18 MONTHS OF CHARCOAL FINES' INJECTION INTO GUSA NORDESTE'S BLAST FURNACES[1]

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Abstract
Ferroeste Group, with a view to reducing energy demand and environmental impact in its operations, took a decision to implement the injection of pulverised charcoal (PCI) through the tuyeres of its blast furnaces at Gusa Nordeste's iron works, located in the town of Açailândia, Maranhão State. The commissioning of the plant took place in October 2006, whereby charcoal fines were injected into the site's three blast furnaces, after a 7 month lead time to build, erect and install the plant. The main characteristics of the blast furnaces are: internal volume: 155m³ (Blast Furnace no. I), 163m³ (Blast Furnaces no. II and III), with average productivity in excess of 2.0 t / d / m³, intermittent tapping and 100% lump iron ore as metallic charge. Consistent results have been observed during the first 18 months of operation of the plant, such as injection rates of 50 to 60 kg / thm and replacement ratio of 1:1 achieved without oxygen enrichment in the hot blast. Amongst the characteristics of the installation, we have: complete reutilization of the charcoal fines generated at the screening process, a unit which is compact and safe to run, operation through a supervisory system, utilization of exhaust gases generated at the glendons for drying of the charcoal at the mill and potential for utilizing fines which captured via the air cleaning systems in the future. The technical paper shall discourse on the charcoal injection unit, operational data prior and after injection took place, financial return generated by the installation and the handling of specific situations which have arisen during the first 18 months of operation.
Key words: Blast furnace; Injection; PCI; Fuel and charcoal.

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INTRODUCTION

An industrial unit operating in the domestic and / or international market, concentrates its efforts so that it may become competitive in items such as: reduction in fuel consumption, flexibility in its energy matrix, productivity improvement, addition of value to its products, stability in the physical and chemical quality of the product and delivering on customer commitments. All these factors must be achieved in-line with the environmental legislation in force.

The ironmaking sector in Brazil produced in 2007 35.6 million tons of this product. The market is divided into two distinct groups: integrated steelworks and independent producers. In 2007, the respective participation of production of pig iron from these two groups was: 25.9 million tons via integrated steelworks (72.9%), and 9.6 million tons via independent pig iron producers (27.1%).

This technical paper addresses the second group (independent producers), who produce pig iron in blast furnaces, intended mainly as raw material for the steel mills (steel production) and foundries (castings). The technology presented aims at injecting charcoal fines into these blast furnaces as an auxiliary fuel, adapted to the existing operational and technical conditions of the plants.

The independent pig iron producers in Brazil amount to a total of 150 mini blast furnaces, ranging from 100 to 500 tons of hot metal (thm) / day / furnace, with installed capacity of about 1.1 million ton a month.

Out of the 9.6 million tons produced in 2007 in Brazil by the independent producers, the division per geographical areas was as follows: Southeast region: 5.5 million tons per year (mtpy); Northern Region: 3.6 mtpy; Others: 0.5 mtpy.

The total energy demand in charcoal charged blast furnaces without injection of auxiliary fuel is in the region of 700 kg raw charcoal / thm produced. Inherent in this material, there is around 80-100 kg of charcoal with grain size distribution below 6 mm (product of the screening process). This material is referred to as unprepared charcoal fines ("*moinha"*), and it is usually intended for sale to third parties (cement companies, brick factories,...), not being used as part of the charge through the top of the blast furnace, as this would result a reduction of the permeability of the process gas which runs in counter current with respect to the column of material to be reduced (iron oxide to metal iron) which in turn would cause a loss of productivity and increase in the energy consumption of the process, clearly not desirable.

The Ferroeste Group, owner of the Gusa Nordeste plant located at in the town of Açailandia/MA, decided to implement the technology of auxiliary fuel injection through the tuyeres of their three blast furnaces (see Table 01) with production capacity of 30.000 thm/month. The raw material to be used in the first phase of implementation (Phase 1) will be the residual material generated from the screening of the charcoal, also called 'unprepared charcoal fines' (*"moinha"*). The unprepared charcoal fines must first be altered to meet certain requirements with respect to: grain size distribution, humidity and chemical composition, in order to be capable to be injected in the front area of the tuyeres (race-way) and to have optimal combustion conditions. The pig iron produced by the blast furnaces at Gusa Nordeste plant is channelled to the export market, meeting the technical specification of the steel-mills (Si content between 0.2% to 0.5%).

The implementation of the technology was planned to happen in two different phases as follows: Phase 1, with target injection rates between 50 and 60 kg of charcoal fines/thm without enrichment of hot blast with oxygen, and Phase 2, with the possibility of reaching rates up to 120 kg of charcoal fines/thm. Phase 2 will require the thermo-dynamic aid of oxygen enrichment of the hot blast to assure combustion of the fines. The charcoal fines act initially as a refrigerant in the front area of the tuyeres, altering its quality into a fuel after it is burnt.

The injection of auxiliary fuel in the blast furnaces, in this case of charcoal fines, will reduce the requirement of lump charcoal via the top of the furnace in the order of 10% in Phase 1 and up to 20% in Phase 2. The injection of charcoal fines during Phase 1 represents a saving of around 3,000 hectares of reforested land, in order to supply the demand of charcoal in the plant (energy self-sufficiency).

IMPLEMENTATION SCHEDULE

The civil works began in February 2006, and the commissioning in Blast Furnace no. 3 and Blast Furnace no. 2 occurring in September 2006, and Blast Furance no. 1 in October 2006.

The target schedule of 7 months for full implementation was successfully met (see appendix 07).

As part of the installation, we highlight: electric substation, grounding, metallic structure including process silo, civil foundations for the mill and fans, construction of control building including control panel room and compressor room, adaptation of the tuyeres to receive the injection lances, positioning of the liquid N_2 tank and respective vaporizers, connection with the duct for the combustion gases at the outlet of the glendons, conveying pipework from the pneumatic injection systems to the lances.

GENERAL DETAILS ABOUT THE CHARCOAL FINES INJECTION INSTALLATION (PCI)

Mill by BTS, of pendulum roll type, with capacity of 5.3 t of charcoal fines/h, with rotary feeder, ejector of impurities, 100 CV motor and dynamic classifier (see Picture 01).

Cyclone for collection of charcoal fines, simple type with 1 stage, with external insulation of rock wool and aluminium sheets, rotary valve at its discharge and relief valve for over pressure.

Bag filter, with filtration area of 306 m^2, 204 anti-static polyester bags, with external insulation of rock wool and aluminium sheets, rotary valve at its discharge and temperature sensor for thermal control of the drying process.

Three main fans, installed between the glendons and the mill (40CV) for conveying of this process gas, between the mill and the cyclone (75CV) for conveying of gas and prepared charcoal fines, and between the cyclone and the bag filters (40CV) for conveying of the pre-cleansed process gas.

Automated air blending system between the atmospheric air and the burnt gas originated from the glendons carried out through shutter type valves driven by pneumatic actuators, in function of the target temperature at the inlet of the mill (drying process).

Steel process silo, with total internal volume of 165 m^3, and 120 m^3 of useful capacity, cylindrical body, conical mass flow discharge, slide gate valve and possibility for manual discharge to drain the silo. Storage capacity of about 60 tons of fines.

Pneumatic injectors by Clyde Materials Handling, one for each blast furnace, with injection capacity of 2.4 t of charcoal fines /h each, operating in an automatic and continuous manner, through a Lock Vessel and Dispensing Vessel arrangement.

Material discharge via a volumetric Rotofeed® feeder. System operates in a loss-in-weight mode, achieving instantaneous mass injection rate +/- 2% from the set point. Working pressure in the region of 3 bar(g), with high level probe in the Lock Vessel and low level probe in the Dispensing Vessel, with pressure transmitters. Spheri Valves® used at the silo outlet, vessel inlets and for venting purposes (see Picture 02).

Three air compressors with dryer included, two of which in continuous operation and a third unit in stand-by mode. Air flow of 610 m^3/h/each, with operating pressure of 6-7 bar(g) with in-line air filter.

Individual charcoal injection lances per tuyere, with removable tip, manufactured in stainless steel, ¾" spherical valve for insulation purposes and internal diameter of 13.8 mm.

Three static "Splitters", two of which with one inlet and 12 outlets and one of with one inlet and ten outlets.

Gas panel, with control via PLC, for N_2.

Supervisory system, with Scada ellipse, trend screens, alarms, emission report, mathematical calculations, interlocks through PLC.

REAL OPERATION DATA IN THE "START-UP" PCI / GUSA NORDESTE PLANT

Commissioning of charcoal injection plant (PCI) took place in October 2006 in Blast Furnace no. 3, with minimum feed rates, in the order of 300 kg / hour (bottom of the equipment's scale), which gives a value of 22 kg of fines / thm.

The injection was made into the 10 tuyeres simultaneously, without altering the charge of the furnace. One day after continuous injection, it was observed that the furnace's operating temperature started go up, inferred through the temperature of the hot metal tapped, chemical composition and visual characteristics of the material (by the supervisors' experience), after which period a charge adaptation program commenced as a result of the thermal response of the process.

The evolution of the injection rate took place with preparations of the charge, in other words, the metallic load through the top of the furnace was altered and after a number of charges, the injection rate of charcoal fines was increased.

The increase in the rate of fines injection followed a programme predefined with the operators of the furnace. The thermal behaviour of the furnace was very positive, responding to the alterations made (see appendices: 01, 02, 03 and 04).

Note: the demand of industrial gases was within the forecasted range for the installation; the specific consumption of nitrogen reached about 1 Nm^3/thm. The consumption points are: fluidization of the fines in the process silo in a continuous manner and purges in case of emergency/safety (ignition of the charcoal) in an intermittent manner.

CONTINUOUS IMPROVEMENT IN THE INSTALLATION

a) Installation of a retractable cover for the bag filters:

The bag filter suffers, in its upper part, the action of the rain mainly against the inspection doors. These doors possess a rubber seal that suffer with the natural elements, by allowing an undesirable intake of water into inner part of the filter if they happen to get damaged or be badly fit. The plant, pre-empting this possibility, built a mobile roof over the filter. This construction took into consideration the need for the inspectors to change the bags at maintenance intervals.

b) Adiabatic cooler for the compressor room:

The compressor room, originally planned to be continuously pressurized, with air blown through 02 extractor fans EP/53, with flow rates of 7,500 m^3/h/each at 5 mmCA, and via an outlet of the hot gas from the motors in thermal insulated exhausting hoods. It was observed that in certain occasions, the temperature of the motor inside the room exceeded 52 °C causing the operation of the compressor to stop (disarming it by high temperature).

In order to overcome this, an adiabatic cooler (BRASFAIBER) was installed, that operates with an air humidifying feature which lowers the temperature by 10ºC, which not only prevents the system from disarming due to the high temperature, it also minimises the entry of airborne dust into the room.

c) Adaptation of the lances in the tuyeres:

In order to reduce the leakage of gas between the lance and its supporting piece, and to facilitate its replacement during overhauls, a new apparatus was designed for such a purpose. The result was positive, minimising the gas leak and making it easier to change. The original piece was welded, whilst the new piece is flanged. All the tuyeres ducts have been adapted in this manner.

d) Change of position of the variable frequency driver:

Initially, the variable frequency drivers (VFDs) were fitted inside the electric panels. Every time the VFDs parameters had to be verified or reprogrammed, the control panel door had to be opened. The HMI (Human-Machine Interface) of the inverter was transferred and fitted on the panel's door, externally faced. As a result, it became possible to visualise the values displayed by the VFD, such as the electric current in Amps, which can now be easily observed by the maintenance and operational staff.

This improved the safety of the operation, as observations and alterations to the VFD's settings no longer require the electric panel to be opened.

e) Installation of charcoal fines samples' collection points at the outlet of the bag filter and process silo:

Initially, the collection and control point of the charcoal fines' sample was located after the rotary valve fitted at the outlet of the cyclone. In order to improve the knowledge of the product's characteristics, additional sample collection points were installed, after the rotary valve of the bag filters and process silo.

These new sampling points aid in the analysis of the influence of the quality of the charcoal fines with respect to the operational performance of the furnace, in terms of grain size distribution and humidity requirement (see Table 02).

f) On-line calculation of the TTF (Theoretical Temperature of the Flame):

Initially, the supervisory system required that the humidity of the air – in g/Nm^3 – be inputted manually. The value was obtained from the result of the room temperature and the relative humidity of the air. The operator with the value of the humidity of the air in grams of H_2O vapor/Nm^3 air, calculated the TTF in the interval of 1x/hour.

As this variable is important to determine normal conditions so that the burning of the fines can occur, it was searched and eventually found an instrument to carry out this function automatically. The equipment transmits on-line a 4-20mA signal of the humidity of the air (g/Nm^3), that feeds the supervisory system automatically. With the TTF value being provided continuously, it became more effective to follow this up by the operators. (see Appendices: 05 and 06).

The typical value at the plant is a TTF above 1,750°C, in order to have appropriate conditions of burning for the fines in the "race-way".

g) Appropriate tools for maintenance:

Several tools were developed for the day-to-day maintenance of the installation, such as: drainage of the oil from the mill pendulums, key for changing the bottom of the mill, key for screws/bolts of the injector vessels, reduction of the screw sizes of the bag filters, utilisation of a pneumatic tool in order to reduce maintenance time, construction of access platforms at the points of replacement of the rupture disks and lubrication points of the mill.

RETURN OF THE INVESTMENT

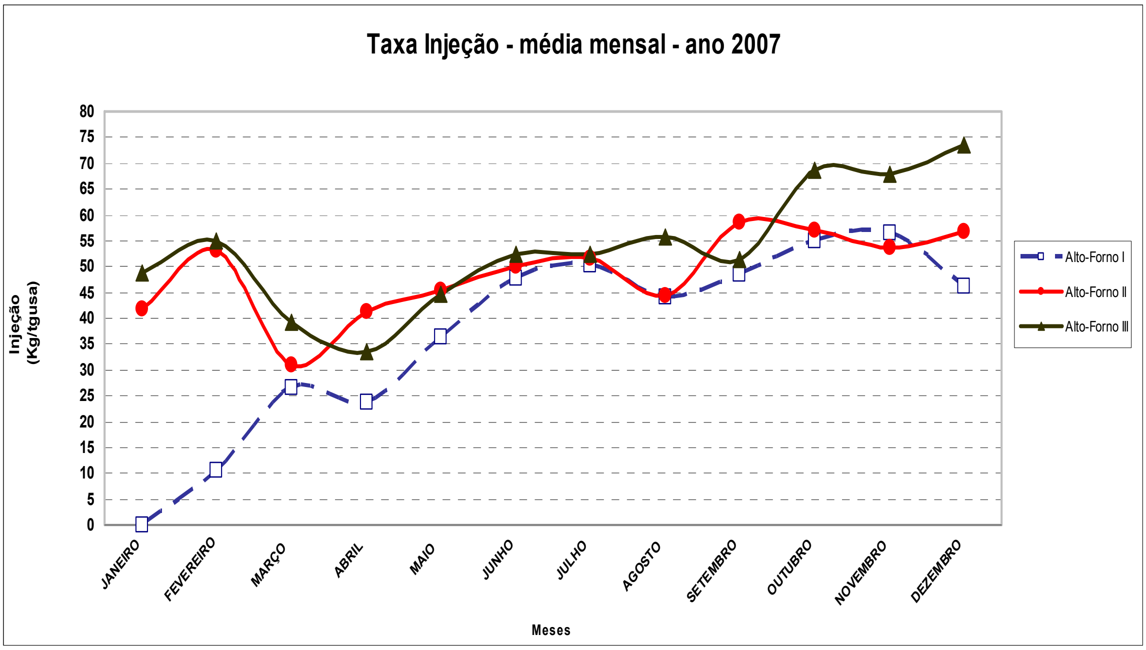
The cost-benefit spreadsheet presented to the end user demonstrated the possibility of the pay-back period to occur within the first year of the installation coming on-line, only taking into account Phase 1 of the project.
Due to continuity and stability of operation this goal was successfully reached.

CONCLUSION

- Unit which is easy to operate
- Possibility of achieving the targeted injection rate within one month of operation
- No loss of productivity of the furnaces
- Fuel replacement ratio of 1:1 (fines : lump charcoal)
- Importance of training before commissioning
- Importance of the quality of the unprepared charcoal
- Improved thermal stability of the furnace
- Future possibility to inject the powder collected in the charcoal dust removal system

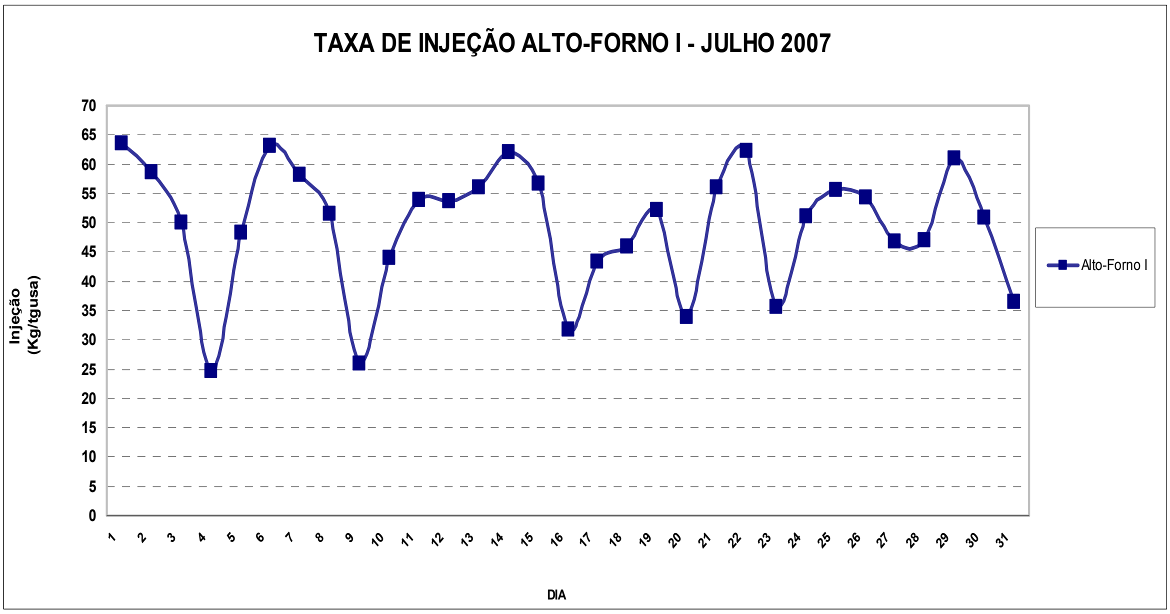
BIBLIOGRAPHY

1 ABM Course – Technological Aspects Relative to the Preparation of Load and Operation of Blast Furnace, www.abmbrasil.com.br.
2 Data of IBS / Brazilian Institute of Metallurgy, www.ibs.com.br
3 SINDIFER Data / Sindicato Ferro Minas Gerais, www.sindifer.com.br



KEY:
INJECTION RATE – MONTHLY MEAN – YEAR 2007
INJECTION (KG / THM)
BLAST FURNACE I
BLAST FURNACE II
BLAST FURNACE II

Appendix 01: injection rate monthly data – year 2007



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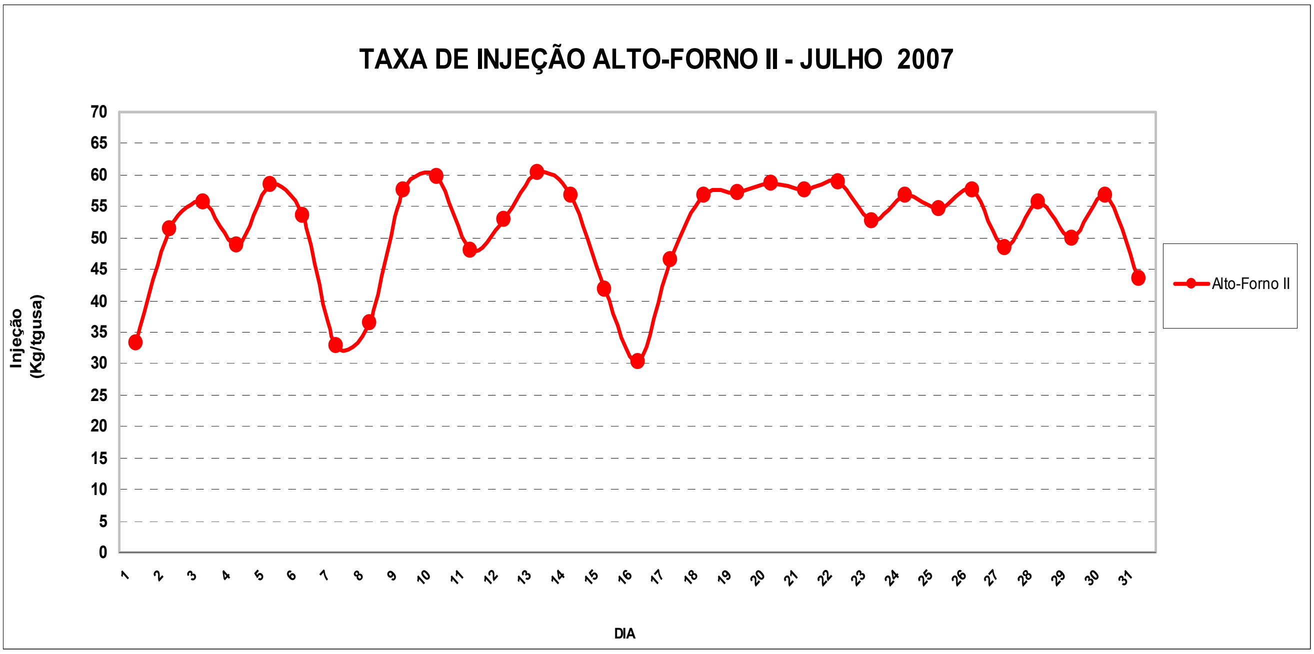
INJECTION RATE - BLAST FURNACE I – JULY 2007
INJECTION (KG / THM)
BLAST FURNACE I

Appendix 02: injection rate data, Blast Furnace 01, month – July 2007.



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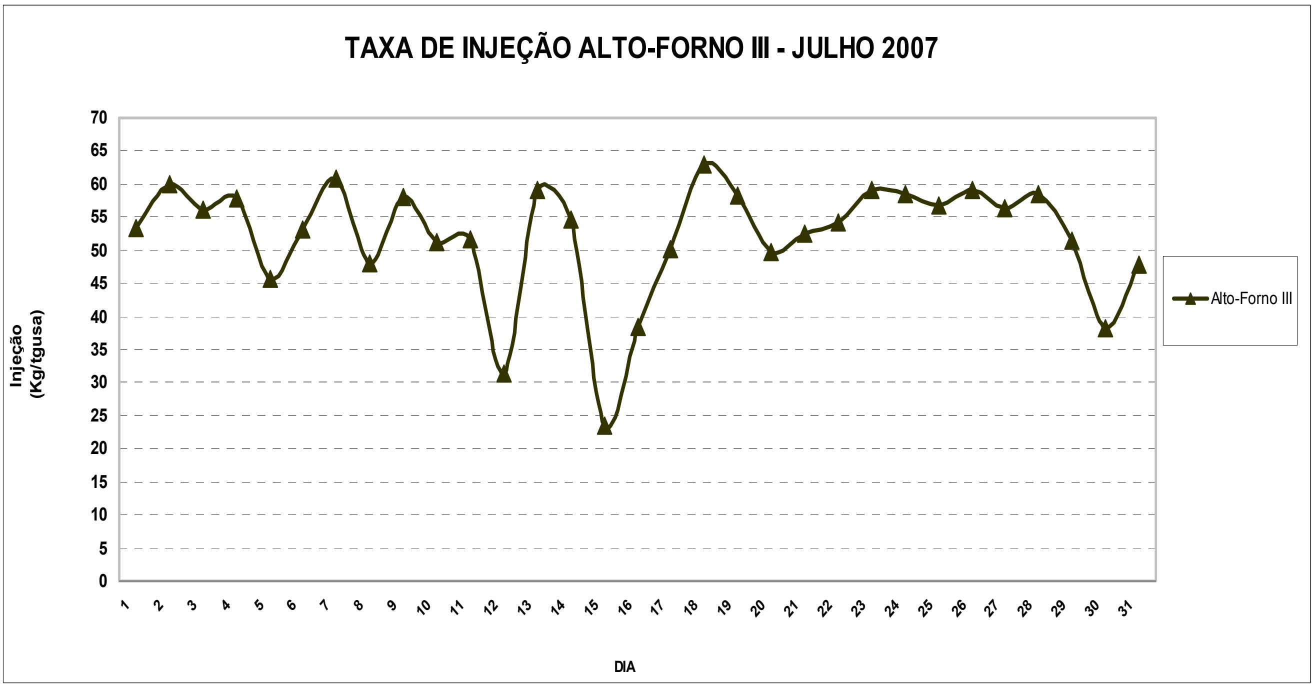
INJECTION RATE - BLAST FURNACE II – JULY 2007
INJECTION (KG / THM)
BLAST FURNACE II

Appendix 03: injection rate data, AF 02, month - July 2007.



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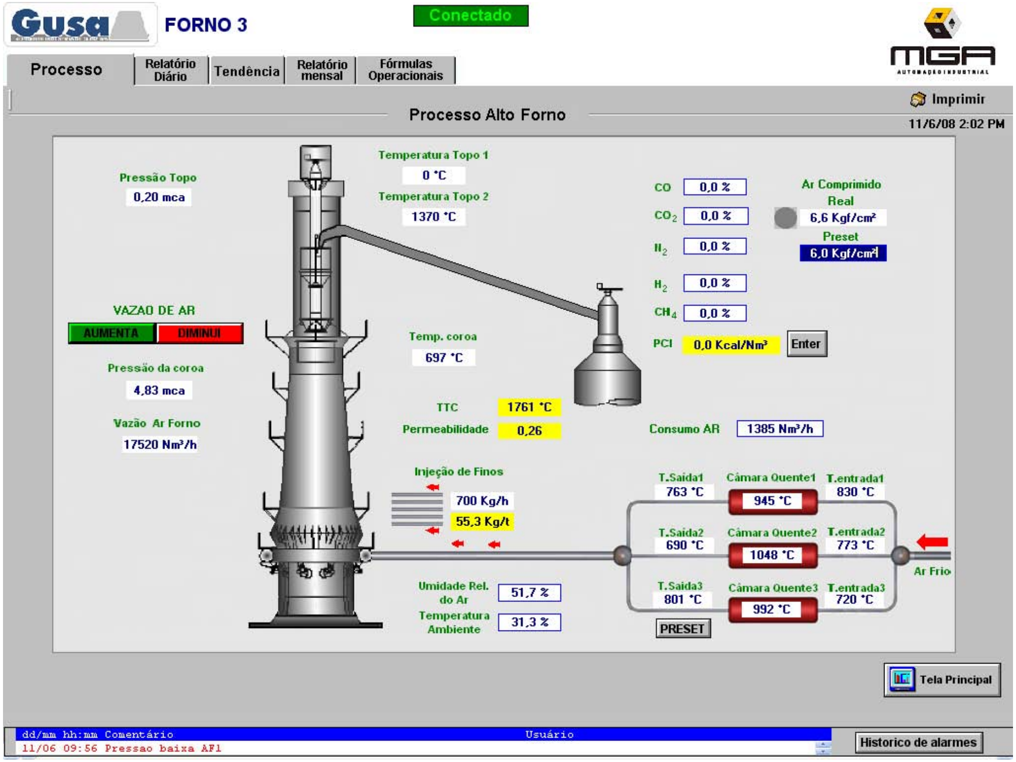
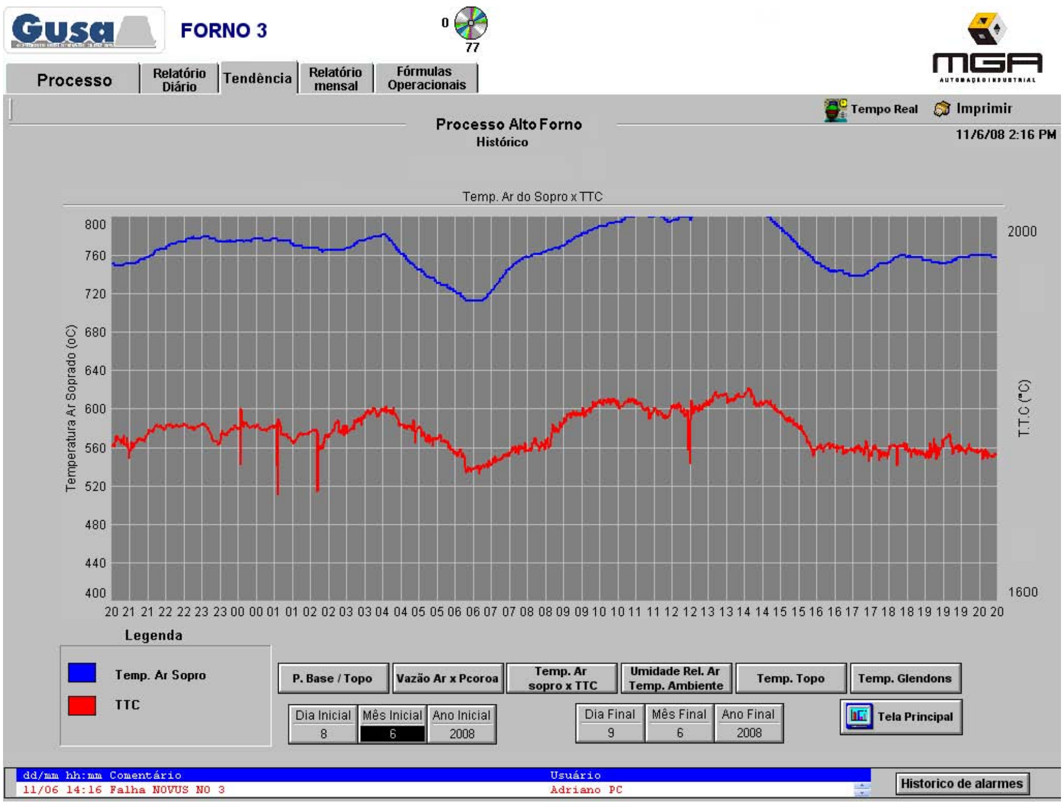
INJECTION RATE - BLAST FURNACE III – JULY 2007
INJECTION (KG / CAST IRON)
BLAST FURNACE III

Appendix 04: injection rate data, Blast Furnace 03, month - July 2007.



Appendix 05: example of supervisory system screen



Appendix 06: supervisory system screen with continuous TTF form

Appendix 07: view of the PCI installation (process silo + control room)

Tables

	AF I	AF II	AF III
Internal Volume	155 m^3	163 m^3	163 m^3
Blowing Temperature	730 ^oC	740 ^oC	750 ^oC
Volume of Blow	18.000 Nm^3 / H	24,000 Nm^3 / H	25,000 Nm^3 / H
Pressure of Blow	7.5 mca	8.5 mca	8.5 mca
In Tuyeres	10	12	12
Leakage	Intermittent	Intermittent	Intermittent
Diameter Tuyeres	100 mm	95 mm	95 mm
Top	Double Cone	Double Cone	Double Cone
Diameter Throat	2,970 mm	2,860 mm	2,860 mm
Diam. Crucible	3,280 mm	3,500 mm	3,500 mm
Cooling System	Spray on the plates	Spray on the plates	Spray on the plates

Table 01: data of the blast furnaces, of the plant Gusa Nordeste

	Control of the pulverized material - July 2007				
	Humidity FM	Humidity Cyclone	Grain size distribution	RPM. Mill	RPM. Classif.
	2.36	1.97	92	87	175
	2.36	2.10	92	86	175
	2.29	2.03	92	86	177
	2.16	1.91	95	87	180
	1.96	1.76	94	83	180
	1.95	1.80	93	83	180
	2.25	2.11	94	71	184
	2.45	2.16	93	74	185
	2.47	2.01	95	83	185
	2.46	2.15	95	86	182
	2.41	1.99	93	84	180
	2.50	2.08	93	87	175
	2.49	1.97	94	81	176
	2.44	1.98	90	83	174
	2.15	2.15	90	89	162
	2.34	2.09	89	71	170
	2.37	2.31	89	85	169
	2.39	2.26	88	83	178
	2.47	2.26	89	84	180
Mean	2.33%	2.06%	92.11%	83	177

Table 02: values of the fines of charcoal, produced in PCI

	CHEMICAL FOLLOW-UP OF THE PULVERIZED MATERIAL - JULY 2007 (% weigh)				
	Humidity	Mat. Vol.	Ash	SiO2	Fixed Carb
	3.94	22.81	10.92	37.30	62.32
	3.93	23.87	9.90	35.70	62.29
	3.01	23.56	10.04	35.85	63.40
	2.87	24.69	10.27	36.75	62.16
	2.13	21.30	12.52	49.85	64.04
Mean	3.18	23.25	10.73	39.09	62.84

Table 03: analysis of the fines of charcoal, produced

Pictures

Picture 01: pendulum type mill - BTS

Picture 02: charcoal pneumatic injectors – Clyde Materials Handling