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CONTINUOUS PROCESSING AND PROCESS CONTROL

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PREFACE

As new sensing devices are developed, manual control in many areas of metallurgical processing is being replaced rapidly by automatic control. Naturally, the areas in which most progress is being made are those in which superior product quality control and dollar return on the product is most sensitive. The steel industry is leading the way in the change-over.

When the Extractive Metallurgy Division of the Metallurgical Society, under the successive Chairmanships of Mr. R. A. Lewis, and Dr. M. E. Wadsworth, was planning for the Second Annual Operating Conference, the time seemed opportune to generate a program on progress in the development of continuous processing and process control. The committee selected to invite papers for the Symposium was fortunate in attracting papers across the field of metallurgical interest from the beneficiation of ores through to the continuous casting of metals. The papers were presented in Philadelphia between December 5 and 8 and are representagive of many of the new developments. They are compiled here in a single volume with the hope that they may provide a cross-fertilization of ideas from one area to another in the Society. The papers on continuous casting were jointly arranged by the Electric Furnace Committee, the Mechanical Working and Steel Processing Committee and the Physical Chemistry of Steelmaking Committee.

The editor is grateful to Dr. J. Convey of the Department of Energy, Mines and Resources of Canada for making available the time and facilities to edit the volume, to the Conference Committee members for continuing support and advice and to Miss Nancy Varette for assistance in preparing the manuscript.

Thomas R. Ingraham

May 3, 1967

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AN ORE SORTING SYSTEM BASED ON X-RAY FLUORESCENCE

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ABSTRACT

An ore sorting system using X-ray fluorescence has been developed in the Mines Branch laboratories. This system allows the upgrading of an ore in the early stages of processing, thus achieving significant savings in the processing costs. Elements in the ore are detected using X-ray fluorescence techniques. The characteristic X-rays are excited using β particles (electrons) from an artificially produced radioactive Sr^{90} source. These β particles bombard the material and produce characteristic X-rays which are used to indicate the presence of valuable mineralization in the sample. The radiation resulting from this electron bombardment of the ore is detected in a proportional counter system, the output of which is analysed with respect to energy. When radiation of an energy corresponding to the characteristic X-rays of a desirable element is detected, the material being scanned is transferred

to the "good bin." If no mineralization has been detected after three examinations, the material is rejected as waste.

INTRODUCTION

In many beneficiation operations, the cost of processing waste material and valuable mineralization is roughly the same. Thus the earlier in the beneficiation process that waste material is detected and rejected, the more economical is the process. The simplest technique is to use visual scanning and hand sorting, but this at present day labor costs is extremely expensive. The success of such a hand sorting operation depends on the skill of the sorter and requires the mineralization to be present on the surface of the rock. Hand sorting is not a widely used technique.

For radioactive ores, the detection of the presence of radioactivity provides a convenient method of sorting. This technique using a Geiger counter has been widely used in the uranium industry. The mechanical components of any ore sorting system have essentially the same requirements, and ore sorting systems differ only in the method of mineral detection. This paper will describe a system based on fluorescent X-ray techniques for the detection of desirable mineralization. This technique is applicable to many elements and is not restricted to those exhibiting natural radioactivity.

FLUORESCENT X-RAY TECHNIQUES

The use of characteristic X-rays for analysis is a widely used laboratory procedure. When a sample is bombarded by either X-ray radiation or high-energy electrons, it emits X-rays which are characteristic of the elements present. This technique is known as X-ray fluorescence. In a few cases[1-3] X-ray fluorescence techniques have also been used to examine the constituents of various slurries and pulps found in mill operations.

The energy of the characteristic X-rays of any element is related to its atomic number. The higher the atomic number, the higher the energy of the X-ray. Since the range of X-rays in air is dependent on the energy of the X-rays, those produced from high atomic number materials will travel a greater distance before being absorbed than those from low atomic number materials. Thus in order to analyze for most elements laboratory X-ray spectrometers are operated in a vacuum chamber. The on-stream X-ray fluorescence analyzers used for pulp and slurry analysis in general operate in air and thus have severe limitations as to the elements which may be detected.

THE ORE SORTER

The basic ore sorting system consists of a conveyor belt for transporting the ore lumps in single file under a scanning head, a castle for holding the radioactive source, a method of analyzing the radiation produced from the bombardment of the ore and a system of controlling a gate which switches the ore depending on whether or not it contains desirable mineralization. Since the mechanical aspects of the system including the conveyor belt and the switch gate are common to many ore sorting systems they will not be discussed in this paper.

The overall view of the ore sorting system is shown in Fig. 1. It consists of the castle which houses the radioactive source and a detector system including a collimator, magnet and radiation detector. Each of these units will be discussed separately followed by some comments on the general applicability of sorting systems using characteristic X-ray detection.

Fail-Safe Castle

The radioactive source used for producing characteristic X-rays in the ore is Sr^{90}. This material is produced in a nuclear reactor and emits extremely high energy electrons (2 MeV). The activity decays with a half-life of 28 years.[4] After one half-life (28 years) the amount of

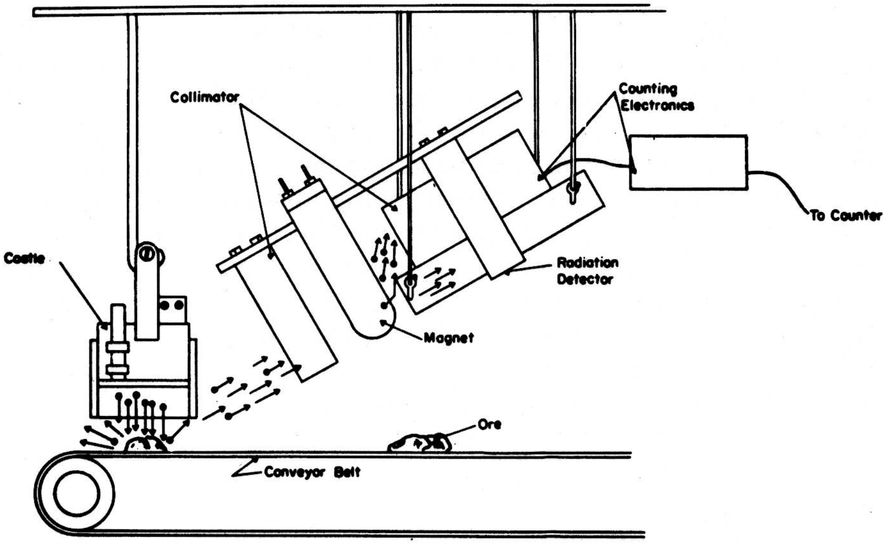

Fig. 1. Overall drawing of ore sorter system.

radioactivity is one half the original value and after two half-lives (56 years) the source has one quarter of its original activity. The decay period is sufficiently long so that the activity remains essentially constant for a year or more. All radioactive materials are dangerous. Sr^{90} is especially dangerous since it will substitute for the bone calcium and its long half-life means that there is a constant source of radiation in the body. This same isotope has caused considerable concern in fallout. Hence, sufficient precautions were taken to prevent any possibility of this material contaminating its surroundings. The source containing the Sr^{90} is in the form of strontium titanate (Sr TiO3) which is an inert ceramic-like material. Strontium titanate does not readily dissolve in water, disintegrates only at extremely high temperatures and is not attacked by most common acids and bases. The strontium titanate source is embedded in a silver matrix and the whole assembly is protected by a fine copper mesh. The source in this chemical form will be completely stable under all reasonable chemical and environmental conditions which are likely to be found in either a laboratory or in a mill operation.

Even when the material is completely contained, the radiation which it emits is dangerous. A special castle was designed so that this radiation may be properly directed only at the ore under study and no extraneous radiation escapes. A sketch of this castle is shown in Fig. 2. The source is mounted in the center of a large lead block and the source radiation is directed downwards towards the ore. Two clam-shell-like doors are mounted on this assembly and close the castle when the source is not being used. When it is desired to irradiate the ore, the clam-shell-like doors are moved into the open position as shown in Fig. 2 and held in place by the vertical holding bars. These holding bars may be lifted by activating the solenoids (see Fig. 2). When these holding bars are released the doors fall into the closed position. The solenoids are not involved in the closing of the doors and hence need only a momentary impulse to release the vertical holding bars. In both the operating and non-operating positions of the castle the solenoids are not energized. This increases the reliability of the system since the solenoids are in use only for a brief interval each time the castle is closed. The solenoids are energized by a large bank of capacitors as shown in the circuit diagram (Fig. 3). The failure of power causes the relay (RY1) to open and thus connects the capacitors to the solenoids. The voltage applied to these solenoids for this short time interval is twice the normal operating voltage, and thus produces a very high specific impulse. This castle has been tested under a variety of environments and found to work satisfactorily. This design has met with the approval of the Atomic Control Board of Canada.

It would seem that the complexity of this castle and the inherent dangers of using Sr^{90} would suggest the use of another means of exciting characteristic X-rays. The most common method of excitation is by means of other X-rays, produced by an X-ray tube, which perform the same function as the electrons of the Sr^{90}. The X-ray excitation system was rejected because it requires the presence of a

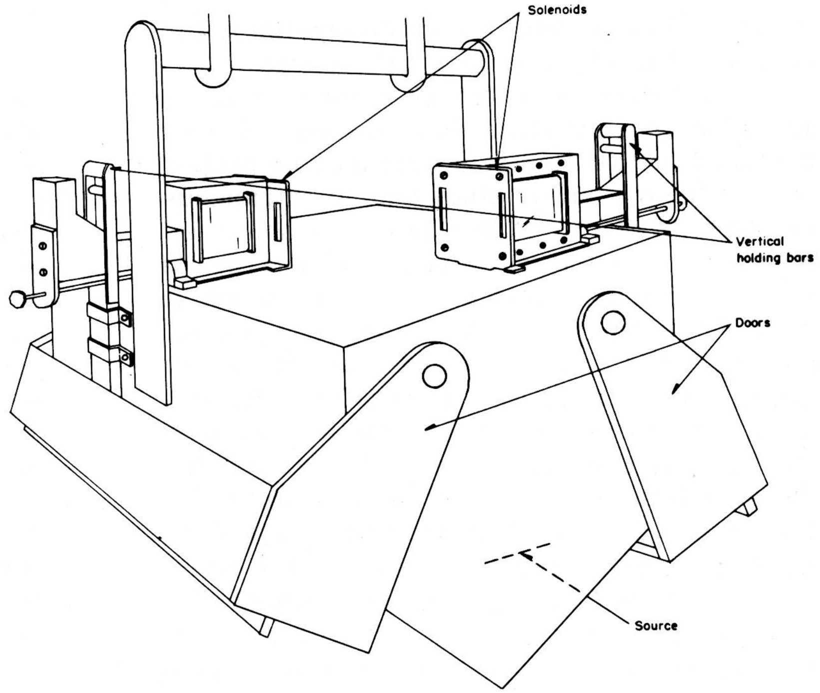

Fig. 2. Perspective view of fail-safe castle.

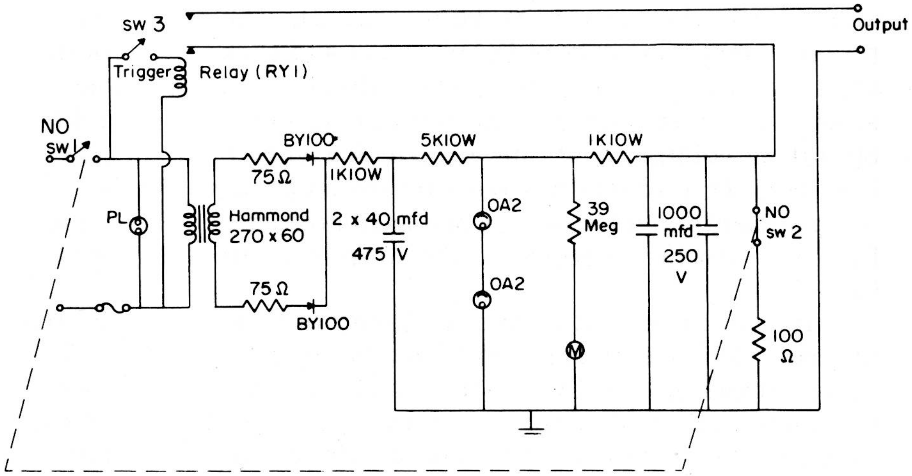

Fig. 3. Circuit diagram of solenoid driver.

delicate large glass bulb which is under vacuum. This bulb houses the X-ray production system and is extremely susceptible to breakage. Also, the X-ray tube requires a high voltage (50 thousand volts or more) and this high voltage is incompatible with the operating conditions in most mine and mill environments. Several other isotopes were considered but no isotope which combined the desirable characteristics of long half-life and high energy β radiation could be found. Thus in spite of the inherent difficulties of using Sr^{90}, it is the most desirable source for economy, convenience and reliability.

Detector System

The ore was passed in a well-separated single line on a conveyor belt under the Sr^{90} castle (Fig. 1). The electrons produced by the Sr^{90} will, when striking the ore, either be scattered, that is, the electrons bounce off the surface, or they will produce X-rays and bremsstrahlung. Bremsstrahlung has a continuous energy spectrum whose intensity decreases rapidly with energy. The characteristic X-rays have peaks in the energy spectrum corresponding to the elements in the sample under bombardment. The detector of radiation used for this ore sorting system is a proportional counter. This counter is sensitive to the scattered electrons as well as bremsstrahlung and X-rays. The electrons are deflected out of the path of the detector by means of a magnetic field. As shown in Fig. 1, a permanent magnet was installed between the two aluminum collimators and thus the problem of electron removal was relatively simple. The separation of the X-rays from the bremsstrahlung was more difficult and required the use of electronic pulse-height analysis techniques. An analysis of the radiation as detected by the proportional counter is shown in Fig. 4. The magnet clearly separates the electrons from the other forms of radiation. The characteristic X-ray peak is distinct from the broad bremsstrahlung spectrum and it is thus possible to set an energy selector on this peak. The output of the energy selector was used to determine the presence of X-rays of the desired element.