CONTROL OF THE REFRACTORY LINING WEAR IN BLAST FURNACES, USING A RADIOTRACER TECHNIQUE

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ABSTRACT

Small metal ^{60}Co sources, double encapsulated with quartz and alumina, were inserted (at different depths and levels) into the refractory bricks of the blast furnace walls, and the initial radioactivity emerging at each location recorded as a reference data for future measurements.

The displacement of the charge inside the blast furnace originates a progressive wear of the refractory lining and after certain time, the inner sources will begin to be scraped off from the wall and then dissolved in the molten iron. By periodically monitoring the radiation level at the points where the sources were placed, it is possible to know if some of them was removed by the wearing process. This, in turn, will indicate the thickness of refractory material lost in each location making possible to record the extent of wear in the controlled cross sections of the blast furnace, as a function of time.

This paper deals with the pratical application of the method in the Brazilian steel industry.

1.0 INTRODUCTION

Technological improvements allowed to increase the production rate of blast furnaces, in the steel industry.

Concomitantly, the rate of wearing of the blast furnace refractory lining also increased.

In order to follow the evolution of such a wearing process without interrupting the furnace operation, a radiotracer technique was developed at IPEN laboratories and applied in two steel factories.

2.0 MATERIALS AND METHODS

2.1 Principles of the method

Small radioactive sealed sources are inserted into the refractory bricks, at different sections of the blast furnace. In each cross section the sources are distributed around, at different depths. The initial radioactive emerging at each location is recorded to serve as reference data for subsequent measurements.

As the wear proceeds the inner sources will be scraped off from the walls and carried down along with the furnace charge materials, being finally dissolved in the molten iron mass at the bottom.

By periodically monitoring the radiation intensity at the sections and locations where the sources were placed and comparing that reading with the previous one, it will be possible to know if some of the sources is missing. This, in turn, will indicate the thickness of refractory lining lost in each position and thus, the extend of wear in the controlled sections of the blast furnace.

2.2 Radioactive source characteristics

The selection of the radioisotope and the source design are of fundamental importance for the proper application of this technique. Among the radioisotopes considered, the ^{60}Co was chosen because it meets the following requirements:

a) high energy gamma emmiter;

b) half-life in agreement with the expected duration of a furnace campaign (estimated in 8 years);

c) high melting point to mantain physical integrity under the temperatures prevailing inside the refractory lining (from 1000° to 1200°C) and low enough to fuse and dissolve into the molten iron;

d) low vapor pressure at the temperatures existing in the lining to avoid diffusion (1).

On the other hand the source activities must be in accordance with the maximum permissible concentration established by recognized radiation safety rules.

In the case of ^{60}Co, this limit for drinkable water, as set by the Comissão Nacional de Energia Nuclear in the basic rules for radiological protection is 5×10^{-4} microcuries per cm^3. Adopting the same value per gram of other solid material (2), the maximum permissible concentration of ^{60}Co in iron is 500µCi per ton. The above limit was taken into consideration for planning and implementing the practical applications of this technique.

For the construction of the encapsulated sources, a metallic cobalt pellet 4.0 mm in diameter and 3.0 mm lenght was first sealed in a quartz ampoule (Ø 7.0 x 10.0mm, aprox.) and then irradiated at the IPEN's nuclear reactor. After completing the irradiation period, the quartz ampoule was placed into another small ceramic capsule and closed with a cemented cap. Both, capsule and cap., were made of ALSINT , a high alumina ceramic (99.7%) with low porosity (1%) and high density (3,79 g/cm^3).

Fig. 1 shows a longitudinal cross section of the sealed source assembly.

The activity of the sources, determined as explained in section 2.2 , varied from 0.24 to 23.2mCi.

2.3 Preliminary tests

Several tests on refractory drilling, lining reconstruction, radiation measurements and sealed source resistance under high temperature were made before installation of the sources.

Different types of machines were tested to compare their performance for boring holes in the refractory materials regarding hole diameter accuracy, bore finishing, number of drills broke during operation, effects on refractory wall integrity and drilling time. It was concluded that low impact electric drillers having high rotation and equipped with widia tools were the best option. Drills of 14 and 16mm in diameter were used for boring carbon and silica-alumina refractory linings, respectively.

The following three methods for re-building the refractory lining and plugging the sources in the holes were tested:

1) pumping injection of a silica-alumina cement;
2) manual filling with a high alumina plastic paste moulded in the form of sticks and beat into the bore;
3) insertion of high alumina solid rods (cemented) with silica-alumina paste.

The last method proved to be the most effective in regard to fast operation, minimum amount of air bubles and physical properties of the finished plug very close to the original material. In the case of carbon refractory, carbon rods with injection of carbonaceous paste was found to be the best solution.

Source activities were calculated empirically, by means of the experimental arrangement illustrated in Fig. 2, for insertion depths varying between 200 to 1050mm from the "cold face" of the furnace. In this experiment, calibrated ^{60}Co sources having three different activities were used as a standards for subsequent calculations. Radiation measurements were performed with the same detectors to be used for monitoring the blast furnace sections.

The thermal resistivity of the double encapsulated source under simulated working conditions was studied by heating a non-active prototype at 1200°C, in an electric oven. No damage was observed after prolonged test.

2.4 Source distribution in the blast furnace walls

In the Companhia Siderúrgica Nacional (CSN) Nº 1 and Nº 2 blast furnaces and Companhia Siderúrgica Paulista (COSIPA) Nº 2 furnace, the source insertion depths in each section varied between 200 and 965mm. The levels of the controlling sections in the blast furnaces were chosen according to the wearing profiles determined at the end of previous campaigns and on the basis of data from available literature.

Up to know a total of 529 radioactive sources were implanted in the three blast furnaces mentioned above: 133 at CSN Nº 1, 204 at CSN Nº 2 and 192 at COSIPA Nº 2, being distributed in several levels as to control the wearing in critical sections of the stack, bosh and mantle.

2.5 Radiation surveys

In monitoring the blast furnace sections a portable detector is simply placed on the labeled positions and the radiation level compared with previous measurements to know if some source has been lost.

This procedure is repeated each 40 days, approximately, taken advantage of the preventive maintenance stops of the furnaces.

The profiles of lining wear are visualized by drawings representing horizontal and vertical cross section of the blast furnaces, as indicated in Fig. 3.

Fig. 4 shows a time sequence of such profiles, giving a schematic picture on the refractory lining wear progress.

3.0.0 RESULTS AND CONCLUSIONS

Among the blast furnaces in which this technique was applied, the Nº 2 at CSN is the one from which first data is being obtained, after 16 months of operation. The lining wear profiles are represented in Fig. 4. The curves of refractory lining wear as a function of furnace production have been plotted in Fig. 5.

From the results obtained during this period it can be concluded that:

a) the wear verified so far, can be considered normal, as compared with reported values for similar furnaces;

b) the radioisotope technique made possible to evaluate the lining wear in several locations, particularly, in regions near the cooling plates;

c) the data already obtained allowed to adjust the operation conditions as to avoid excessive or localized wear of refractory lining;

d) the method proved to be reliable and safety.

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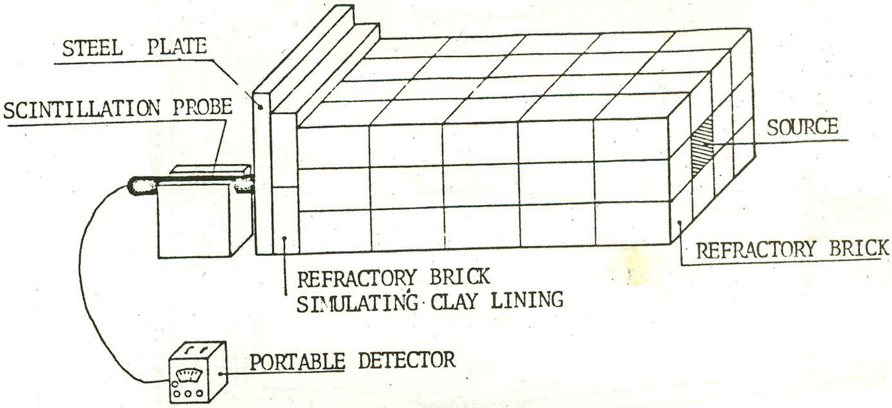

Fig. 1 - Experimental arrangement with silica-alumina refractory bricks

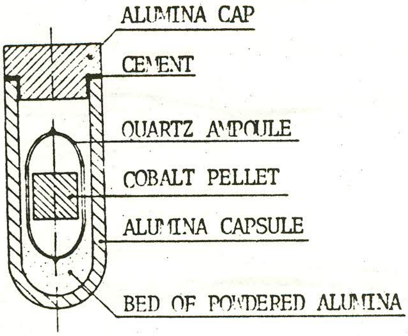

Fig. 2 - Double encapsulated source assembly (cross section)

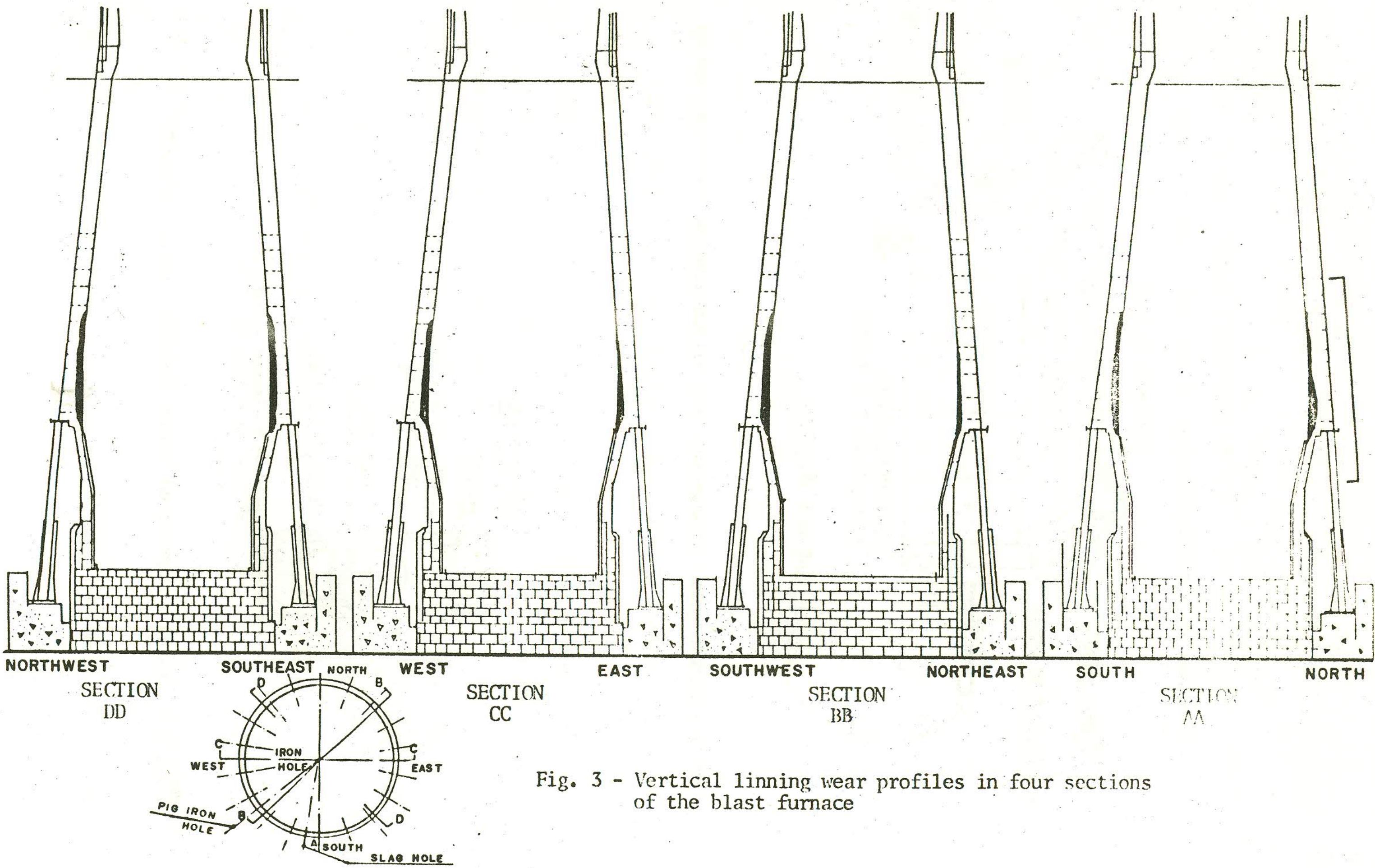

Fig. 3 - Vertical linning wear profiles in four sections of the blast furnace

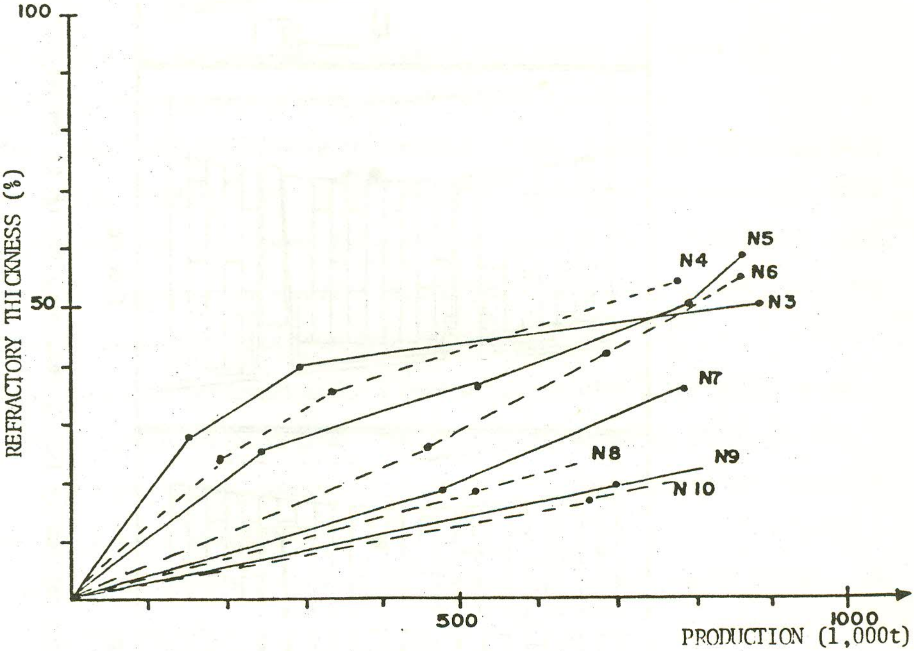

Fig. 4 - Refractory lining wear of CSN Nº 2 blast furnace, as a function of production.

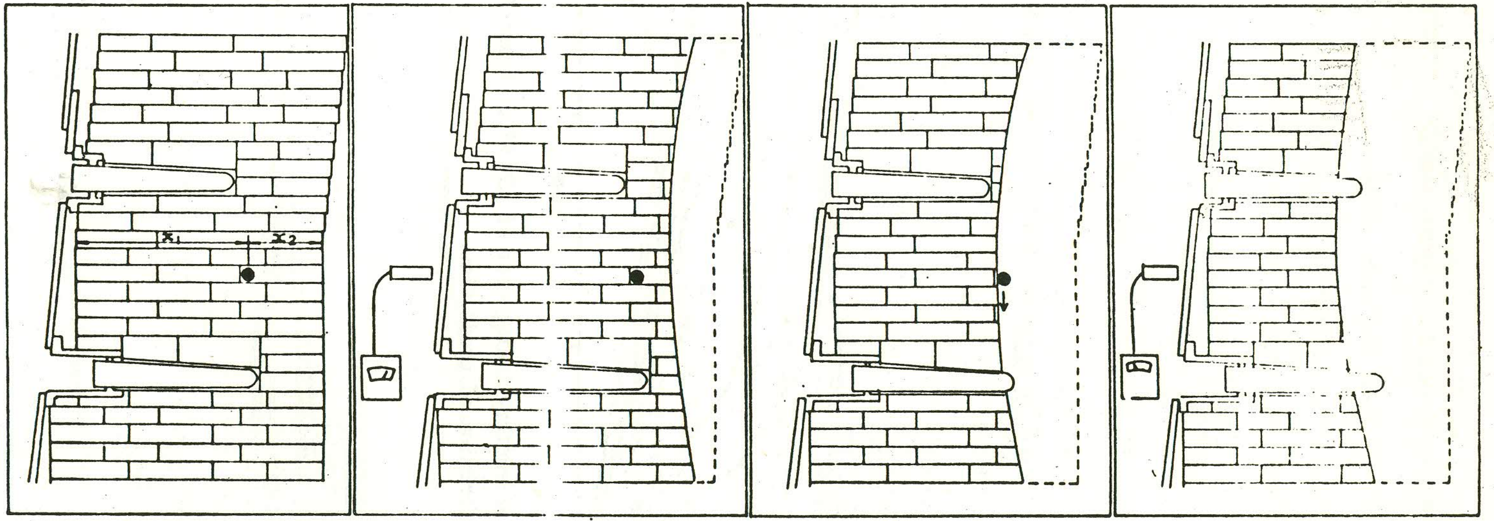

FIG. 1a FIG. 1b FIG. 1c FIG. 1d

Fig. 5 - Schematic time sequence of the refractory lining wear progress up to removal of a radioactive source.