DEVELOPMENT OF A MEASUREMENT SYSTEM OF BLAST FLOW RATE IN THE TUYERE BREAST IN ARCELORMITTAL MONLEVADE BLAST FURNACE A[1]

Fabiano Cristeli de Andrade [2]
Arilson de Oliveira Mol [2]
Carlos Roberto Gomes [2]
Fabiano Harley Araújo [2]
Seleme Marlon Benício Dias [2]
Márcio Inácio dos Anjos [2]
Rodrigo Junqueira dos Santos [3]
Roberto Parreiras Tavares [4]

Abstract

With the goal to know the radial distribution of the blast flow rate in blast furnace, a work was carried out to implant a trustworthy measurement system of blast flow rate in the tuyere breast of ArcelorMittal Monlevade blast furnace A. The main methodologies of fluids flow rate had been considered, amongst which the Venturi tube, that showed to be the most viable technically. It was elaborated a mathematical study and a physical analysis for the posibility of installation of this device in a tuyere breast. The industrial test results had shown a good reliability in the developed system, with easy implementation and low cost. With this system implanted in all the 22 tuyeres of the blast furnace A, there is a expectative to be able to monitor the blast flow rate in each quadrant of blast furnace, and with this, to do correlations about wear hearth, skull formation, heat losses peaks, amongst others informations.

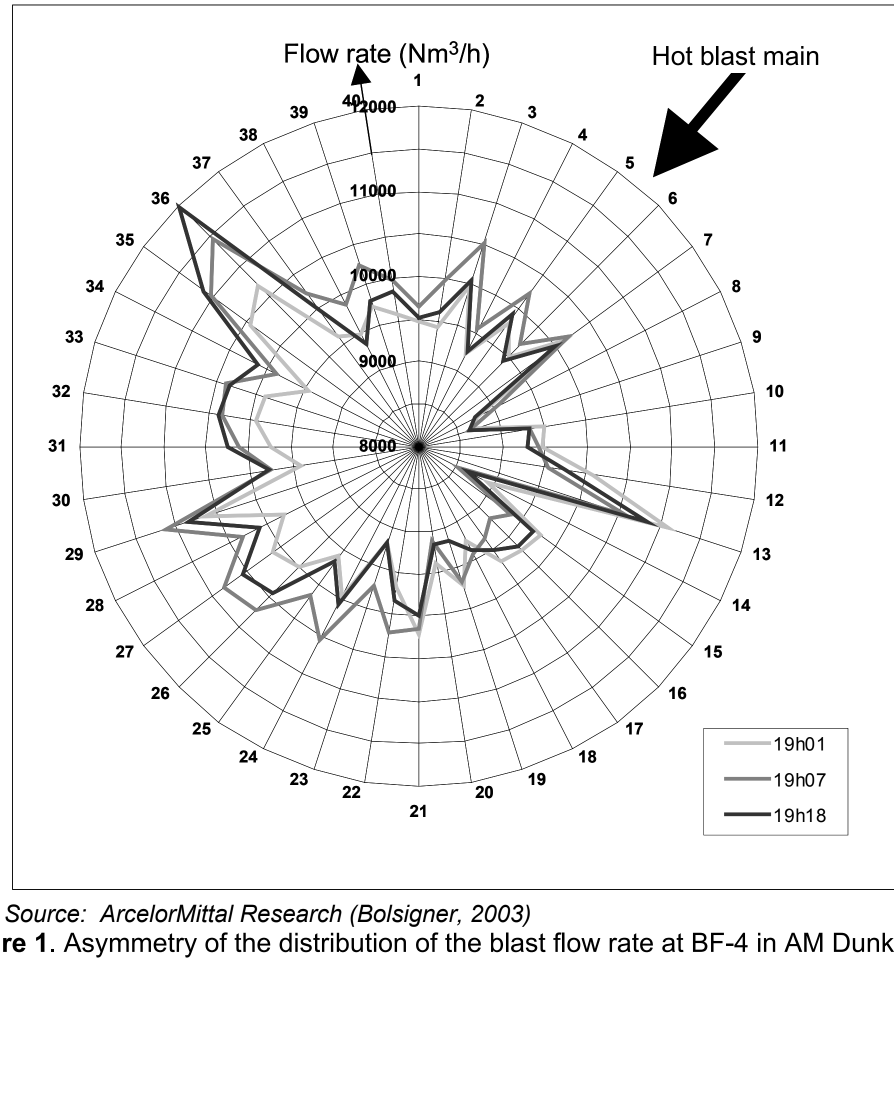
Key words: Blast furnace; Flow rate; Blast; Tuyere breast.

1 *Technical contribution to the 3rd International Meeting on Ironmaking, September 22 – 26, 2008, São Luís City – Maranhão State – Brazil*

2 *Ironmaking area, ArcelorMittal Monlevade*
3 *M.Sc. and Ironmaking area manager, ArcelorMittal Monlevade*
4 *Ph.D., Metallurgical and Materials Engineering Department of EEUFMG*

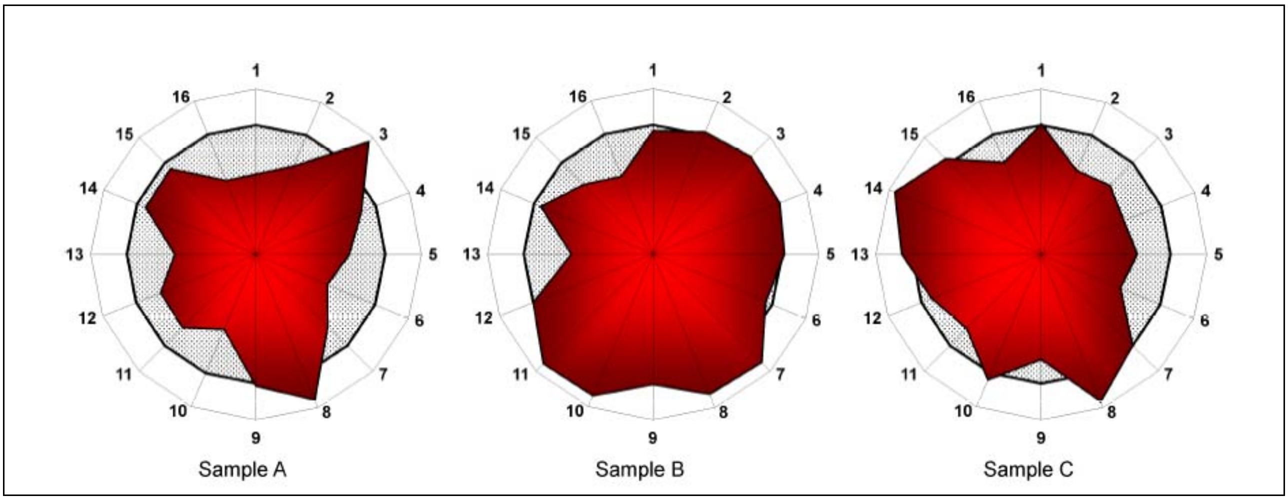
1 INTRODUCTION

Nowadays, the blast furnace is the most used process used worldwide in the production of the hot metal. This kind of reactor works closed and under pressure with the presence of solids, liquids and gases in countercurrent, therefore, the controlling of the process through these variables is essential for the safety and low cost operation. The process information like hot metal chemical analysis, pressure and blast flow rate, amount of coal injected through the tuyeres are some of the keys for controlling the blast furnace process.
In this scenario can be seen the blast furnace A of ArcelorMittal Monlevade. The blow-in was in December, 1999, replacing five smaller older charcoal blast furnaces, which had a low level of automation and were technologically out-of-phase. In the last years, after spent some time for the best understanding of the new practice (coke operation), the ironmaking team of ArcelorMittal Monlevade has been looking for new alternatives to improve our performance. With this goal, this project aim to development of a measurement system of blast flow rate trough tuyere in the blast furnace A of Monlevade plant. The development of this system, already observed in some European blast furnaces(1), allied with a future control injection system of coal in each tuyere(2), can help in keeping the operational stability, increasing the productivity and decreasing the fuel consumption mainly the metallurgical coke. Figure 1 shows the asymmetric flow rate of the blast in each tuyere in a French blast furnace.



Source: ArcelorMittal Research (Bolsigner, 2003)
Figure 1. Asymmetry of the distribution of the blast flow rate at BF-4 in AM Dunkerque

In Figure 2 it can be seen an irregularity of injection coal in perimeter of a German blast furnace.



Source: AMEPA (Weiser, 2000)

Figure 2. Distribution of the coal injected in 16 tuyeres during 3 distinct moments

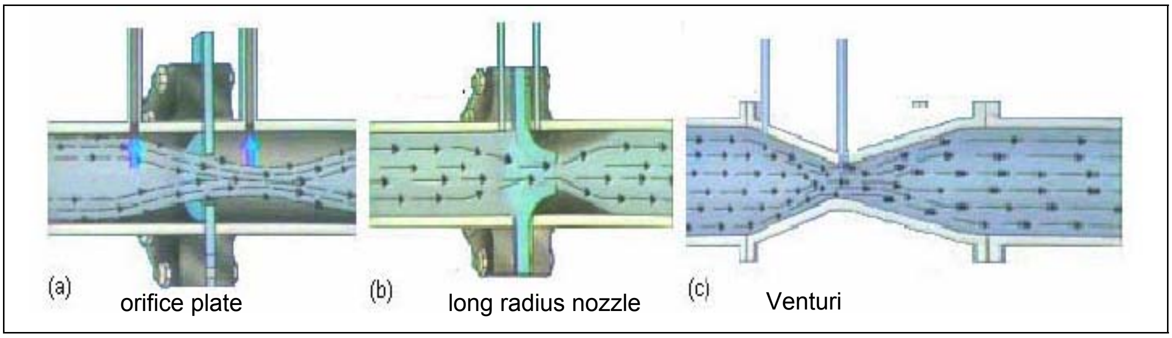
It can be expected that all the blast furnaces operate in these situation and because of this, some kind of asymmetry could happen in the process:

- gaseous flow asymmetry inside the blast furnace;
- flame temperature asymmetry;
- asymmetry of cohesive zone height;
- burden descent asymmetry;
- overload of no-burned coal in some areas of the hearth, which can lead to a substantial decreasing in the permeability of this region.

The deleterious effects observed in the presence of these kinds of asymmetries could generate a localized wear hearth, peak of heat losses, a tendency to skull formation, increasing of the blow pressure, loss of productivity, increasing in fuel consumption, and others.

2 LITERATURE SURVEY

The proposal is to evaluate the possibilitie of installing a geometric element in the “down-leg”, or straight tube, that will create a pressure drop in this region.[3] The blast flow rate measurement in the tuyere could be determined from this pressure drop and from the knowledge of the fluid characteristics as well as the situation that this geometric element is used. Figure 3 shows the working principles of each three main fluid flow rate measurers based on the pressure drop.



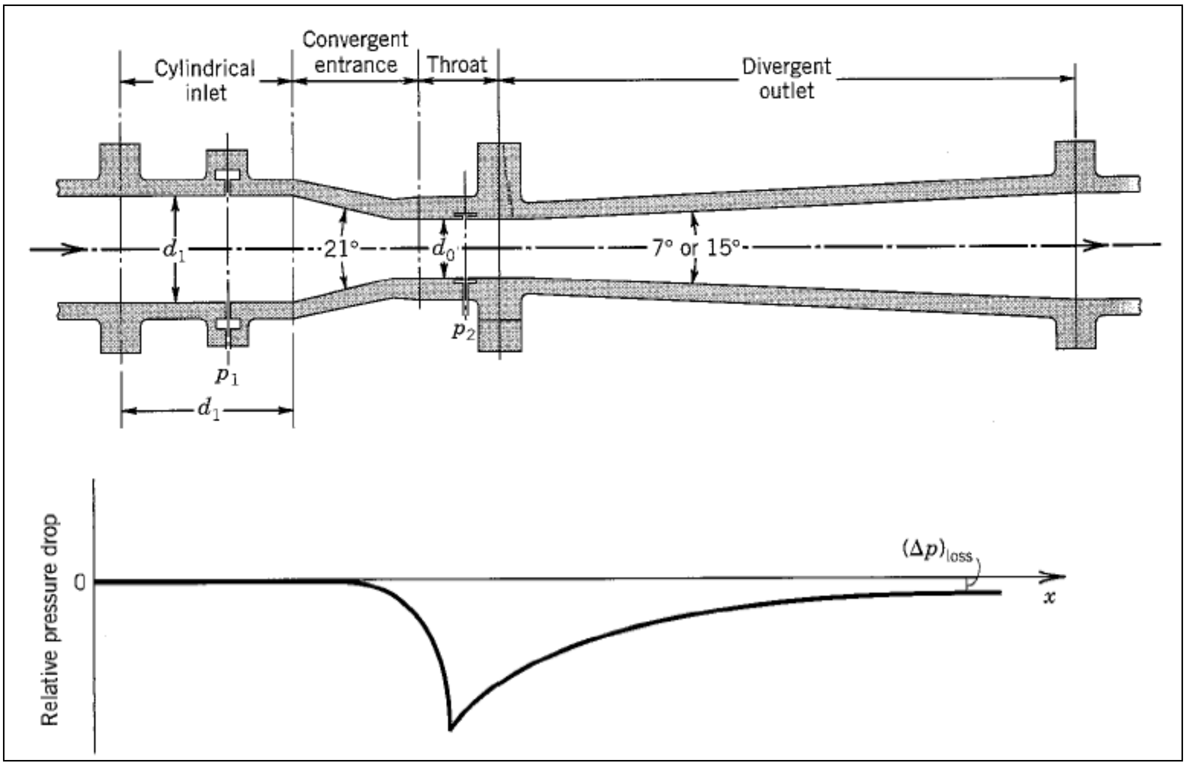
Source: Ibars, 2004

Figure 3. Measurers devices of fluid flow rate based in pressure drop

According to Ibars,[4] amongst the measurers fluid flow rate based in pressure drop, the Venturi tube leads a lower pressure loss. Because of this, is the option most recommendable when there is a limitation for spent energy in the system. Moreover, the Venturi tube is indicate when there is gas with high temperature like a tuyere breast.

2.1 Venturi Tube

The Venturi tube is a simple unit with a cylindrical neck between two conic sections of bigger diameter, where the first one is convergent and the other is divergent. The objective of this measurer is accelerate temporary the fluid and decrease its pressure. Figure 4 shows the relative pressure drop through the Venturi and the Table 1 shows the mains dimensions proposals for a Venturi tube.



Source: Figliola, 2000

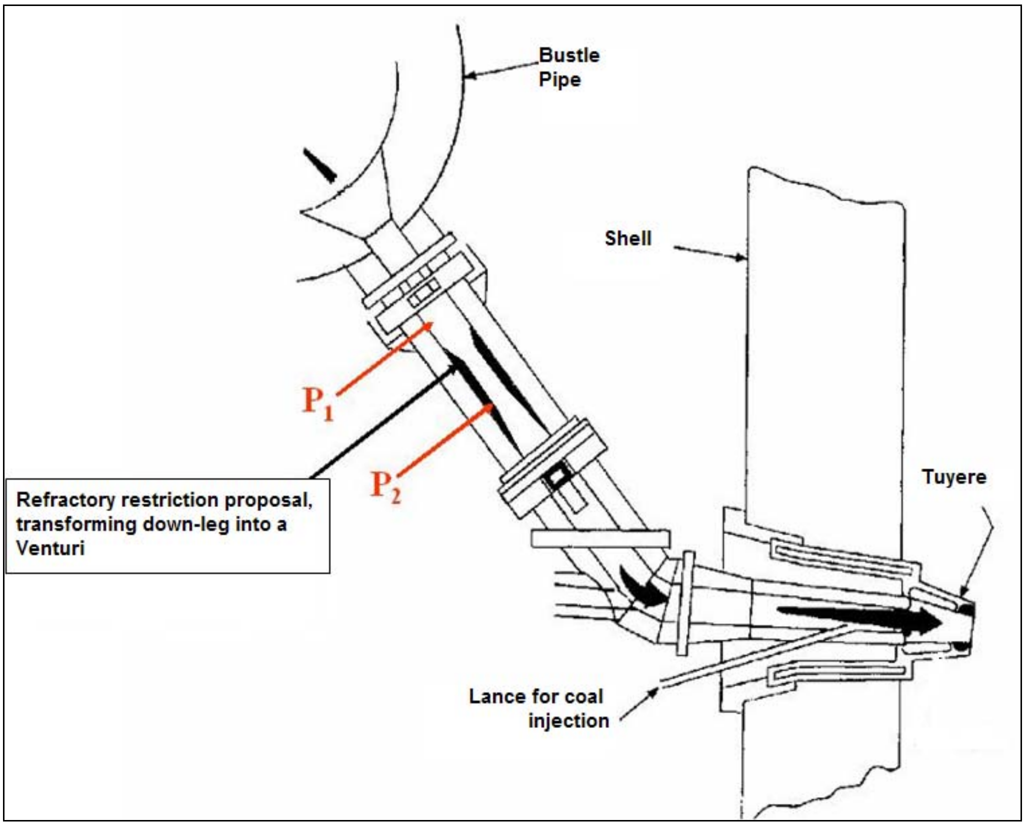
Figure 4. Relative pressure drop at Venturi tube

Table 1 – Summary of the dimensions and relations proposals for a Venturi tube

Source	Convergent angle	Throat diameter	Divergent angle	Total length
Leopoldo *et al.* (1979), e Losada (1988) cited in Ibars (2004)	20°	-	5 a 7°	-
Delmée (1983)	21° (±1°)	(0,40 a 0,75).D	7 a 15°	-
Paco (1993)	-	(0,25 a 0,75).D	-	-
Netto *et al.*, (1998)	-	(0,25 a 0,75).D	-	(3,5 a 12,0).D
Botrel *et al.*, (2001)	15°	0,33.D	5°	-

2.2 Mathematical Analysis

The system used for the mathematical analysis is showed in Figure 5. It was developed using the energetic balance with Bernoulli's Equation(7) in the stationary state.



Source: ArcelorMittal Monlevade, 2008

Figure 5. Refractory restriction proposal for BF-A down-leg

The mathematical equations is showed below as well as the considerations that have been done.

$$\frac{v_1^2}{2} + gz_1 = \int_1^2 \frac{dp}{\rho} + \frac{v_2^2}{2} + gz_2 + W_s + losses_{1-2} \qquad (1)$$

Where:

- v_1, v_2: the average velocity of the fluid in the points 1 and 2, respectively, in [m/s];
- z_1, z_2: height of points 1 and 2, respectively, in [m];
- g: gravity acceleration, in [m/s^2];
- p: pressure made by the fluid;
- ρ: fluid density;
- W_s: mechanical work made by the fluid in the system;
- $losses_{1\text{-}2}$: frictional losses through the Venturi.

Considering:
- the work made in the Venturi is zero ($W_s = 0$);
- the frictional losses are negligible ($losses_{1\text{-}2} = 0$);
- the density of fluid is constant;

Substituting the Continuity Equation in equation 1, with the aim of isolate v_2, and multiplying the result for the value of the neck area, the blast flow rate through the Venturi (in m^3/s) can be obtained, given by the equation 2:

$$Q = A_2 \times \sqrt{\frac{\left(\frac{\Delta p}{\rho} + gh\right) \times 2}{1 - \left(\frac{d_2}{d_1}\right)^4}} \qquad (2)$$

Where:
- d_1, d_2: internal diameter of the down-leg in the points 1 and 2, respectively, in [m].
- Δp: pressure drop ($p_1 - p_2$), in [Pa].
- Q: blast flow rate through tuyeres, in [m^3/s].

There are some viscous, inertial and frictional effects that have to be considered in the system. Because of this, the real pressure drop will be higher that the considered in the equation 2. For this purpose it's enough to multiply the theoretical flow rate by Cd (coefficient of discharge) that is a function of the Reynolds' number. In our case the Cd is 0,985[(5)]. So, the expression to calculate the real blast flow rate in a tuyere is given by equation 3:

$$Q_{real} = C_d \times Q \Rightarrow C_d \times A_2 \times \sqrt{\frac{\left(\frac{\Delta p}{\rho} + gh\right) \times 2}{1 - \left(\frac{d_2}{d_1}\right)^4}} \qquad (3)$$

In the projected system, the effects of air compressibility will be rejected in the mathematical analysis because the restriction proposed is slight.

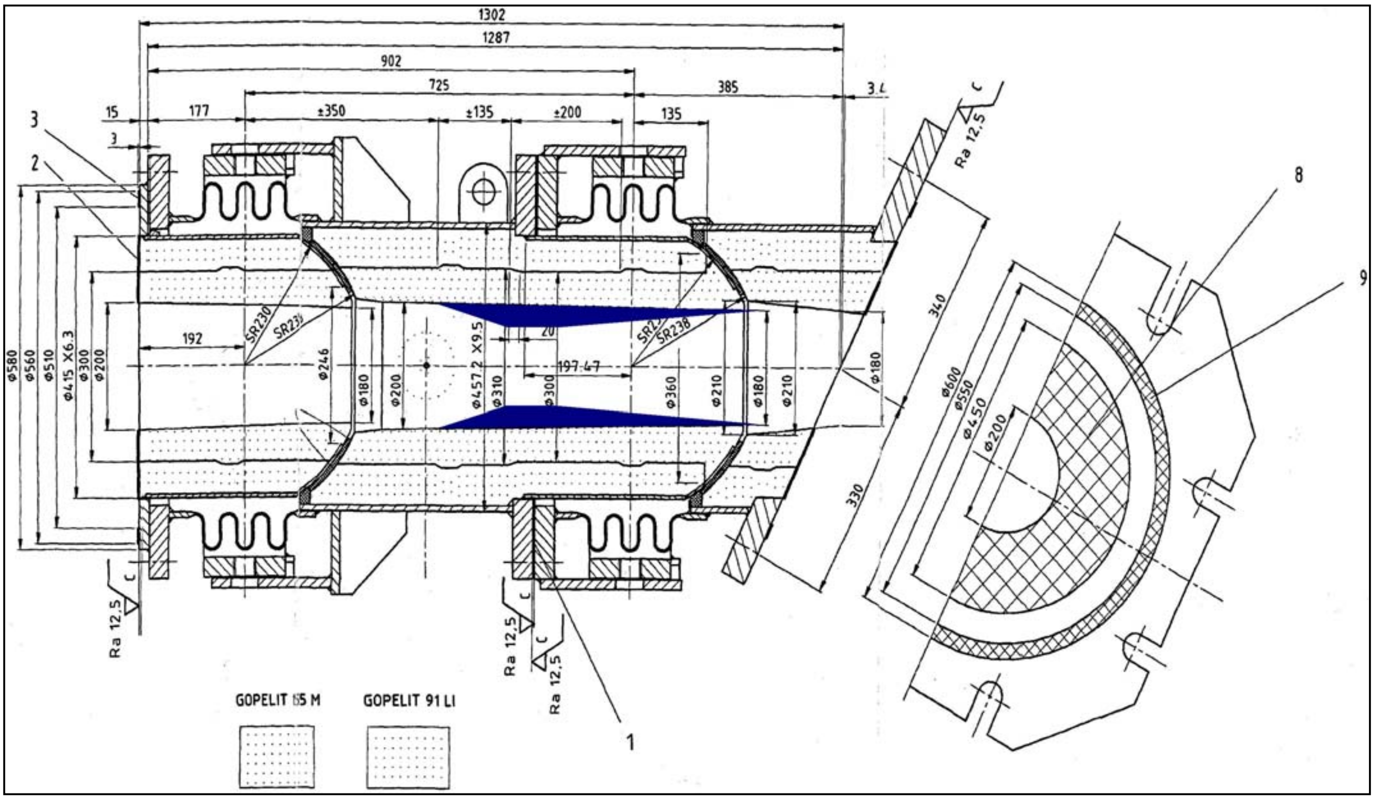
3 METHODOLOGY

The methodology for development of the proposed system involved the steps below:

- Mathematical simulation of a Venturi in the down-leg;
- Analysis of physical interferences of the down-leg;
- Industrial test;
- Analysis of these results;
- Automation of this system.

3.1 Mathematical Simulation of Venturi and the Project of the New Down-Leg

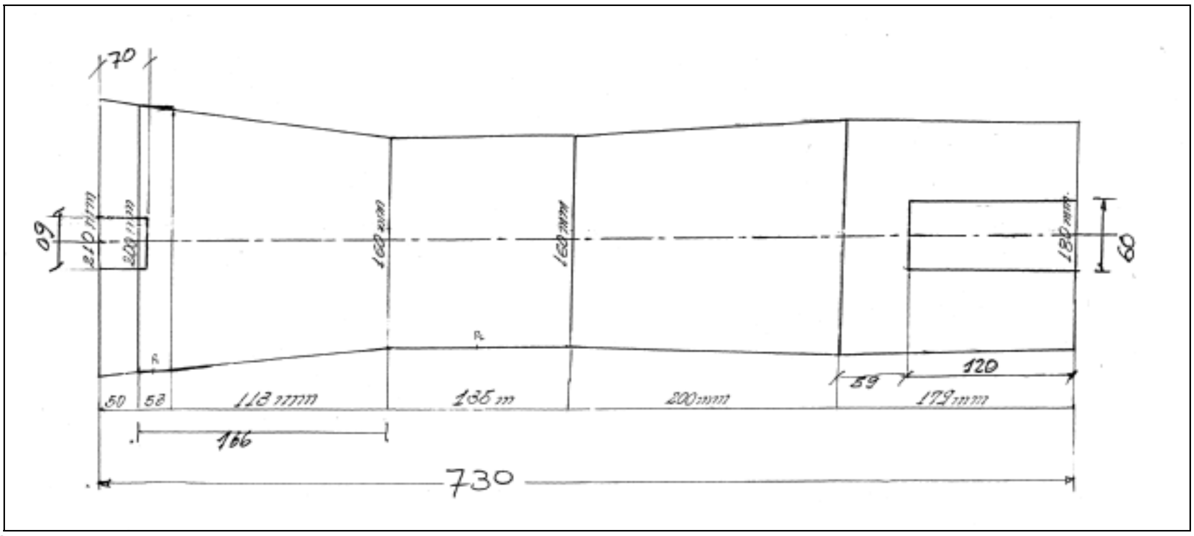
Aiming in checking the possibility of the implementation of the blast flow rate system in the tuyere in the blast furnace A, the variables in the equation 3 were simulated from values next to the real conditions of the blast furnace operation, in a normal situation. The obtained blast flow rate was 5.933Nm3/h, which is fairly the waited blast flow rate in each 22 tuyeres of the blast furnace A that was worked in these conditions with a total blast flow rate of 131.000Nm3/h.
In this moment, the possible values for the Venturi's diameter had been proposed, considering the mechanical interferences given by Figure 6 and dimensional relations given in Table 1.



Source: ArcelorMittal Monlevade, 2008

Figure 6. Mechanical and refractory drawing of BF-A down-leg

Figure 7 shows the final dimensions proposed for the mold that will be used for the Venturi's manufacturing.

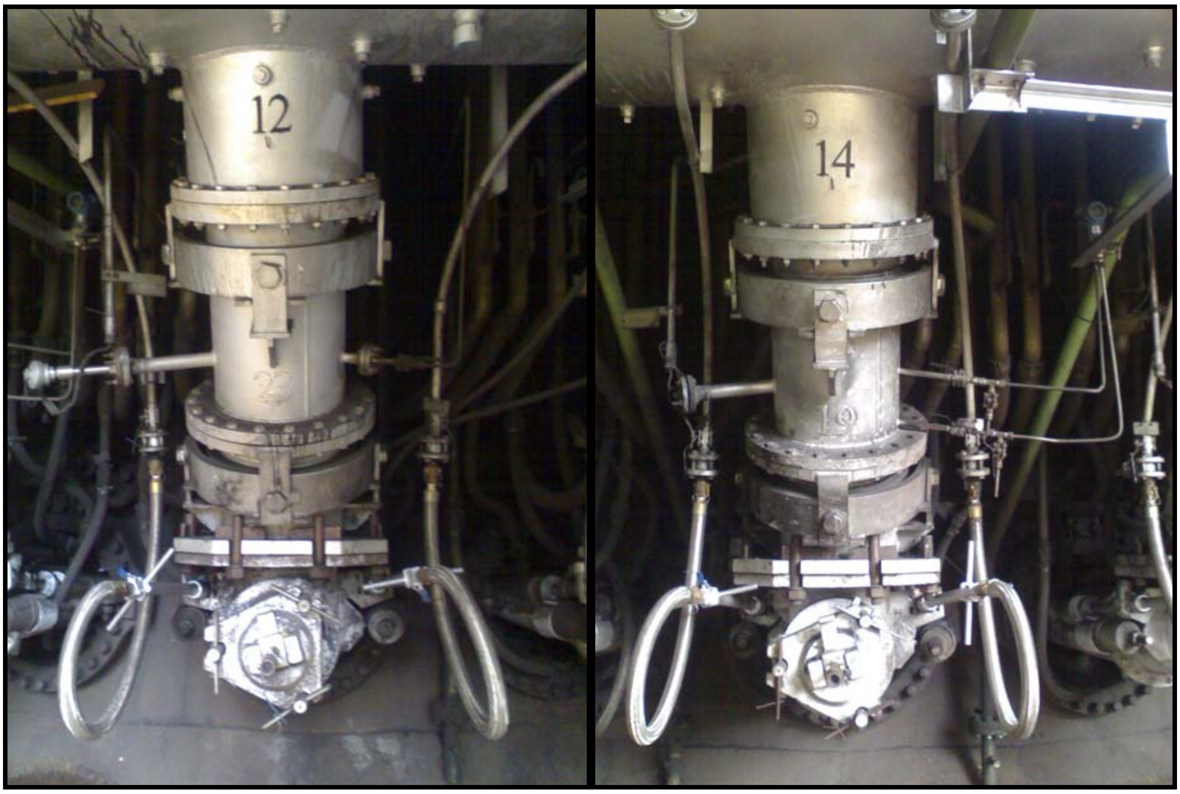


Source: ArcelorMittal Monlevade, 2008

Figure 7. Dimensions of the down-leg mold

3.2 Industrial Test

The industrial test was carried out in January, 2007. During a maintenance stoppage of the blast furnace A, it was installed a “down-leg” Venturi in the tuyere breast number 14 (Figure 8). The connection of instrumentation (tubes and pressure differential device) was done in the following days. Two months were used for evaluation.



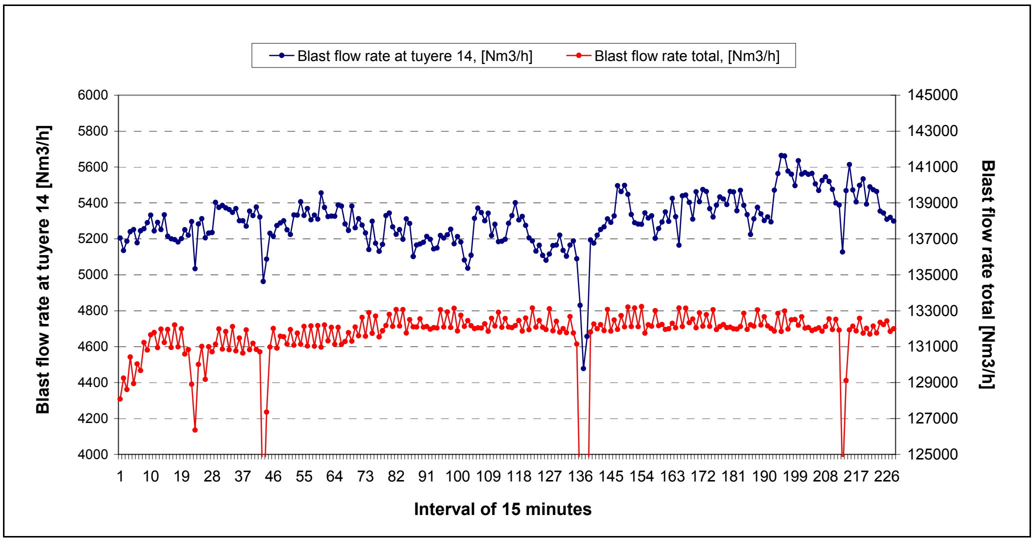
a b

Source: ArcelorMittal Monlevade, 2008

Figure 8. a) Standard down-leg at tuyere 12; b) Venturi down-leg at tuyere 14

4 RESULTS AND DISCUSSION

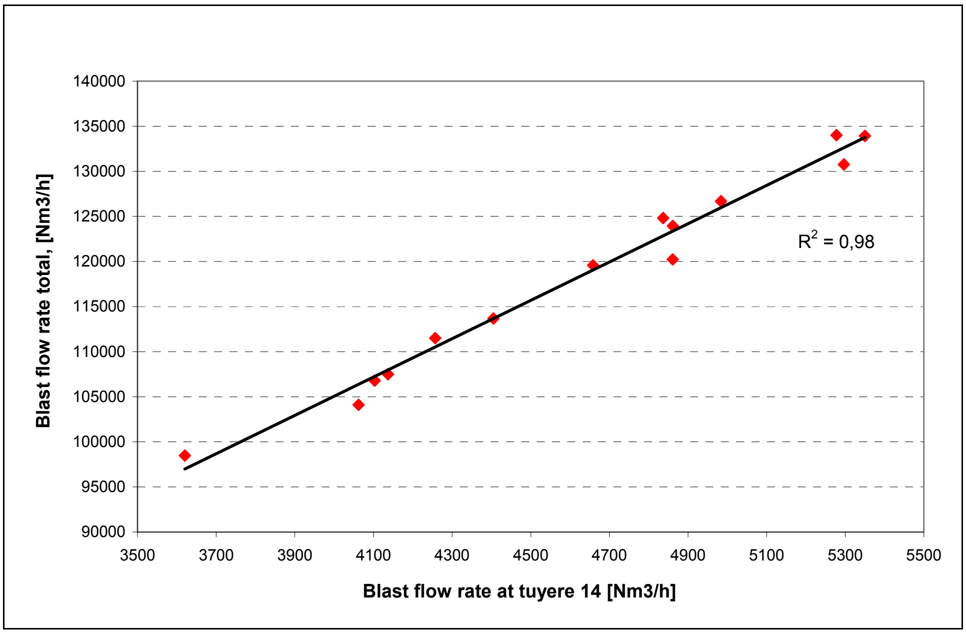
Figure 9 shows the results of the calculated blast flow rate in the tuyere number 14 in the begin of the test. The calculated blast flow rate was between 5.000 e 5.700Nm3/h on this period of time. The results were very close to that obtained mathematically.



Source: ArcelorMittal Monlevade, 2008

Figure 9. Calculated blast flow rate at tuyere 14 in BF-A

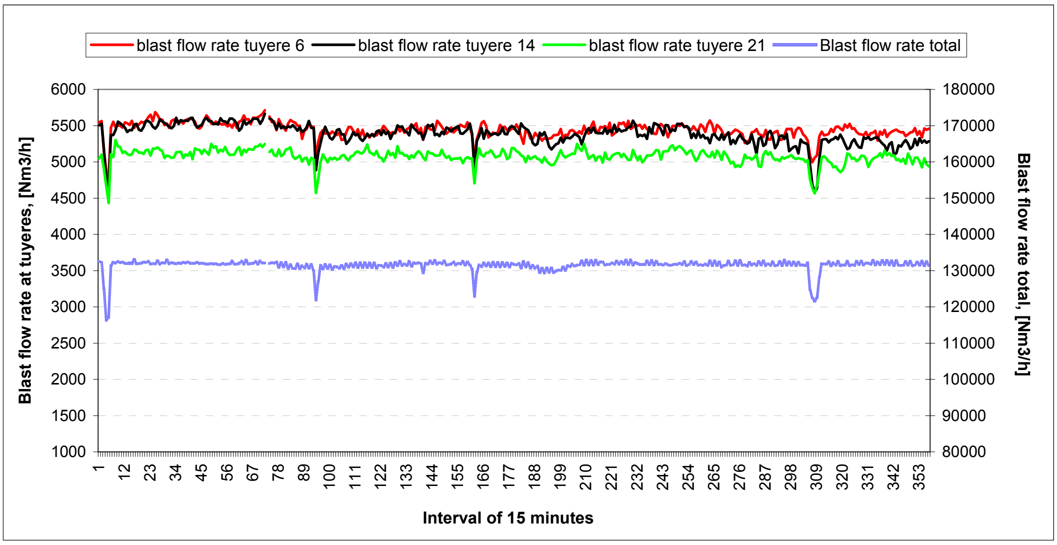
Figure 10 it can be observed the correlation between the calculated blast flow rate in the tuyere number 14 and the total blast flow rate of the blower during a reducing of the blast in the blast furnace. There is an excellent correlation among the blast flow rate in the blower and the measured blast flow rate in the tuyere number 14, R2 = 0,98.



Source: ArcelorMittal Monlevade, 2008

Figure 10. Correlation between the calculated blast flow rate in tuyere 14 and the total blast flow rate

Aiming in verifying the repeatability of the process, it was decided to install new “down-legs” Venturis in the tuyeres number 6 and 21. Figure 11 shows the obtained results. It can be observed that the calculated blast flow rate in the tuyeres number 6 and 21 shows quite similar behaviors found in the tuyere 14, including during a periods of reduced blast.



Source: ArcelorMittal Monlevade, 2008

Figure 11. Blast flow rate at tuyeres 6, 14 and 21 of the BF-A

6 CONCLUSION

The system of measurement of the blast flow rate by tuyere developed in the blast furnace A of ArcelorMittal Monlevade using the theory of Venturi measurer shows had a good operational performance. With a low cost investment it is possible to install this system in all tuyeres in the blast furnace. Furthermore it can be possible to evaluate the behavior of blast flow rate variation through the diameter of the furnace. The knowledge of this asymmetry can be a base for implementation of a complete control injection system of the air and coal in each tuyere.

REFERENCES

1 1 BOLSIGNER, J. P., BAILLY, J. L., ALVAREZ, M.; Tuyere blast fow rate measurements on Sollac Atlantique BF04, ARCELOR Research, 2003, 23p.
2 WEISER, R., BRAUNE, I., MATTHES, P.; Control Blast Furnace Pulverized Coal Injection to Increase PCI Rates, Germany, AMEPA Gmbh, 2000. 9p.
3 ABNT, Rio de Janeiro. ISO 5167-1; Part 1: General principles and requirements, 2008. 33p.
4 IBARS, R. A. F.; Development and Evaluation of Venturi Tubes for Flow Rate Measurement. Piracicaba: Luiz de Queiroz Agriculture School, 2004, 61p. (Master of Science, master of science on Irrigation and Draining).
5 FIGLIOLA, R. S., BEASLEY, D. E.; Theory and Design for Mechanical Measurements. Third Edition. United States of America: John Wiley & Sons Inc. Chapter 10, Flow Measurements, p 394-405.
6 DELMÉE, G. J.; Handbook of Flow rate. 2º edition. São Paulo: Edgard Blücher, 1983. 476p.
7 TAVARES, R. P.; Phenomena Transport, UFMG, 2002.