatment. The lean amine solution leaves the bottom of the stripper and passes through the rich/lean solution exchanger and is then pumped back to the top of the CO₂ absorber column.

Since 1998, CO₂ gas, from the CO₂ absorption system of HYL/ENERGIRON plants, has been used as by-product by different off-takers and industries, for instance:

- food and beverage industries,
- enhanced oil recovery (EOR)
- dry ice production, among others.

For further and direct use/disposal of CO₂ and in order to offer a complete and integrated solution on this issue, currently Tenova HYL is engaged in R&D programs with associated companies looking for environmentally friendly capture and application of CO₂.

Examples:

- Biomimetic CO₂ capture and mineralization technology over a substrate to produce cement.

**Benefits:**

- Potential use of steelmaking dust/fines/sludge as seeding substrates, and alkaline sources
- CO₂ capture and disposal
- Use of CO₂ in reforming, through alternate energy sources to produce methanol and other fuel products.

In case CO₂ commercialization is viable, then the overall CO₂ emissions in a DRP + BF-BOF steelworks can be further decreased to about 1,400 kg CO₂ / tLS.
As described in the present document, the CO$_2$ emissions in an integrated steelworks can be significantly reduced by feeding High-C DRI/HBI to the Blast Furnace. Further CO$_2$ reductions can be reached if the CO$_2$ selectively removed from the DR Plant can be commercialized or used for different applications and/or if hydrogen is used as energy source to the DR Plant.

Below plot (Figure 10) shows a summary of the reduction of CO$_2$ emissions. Other variable is the DR Plant location, which associated CO$_2$ emissions, in terms of power generation, could or could not count for environmental impact.
The following analysis has been developed to compare the impact on CO₂ emissions, based on the following scenarios:

I. The typical BF-BOF integrated facility, as described above.
II. Feeding High-C DRI into the BF, based on 100% NG use
III. Feeding High-C DRI into the BF, based on the use of 35% H₂ as energy feed along with NG.
IV. Replacement of BF-BOF by DR-EAF, based on 100% NG and the use of High-C DRI in the EAF.
V. Replacement of BF-BOF by DR-EAF, based on 70% H₂ as energy feed along with NG.

For BF-BOF cases, a mix charge to the BOF of 80% Hot Metal and 20% scrap was considered. For simplicity, the mix charge in the EAF is kept at 80% Hot DRI and 20% scrap.

As indicated in Figure 11 below, the latter represents the maximum reduction of CO₂ emissions, to just 190 kgCO₂/tLS, representing only about 10% of that of the BF-BOF route. In this respect, the ENERGIRON ZR technology presents the most adequate scheme for the future of steelmaking.

For case (IV), DRI produced in the ENERGIRON ZR scheme has still High-C; >3%. For case (V), due to the very high use of H₂, %C in the DRI will be < 2.0%.

![Figure 11](image-url)

**Figure 11**
Effect of CO₂ Emissions Reduction in different steelmaking routes and use of hydrogen in the DRP
In case electric energy is generated from renewable energy sources (power is CO$_2$-neutral), feeding High-C DRI/HBI to BF, which can be only produced through the ENERGIRON ZR scheme, allows reduction of CO$_2$ emissions in about 18% with respect to the reference emissions figure of BF-BOF which is much lower than the predictive value for the standard DRI/HBI (11%). Replacing natural gas by 55% hydrogen as energy (or 80% gas volume) of reducing gas, the figure can be as low as 23% with respect to the reference emissions figure of BF-BOF.

Replacement of BF-BOF by DRP-EAF and intensive use of hydrogen in 70% as energy (or 88% gas volume) as reducing gas, using the ENERGIRON ZR scheme, will be reflected in reduction of CO$_2$ emissions in nearly 90% with respect to the reference emissions figure of BF-BOF.

The above analysis was done under certain considerations and shall be adjusted on case-by-case basis depending on the local CO$_2$ regulations and CO$_2$ emissions per kWh prevailing for each specific location.
Due to the increased need of a reliable source of metallic units for steelmaking, mainly associated to a more demanding market for high quality steel products (using raw materials with less impurities), the production methods of virgin iron units have been experiencing an important growth.

Since the start up of the first gas based DR plant in 1957 (based on the HYL fixed bed process), the direct reduction technology has now reached a stage of maturity, with reliable and simpler plant operation and very attractive economic conditions for the steel industry.

Although over 75% of the world DRI production is currently used in EAF’s near the DR plant, the advantages of using DRI are also available to non integrated steel plants which can obtain this product from merchant plants. Moreover, the use of this type of product is not exclusive for the EAF, but it can be also used to increase productivity in the blast furnace and to optimize the thermal balance in the BOF.

However, successful commercialization of DRI implies both ease in transportation and long term storage, which require that the product keeps adequate chemical and physical properties while complying with safety regulations. As reduced iron is sensitive to re-oxidation in varying degrees, diligence must be taken to prevent re-oxidation from decreasing the product metallization level. This situation should not give a wrong impression about a hazardous nature of DRI, but only to make sure that the product is properly handled, shipped and stored to avoid losses in the product quality.

Over the last years, several million tons of DRI have been shipped by truck, rail, barge and ocean-going vessel. Very few incidents involving re-oxidation and overheating have occurred, mainly because of negligence and handling of this material under extreme circumstances.

Since the issue of DRI transport has raised discussions and controversy between the steel industry and transport organizations, deep research and extensive test programs have been carried out by Tenova HYL to show that the High Carbon DRI can be transported safely.

**DRI Reactivity**

Because of its nature and structure, DRI reacts differently in many ways when compared to solid compact iron. Several inherent characteristics of DRI are: a high porosity, low density, high surface area, and low thermal conductivity, due to the spaces between metallic surfaces.

Most of the possible chemical reactions associated to the re-oxidation process are exothermic. The main re-oxidation reactions are the following:
STABILITY OF HIGH CARBON DRI

Reaction (1) is the ordinary oxidation by air, which is normally very slow at ambient temperatures in dry air. Reaction (2) is usually controlled by the reaction rate in the cathodic areas where hydrogen is produced. This reaction can be accelerated by dissolved oxygen, which depolarizes the cathodic areas and produces ferrous hydroxide by reaction (3).

The main reason for DRI sensitivity to fast re-oxidation is associated to its high surface to volume ratio (surface area). It has been determined that this surface area, directly linked to the DRI reactivity, depends on the raw material (iron ore) characteristics and on the operating conditions during reduction.

The operating conditions of the ENERGIRON (formerly HYL) Zero Reformer (ZR) process, improve the DRI stability, thus decreasing the tendency to re-oxidation. Based on a reduction temperature of approximately 1050°C, a pressure between 6 to 8 bar, methane content in the reducing gas stream higher than 20% and using H₂ rich reducing gases (H₂/CO ratio of approx. 4 - 5), the high carbon DRI produced is a material that offers a significantly decreased re-oxidation tendency, and thus the High Carbon DRI (Carbon content of up to 4.5%) has a higher stability than the typical DRI (carbon content ~ 2.5%).

The importance of stability of DRI is related to 2 aspects:

- Safety
- Storage, handling and transport

For safety, main parameters to be considered are:

1. Tendency to be re-oxidized, generating combustible gases, which may cause firing/explosions. This behavior is normally predicted through laboratory tests by:
   - Oxygen Demand Reactivity Test (ODR). This test corresponds to the determination of liters of oxygen consumed per ton of DRI per day @ 65°C.
   - Substances that in Contact with Water Emit Flammable Gases. This test is conducted to determine the propensity of the sample to generate flammable gases when into contact with water.

In this regard, the High-Carbon DRI, as per tests carried out by Chilworth Technology Ltd, UK on March, 2008, has demonstrated to be a safe material in terms of:

ODR: «negligible» l/ton/day, and Rate Generation of Flammable Gases: «0» l/hr/kg.
STABILITY OF HIGH CARBON DRI AND STORAGE

2. Aerated Powder Tests. This test is conducted to determine information on the thermal stability of solids substances at elevated temperatures, to estimate the Onset Temperature or limiting temperature for thermal activity. The higher, the more stable the DRI.

The Onset Temperature for the High-Carbon DRI showed an exotherm of 206°C to 212°C under ambient air and air saturated with water (at 25°C & 40°C), much higher than typical figure of ~140°C for standard DRI.

Storage of Cold DRI:

The freshly reduced-untreated standard DRI presents the highest risk to re-oxidation. This initial reactivity is decreased during the first hours by “natural aging” when DRI is exposed to air. When “aging” of bulk DRI in piles, only the outer layer is re-oxidized, leaving the inner portion without natural “passivation”. To handle this, most of the standard DR plants uses silos to induce formation of a thin protective layer of magnetite with a controlled inert gas atmosphere containing a small amount of oxygen, loosing metallization in some degree.

For the case of High-Carbon DRI, as per actual industrial plants operations, such «passivation» procedure is not compulsory/necessary, as demonstrated in ZR-based plants, such as 3M5 and 4M plant at Monterrey (Ternium), Suez plant in Egypt and Micromodule in Abu Dhabi, without loss of metallization.

Regarding storage, standard DRI is sensitive to direct contact with water and excessive fines content because of heat dissipation (due to re-oxidation) and sudden temperature rise, promoting formation of unstable material spots. For the case of High-C DRI, such situation has not been observed when the product is in open yard, as per facilities at Ternium.

Although High-C DRI is an stable material and can be stored in open spaces, given that it is by nature a porous material, contact with rain shall be prevented to avoid wet material being fed to EAF thus, provoking risky operations. Shedding is recommended for rainy/snowy locations.

DRI fines accumulation in confined spaces is considered as hazardous material, to be managed according to standard procedures.

High-C DRI at open yard; not screened, no subject to passivation, no monitoring for re-oxidation detection; 3M5-ZR plant at Ternium Monterrey
STABILITY OF HIGH CARBON DRI

Handling of CDRI:
The relative uniform sizing of DRI makes it well suited to high volume, high tonnage, and attendant low cost-material handling methods. Main provisions are: preventing moisture excess, minimizing fines generation during handling; i.e., free fall heights and the number of transfers should be minimized. Stockpiling with tracked, bulldozer or front end loading equipment operating to the surface of the DRI should be also minimized.

Overseas transport of DRI:
For overseas transport, special provisions shall be taken into account for both, standard and High-C DRI, since as per IMO there is no different classification and shall follow the corresponding regulations [scheduled as DRI(B)].

In-land transport of CDRI:
For standard CDRI to be loaded into truck or gondola cars, some provisions related to temperature, humidity, air draft, shall be followed.

For High-C DRI, such provisions are not applicable, as per experience of millions of tons been transported between DR plants in open gondola cars throughout Mexican country, under different weather conditions. Trucks transport is common in Egypt.

For river transport, covered barges to prevent water intake, are enough for transporting High-C DRI, as per Nucor distribution of this material through the Mississippi river for the various melt shops.
CALENDAR OF EVENTS

June 2017 - December 2017

Look for Tenova HYL at the following events:

- June 26 - 27
  AMM & WSD Steel Survival Strategies XXXII
  New York, USA

- August 30
  Annual International seminar of Steel Tech
  Kolkata, India

- October 11 - 13
  IIMA 2017 Autumn members meeting
  Dusseldorf, Germany

- November 13 - 14
  AMM 5th DRI & Mini-mills Conference
  Chicago, USA

- December 4 - 6
  Metal Bulletin 21st Middle East Iron & Steel Conference
  Dubai, UAE