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RESIDENCE TIME MEASUREMENTS OF A SHAFT FURNACE FOR THE IRON ORE COMPANY OF CANADA LTD.

by

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MINERAL SCIENCES DIVISION

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SUMMARY OF RESULTS

Tracer tests using silver-110 as the radioactive tracer have been conducted at Schefferville to determine the residence time of calcine in a vertical shaft furnace at charge rates of 400 lb/hr and 600 lb/hr. While there appeared to be little dispersion of ore in the upper five hearths, there was evidence of surging pile-up on the bottom hearth, which led to the appearance of sharp double peaks in the discharge graph. In a separate tracer test the cooler transit time was established to be 20 minutes.

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INTRODUCTION

At the request of Dr. H.E. Neal, Supervisor of the Ore Testing and Research Division of the Iron Ore Company of Canada Ltd., Schefferville, Que., the writer went to Schefferville with Mr. A.F. Seeley on December 7-9, 1961 to determine the residence time of a shaft furnace by means of radioactive tracers. The furnace in question is a vertical shaft furnace with six hearths and is used for test work on the roasting and calcining of Knob Lake ore. The shaft rotation, temperature and feed rates are variable. Each hearth is cleared by four rotating rakes, three of which are angled forward and one backward. Current tests are conducted with a reducing atmosphere containing 8% CO and 4% H_2; however, for the residence time tests pure air was used, as it was felt that the residence time is not dependent on atmosphere composition. The furnace is oil-fired and the hearths were maintained at varying temperatures ranging from 950°F at the top hearth, No. 1, to 1400°F at the lowest hearth, No. 6.

The ore charged was a goethite-hematite ore, estimated to range in size from $\frac{1}{4}$ in. to 150 mesh. The ore is fed into the furnace from a small hopper by means of a screw feeder. The ore from the lowest hearth falls through an eccentric hole into an 8 ft long cooler with a longitudinal screw drive from which it is discharged. The reason for conducting the tests was some uncertainty in the actual

residence time in the furnace, since it was suspected that there was an undetermined hold-up of ore in the bottom of the furnace. The movement of the charge is alternately inward-outward as it moves from hearth to hearth.

TEST DETAILS

As it was thought that the charging rate was the main factor influencing the residence time in the furnace, two tests were planned at feed rates of 400 lb/hr (Test 1) and 600 lb/hr (Test 2). The shaft rotation rate was fixed at 0.6 rpm, representative of normal operation.

The radioactive tracer used was silver-110, half-life 270 days, in the form of silver nitrate solution. The charge was tagged by soaking a quantity of ore, about 2 lb, in the active solution and mixing it thoroughly. Since the degree of dispersion in the furnace was uncertain, about 8 millicuries (mc) of activity were provided for each test. After it became evident that little dispersion took place, only 6 mc were used for Test 2 and the remaining 2 mc were retained for a residence time determination of the cooler alone (Test 3).

Samples were collected at the door of No. 6 hearth and at the discharge of the cooler. The material collected at No. 6 door actually represented particles falling from No. 5 hearth. Collection of this sample was slightly uncomfortable and varying amounts only could be collected during each sampling period of two

shaft revolutions (2-3 min). The sample collection was done by Dr. Neal and Mr. G.M. Major, the senior engineer. No difficulty was encountered in collecting an adequate sample at the cooler discharge.

The samples were counted with a portable Geiger counter, Electronic Associates type EA135P. The Geiger probe of this counter was mounted horizontally inside a small shielding cave made up of small bagged ore samples. The background count rate was of the order of 80-130 c/m for all tests. Film badges were worn by Mr. Seeley, Mr. Major, Mr. G. Losier, one of the operators, and the writer as a control of radiation exposure. A "Cutie Pie" portable survey meter Tracerlab Model SU-1H was used to check source shielding before the tests and to monitor radiation levels around the drums containing the discharged ore.

TEST RESULTS

Test 1

The active ore sample was placed in the feeder screw at the bottom of the feed hopper. From the screw rotation rate Mr. Major estimated that it would take 5 minutes for the active material to reach the inside of the furnace. The active material was placed into the feeder screw at 10:32 am on December 8 and hence entered the furnace at 10:37 am.

The estimated residence time for a feed rate of 400 lb/hr was about one hour. Samples were, therefore, scheduled to be taken at No. 6 door every 10 minutes for the first 40 minutes, every 5 minutes for the next 40 minutes, and every 10 minutes for the next half hour. This schedule was somewhat modified in the light of actual counting results. The furnace heat was shut off during the 5 minute sampling period. The discharge samples were collected every 5 minutes throughout the test.

The results obtained are plotted in Figure 1 and will be discussed later.

Test 2

This test was similar in all respects to Test 1, except that the charging rate was increased to 600 lb/hr. In this test the tracer was placed into the feeder at 2:52 pm on December 8 and entered the furnace at 2:57 pm. The results appear in the right half of Figure 1 and show again a sharp single peak for the samples from No. 6 door and a very pronounced, well-resolved double peak for the discharge samples. The area under the curves for Test 2 is slightly smaller than that of Test 1, reflecting the lower activity used in the tagged sample of Test 2.

Since the discharge samples showed a pronounced double peak the samples were screened subsequently into + 100 and - 100 mesh fractions to establish whether or not any segregation by

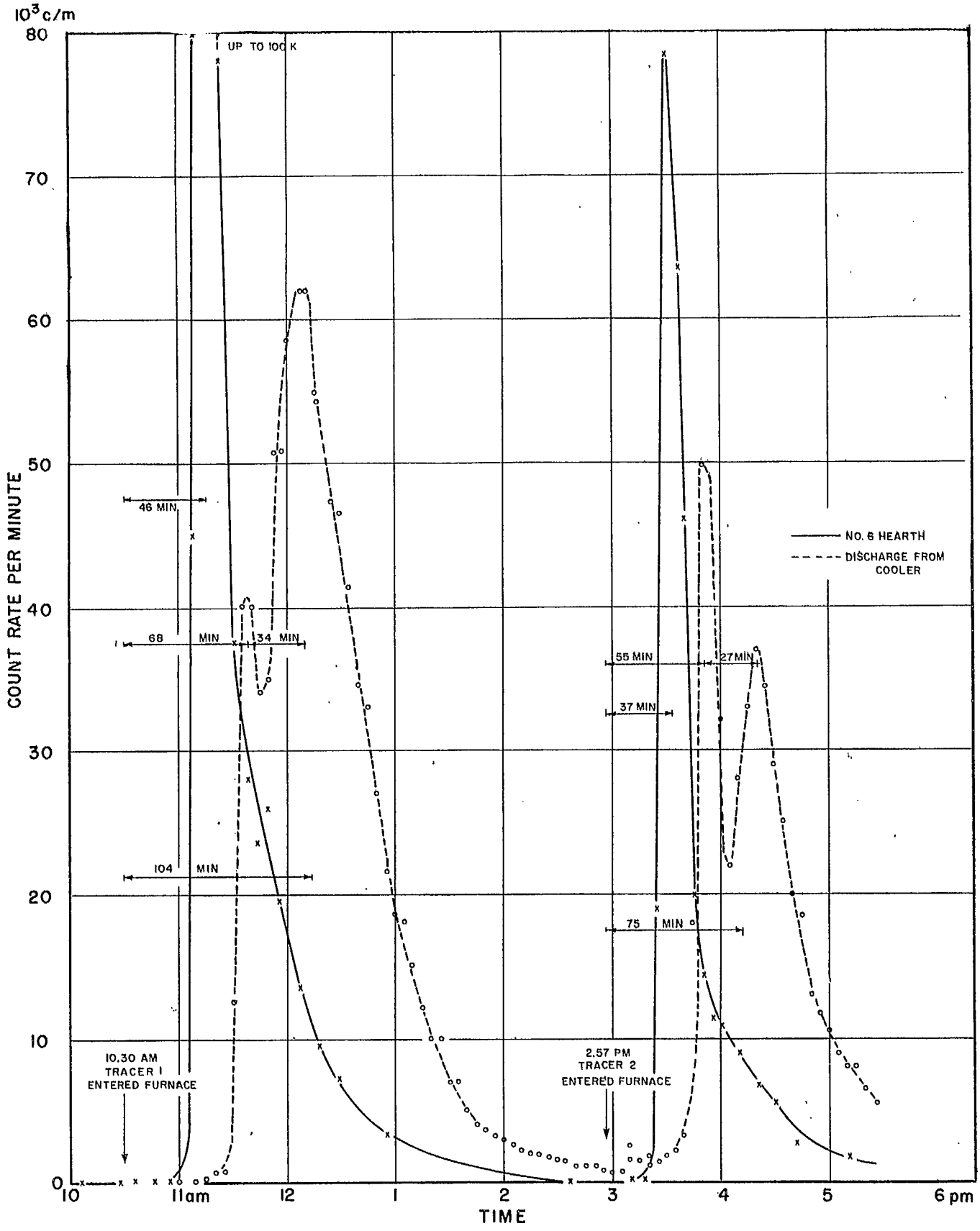

FIGURE 1 – CONTACT TIME MEASUREMENTS
SHAFT FURNACE - IRON ORE CO. OF CANADA

size had taken place at the bottom of the furnace. The fine fraction would be expected to show slightly higher activity for a given mass of sample because of its larger surface area and consequent relatively greater absorption of activity. Table 1 lists the count rates obtained. It is seen that there was no evidence of any size differentiation between the two peaks.

TABLE 1

Comparison of Screened Discharge Samples

	Sampling Time	+ 100 M	- 100 M
Test 1			
(peak 1)	11:30 am	1150 c/m	2800 c/m
	11:35	4100	11500
	11:40	6500	10500
(peak 2)	11:55	7000	10500
	12:00 noon	8000	12500
	12:05	8500	13500
	12:10	10000	16500
	12:15	11000	15500
Test 2			
(peak 1)	3:45 pm	250	400
	3:50	1700	4000
	3:55	9000	14000
	4:00	6000	12000
	4:10	1800	4800
	4:15	3200	9000
	4:20	3600	10500
(peak 2)	4:25	6000	13000
	4:30	3300	10000

Test 3

To separate the cooler transit time from the overall residence time a separate test was done on December 9 for this purpose. Dry tagged ore containing about 2 mc of activity was placed into the discharge hole under No. 6 hearth at 10:04 am on December 9. The shaft rotation was stopped momentarily while the tracer was inserted. Although the furnace had been fed at 600 lb/hr for over an hour an apparent blockage seemed to occur at the discharge and the first sample could be collected only at 10:18 am with the peak of activity occurring already at 10:21, or shortly after. For this reason the samples showing the highest activity collected during this run (10:21-10:30 am) at 3 minute intervals were used as a tracer material for a second run and were placed under No. 6 hearth again at 10:55 am. The peak for this run occurred around 11:17 am, so that the two runs gave residence times in the cooler of 18 minutes and 23 minutes, for an average value of 20 minutes.

DISCUSSION OF RESULTS

Inspection of the curves in Figure 1 shows the striking similarity between the two tests. In both cases the sample collected at No. 6 door showed a sharp, well-defined single peak. The sharp rise and gentle slope on the falling side indicate that only little dispersion and no short-circuiting took place in the furnace. A logarithmic plot of the two peaks is shown in Figure 2 and indicates some spreading and mixing on the hearth with an average retention time of 26.6 minutes, of the same order as the front travel time of the sample. The mean residence time in Hearths No. 1-5 was 46-50 minutes at 400 lb/hr and 37 minutes at 600 lb/hr.

The double peaks observed for the discharge samples are harder to explain. The times of arrival of the first peak almost coincide with the mean residence time to Hearth No. 6 after subtracting the 20 minute cooler time. The first peak, therefore, may represent material which was swept into the discharge hole from No. 6 Hearth on the first sweep of the rakes and had probably fallen from the sector immediately over the hole. The second peak which accounts for about 90% of the charge in Test 1 and about 50% in Test 2 represents material which was held up at Hearth No. 6 for a prolonged period. Allowing again for the cooler time, the effect of this hold-up has been an extension of the mean residence time in the furnace from an expected time of about 55 minutes to

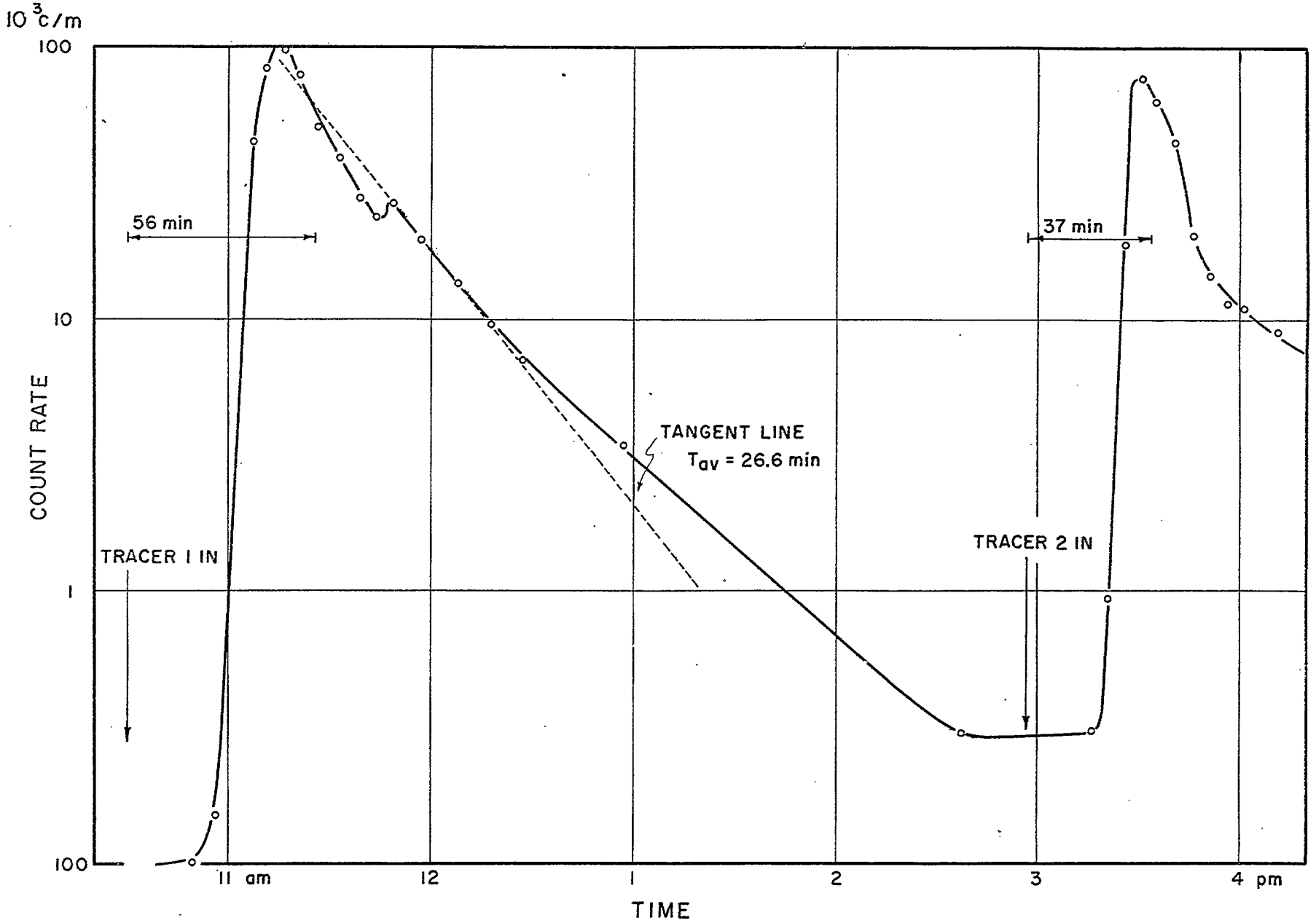

FIGURE 2- CONTACT TIME MEASUREMENTS, IRON ORE CO. OF CANADA.
NO. 6 HEARTH SAMPLES (LEAVING NO. 5)

approximately 84 minutes at 400 lb/hr, and from about 45 minutes to 55 minutes at 600 lb/hr. This still leaves unexplained the discreteness of the two peaks and one must assume that the hold-up on Hearth No. 6 takes the form of some caking or clinkering, with a sudden, abrupt collapse of the pile-up which is then swept out rapidly. This feature may indicate the need for a redesign of the bottom hearth or an improvement in the rake arrangement there. The time interval between the peaks of 34 and 27 minutes is surprisingly long and some further work may be required to investigate this point.

The active material was collected in three drums for burial in the vast waste dumps. Dose readings were taken above and alongside these drums which showed a maximum reading of 5 mr/hr at 1 ft from the middle of any two of the drums. Handling and disposal of the material of the drums was arranged by Mr. Major and was not expected to present any problem or health hazard.

CONCLUSION

The test work proceeded smoothly and showed how much information can be obtained relatively easily and rapidly on the performance and characteristics of plant equipment of the kind involved. The friendly co-operation of all staff members of the Iron Ore Company of Canada is gratefully acknowledged.

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