

WATER LEAK DETECTION IN THE COOLING SYSTEM OF THE BLAST FURNACE WALLS, BY  
USING RADIOTRACER TECHNIQUES.

P. AOKI, H. ROCCA, A. CASTAGNET

Department of Applications in Engineering and Industry  
Instituto de Pesquisas Energéticas e Nucleares - CNEN/SP

ABSTRACT

The walls of a blast furnace are cooled by water that circulates through a system of copper plates inserted in the refractory lining. These plates are fed by two independent annular pipes (or distribution rings) located around the furnace at different levels.

Tritiated water was continuously injected in the upper ring, to investigate the presence of leaks in the plates fed by that distribution ring. During and after injection, water samples were periodically collected at the top of the blast furnace by condensing moisture from exit gases.

The tritium activity, when present in the samples, indicates the existence of leaks in the cooling plates and, in some cases, allows to estimate the total water flow rate entering the blast furnace.

Actual applications of this technique are described.

1.0 INTRODUCTION

The cooling system of the blast furnace walls, consists, basically, in different copper plates assemblies, that are protected by refractory bricks and fed by water distribution rings.

As a consequence of the inner lining wear during blast furnace operation, some plates may be subjected to a corrosion process that, in turn, may cause water leaks.

In order to detect the presence of such leaks and to evaluate their total flow rate, a series of 13 tests was performed in the blast furnace N° 1 at

Companhia Siderúrgica Paulista S.A. The tests were based on the continuous injection of tritiated water into the distributing ring, followed by periodic collection of water samples from exhaust gases, at the top of the furnace, by moisture condensation.

The tritium activity, when present in the samples, indicates the existence of leaks in the cooling plates and, in some cases, allows to estimate the integrated flow rate of water entering the blast furnace, as explained in section 2.1.

## 2.0 TRACER TECHNIQUE

### 2.1 Fundamentals of the method

The physical model proposed to evaluate the integrated flow rate from water leaks, is based on the continuity principle i.e., at equilibrium conditions and assuming no losses of tracer inside the system (by accumulation, decomposition or reaction), the amount of tritium entering the furnace in a given time period must be equal to the amount of tritium leaving it during the same interval.

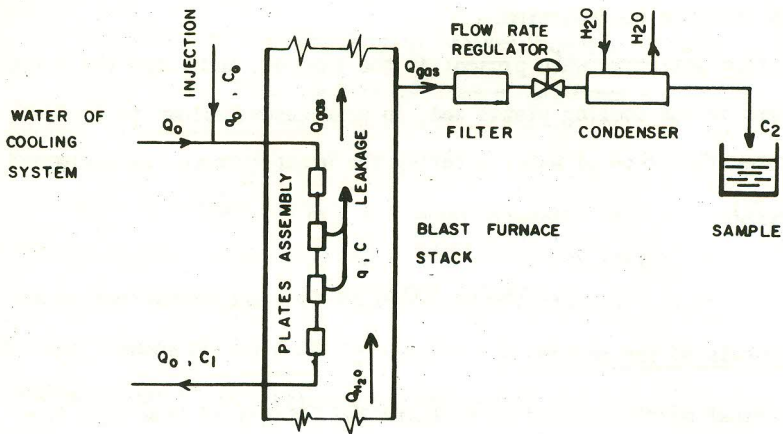
Fig. 1 shows, schematically, the blast furnace stack, the injection point of tritiated water in the cooling circuit and the condensation system for collecting the samples. The principal parameters involved in the calculation procedure are also indicated.

At a given time from the beginning of the continuous tracer injection (with constant flow rate  $q$  and tritium concentration  $C_0$ ), an equilibrium concentration  $C_1$  of tritium will be reached along the water flowing through the cooling system, such as:

$$C_1 (Q_0 + q_0) = q_0 C_0$$

or

$$C_1 = \frac{q_0}{Q_0 + q_0} \cdot C_0 \quad \mu\text{Ci. cm}^{-3}$$



NOTATION :

$Q_0$  = WATER FLOW RATE IN THE DISTRIBUTION RING

$q_0$  = FLOW RATE OF TRITIATED WATER USED AS TRACER

$C_0$  = TRITIUM CONCENTRATION IN THE TRACER

$q$  = FLOW RATE DUE TO TOTAL LOSSES

$Q_{H_2O}$  = WATER MASS FLOW RATE IN THE BLAST FURNACE GASES

$C_2$  = TRITIUM CONCENTRATION IN THE CONDENSED WATER

FIGURE 1 - Scheme and notation of measurement process

In the practice  $Q_0 \gg q_0$  and the above expression becomes:

$$C_1 = \frac{q_0}{Q_0} \cdot C_0 = r_0 C_0$$

being  $r_0 = \frac{q_0}{Q_0}$  (dilution rate)

If the water leakage from the cooling plates represents a flow rate  $q$ , the tritium activity entering the furnace per unit time will be:

$$A = q C_1 = q r_0 C_0 \quad (1)$$

Assuming that all this activity is immediately and homogeneously mixed inside the furnace with the water vapor carried at mass flow rate  $Q_{H_2O}$  by the gas current, the tritium concentration  $C_2$  in the water vapor, after reaching equilibrium conditions of the dilution process, will be.

$$C_2 = \frac{A}{Q_{H_2O}}$$

From eq. (1):

$$q = \frac{Q_{H_2O} \cdot C_2}{r_0 C_0} \quad (2)$$

From this expression, the integrated flow rate of the cooling water leakage can be calculated, provided that the following requirements are satisfied:

- a)  $Q_0$ ,  $Q_{H_2O}$ ,  $q_0$  and  $q$  should remain reasonably constants along the measuring interval;
- b) the water leaks are readily and homogeneously mixed with the flowing vapor mass  $Q_{H_2O}$ ;
- c) no loss of tritiated water occurs inside the furnace;
- d)  $C_2$  really corresponds to steady state conditions of dilution process.

It should be noticed that  $C_2$  will be also the tritium concentration in

the water condensed from the exhaust gases.

As the activity measured under same conditions in the samples is directly proportional to their tritium concentration, the following relation will hold:

$$n_0 = k C_0$$

$$n = k C_2$$

where,

$n_0$  and  $n$ : counting rate from samples of injected water and condensed vapors, respectively;

$k$ : constant coefficient for the measuring system.

Consequently:

$$\frac{C_2}{C_0} = \frac{n}{n_0}$$

and, from eq (2)

$$q = \frac{Q_{H_2O}}{r_0} \cdot \frac{n}{n_0} \quad (3)$$

All the values in the right side of this equation can be known or, otherwise, experimentally measured.

If (as was actually the case in this work) the water flow rate  $Q_0$  in the distribution ring is not accurately known, it could be determined by tracer techniques, such as the "total count" method or the "two peaks" method. The last one, because it is simpler than the former, was chosen for measuring  $Q_0$ .

The "two peaks" method can be applied whenever the internal cross section of the pipe, between two accessible points separated by a convenient distance, remains constant and has a known value. Two radiation detectors, one in each point, are attached to the pipe walls and an instant tracer injection is made upstream through any suitable inlet. The instants  $T_1$  and  $T_2$  at which the radioactive "cloud" pass through the measuring sections are recorded and the

flow rate is calculated from the formula:

$$Q_0 = v.S = \frac{d}{T_2 - T_1} \cdot S \quad (4)$$

where,

v: mean linear velocity of the water flow;

S: area of the constant cross section;

d: distance measured along the pipe axis, between the detection sections.

In practice, the interval  $\Delta T = T_2 - T_1$  is determined with a two channels recorder by measuring the distance between the center of mass of the two activity peaks. Since the recorder paper velocity is known, the time interval corresponding to the measured distance is easily calculated.

## 2.2 Test implementation

The tracer water used for the continuous injection in the cooling system was obtained by dilution of a tritiated water of high specific activity (about  $10.6 \text{ Ci/cm}^3$ ).

In order to determine the dilution rate and the volume of such a preparation, the following factor were taken into consideration:

- 1) sensibility limit of the measuring system to be used;
- 2) minimum leakage flow rate to be detected;
- 3) estimated equilibrium time for the dilution process in both the cooling system and the furnace, after beginning of the injection;
- 4) maximum permissible concentration of tritium in the residual waters.

Considering the complexity of the whole dilution process, the time period referred to point 3) was initially assumed to be 180 min.

The purpose of point 4) was to comply the radiation safety rules establishing the maximum permissible level of  $3 \times 10^{-2} \text{ } \mu\text{Ci/cm}^3$  for tritium concentration in water.

Based on the preceeding consideration, the total tritium activity injected into the cooling system was about 3Ci per test.

The tracer injection in the distribution ring was made at a pressure above  $6 \text{ kg/cm}^2$ , to overcome the internal pressure of the water cooling system, using a positive displacement micro-pump of constant flow-rate.

The water samples from condensed vapor, of about  $20 \text{ cm}^3$  each, were collected at 15 min intervals, using a special system equipped with filtering and condensing units.

In order to obtain additional information on the leaks dilution process inside the blast furnace, collection of samples was continued for more than one hour after finishing the tracer injection.

The condensed water samples were purified by distillation and measured in a liquid scintillation counter. Counts were accumulated during 30min to reduce statistical errors.

The mass flow rate of water vapor carried by the blast furnace gas was calculated from the gas flow rate and moisture content values, supplied by COSIPA.

The gas moisture content was determined with the same system used for condensing the water vapors, by sampling the gas under controlled conditions.

Finally, the water flow rate in the cooling system was measured by the two-peaks method, using an aqueous solution of  $^{82}\text{KBr}$ , as radioactive tracer. The instant injection was made under nitrogen pressure, with an special device. Two portable GM counters associated to a two channels recorder, were used to detect the passage of the radioactive tracer through the measuring sections.

### 3.0 RESULTS AND CONCLUSIONS

The first test, performed in May 5, 1982, allowed to confirm the presence of leaks in a set of copper plates fed by the upper distribution ring. The maximum flow rate of such a leakage was estimated in  $q = 1830 \text{ l/h}$ . This rather high value called for urgent repairs in the cooling system. After finishing

the repair work, a survey program based on periodical tracer testing was established and executed, with the results shown in Table 1.

It can be observed that the flow rate obtained in the 6<sup>th</sup> test ,  $q = 1348$  l/h, indicated the need of performing new repairs in the cooling plates. The effectiveness of that services were demonstrated by the results of subsequent tests.

Based on the experience gained through the application of this technique, the following additional conclusions can be drawn:

- 1) the diffusion of water leaks through the gas current inside the furnace, is not a continuous process of homogeneous dilution; there are retention zones and preferential pathways originating random results along the same test;
- 2) the residence time of water leaks entering the furnace volume is relatively high as compared with the injection period.
- 3) the flow rate of water in the cooling system, as measured by the two peaks method, showed variations up to 15% from one test to another;
- 4) the original moisture content and the flow rate of exiting gases , should be measured frequently and accurately along the injection period, to give more reliable information;
- 5) in spite of its intrinsic limitation regarding to the accuracy of quantitative calculations, the method has proven to be a powerful tool to detect very small leaks and to estimate their integrated flow rate.

Improvements in the experimental procedure for collecting complementary data, may increase the quantitative value of this technique.

Table 1. Flow rates of circulating water ( $Q \text{ m}^3/\text{h}$ ) and total leakage ( $q \text{ l/h}$ ) for the upper ring cooling assembly.

TEST N°	DATE	FLOW RATES	
		Q ( $\text{m}^3/\text{h}$ )	q (l/h)
01	82/05/20	442,05	1831,80
02	82/06/24	442,05	34,80
03	82/06/28	382,69	16,20
04	82/06/30	422,14	57,00
05	82/09/23	438,37	18,00
06	83/04/14	386,35	1348,20
07	83/04/28	382,03	7,80
08	83/05/27	331,96	5,40
09	83/08/09	427,40	1,86
10	83/11/18	398,74	1,32
11	84/02/08	383,10	2,93
12	84/03/29	434,18	4,31
13	84/05/18	382,03	5,26