QUICK RECOVERY FROM A CHILLY HEARTH OF COSIPA #1 BLAST FURNCE [1]

Eduardo Maurell Lobo Pereira [2]
Ivanir Torres de Lima [3]
Vinícius Martins Vilela [3]
Filipe Varvela Paschoalini [3]
Josemar Veiga Pedro [4]
Ton Spiering [5]
Geert Jan Gravemaker [6]

Abstract

This paper describes all the operations carried out and the lessons learned in the recovery of Cosipa # 1 blast furnace from a hearth chilling occurred in October 2007 after a 52,8 hours stop. The furnace recovery strategy involved the coke rate changing at the burden column, the accomplishment of the connection between tuyeres and tapholes by lancing and the sequential tuyeres preparation and opening after programmed stops. The slag – iron separation and the two tap holes operation succeeded 4 and 6 days after the blow in respectively which helped the recovery to be controlled, safe and very fast and also allowed the furnace to going back to normal operation in 10 days only. The operation and maintenance crews did excellent jobs and Cosipa and Danieli Corus teams worked in a constructive atmosphere sharing all the information, decisions and actions in one of the quickest recoveries worldwide.
Key words: Blast furnace; Recovery; Hearth; Chilly

1 *Technical contribution to the 3rd International Meeting on Ironmaking, September 22 – 26, 2008, São Luís City – Maranhão State – Brazil*
2 *Metallurgical Engineer, Ironmaking Technical Support Division, Manager – Cosipa*
3 *Metallurgical Engineer, Ironmaking Technical Support Division, Operation Analyst – Cosipa*
4 *Metallurgical Engineer, # 1 Blast Furnace Division, Manager – Cosipa*
5 *Metallurgical Msc, Blast Furnace Production Specialist – Danieli Corus*
6 *Geophysics Msc, Blast Furnace Technologist – Danieli Corus*

1 INTRODUCTION

The Cosipa # 1 Blast Furnace (BF1), is a furnace with 1829 m³ of inner volume, 24 tuyeres and a 9,8 m diameter hearth. The blow in of its 5 th campaign was in October 2000 and since then it has been running under a low productivity level in a range of 1,8 to 2.0 t/d/m³ of inner volume due to a high temperature at its hearth carbon blocks.
After a seven years period of a stable operation, a sudden burn-out of # 23 tuyere and cooler occurred on October 13 th 2007 at 7h30 am causing a 52,8 hrs emergency stop. This situation took the furnace to loose the connection between the tuyeres and tap holes and 7h30 after a first blow in the furnace had to be stopped again in order to restore the necessary conditions to do a new start up.
During this second stop many tasks were done to prepare the furnace to a second and safe blow in by means of special procedures regarding the recovery operation.
The aim of this report is to describe all the operations involved in the recovery of Cosipa #1 blast furnace from a hearth chilling occurred in October 2007 and also to relate the lessons learned about the circumstances that took the furnace to such a critical situation.
Starting from the events that contributed to stop the normal operation, a critical analysis was made and the successful recovery actions were pointed out in one of the quickest recoveries worldwide.
Cosipa had the technical support of Danieli Corus (DC) during the recovery, in the beginning with the intention of using oxi-fuel lance technology, but as the connection between tuyere and taphole succeeded through classical oxygen lancing DC team put across their advising in all other steps of the Recovery process.
Cosipa and Danieli Corus teams worked in a constructive atmosphere sharing all the information, decisions and actions in this short recovery period.

2 BURN-OUT OF # 23 TUYERE AND COOLER

As it was said above, # 23 tuyere and cooler burnt out suddenly without any signs that could help the operators to prevent this occurrence. The operation was being held quite normally at that time and the main process variables were going under control as it can be seen at the following Figures 1 and 2.
It can be noticed from the Figure 1 that the hot blast volume and burden descent were very stable and the hot blast pressure presented only a small normal drop during the stoves change.
Form the Figure 2 it can be seen a regular value of the inlet and outlet water volume and it means that there was no problem at the tuyere cooling system. The difference between the inlet and outlet values represents only that the measuring equipments were not equalized, because it was known that there was no leakage at the cooling system. On the other hand the outlet water volume value was in a higher level than the inlet water volume value fact that is impossible to happen when a tuyere burns.

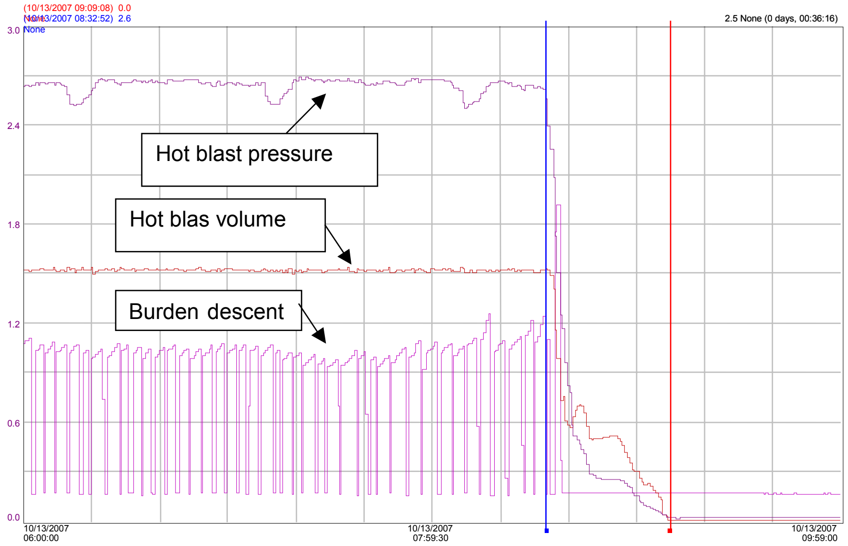


Figure 1 – Main process variables

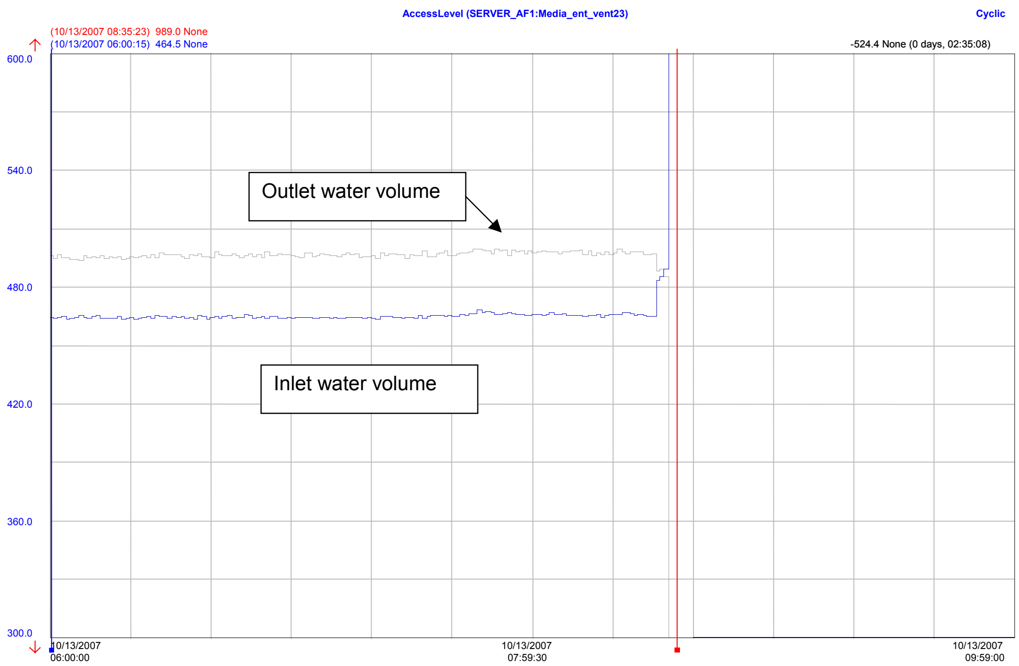


Figure 2 – Inlet and Outlet water volume of # 23 tuyere

3 PROBABLE CAUSES OF THE # 23 TUYERE AND COOLER FAILURE

The Blast furnace nº1 due to its hearth problems since the beginning of this campaign, has operated with up to 8 tuyeres closed in a same region between # 21 to # 4 tuyeres, above # 1 tap hole, included # 23 in this area. As it was expected to make a 90 days relining in the first semester of 2008 some measures were taken in order to guarantee an excellent blow out operation.

One of these measures was the opening of the closed tuyeres, and the last ones, # 23 and # 24 were opened in august 2007. This fact led us to wonder that the flow of liquids flowing from the tuyere to the hearth was worst at this region because during the campaign the most of the tuyeres burnt were located aside of closed tuyeres.

Immediately after the tuyere burn-out when several actions were taken to start up the furnace again as soon as possible, 3 sets of cooling plates with 3 plates each one were found without water at the outlet, right above the # 23 tuyere. It is difficult to say if these plates burned before the tuyere or after it, but there is a huge chance that the zone in front of the tuyere had worsened by the presence of water leakage from cooling plates.
Another possibility to explain the tuyere and cooler failure was the descent of some scaffold, because some thermocouples accused variations before it.
One another possible contribution to the tuyere and cooler failure was the fact that the # 23 cooler was being cooled by nitrogen instead of water which decrease its cooling capacity. It was an emergency procedure used in this furnace in case of any cooler damage and no problem was related from this practice at all until that moment.
At the time of the start of tuyere water leakage the tapping situation was good and no slag came into the blowpipe during the stop operation.
No evidence of carbon from the PCI system was found into the blowpipes removing from the list of probable causes the possibility that the tuyere or even the blowpipe have been damaged by carbon powder.

4 FIRST BLOW IN - LOSS OF CONNECTION BETWEEN TUYERES AND TAP HOLES

After 52,8 hrs stop was decided to blow in the furnace with all tuyeres opened because of the relatively short time of the stop, based on past experiences, and the good conditions of the tuyeres that seemed to be still hot.
Operational variables were defined as following:
Initial blast volume: 1900 Nm3/min (approximately 82 Nm3/min/ tuyere)
Blast humidity: valve closed.
Blast temperature: Maximum depending on stoves and blast conditions
PCI: 150 kg/t.
Oxygen volume: the necessary amount to keep TFT >= 1950 ºC.
Natural gas = 14 kg/t (on tuyeres 5, 11, 15 e 19).
Charging conditions of the Burden:
Recovering of the burden level up to 3m before blow in.
Charging of 1 Extra coke (10,3 t) and 6 charges: 2 x CR 1000 kg/t + 2 x CR 900 kg/t + 2x CR 800 kg/t. After that charging charges with CR 750 kg/t.
Slag calculated Al_2O_3 <= 14 % and MgO between 7 and 8%.
Slag calculated binary basicity: 0,90.
Silicon content in charges with coke rate 750 kg/t: = 3%
Coke consumption: 100% own production coke.
Blow in was started on 15/10 at 00:03 hrs pm and the blast volume of 1900 Nm^3/ min was reached at 14:10 hrs pm.
After 3h13 min of operation the blast volume started to be reduced because there was no signs of liquids at the tap holes and accumulated amount of pig iron inside the hearth totaled 200t (see figure 3).
Initially the tuyeres were operating well but they worsened at the same time the remaining liquid material increased inside the furnace. Tuyeres # 22, 23, 24, 1, 2 and 3 were blocked with slag at 16 hrs pm and signs of water were seen at tuyeres # 9, 19, 21 and 24.

The blow out happened at 19h 30 min on 15/10 due to the critical situation of the tuyeres and no evidence of connection between tuyeres and tap holes. Almost all tuyeres and the blowpipes were horizontally filled with slag during the stop operation. During this recovery attempt 20 complete charges were charged with the coke rate varying from 1000 to 750kg/t.

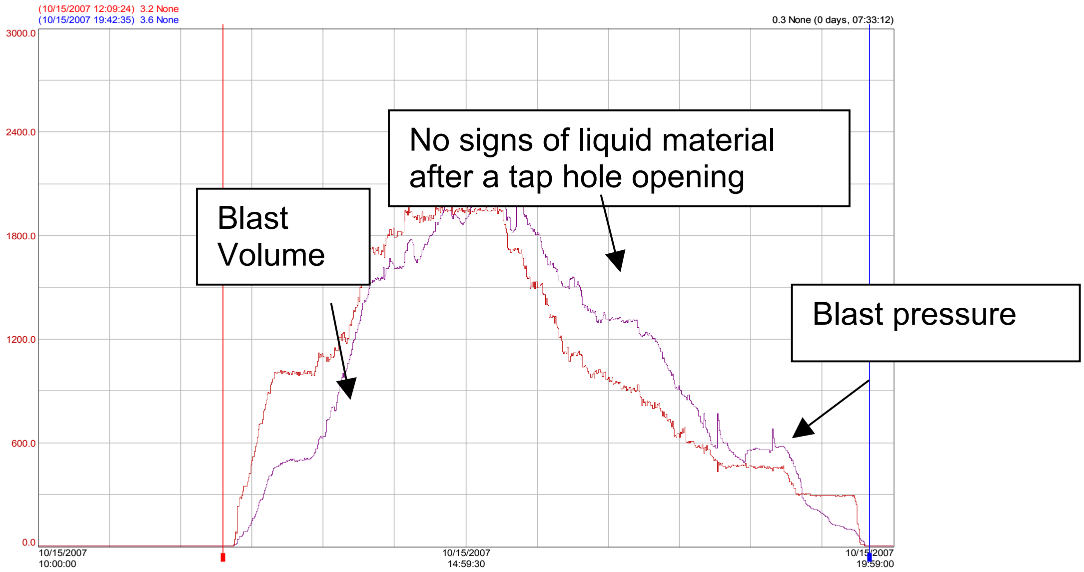


Figure 3 – Blast volume and pressure during the first blow in

5 STRATEGY OF THE RECOVERY

Immediately after the furnace stop it was decided to connect tuyeres and tap holes by classical lancing while it was made a contact with DC personnel in order to contract the oxi-fuel lance technology.
The # 2 tap hole and 4 tuyeres above it were chosen to make the connection in view of their position being farther from the # 23 tuyere than # 1 tap hole.
Figure 4 below shows the burden column at the time of the stop after the first blow in. It was set that the coke rate would be maintained at 1000 kt/ t up to the recovery of the furnace thermal level.

- **1 Extra Coke**
- **7 X CR 1000 Kg/t**
- **1 Extra Coke**
- **6 x CR 1000 Kg/T**

- **15 CR 750 Kg/T**
- **2x CR 800 Kg/T**
- **2x CR 900 Kg/T**
- **2 x CR 1000 Kg/T**
- **1 Extra Coke**

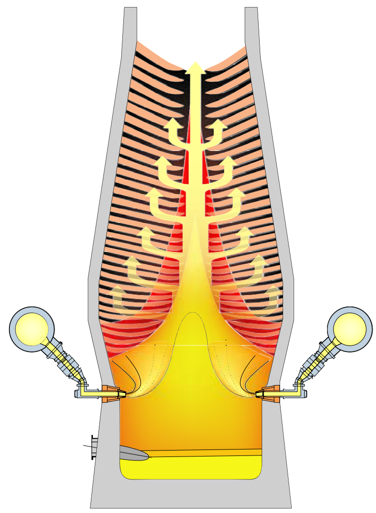


Figure 4 – Situation of the burden inside the furnace at the time of 2nd stop

Special emphasis was given to the communication process. Two meetings a day were done at the beginning of each shift of 12 x 12 hrs. During these meetings all the discussions results were put down on a white board as a guide to the next shift becoming the operation clear and easy to understanding to all operators.

6 CONNECTION BETWEEN TUYERES AND TAP HOLES BY LANCING

Tuyeres # 7, 8, 9 and 10 above # 2 tap hole were chosen to the lancing task and tuyeres # 7 and 10 was burnt during this process which led us to decide to start up operation with only 2 tuyeres # 7 and 8 above this tap hole.
Figure 5 below shows the connection scheme between tuyeres and tap hole to be made by classical lancing method.

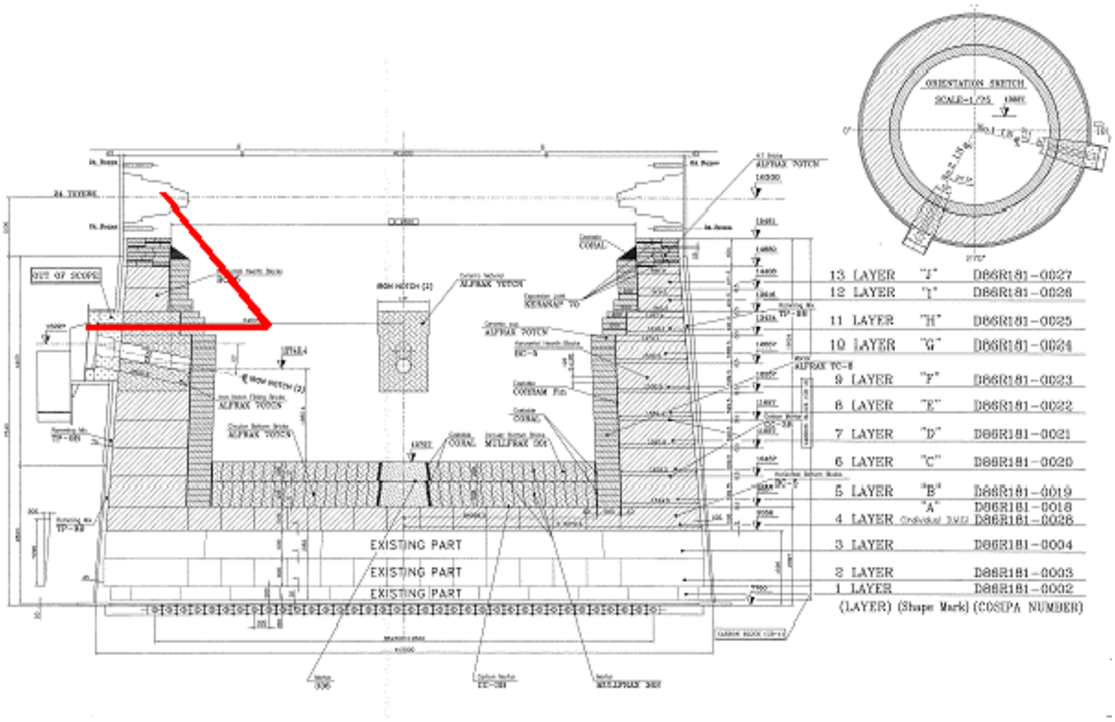


Figure 5 – Connection scheme between tuyere and tap hole.

This method consisted in removing both tuyeres # 7 and 8 after initial slag cleaning in front of them to make easier the task of lancing downwards inside the furnace.
The oxygen lancing was made simultaneously at tuyeres and tap hole, which was prepared through the adjustment of the opener and the mud gun.
The maintenance crew worked hard and finished the adjustment of the mud gun with its nose turned up on 16/10 at 00h30 hrs am. The opener was ready to operate on the same date at 08h00 am in a position 330 mm above the original tap hole with an angle of 6º quite different from the original 18°.
This was made in order to shortening the distance between the tuyere and the tap hole as much as possible.
The connection was thought to be good approximately after 24 hours of oxygen lancing. It was judged by the presence of gas at tuyeres, when the operators blew oxygen through the tap hole, and specially by tapping of liquid iron and slag in the main iron trough.

On 16/10 at 10h00 pm was started the oxygen lancing after the withdrawal of tuyeres # 7 and 8 and the changing of tuyere #10. The method consisted in bending the oxygen lance as downward as possible through the truyeres while horizontal or upward lancing was made from the tap hole 2,5 m inside the furnace (see figure 6).
On 17/10 at 10h30 am occurred the first tapping when the material reached the tilting runner.
At 4h00 pm on 17/10 after 18 hours of continuous oxygen lancing was considered that the connection was completed.
The hole in front of the tuyeres # 7 and 8 was filled in with fresh coke and the furnace started up to its second blow in on 18/10 at 04h00 am.

Figure 6 – The connection preparation

7 TUYERE PREPARATION

It was planned to prepare the tuyeres in scheduled furnace stops, in order that they could to be opened during the operation spontaneously.
Afterwards an horizontal oxygen cleaning was made with the aim of finding coke in front of them, and 2 or 3 tuyeres were prepared at both sides of the opened tuyeres.
See in the figures 7 and 8 the opening scheme of the tuyeres showing three different types of adjacent tuyere preparation with clay at the tuyere nose (a), with clay and a piece of wood (b) and clay inside of tuyere body (c).

(a) Clay at the nose (b) clay and wood (c) clay inside the body

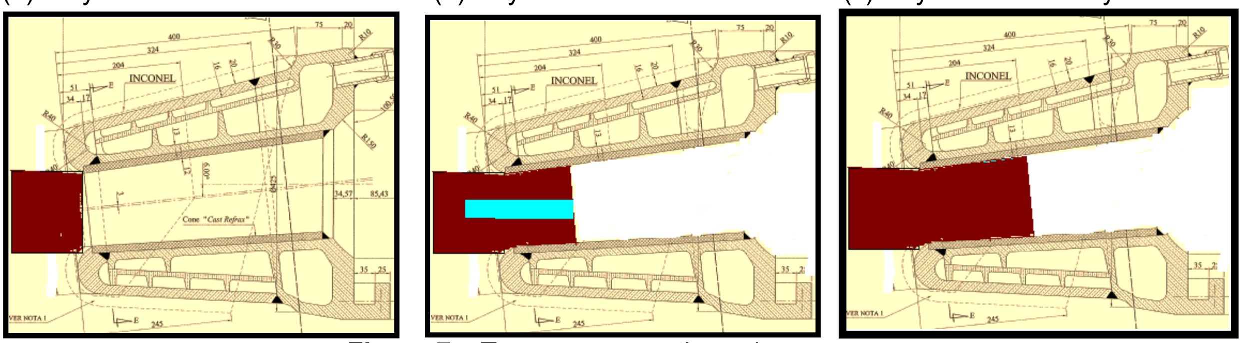


Figure 7 – Tuyeres preparation scheme

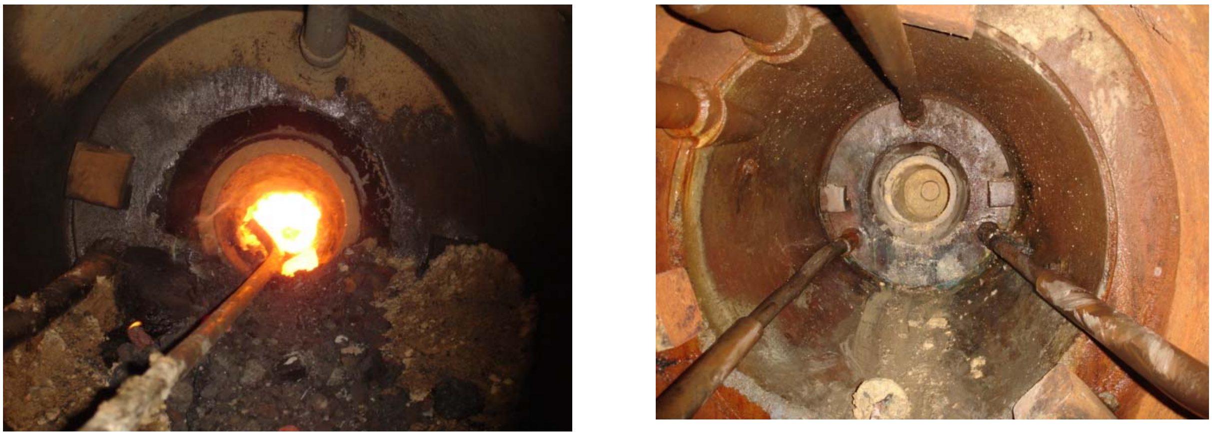


Figure 8 – Tuyere cleaning and preparation

At the end of the recovery, the tuyere preparation process presented good results as it follows:

- Only one tuyere didn't open spontaneously
- Only one tuyere was burnt at the end of the recovery

8 CAST HOUSE PREPARATION AND OPERATION

The second blow in was made with only the # 2 cast house in operation. The main iron trough was filled with sand in order to facilitate the cleaning between taps and on its borderline was installed a steel sheet to prevent leakage of liquid iron and slag during the taps (Figure 9).
It was adopted to pass the pig iron under the skimmer when the temperature reached 1400ºC.
An important help in cleaning of the main iron trough was the bobcat machine that worked at cast house making easier the operators handy work (see figure 9).
Four days after the 2nd blow in the pig iron was passing under the skimmer and after two days more both cast houses were in operation.

Figure 9 – Main Iron trough filled with sand and the bobcat machine working

9 RECOVERY PROCESS

The Recovery process was driven starting with only 2 tuyeres in operation with the aim of blowing 200 Nm³/ min/ tuyere. In the next figures 10 and 11 it can be seen the increasing of the number of tuyeres opened and the hot blast volume.

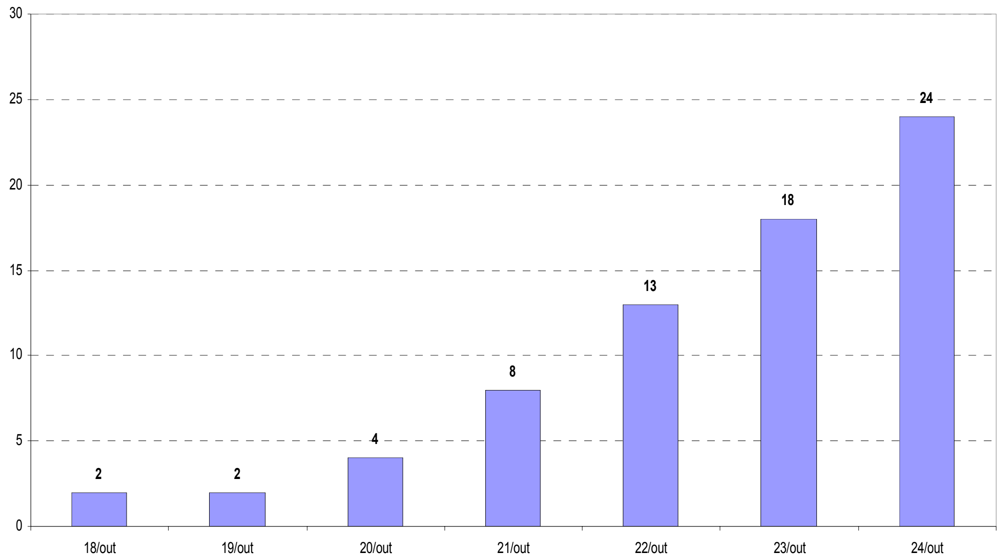


Figure 10 – Number of tuyeres opened

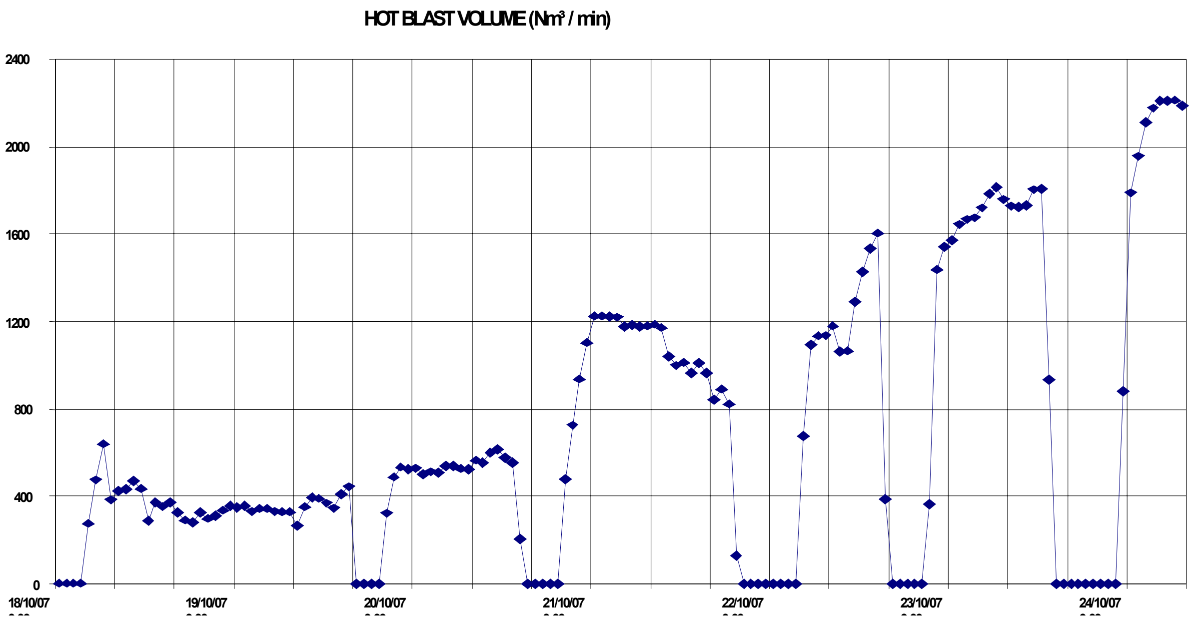


Figure 11 - Hot blast volume increasing

From these Figures 10 and 11 one also can see that were made 5 stops to open all 24 tuyeres and to adjust the hot blast volume to the normal level of 2400 Nm³/ min. The next figure 12 gives an interesting idea of the tuyeres openings along the time and how it occurred around the tap holes.

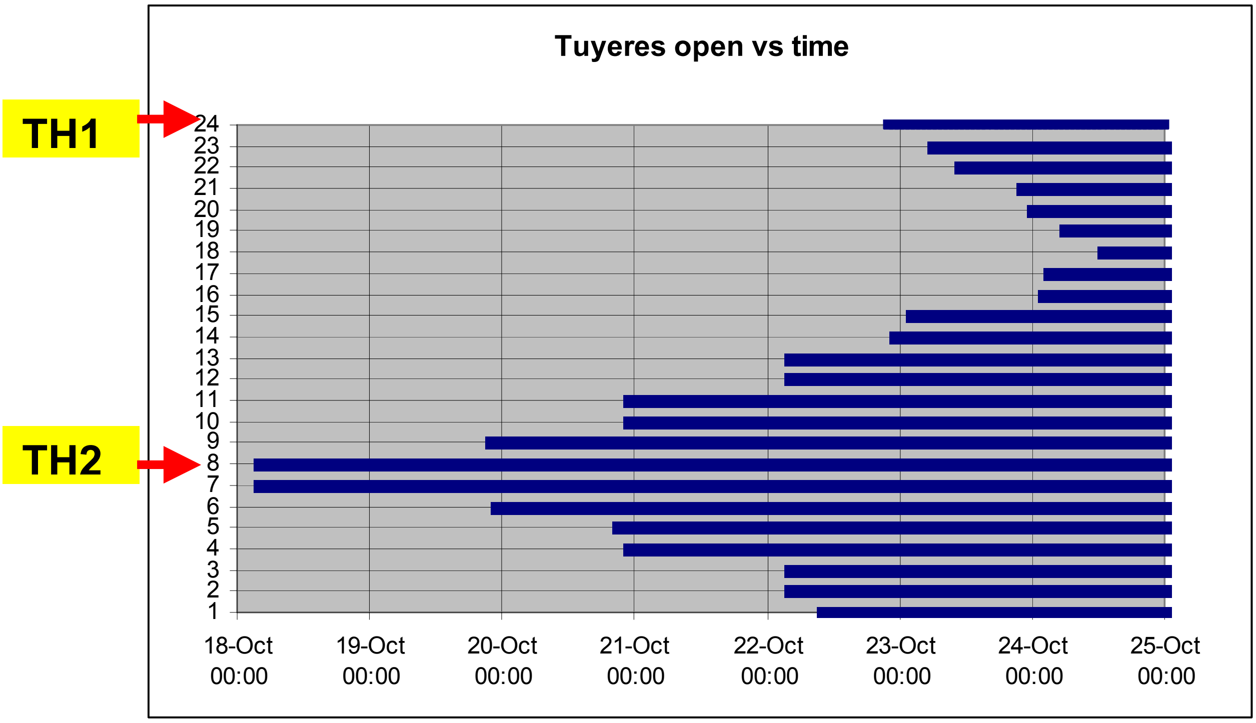


Figure 12 – Tuyeres opened over the time

At the Figure 13 is showed the behavior of the hot metal production during the recovery reaching the previous level of 3500 t/day at end of it.

One of the highlights of this recovery was the coke rate decreasing during this process that was made very quickly observing more the behavior of the silicon content in the pig iron than the hot metal temperature as a guide of the furnace thermal level (Figures 14,15 and 16).

Other important factor of the recovery was the control of slag binary basicity that remained in the range of 0,7 to 0,9 all the time reaching 1,1 only at the end of the recovery process. This is a key factor to assure the stability and safety of the operation keeping an appropriate flow of slag during the hearth cleaning process.

All the main variables of the process were controlled during the recovery being relevant to point out the top temperature that was controlled to avoid top spray openings.

The conditions at the tuyere specially the blast pressure was monitored through a pressure gauge installed in a PCI lance case as shown in the figure 17. It was very useful because the normal blast pressure measuring point at the bustle main is not appropriate to monitor this variable in these special conditions due to the high pressure loss at the closed tuyere. The special measuring point allowed us to know exactly how much the pressure loss in the burden column was, avoiding inappropriate operations.

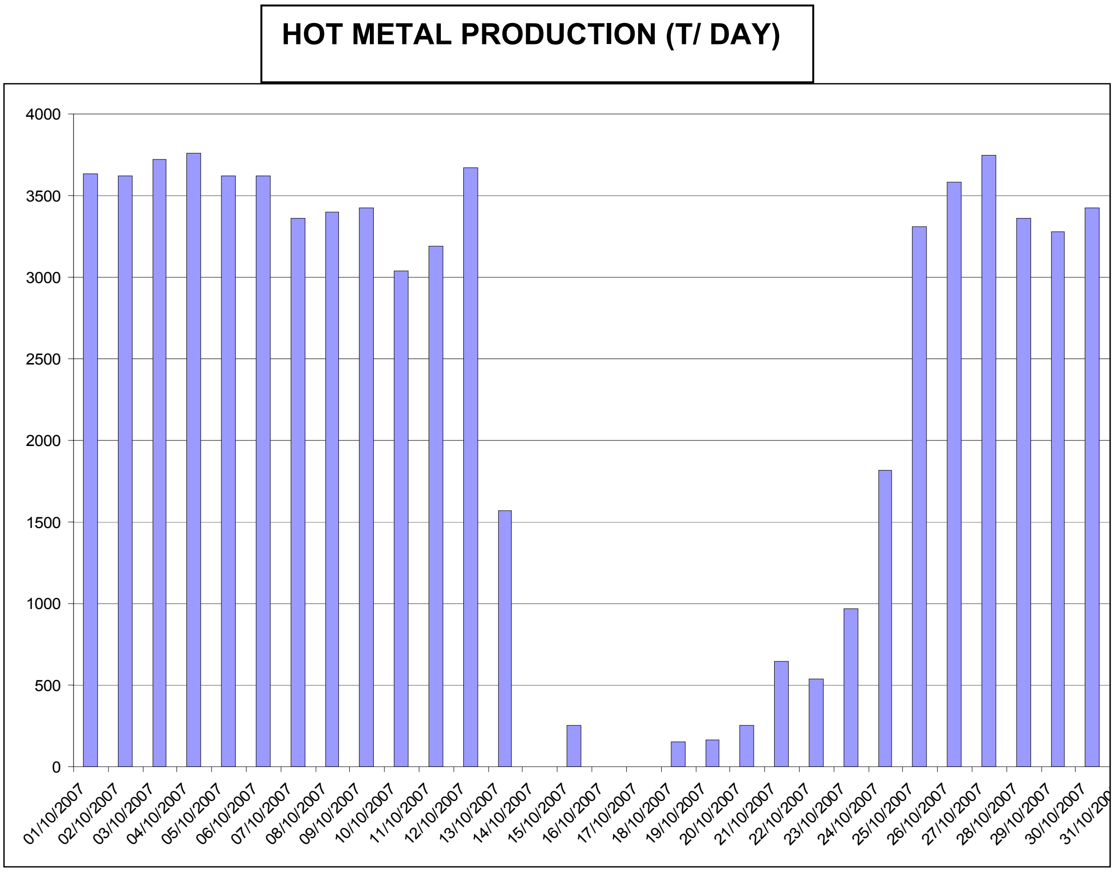


Figure 13 - Hot Metal Production

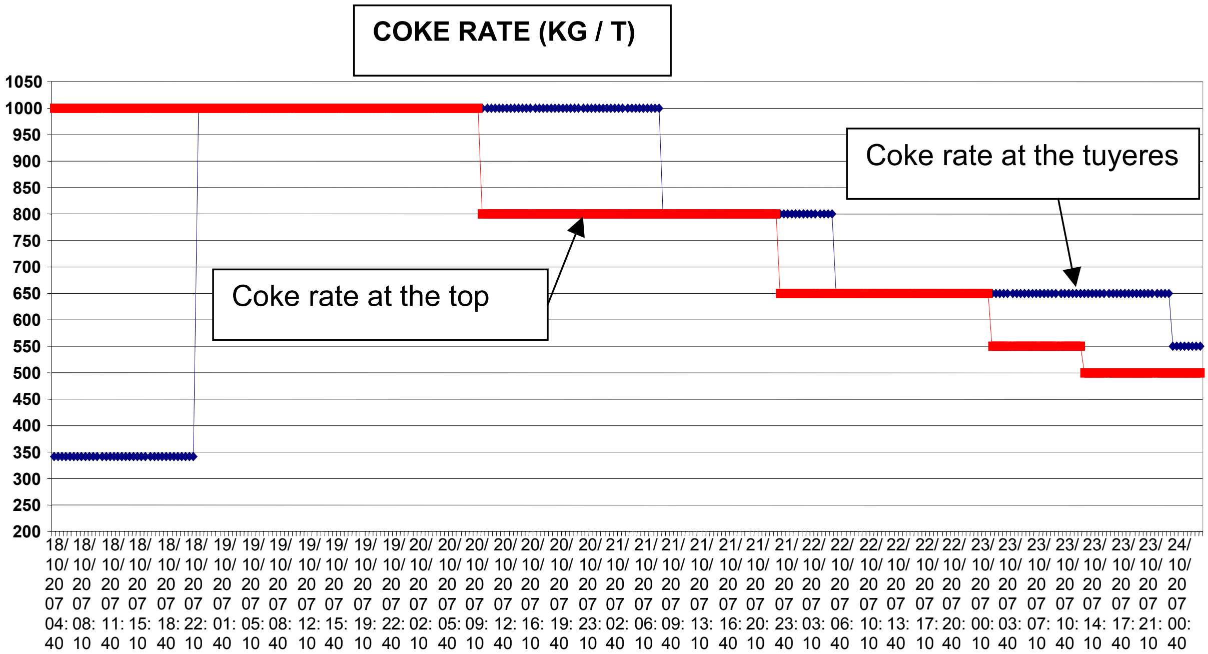


Figure 14 – Coke rate decreasing

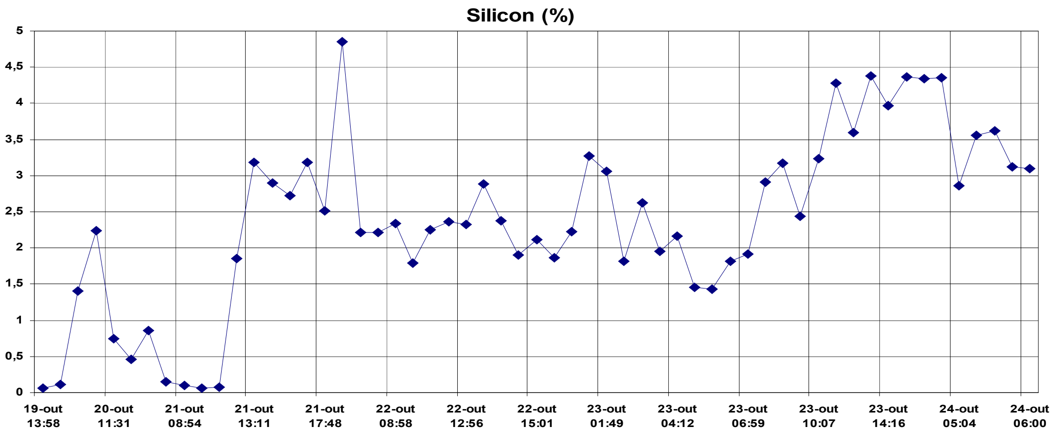


Figure 15 – Pig Iron Silicon content

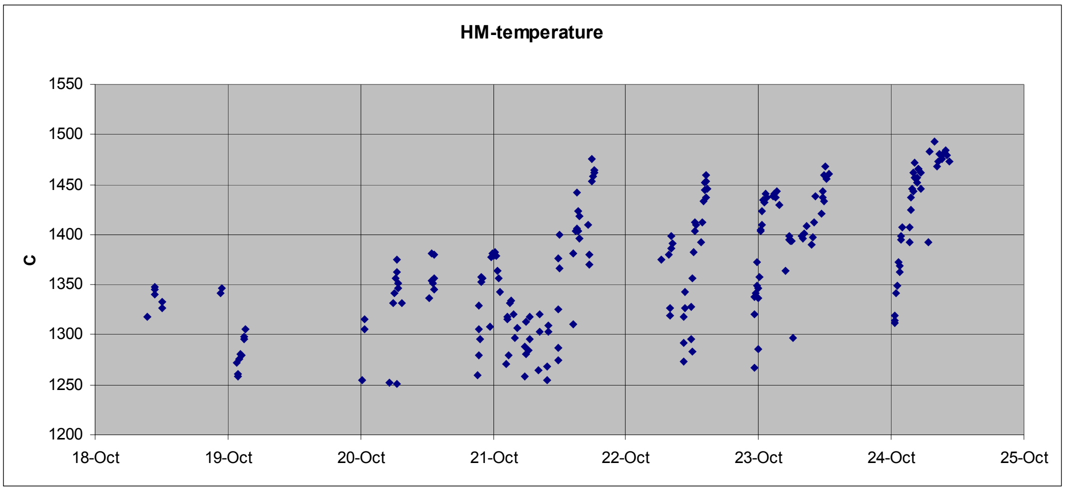


Figure 16 – Hot metal temperature

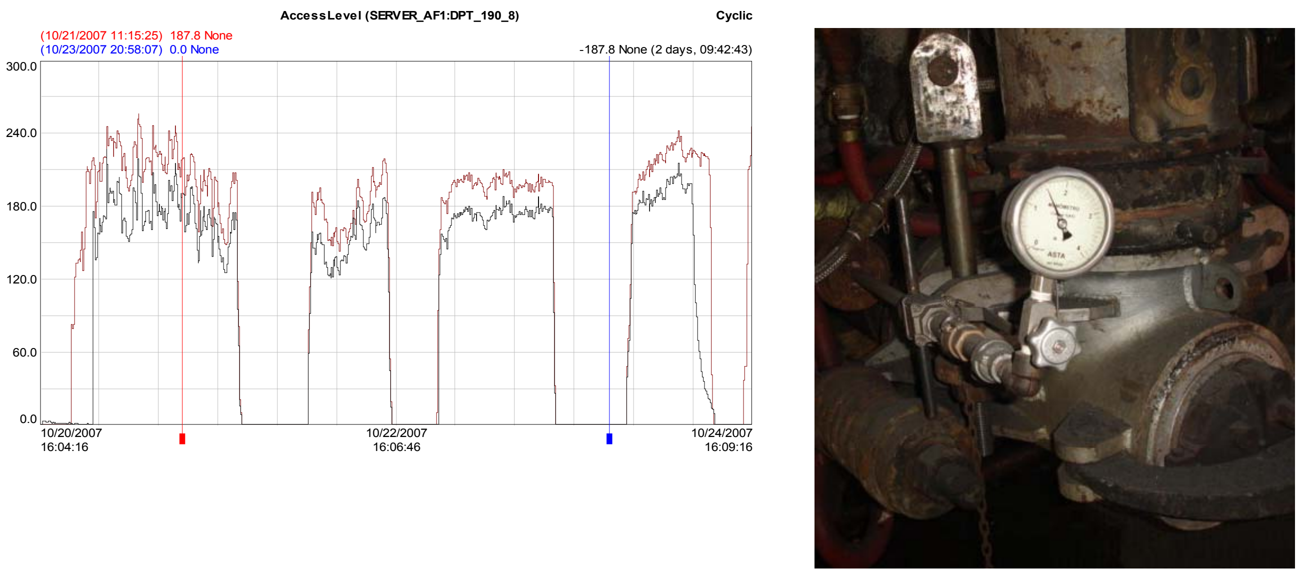
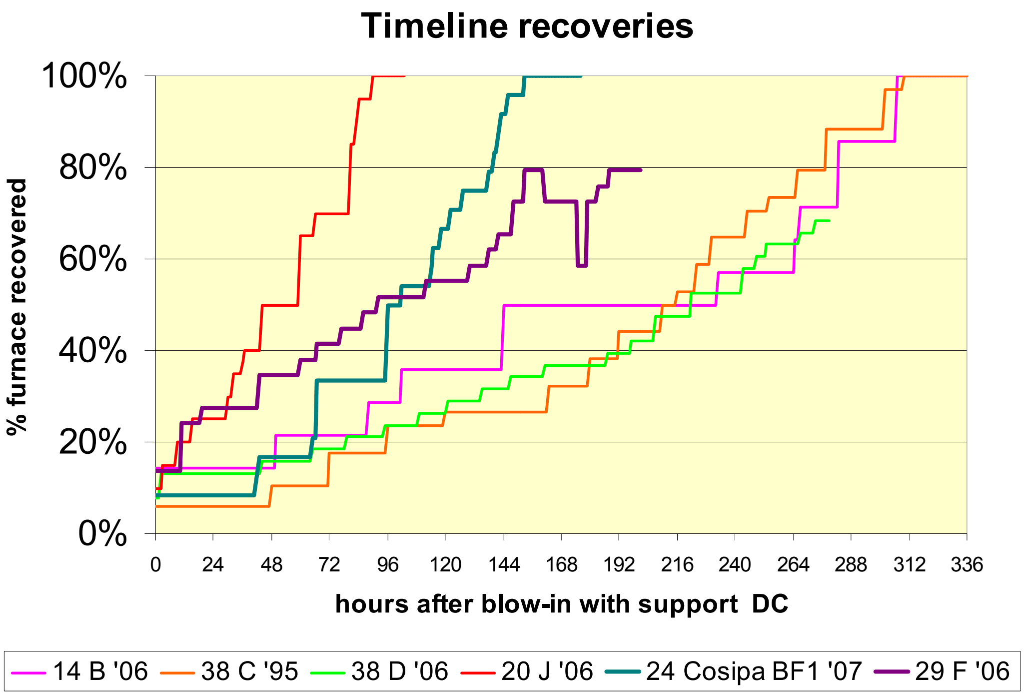


Figure 17 – Blast pressure measuring and blast pressure gauge

The Figure 17 present several recoveries according with the DC experience and support showing this recovery as one of quickest worldwide and the quickest with PCI.



10 CONCLUSIONS

- Recovery was controlled, safe and very fast
  In experience of DC the fastest to low coke rate (< 450 kg/THM)
- Cosipa estimated a recovery time of 15-30 days, but achieved 10 days only.
- Morning and afternoon meetings promoted a good visualization for everybody about what had to be done.
- Cosipa and Danieli Corus teams worked in a constructive atmosphere.
- Casthouse and maintenance crews did a very good job. (Exchanging blowpipes, preparing tuyeres, removing scab in front of tuyeres etc.)
- Preparation of tuyeres was excellent. Apart from # 18 tuyere opening, all other tuyeres opened by themselves.
- Only 1 tuyere (# 8) burned at the end of the recovery.
- Separation of HM and slag on TH2 started 4 days after blow-in.
- Both tapholes in operation within 6 days after blow-in.