HIGH PRODUCTIVITY AND COKE RATE REDUCTION AT SIDERAR BLAST FURNACE #2(1)

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Siderar is the largest steel company in Argentina and is located in San Nicolás, in the Province of Buenos Aires. It is a fully integrated producer of hot and cold rolled strip and products of higher value added such as coated products: galvanized, electro-galvanized, pre-painted, formed sheets for road construction and tinplate. Presently, Siderar operates a blast furnace to meet the hot metal needs.
Increasing productivity was a goal of Siderar BF2 ,and was achieved by increasing blast enrichment as the level of natural gas injection was increased.

The combined injection of natural gas and oxygen was performed from the very beginning of #2 blast furnace start up(1) , also following these targets:

1. Increased production, meeting the BOF process requirements.

2. Balanced coke plant production, thus preventing coke import.

KEY WORDS : blast furnace, productivity, coke rate.

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Blast Furnace # 2 Technical Description.

The main characteristics of blast furnace # 2 are shown in Table I.

Table I – Main Characteristics of BF #2

Start Up Date	September 1995
Hearth Diameter (m/ft)	10.4 / 34
Inner Volume (m^3/cuft)	2421 / 85510
Working Volume (m^3/cuft)	2134 / 75373
Number of Tuyeres	27
Taphole	2 (west – south)
Hot Stoves	3 (Mc Kee HW)
Charging Equipment	Skip
Injection	Natural Gas
Cooling System	Plates
Tuyeres Type	2 – chamber
Slag Treatment	INBA System
Gas Cleaning	Bischoff System

Basic considerations about productivity.

In a blast furnace, productivity can be expressed as the relation between the generated reducing gases flow rate and the gas consumption per produced hot metal ton.

Productivity ~ gas flow rate / specific gas volume

Thus, in order to increase productivity it is necessary to raise the gas flow rate or reduce the specific gas volume.

Gas flow rate: it is the quantity of gases which go through a packed bed, represented by Ergun's Equation :

$\Delta P / H \sim K \cdot V^2 \cdot \rho$

where :

$\Delta P / H$: pressure drop
K : burden permeability index
V : shaft gas velocity
ρ : gas density

Burden permeability is a physical properties function of the raw materials such as particle mean size, porosity, shape factor, and fines generation during degradation at the temperatures reached in the blast furnace stack as well.

Gas density is associated with the bosh generated gases composition according to the type of substitute fuel injected at the tuyeres level. The resulting gas density is inversely proportional to their H2 content$^{(2)}$.

Specific gas volume : the injection of O2 to the air blast (oxygen blast enrichment) reduces the specific gas flow causing a reduction of the top temperature and an increase of the adiabatic flame temperature (RAFT) in the tuyeres.
These effects are compensated by the injection of substitute fuels. Therefore, the combined injection of oxygen and fuel at tuyeres level is a valid alternative to increase productivity and reduce the coke rate at the same time.

Taking into account the factors which maximize a blast furnace's productivity, the following items were addressed:

- Burden quality
- Burden distribution
- Combined Injection of Natural Gas and Oxygen

Burden.

The composition of the burden used at Siderar BF2 since the beginning of its current campaign is shown in Figure 1.

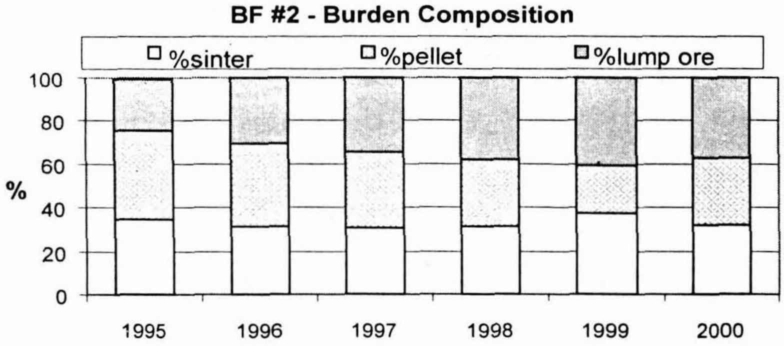


Figure 1 Burden composition

Sinter: The percentage in the blast furnace burden is limited to 30 – 40 %, depending on the productive level of the blast furnace. This value represents the maximum production capacity of the sinter plant.

The fines generated during its handling and transportation are eliminated by means of screens installed at the blast furnace and the fines generated inside the blast furnace by degradation during low temperature reduction are controlled through the RDI (degradation reduction index) test.

As regards its chemical composition, the percentage of MgO is controlled, fixing it on the basis of MgO requirements in blast furnace slag and the basicity index, a parameter linked to sinter production.

Sinter quality requirements related to its physical resistance and degradation inside the blast furnace are shown in Table II.

Table II : Sinter Quality

CaO/SiO_2	2.10 ± 0.07
MgO (%)	1.80 ± 0.20
SiO_2 (%)	5.75 ± 0.30
FeO (%)	< 8.00
P (%)	< 0.050
Na2O+K2O (%)	< 0.090
ZnO (%)	< 0.015
Shatter Index (%)	> 85.0
RDI (%)	< 20.0

Lump Ore: Lump ore maximization in the blast furnace burden has been a permanent goal for Siderar due to the strong economic impact it represents vis-a-vis the utilization of imported pellet (3). Its use in BF2 has increased progressively since the beginning of the campaign (20 %) reaching a participation of 40 % during the year 2000. It is worth mentioning now, and as explained later, that its high participation in the burden did not represent any obstacle to reaching productivity levels of 2.8 t / d m^3 W.V (2.5 t / d m^3 I.V).
Lump quality requirements are shown in Table III .

Table III : Lump Ore Quality

Parameter	Value
% > 1 ½ "	< 5
% < ¼ "	< 5
RDI (%)	< 20
Decrepitation (% < 6.35 mm)	< 4
IT (%)	> 85
IA (%)	< 10
Reducibility (%)	> 50

Pellet: Burden participation of this raw material imported from Brazil has been decreasing as the burden percentage of lump ore increased.
The physical quality requirements of pellet are shown in Table IV.

Table IV : Pellet Quality

Parameter	Value
% < 5 mm	< 5
% > 18 mm	< 5
IT (%)	> 93
IA (%)	< 6.5
RDI (%)	< 10

Pellet, as lump ore, is screened before entering the BF.

Metallurgical Coke.

Coke plays a fundamental role in the blast furnace process.
Cold and hot properties(see Table V) should be controlled in order to improve the gases distribution in the stack, and percolation of liquids in the hearth (dead man permeability)as well. In Figure 2 we can see the evolution of Siderar's coke mesh size since the beginning of the campaign, in which the metallurgic coke size was gradually increased with the intention of improving permeability in the center of the furnace, increasing small coke generation at the same time. The latter is a necessary resource to meet the fuel requirements in the wall at high fuel injection rates.

Table V : Metallurgical Coke Quality

Parameter	Value
Stability	> 60
Hardness	> 66
% > 75 mm	14 max
Ash content (%)	< 8
CSR (%)	> 68

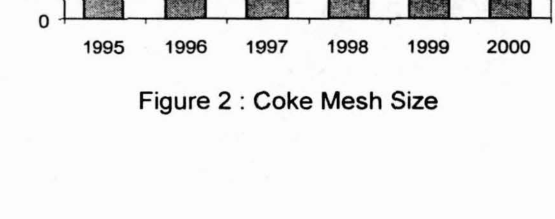


Figure 2 : Coke Mesh Size

Burden Distribution : the burden distribution control philosophy implemented in Siderar BF2 in order to meet the high productivity requirements is based on the following :

- Ensuring a stable burden descent. The current practice consists in spiralling coke and ore, ensuring a central column with a limited area which contains 100 % of the coke.
- Adjusting the gases flow in the wall to avoid high heat load without generating inactive zones. The goal is to work with 35 % of the coke in the wall.
- To achieve a good solid-gas contact to guarantee an efficiency which minimizes fuel consumption.

In Figure 3 we can see the efficiency profile of CO (etaCO) characteristic of a high productivity run at Siderar BF2 .

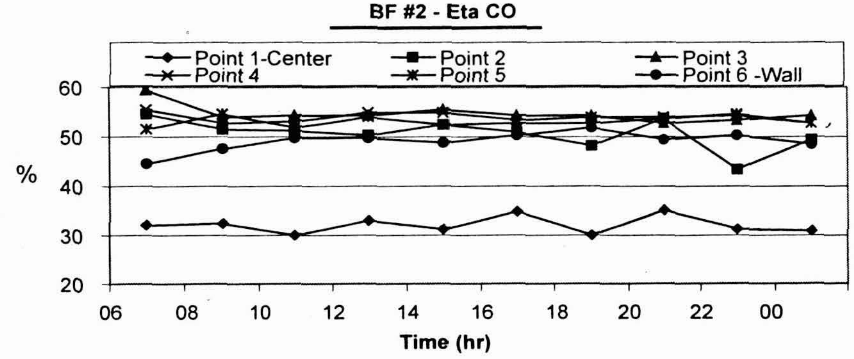
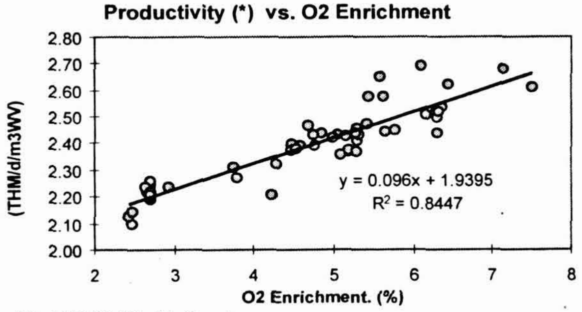


Figure 3 : Eta CO Radial Profile

Combined Injection of Natural Gas and Oxygen : the combined injection of natural gas and oxygen has been widely used by Siderar [(4)] and other integrated plants [(5)] to increase productivity, reducing coke rate at the same time. The evolution of productivity versus oxygen enrichment is presented in Figure 4.



(*) Corret to 1150 °C, 25 g/Nm3 and no scrap

Figure 4 : Productivity vs Oxygen Enrichment

Blast oxygen enrichment raises the adiabatic flame temperature (RAFT), while natural gas moderates it, because it requires energy for its cracking.
In Figure 5 we can see the evolution of RAFT versus natural gas injection rate. It is worth mentioning that BF2 operated in a stable way at temperatures lower than 2000 °C.

The primary reason for this operational condition is explained by the presence of high concentrations of hydrogen in the bosh gases (Figure 6), which affect the thermal and chemical balance of the blast furnace.

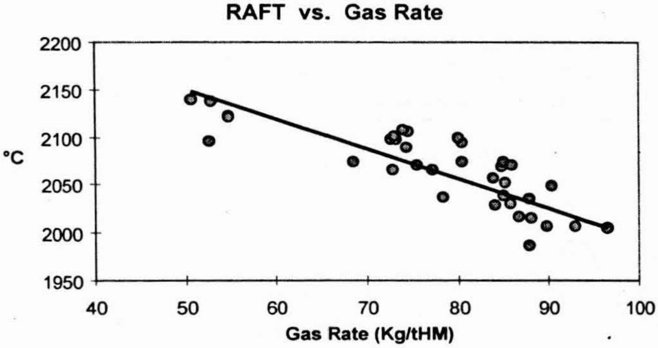


Figure 5 : Flame temperature (RAFT).

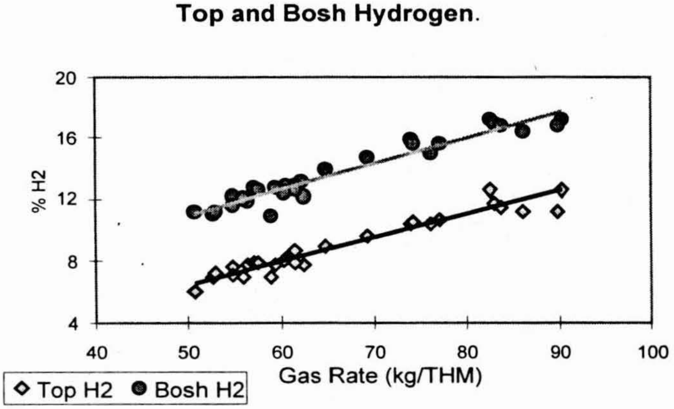


Figure 6 : Bosh H2 vs Natural Gas Rate

The high hydrogen concentrations enable the minimization of the solution loss reaction as indicated in Figure 7.

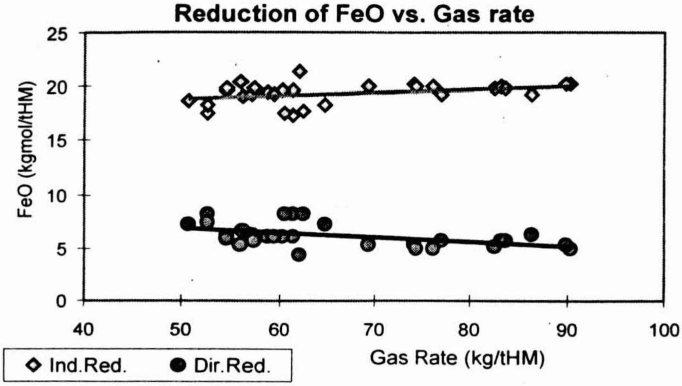


Figure 7 : Solution loss reaction.

Replacement Rate.

The replacement ratio for a supplemental fuel is defined as the kilograms of coke that are displaced as a result of the injection of a kilogram of fuel. Higher replacement ratios are achieved with natural gas than with other supplemental fuels because its higher hydrogen content increases the amount of indirect reduction that takes place and so decreases the extent of the highly endothermic solution loss reaction.

The achieved replacement of coke by natural gas in BF2 was of 1.2 kg coke / kg natural gas as shown in Figure 8. The obtained replacement enabled a reduction in the import of coke during the highest productivity periods.

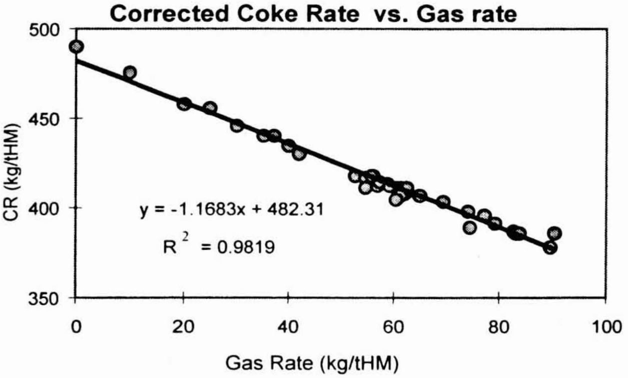


Figure 8 : Replacement Rate

Hot metal quality.

The high natural gas injection rates achieved in BF2 had a noticeable impact on the content and standard deviation of silicon in the hot metal as shown in Figures 9 and 10.

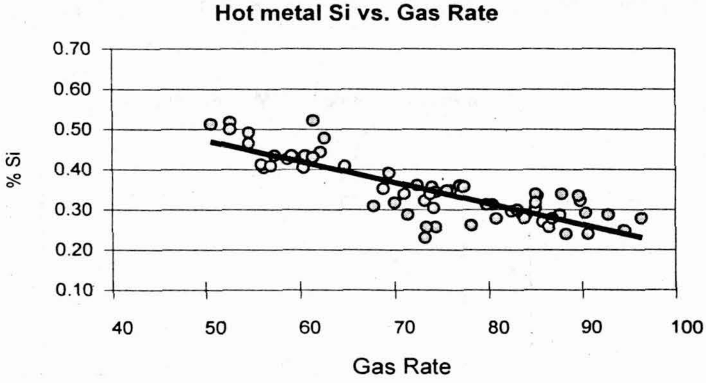


Figure 9 : % Si vs Natural Gas Rate

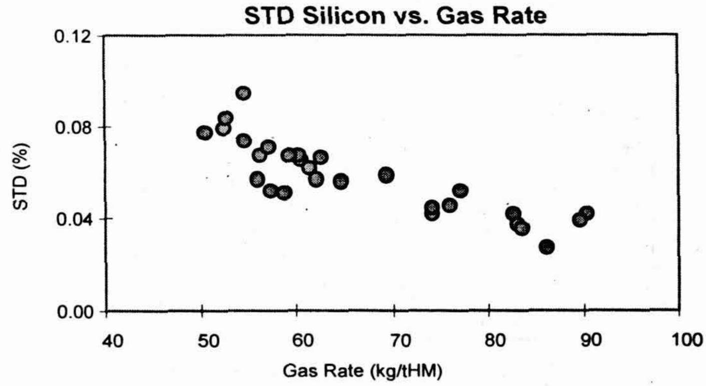


Figure 10 : STD Si vs Natural Gas Rate

At high productivities and natural gas injection rates, the ore-coke relation increases and consequently the cohesive area is moved downwards, generating a lower volume for the transfer of silicon to the hot metal.

The low standard deviation of silicon is related to the high hydrogen concentrations in the bosh gases, which improve the burden descent.

Results.

Productivity increase and coke rate reduction have been Siderar BF2's permanent challenges since the beginning of its campaign (Figures 11 and 12).
During the year 2000, the maximum annual average productivity of 2.81 t/d.m3WV (2.46 t/d.m3 IV) was achieved. Likewise, natural gas injection enabled the balance of the coke oven production resulting in a consumption of 375 kg coke/t HM .

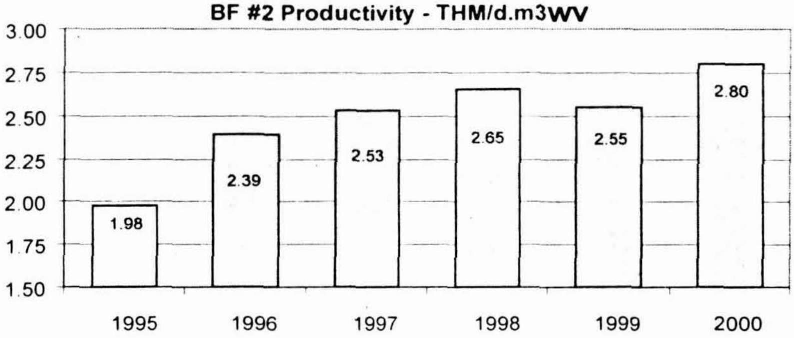


Figure 11 : Blast Furnace Productivity.

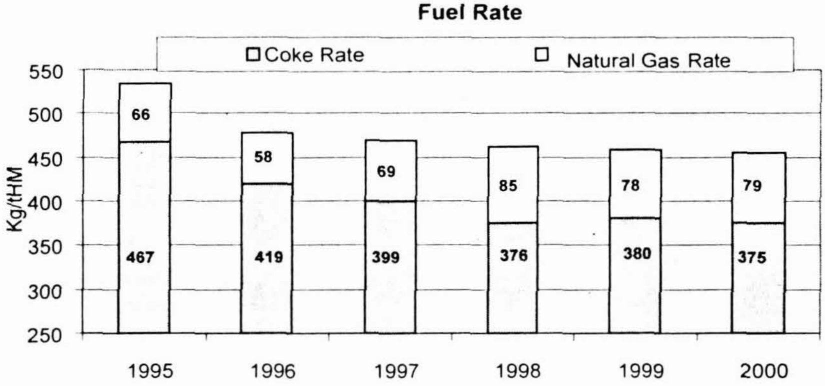


Figure 12 : Fuel Rate.

In Table VI representative operation periods are shown where higher than previously presented annual average performances were achieved.
These values represent Blast Furnace #2 current objectives for the next years of the campaign.

Table VI : High Performance Periods of Siderar BF 2

Period	Productivity THM/d.m3WV	Coke Rate kg/THM
March 2000	3.04	360
November 2000	2.94	363

Conclusion.

During the present campaign of the Blast Furnace #2 our objectives were to maximize as much as possible the charge of lump ore in the burden and the use of natural gas while not reducing the Blast Furnace productivity, nor increasing the Fuel Rate, and maintaining a stable pig iron quality to meet the Steel Shop requirements.

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