USE OF CIRCAL™ HBI IN EAF STEELMAKING AT NORTH STAR STEEL TEXAS

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***Abstract**:* Circal™ Hot Briquetted Iron is a unique, zero carbon, low gangue, very high iron, low phosphorous, reduced iron product made by Cliffs and Associates Limited at Point Lisas, Trinidad and Tobago. This paper gives a brief overview of the Circal™ process and plant facility and describes the results of successful trials of Circal™ HBI in EAF steelmaking at North Star Steel Texas.

INTRODUCTION

Circal™ Hot Briquetted Iron is a unique, zero carbon, low gangue, very high iron, low phosphorous, reduced iron product made by Cliffs and Associates Limited at Point Lisas, Trinidad and Tobago. CAL is owned 82 percent by Cleveland-Cliffs Inc and 18 percent by Lurgi Metallurgie GmbH. Cleveland-Cliffs is the largest supplier of iron ore products to the North American steel industry and is developing a significant ferrous metallics business. Subsidiaries of the Company manage and hold equity interests in iron ore mines in Michigan, Minnesota and Eastern Canada. Cliffs has a major iron ore reserve position in the United States and is a substantial iron ore merchant.

North Star Steel in Beaumont, Texas, a division of Cargill Steel, is an ISO 9002 and A2LA Certified EAF-based steelmaker. Mill products include wire rod used to make a wide range of consumer products from nails to high quality tire chord wire, as well as coiled rebar for construction applications. The plant can melt 650,000 tons per year and roll 540,000 tons per year.

This paper describes (1) the process used by Cliffs and Associates to produce HBI at Point Lisas, Trinidad and Tobago, (2) the properties of that unique HBI, and (3) the use of the first commercially produced Circal™ HBI in successful trials at North Steel, Beaumont, Texas.

Production and Properties of Circal™ HBI

Circal™ HBI is produced at the Cliffs and Associates (CAL) direct reduction facility at Point Lisas, Trinidad and Tobago. The technology used at Point Lisas is the Circored® Process developed by Lurgi Metallurgie GmbH. This process is described in detail in another paper presented at this conference, but a short description of the process is given below to explain the uniqueness of Circal™ HBI.

The Circored® process is a fluid bed process that uses only hydrogen to reduce iron ore fines (the fines used by CAL are of Brazilian Carajas ore). The ore is sized to -1 mm + 0.1 mm. Reduction takes place at relatively low pressure (4 bars) and temperature (630°C). Upon completion of the reduction step, the fines are briquetted.

The process flow diagram is shown in Figure 1.

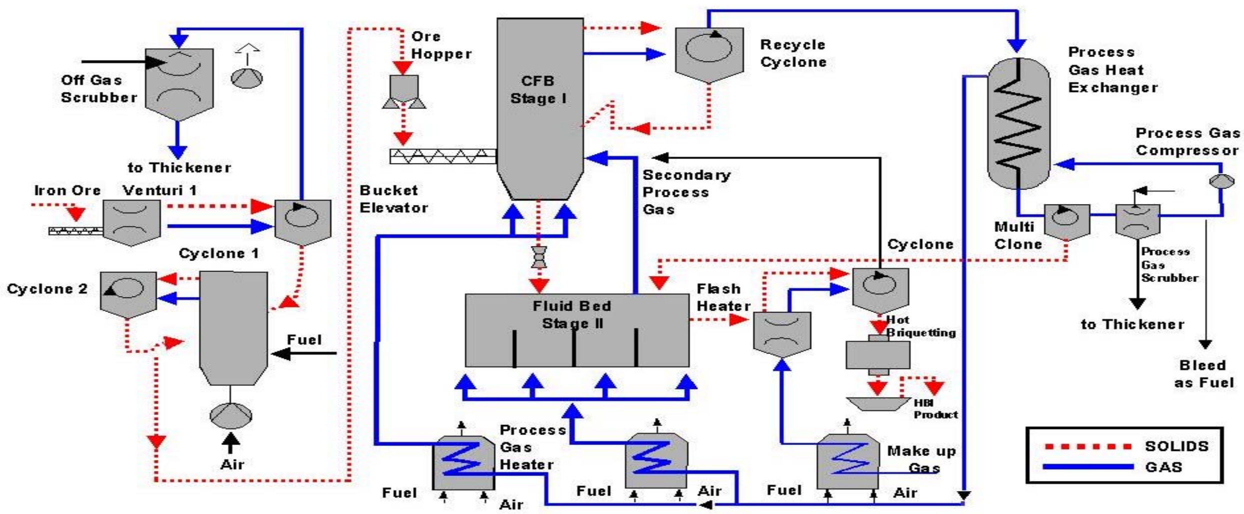

Figure 1. Circored® Process Flow Diagram

As the only reductant is hydrogen, the final briquetted iron product contains no carbon at all. The Brazilian Carajas ore used by CAL is very pure, and the resulting HBI is very high iron, has high metallization and contains very low levels of gangue and phosphorous. The briquette size is nominally 31 x 58 x 137 mm. The chemistry of the briquettes consumed in the first trial at North Star Steel Texas is given in Table 1.

Constituent	Wt %	Constituent	Wt %
Total Fe	94.71	SiO_2	0.90
Metallic Iron	89.65	Al_2O_3	0.47
% Metallization	94.66	MnO	0.14
FeO (calc.)	6.51	CaO	0.02
P	0.019	Na_2O	<0.01
S	0.010	K_2O	0.01

Table 1. Circal™ HBI Chemical Analysis

The First Trial at North Star Steel Texas

The purpose of the trial at North Star Steel in Beaumont, Texas (NSST) was to demonstrate that Circal™ hot-briquetted iron (HBI) could be used successfully in an electric arc furnace (EAF). Circal™ does not contain carbon, and some EAF operators feared that without internal carbon to reduce the contained FeO, yield (charge tons to steel tons) for the Circal™ HBI would be lower than that of other scrap substitutes which contained carbon. Furthermore, there was concern on the part of some that a no-carbon reduced iron product would stick to the furnace walls and form "ferrobergs" (clumps of fused briquettes), impeding operations.

About 1300 metric tons (tonnes) of Circal™ were shipped to Beaumont. 1100 tonnes were used at Beaumont, and about 150 tonnes were shipped to Beaumont's sister operation in Delta, Ohio. As can be seen in Figure 2 below, the briquettes arrived in Beaumont in excellent condition.

Figure 2. Circal HBI in the stockpile at NSST

The NSST melt shop has one EAF. The furnace capacity is about 120 tons, and it is powered by a 66 MVA transformer. The furnace has a shell diameter of 22 feet and taps 125-ton heats, leaving a hot heel of about 10 tons. Tap-to-tap times on the order of 80 minutes are typical. The furnace operation also uses an oxygen door lance, a door burner, and three oxy-fuel burners located around the circumference of the furnace.

NSST has a three-bucket charge practice. The first two are full charges and the third contains about half the weight of the first bucket. Charge carbon is dropped into the furnace after the first bucket. Fluxes are added in the bucket or through the roof. The second bucket is added after the first charge is mostly melted, from 5 to 15 minutes into the heat. The process is repeated for the third charge. During the melting operation, carbon is injected through the door lance to create and maintain a foamy slag.

The Trial

The amount of Circal™ HBI available for the first trial at Beaumont was relatively small. The trial was designed to answer four questions:

1) Can HBI having no carbon be used successfully in significant amounts in a commercial carbon steel EAF melt shop?
2) Will zero carbon HBI cause melting problems, such a "ferrobergs"?
3) Will zero carbon HBI adversely impact yield?
4) What is the effect of charge position (distribution among charge buckets) on the use of zero carbon HBI?

The Circal™ HBI available was sufficient for about 20 heats of steel over a two day period. It was decided to divide the trial into four sets of five heats each. HBI was used as 14 to 20 percent of the metallic charge in four configurations as shown in Table 2.

Test Run #	**Circal™ %**	**P&S %**	**#2 Shred %**	**#2 HM %**	**CPI %**	**Aim Metallic Charge wt., lbs.**
1	14.3	30.4	21.4	19.6	14.3	280,000
2	14.3	30.4	21.4	19.6	14.3	280,000
3	20.0	28.9	21.4	19.6	10.0	280,000
4	20.4	31.4	28.6	19.6	0.0	280,000

Note: P&S = plate & structural scrap; #2 Shred = #2 shredded scrap; #2HM = #2 heavy melting scrap; CPI = cold pig iron

Table 2: Aim Charge Make-up for Circal™ HBI Trial Test Runs

The difference between Run 1 and Run 2 was that the HBI was evenly divided between the first and second charge buckets in Run 1, while the all the HBI was charged in the second bucket in Run 2. In Run 3, a high percentage of HBI was charged with a smaller amount of pig iron. In Run 4, the pig iron was omitted. Using the different charge practices it was possible to obtain a reasonable amount of data to answer the concerns posed above about the melting characteristics of zero carbon HBI.

In all cases, the HBI was placed in the bucket near the bottom of the bucket and a layer below the pig iron. This position in the bucket took advantage of the density of the HBI to compact the lighter scrap placed lower in the charge bucket (light scrap is normally placed in the bottom of the bucket to protect the furnace hearth refractory when the charge is dropped into the furnace).

Melting Results

The entire trial was closely monitored. No attempt was made during the runs to optimize the blowing practice to maximize yield. Visual observation showed that the Circal™ HBI briquettes melted without problems during the furnace operation. This was true for all 20 of the trial heats. Operator comments confirmed that observation. Melting went smoothly. No problems were encountered during handling of the briquettes in the scrap yard, bucket loading station or furnace. No sticking of briquettes was observed in the furnace, and no "ferrobergs" were formed, even when 40,000 lbs. of the HBI were charged as one layer in the second bucket during each of the five heats of run 2.

The average operating data, slag chemistry averages, and metal chemistry averages are shown in the following Tables 3, 4 and 5, respectively.

Test Run #	**KWh per charge ton**	**Power on, min.**	**Injected Oxygen, scf per chg ton**	**Burner NG, scf / chg ton**	**Tap Temp Deg. F**	**Tap O ppm**	**Charge Wt., Tons**
1	308.5	70.2	556.7	1189.9	2990.4	842	147.73
2	298.1	60.0	726.3	1192.8	2983.0	943	143.98
3	295.0	61.0	672.9	1324.8	3007.0	1133	146.75
4	287.6	63.8	800.8	1300.7	2995.6	1220	145.03

Note: scf = standard cubic feet; NG = natural gas; ppm = parts per million

Table 3. Average Operating Data For Circal™ Trial Heats

Test Run #	V-Ratio as CaO/SiO_2	Steel O ppm	Fe %	Mn %	P %	S %	Ca %	Si %	Mg %
1	1.89	842	35.3	8.3	0.79	0.068	24.89	13.20	6.32
2	1.78	943	39.6	7.6	0.78	0.088	21.96	12.35	6.11
3	1.72	1133	42.3	6.8	0.65	0.090	21.41	12.24	5.87
4	1.87	1220	46.5	6.3	0.44	0.107	18.36	9.86	6.54

Note: Although shown as elemental, wt. %s given in the table are for the oxides of the metals shown.

Table 4: Average Slag Analysis by Trial Run

Test Run #	O ppm	C %	Mn %	Si %	Al %	Residuals %	N ppm	P %	S %
1	842	0.036	0.084	0.000	0.16	0.26	53	0.011	0.030
2	943	0.027	0.062	0.002	0.17	0.25	67	0.012	0.034
3	1133	0.024	0.053	0.002	0.16	0.28	58	0.011	0.031
4	1220	0.012	0.046	0.000	0.13	0.28	69 *	0.007	0.032

* Excludes a reading of 180 ppm believed to be erroneous

Table 5: Average Steel Chemistry Analysis – Final EAF Metal Sample

Observations from the First Trial

Trends noted during the trial included:

1) The trial demonstrated that even though Circal™ HBI contains no carbon, recovery of Fe from the contained FeO is achieved if sufficient carbon is supplied to the furnace in other forms.

2) No clumping or sticking (no "ferrobergs") of the Circal™ HBI occurred during the trial, even when 40,000 lbs. of HBI were charged as a single layer.

3) Use of HBI in the charge improved charge density and resulted in a decrease of the time between the first and second bucket charge.

4) Circal™ briquettes handled well during shipping, transfer and charging.

5) Use of HBI produced a significant decrease in residual levels in the resulting steel.

6) Phosphorous removal from the bath was very good.

7) Sulfur removal during the trial was normal.

8) Despite the fact that no attempt was made to optimize blowing practice or charge carbon, relatively high recovery of the Fe in FeO of the Circal™ HBI was achieved. Increase in slag FeO attributable to HBI was minimal.

9) No difficulties occurred during casting due to steel chemistry.

Subsequent Experience at North Star Steel Texas

In June of 2001, NSST ran two sets of low residual heats using Circal™ in the charge. Seven heats were run on June 8th, 2001 and another four heats were run on June 25th, 2001. There was no problem meeting the residual requirements in the steel due to the large amount of pig iron and HBI used. For these heats the melting practice was adjusted by delaying the initiation of oxygen injection, resulting in higher electrical energy use than was observed in the first Circal™ trial.

In the first series of heats there were some problems achieving the low nitrogen specification (50 ppm) on the first two heats and in maintaining good foamy slag during the run. Adjustments were made before the second series, and the nitrogen specification was met on all four heats in the series and slag foaming was improved. The low residual requirement was met on all heats in both series. Circal™ HBI averaged 22% of the metallic charge during the two runs.

Conclusion

The trials at North Star Steel Texas have demonstrated that Circal™ HBI with its excellent mechanical and physical properties, unique combination of zero carbon content, high total iron, low phosphorus and low gangue can be used to advantage in a commercial EAF operation even as a partial replacement for more costly pig iron. No "ferrobergs" were observed. As with any new charge material, some adjustments in operating practice are required to optimize the use of no carbon HBI. Very good recovery of the Fe from HBI FeO was achieved, and slag foaming was satisfactory with slight modification to charge practice.

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