CHARCOAL BLAST FURNACES PERFORMANCE MONITORING IN CORPORATE SYSTEMS[1]

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Abstract

An experimental model was developed aiming the monitoring of the charcoal blast furnaces performance, focused on tools for calculation and graphic visualization of the parameters facilitating the interpretation of the pig iron production progress. Such tools are made available in the form of charts in a PIMS (Plant Information Management System) application generated from mathematical calculations based on data from the corporate data bases of steelmaking industries. The data gathering stage is made by a historian, which is a quick tool to seek the data bases with high data compression. The indexes made available in the tools are as follows: the calculation of flame temperature, of the melting bed, analysis of the gases and data referring to the production. A worksheet for generating random data for simulating a steelmaking plant data base was used for this work, such data being those gathered by the historian. The accomplishment of the calculations and the generation of charts are also made on a worksheet, where one can access the historic data or on-line data. Such tools are easily applied, suggesting high implementation feasibility.

Key words: Blast furnace; Performance; Historian; PIMS.

MONITORAMENTO DE DESEMPENHO DE ALTOS-FORNOS A CARVÃO VEGETAL EM SISTEMAS CORPORATIVOS

Resumo

Foi desenvolvido um modelo auxiliar visando o monitoramento do desempenho dos altos-fornos a carvão vegetal, focado em ferramentas para o cálculo e visualização gráfica de parâmetros que facilitem a interpretação do andamento da produção de ferro gusa. Tais ferramentas são disponibilizadas na forma de gráficos em aplicativo no sistema PIMS (Plant Information Management System) gerados a partir de cálculos matemáticos baseados em dados dos bancos de dados dos sistemas corporativos de indústrias siderúrgicas. A etapa da coleta dos dados é feita por um historiador, uma ferramenta rápida de busca às bases de dados com alta compactação dos dados. Os índices disponibilizados nas ferramentas são: o cálculo da temperatura de chama, do leito de fusão, análise dos gases e dados relativos à produção. Para este trabalho foi utilizado uma planilha para geração de dados aleatórios para simulação de um banco de dados de uma siderúrgica, dados que são coletados pelo historiador. A efetuação dos cálculos e a geração dos gráficos são feitas também em uma planilha, onde pode-se acessar os dados históricos ou on-line. Essas ferrmanentas se mostraram de fácil aplicação, sugerindo alta viabilidade de implementação.

Palavras-chave: Alto-forno; Desempenho; Historiador; PIMS.

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1 INTRODUCTION

The steelmaking industry is one of the most important industries for the Brazilian economy and the pig iron production in charcoal blast furnaces has been showing a big production growth in Brazil, driven forward by the product quality and by the importance of a production with less environmental impact.

However, charcoal steelmaking plants need investments in Automation Technologies, AT, and Information Technologies, IT, when compared to those using coke as their main fuel.

Investments in ATs and ITs of the corporate systems are a trend in the different industrial fields. In this case, tools were developed in the PIMS system for the industries producing pig iron with charcoal as the main fuel.

Located among the supervision and control layers and all the other systems of the industries the PIMS (Plant Information Management System) is comprised by tools for information management. Actuating in order to concentrate the important information of the whole process (supervision, SDCDs, CLPs, etc.) and making them available for any organization within the corporate systems.

The PIMS system is very efficient in the gathering, storing and arrangement of data. The data gathering is made through specific tools for communication with the different industry systems. The storage is made in a data base with high compression and high response speed.

The historian (PIMS) has as its main characteristics the following: the high capacity of gathering, filing and distributing a high number of data of industrial systems in an efficient manner and with high performance. An interesting resource for use in the corporate systems is the option of using an OPC gatherer which accesses and sends the process data to the server in the DPC. Once the process data is stored the corporate system program connects with the historian temporal data base through an OLEDB interface.

The charcoal blast furnace performance analysis is intended to monitor the influent variables in the pig iron production. Production, raw material consumption, production follow-up reports and charts of the productive parameters trends are created by means of data gathering tools from a historian.

2 MATERIAL AND METHODS

A simulation model of those proposed tools was developed. That model is composed of a blast furnace data simulator, a historian and a graphic interface. The data are aleatoric for the process ranges, based on the literature as CASTRO (3) (4), to simulate a theoretical blast furnace.

The data simulator was prepared in a worksheet software, where random data is generated within certain values ranges known to the process variables. The used variables are in Table 1. Whenever the data is updated, files are generated with it, and such files are periodically gathered by the historian.

The graphic interface was made with charts generated in a file also in the worksheet software, and the variables values for the calculations and the generation of charts are automatically updated with the updating in the historian.

Table 1. **List of variables and description**

Name	Description
LAB_AL2O3BAUXITA	Al_2O_3 in bauxite
LAB_AL2O3CINZACARVAO	Al_2O_3 in coal ash
LAB_AL2O3ESCORIA	Al_2O_3 in slag
LAB_AL2O3MINIRON	Al_2O_3 in iron ore
LAB_AL2O3MINMANGANES	Al_2O_3 in manganese ore
LAB_AL2O3POEIRATOPO	Al_2O_3 in the top dust
LAB_AL2O3QUARTZO	Al_2O_3 in quartz
LAB_ALCALISCINZACARVAO	Alkali in coal ash
LAB_ALCALISMINIRON	Alkali in iron ore
LAB_ALCALISPOEIRATOPO	Alkali in the top dust
LAB_CAOCALCDOLO	CaO in limestone and dolomite
LAB_CAOCARGAMETALICA	CaO in the metallic charge
LAB_CAOCINZACARVAO	CaO in coal ash
LAB_CAOESCORIA	CaO in slag
LAB_CAOPOEIRATOPO	CaO in the top dust
LAB_CAOQUARTZO	CaO in quartz
LAB_CCARVAO	Fixed carbon in the charged coal
LAB_CGUSA	Carbon in pig iron
LAB_CH4TOPO	CH_4 at the top
LAB_CO2TOPO	CO_2 at the top
LAB_COTOPO	CO at the top
LAB_FEBAUXITA	Iron in bauxite
LAB_FECALCDOLO	Iron in limestone and dolomite
LAB_FECARGAMETALICA	Iron in the metallic charge
LAB_FECINZACARVAO	Fe in the coal ash
LAB_FEGUSA	Iron in the pig iron
LAB_FEMINMANGANES	Iron in the manganese ore
LAB_FEOESCORIA	FeO in slag
LAB_FEPOEIRATOPO	Fe in the top dust
LAB_H2TOPO	H_2 at the top
LAB_MGOCARGAMETALICA	MgO in the metallic charge
LAB_MGOCINZACARVAO	MgO in the coal ash
LAB_MGOESCORIA	MgO in slag
LAB_MGOPOEIRATOPO	MgO in the top dust
LAB_MGOQUARTZO	MgO in quartz
LAB_MNCINZACARVAO	Mn in the coal ash
LAB_MNGUSA	Mn in the pig iron
LAB_MNMINIRON	Mn in the iron ore
LAB_MNMINMANGANES	Mn in the manganese ore
LAB_MNOESCORIA	MnO in slag
LAB_MNPOEIRATOPO	Mn in the top dust
LAB_N2TOPO	N_2 at the top
LAB_PECINZACARVAO	Weight of the coal ash
LAB_PEPOEIRATOPO	Top gas dust weight
LAB_PGUSA	P in pig iron
LAB_SGUSA	S in pig iron
LAB_SIGUSA	Si in pig iron
LAB_SIO2BAUXITA	SiO_2 in bauxite
LAB_SIO2CALCDOLO	SiO_2 in limestone and dolomite
LAB_SIO2CINZACARVAO	SiO_2 in coal ash
LAB_SIO2ESCORIA	SiO_2 in slag

LAB_SIO2MINIRON	SiO_2 in iron ore
LAB_SIO2MINMANGANES	SiO_2 in the manganese ore
LAB_SIO2POEIRATOPO	SiO_2 in the top ash
LAB_SIO2QUARTZO	SiO_2 in quartz
LAB_VOLATEISCARVAO	Volatile coal materials
ONL_ENRO2	O_2 Enrichment
ONL_PSOPRO	Blast pressure
ONL_PTOPO	Top Pressure
ONL_TSOPRO	Blast Temperature
ONL_TTOPO	Top Temperature
PRO_ESCORIAGR	Granulated slag
PRO_PEBAUXITA	Charged bauxite weight
PRO_PECALCDOLO	Charged limestone and dolomite weight
PRO_PECARGAMETALICA	Charged metallic load weight
PRO_PECARVAO	Charged coal weight
PRO_PEMINMANGANES	Charged manganese ore weight
PRO_PEQUARTZO	Charged quartz weight
PRO_PRESCORIA	Slag production
PRO_PRGUSA	Pig iron production
PRO_PRGUSAPR	Anticipated pig iron production
PRO_TESCORIA	Slag temperature
PRO_TGUSA	Pig iron temperature
PRO_UMICARVAO	Charged coal humidity
PRO_UMISOPRO	Blast air humidity
PRO_UMITOPO	Top gas humidity
PRO_VOLARSOPRO	Blast air volume
PRO_VOLCARVAO	Charged coal volume
PRO_VOLGASTOPO	Top gas volume
PRO_VOLINTERNOAF	Blast furnace inner volume

The tools were developed for calculation, analysis and generation of charts for the following indexes:

- Flame temperature;
- Melting bed;
- Blast furnace operating indexes (productivity, production, fuel consumption, slag basicity, blast flow);
- Gas analysis (blast furnace top gas, gas yield, top temperature, blast furnace permeability).

Flame temperature[1]:

Flame temperature is the temperature of the gases when leaving the combustion zone. It may be estimated by thermal balance. The attainment of its value and control are largely important for the blast furnace operation. It has influence on the furnace thermal levels, thus affecting the pig iron and slag temperatures, the gas yield and the incorporation of elements to the pig iron. The used mathematical formula is given below:

$$T_{CHAMA} = 1267,9 + 0,9742 \times T_s + 57,6358 \times E_{ar} - 7,1458 \times U_{ar}$$

Where,

T_{CHAMA} is the flame temperature;

T_s is the blast air temperature;

E_{ar} is the oxygen enrichment rate in the blast air;

U_{ar} is the blast air humidity.

Melting bed:
Melting bed is the calculus of the quantity of raw materials required to be charged at the blast furnace top for a stipulated pig iron production. With the composition and weight of the pig iron and slag produced and the composition of the raw materials, a mass balance is made to obtain the quantity of raw materials to be charged in the blast furnace to produce a ton of pig iron.
Fuel consumption:
It is the relationship between the coal quantities consumed by the pig iron production.
Blast flow:
Once the fuel consumption amount per pig iron production is achieved, the blast flow required to meet the anticipated production is computed.
Blast furnace top gas:
The composition of the gases leaving at the blast furnace top show how the iron ore reduction is being accomplished. The main gases are carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H), nitrogen gas (N_2) and the aromatic compounds (C_mH_n).
Gas yield[2]:
It is the relationship between gases CO and CO_2. The formula below:

$$\eta CO = \frac{CO_2}{CO + CO_2}$$

Where,
ηCO is the gas yield;
CO CO_2 are their amounts at the blast furnace top.

Blast furnace permeability[2]:
Permeability is an index that quantifies the gas yield facility through the blast furnace body. The mathematical formula used for its calculation is given below.

$$\frac{V}{P_S - P_T}$$

Where,
V is the gas blast flow in the blast furnace;
P_S is the blast pressure;
P_T is the blast furnace top pressure;

3 RESULTS

Once the simulation is done, it was possible to follow up the performance of a virtual blast furnace. Some of the charts generated in that model are given below.
Figure 1 shows charts with the flame temperature and with parameters affecting it: blast temperature, blast air oxygen enrichment and its humidity.
Figure 2 shows the chart indicating the Melting Bed calculation, which can be computed in many ways and adapted to each operation team of each blast furnace.
The blast furnace permeability calculation may be reviewed through the chart exposed in Figure 3, where one can also find the charts of the influent variables in that calculation, blast flow, blast pressure and top pressure.

The gas yield, or CO yield, is shown in Figure 4, along with the blast furnace top gases chart.

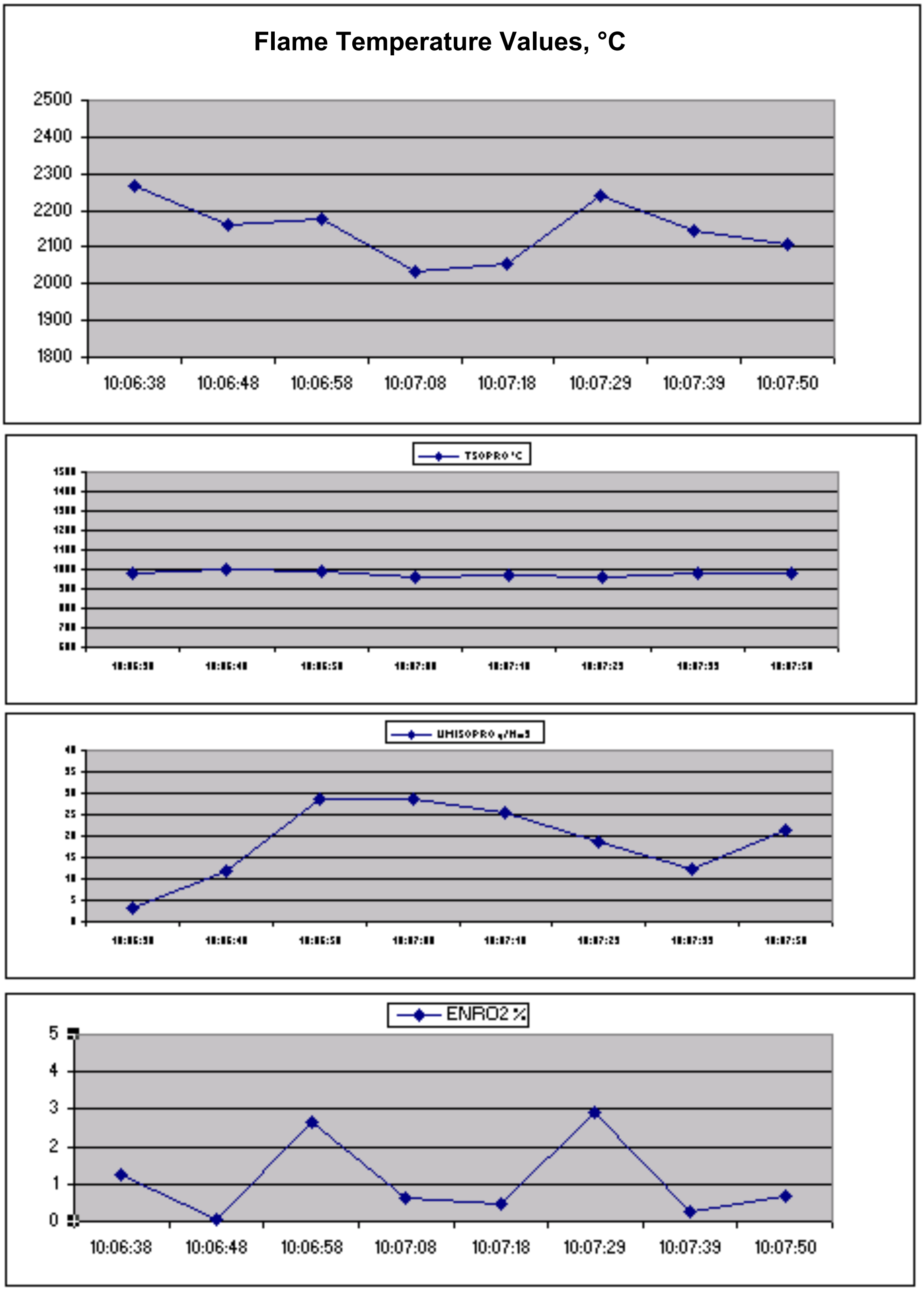

Figure 1. Flame Temperature Calculation.

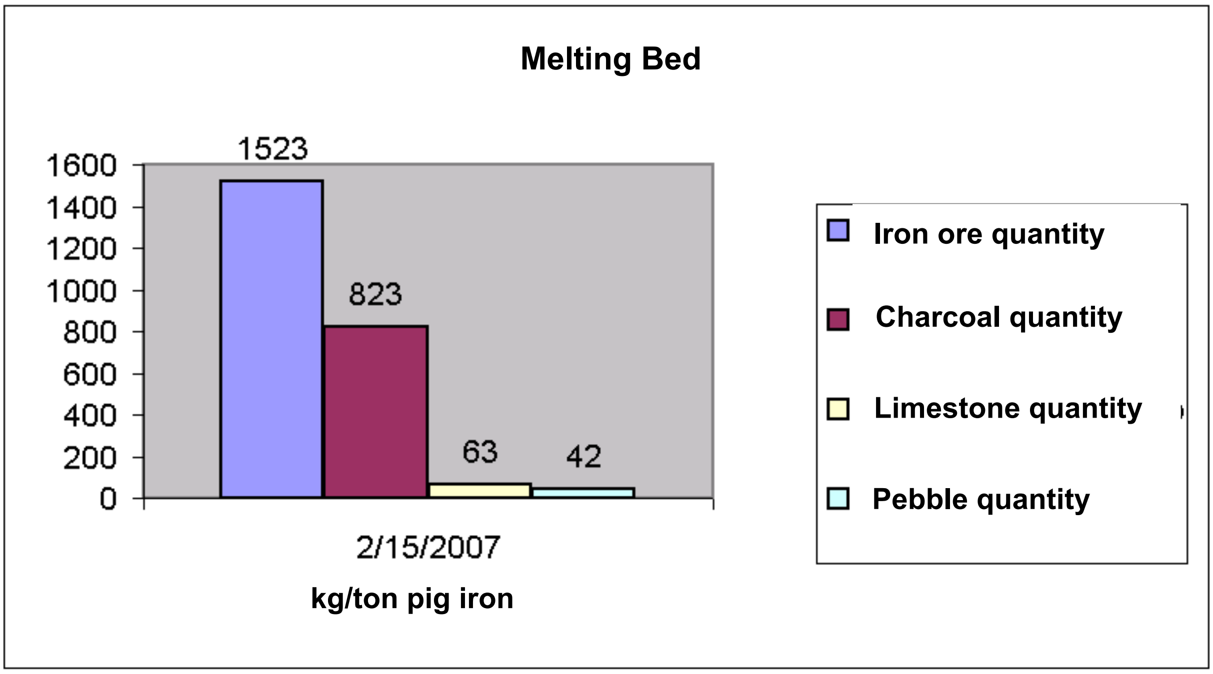

Figure 2. Melting Bed Calculation

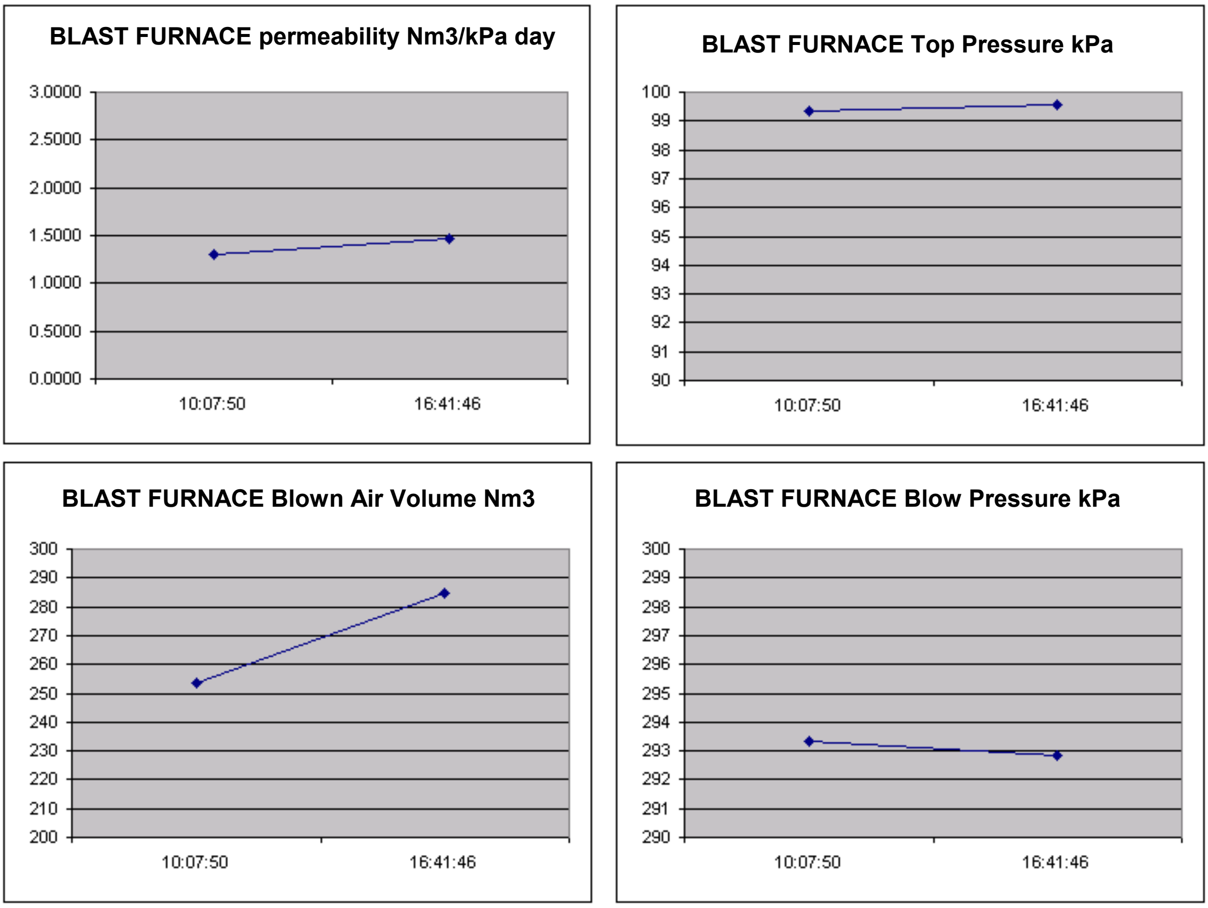

Figure 3.Blast furnace permeability calculation

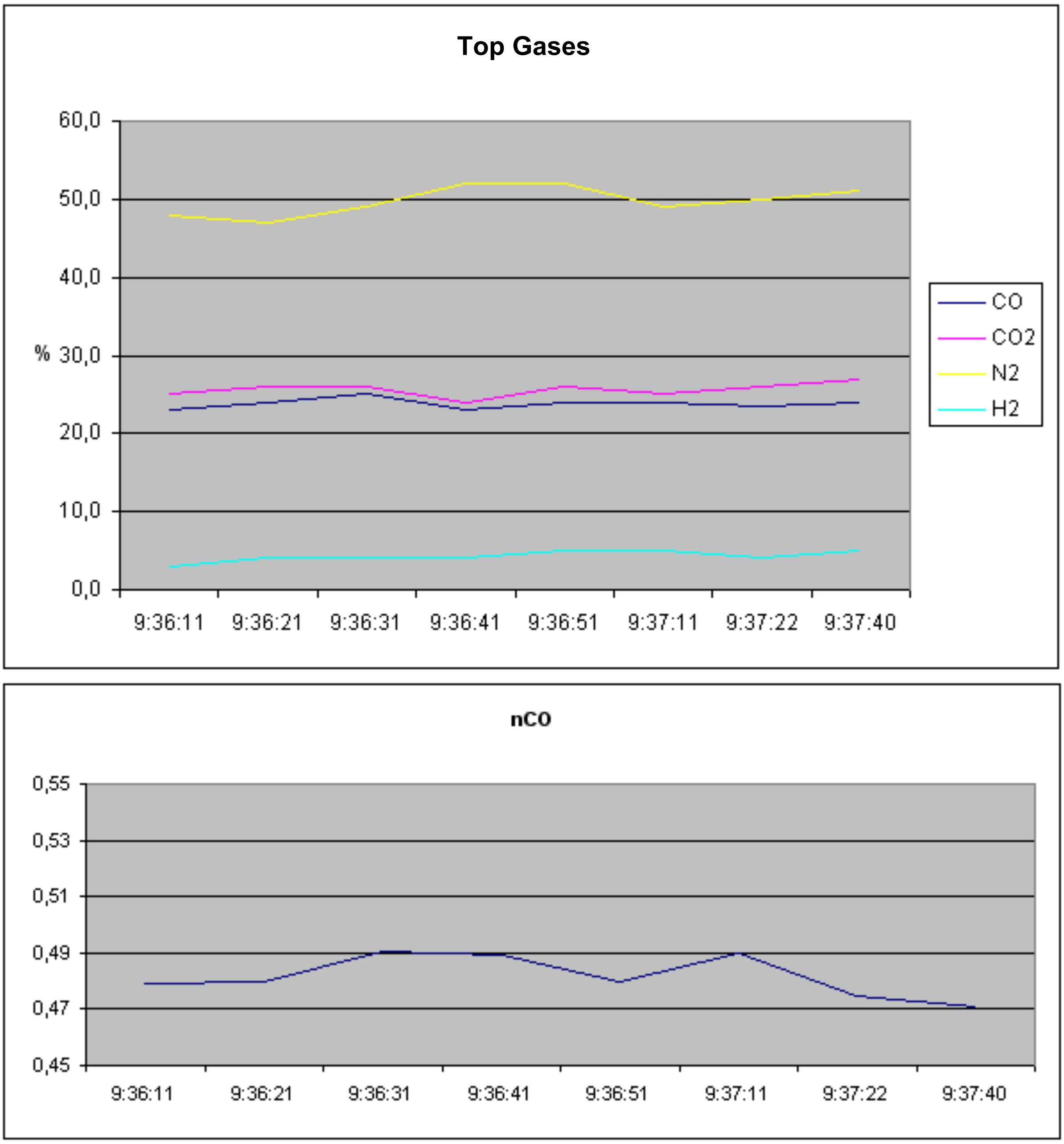

Figure 4. Gas yield (CO yield).

4 DISCUSSION

The methodology used for simulating data from a blast furnace has been shown to be satisfactory, the utilization of an OPC server not being very different.
The historian had the expected performance, suggesting a feasible application for solution in IT and AT in the referred steelmaking plants.
The graphic visualization in worksheet software meets the simulation expectations of the graphic softwares.
The proposed method presented a low implementation complexity as compared to other information and automation technologies resources for steelmaking plants.

5 CONCLUSION

The simulations complied with the application expectations in an industrial process.
The implementation feasibility of suitable tools to manage blast furnaces is high, since most of the charcoal steelmaking plants require automation and information systems.
The reliability of the information enables to implement such tools for production analysis with indication calculations of integrated numbers for maintenance and production.
Such resources may be made available in the intranet, allowing remote accesses for performance supervision of those blast furnaces, enabling the variability decrease of the process with a direct impact on the company's profit. The discussion is the main part of the work.

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