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RADIOACTIVE MARKING OF STEEL BALLS FOR GRINDING TESTS

by

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SYNOPSIS

Tests have been carried out to label steel balls with radioactive iron for investigations on the life and wear of the balls under operating conditions in grinding circuits. The method of introduction of the tracer and the monitoring procedure are discussed in detail.

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Direction des mines

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ÉTIQUETAGE RADIOACTIF DE BOULETS D'ACIER UTILISÉS AU COURS D'ESSAIS DE BROYAGE

par

G.G. Eichholz*

RÉSUMÉ

On a procédé à des essais de marquage des boulets d'acier à l'aide de fer radioactif, en vue de déterminer la durée et l'usure de ces boulets dans les conditions de travail des circuits de broyage. Le présent bulletin traite en détail du procédé d'introduction du radio-indicateur et de la technique de détection.

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INTRODUCTION

In the assessment of the performance of grinding balls and similar media it is of obvious importance to be able to follow a given batch of balls under operating conditions for a reasonable period. Ordinarily this is not possible, because the balls lose their individual identity a few moments after they are charged into a mill. The only practicable alternative is to label the balls with a radioactive tracer, so that they can be picked out and the wear determined after various times and conditions of use.

To gain some experience in this approach and to assist in some comparative wear tests of different types of grinding balls, a batch of radioactive balls was made up for Neelon Steel Limited at its plant at Sudbury Junction, Ontario. The preparation and use of such radioactively tagged balls may be of wider interest for grinding performance investigations and related studies, and for tests on foundry operations.

The choice of radioactive isotope for these tests was governed by several considerations: availability, ease of handling, compatibility with the molten metal, ease of detection, convenient half-life, and cost. Cobalt-60 and Iron-59 are two isotopes that meet these conditions. Iron-59 was chosen for the present tests on account of its shorter half-life (45 days) and more certain compatibility.

The level of activity is governed by the lowest amount of activity that can be detected at the end of the tests in the smallest size of ball that would still be considered of interest. The operation of the furnace at Neelon Steel Limited required normally a charge of 12,000 lb of metal per heat. The balls are 2 inches in diameter and weigh approximately 1.2 lb each. After one month's grinding, the balls were expected to be down to 1 inch in diameter and to weigh approximately 0.15 lb each. At that time such a ball represents, therefore, approximately 10^{-5} of the original metal in the charge. If 50 millicuries of Fe-59 were added to the initial charge, this would represent 0.5 microcurie (μc) per 1 inch ball, or 0.25 μc after six weeks, allowing for decay, an amount readily detectable with a portable scintillation counter.

TEST DETAILS

The radioactive material was prepared by irradiation of pure iron wire in the NRX reactor at Chalk River. Because of time limitations the target material was split into four equal amounts of 22 grams each, which were irradiated for one week. The combined activity of the active sources at the start of the test work was 50 millicuries; however, rather higher activities were encountered when the sources were picked up at Chalk River a day earlier, due mainly to Mn-56, which decayed away with a 2.6 hour half-life overnight.

The active iron was introduced into the stream of metal to the ladle, rather than to the furnace, to avoid losses to the slag. The particular heat used contained 6 tons of metal poured at a carbon content of 0.85%. The tracer material was added to the molten metal at 10:45 a.m. on September 18, 1959. The metal was cast to make about 4 tons of 2 inch balls and 300 lb of $2\frac{1}{2}$ inch balls, the balance of metal going to risers and scrap. After cooling, the balls were tumbled in a barrel and sorted by hand on a conveyor belt to remove scrap. Steel plates of one inch thickness had been fastened to both sides of the conveyor to protect the sorters from radiation from the balls. The balls were filled into steel drums and shipped out by truck.

RADIATION MONITORING

To ensure safe handling of the active material careful checks were maintained at all phases of the test. Film badges were worn by the Mines Branch staff concerned with the test and were also issued to four Neelon employees most likely to be exposed to radiation during the test: the foundry foreman, the ladle man, the first sorter, and the shake-out man. The films were processed by the Department of National Health and Welfare, Radiation Services, which reported negligible exposure (less than 40 milliroentgens) for all badges.

The source material was received at Chalk River in four cylindrical lead containers, which were transported to Sudbury at the back of a station wagon. Radiation levels at the driver's seat were of the order of 1 milliroentgen per hour (mr/hr)[*]. Before inserting the active wire into the molten metal on the following day, radiation levels were checked to ensure decay of all impurity activities. Observed radiation levels were 12, 13, 18 and 19 mr/hr on top of the lead containers, which were of two sizes, and 1600, 1800, 2100 and 2400 mr/hr in direct contact with the four irradiation capsules. The active iron wires were kept behind lead until the right moment for use arrived, at which time they were thrown into the metal stream while still in their aluminum capsules, but with the lids pried off.

In the sorting operation the radiation level at the conveyor belt was about 1 mr/hr right over the belt at the start and negligible behind the steel plates which protected the sorters. The sorting table was checked when two-thirds full and showed a maximum value of 5 mr/hr over the middle, 2 mr/hr at the edge. After cooling, the empty ladle was checked and showed a level of 2 mr/hr inside. Most of that remaining activity would be removed by successive heats on the same day.

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[*] Accepted maximum occupational exposure is 100 mr/week, or up to 7.5 mr/hr for intermittent exposure.

The full barrels were monitored and showed a reading of 5 mr/hr on contact to the sides, less than 1 mr/hr at one foot distance. The loaded truck with 3.7 tons of balls at the back was found to read $1\frac{1}{2}$ mr/hr outside the back panels, and zero at the driver's cab.

MILL TEST

The 2 inch balls were shipped to Lowphos Ore Limited, Capreol, Ont., and charged to a ball mill with 80 tons of non-active balls. After a week the balls were inspected with a scintillation counter and some active balls, in various conditions of preservation, were identified. Figure 1 shows a few balls as cast and after one week's use in the mill.

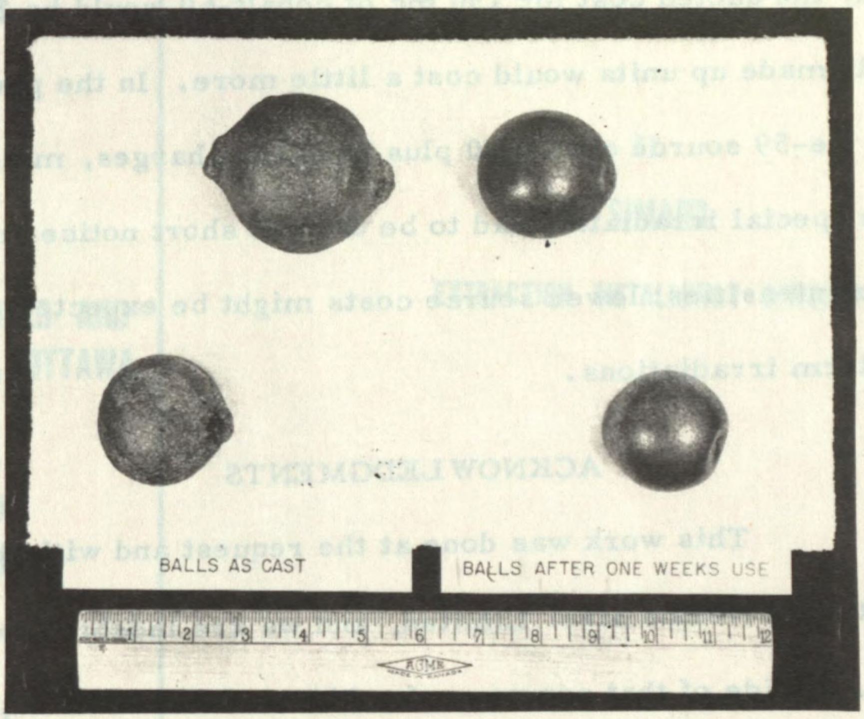

Figure 1. - Photograph of Active Balls

DISCUSSION

The picking of the active balls in the mill was a very tedious process, as the active material represented only five per cent of the grinding medium during the first week and progressively less in subsequent weeks. However, this procedure does offer a way of getting information on ball life and wear which cannot be obtained in any other way.

The main merits of radioactive tagging are ease of handling, no need for interrupting the routine operation of the foundry, and specific labelling of a given batch of material. The cost of doing a test of this type is quite low; if one were prepared to accept a standard irradiation unit from Atomic Energy of Canada Limited, the quoted cost for 150 mc of cobalt-60 would be $37. Specially made up units would cost a little more. In the present test the Fe-59 source cost $100 plus handling charges, mainly because special irradiation had to be done at short notice and at high flux intensities; lower source costs might be expected on longer-term irradiations.

ACKNOWLEDGMENTS

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