CENTER FOR ENGINEERING APPLICATIONS OF RADIOISOTOPES

at

North Carolina State University

Raleigh, North Carolina

INTRODUCTION

In order to identify and more fully utilize certain unique capabilities existing in the Departments of Nuclear and Chemical Engineering, a CENTER FOR ENGINEERING APPLICATIONS OF RADIOISOTOPES (CEAR) has been established at North Carolina State University. Research, training and technical services to industry on measurement problems capable of solution by the use of radioisotopes are the primary activities of the Center.

Personnel at CEAR include members of the faculty of nuclear and chemical engineering, industrial affiliates, post-doctoral fellows, and students. The Center is housed in the Burlington Engineering Laboratories at North Carolina State University in close proximity to the nuclear reactor facilities and the Engineering Research laboratories.

AREAS OF TECHNICAL INTEREST

Industrial measurement problems that can be solved with radioisotope methods represent the primary applications of interest to the Center. These applications fall into the three broad categories:

(1) the use of radioactive tracers,

(2) the design and use of radioisotope gauges,

and (3) the design and use of analyzers with radioisotope sources of excitation.

Center experience with tracers concentrates on flow rate measurement and process analysis. Radioisotope gauge experience include the design and use of alpha--particle, beta-particle, gamma-ray, and neutron gauges to measure thickness, density, and moisture in a wide variety of sample types. Radioisotope excited analyzer experience includes energy-dispersive X-ray fluorescence and neutron-capture, prompt-gamma-ray analyzers to measure elemental compositions in such diverse samples as particulates collected on thin filters and bulk samples of coal.

The primary approach to each new problem in all areas is based on an initial thorough analysis. A variety of analysis methods are utilized, including rigorous techniques of radiation transport; the very empirical techniques such as the use of data fitting; or a combination of empirical and rigorous methods. The initial analyses are thoroughly tested by careful experimental verification before they are used for eventual design or calibration purposes.

CURRENT RESEARCH PROGRAMS

Current research programs include: (1) the use of radioactive tracers for the study of the mineral processes: comminution, flotation, and crystallization; (2) the design and testing of a beta-particle gauge for the continuous, in-situ measurement of filter cake thickness of airborne particulates collected on bag filters; (3) the development of mathematical methods for the processing of spectral data from energy-dispersive X-ray fluorescence analyzers; and (4) the development of a Monte Carlo simulation of the neutron-capture, prompt-gamma-ray analyzers for mineral exploration and on-line industrial measurement.

Process Analysis with Radioactive Tracers

The first of these research programs concentrates on the use of radioactive tracers in the development of the mechanistic approach to first-order particulate processes in the mineral industry. Radioactive tracers are used to obtain the residence time distributions (RTD's) and appropriate first-order rate constants that are necessary to obtain the mechanistic models of each process. Short-lived radioactive tracers are produced by neutron irradiation of the material of interest in a nuclear reactor. These tracers are subsequently injected with the feed into the process of interest and monitored in the process product. Subsequent analysis of the tracer data allows the development of mechanistic models for the process of interest. These models can be used for both control and design purposes.

For example, a large study program has been carried out on full-scale industrial ball mills at a number of locations throughout the United States. Performance of mills as large as 4.6 m in diameter by 9.3 m in length with a feed rate as large as 200 tons/hour has been studied without interruption of their normal operation. This research program on comminution was sponsored by the National Science Foundation. Further research extending this approach to flotation and crystallization processes has been initiated. Investigations such as these lead to improvements in the operation and control of the process equipment.

Beta-Particle Gauge Design

The Environmental Protection Agency is sponsoring the design and construction of a beta-particle backscatter gauge for the study of the airborne particulate filtration process with bag filters via the nondestructive, continuous measurement of filter cake thickness. Bag filters are subjected to pressure variations and are accordingly displaced from the support structure by unknown amounts. This displacement represents a measurement interference for a conventional beta-particle gauge.

The solution being pursued is to use two beta-particle gauges simultaneously, each with a different relative sensitivity to filter cake thickness and filter position. The response models of this dual-gauge are solved simultaneously to yield a measurement of filter cake thickness unaffected by filter position.

This problem is representative of a number of similar radioisotope gauge applications where measurement intereferences are encountered. The dual-gauge approach has been successfully applied to various measurement problems, typical examples of which are the gamma-ray and neutron gauges for measuring the density and moisture content of compacted soil in highway construction.

Energy-Dispersive X-Ray Fluorescence Analyzers

The relatively new energy-dispersive X-ray fluorescence [EDXRF] analyzers are easily adaptable for the automatic or semi-automatic processing and analysis of multiple samples for many elements simultaneously at very high rates. A major feature of the EDXRF analysis is that the intensities of the characteristic X-rays from a wide range of elements are obtained simultaneously, thereby precluding the tedious scanning procedures necessary with wavelength dispersive X-ray analyzers. To take full advantage of this feature, mathematical techniques and subsequent computer software are being developed for the rapid and accurate processing of X-ray fluorescence spectral data. This program has been sponsored by the Environmental Protection Agency for the processing of energy-dispersive X-Ray fluorescence spectra from airborne particulates collected on thin filters.

The primary efforts in this program have been devoted to the development of the library linear least-squares method for the determination of characteristic X-ray intensities and the development of Monte Carlo simulation methods for the determination of elemental amounts from the known characteristic X-ray intensities when matrix effects and interferences must be accounted for. Present research is directed toward Monte Carlo simulations of complete X-ray fluorescence spectra. The final objective of this work is the complete utilization of all the available information in energy-dispersive X-ray fluorescence spectra.

Neutron Capture Prompt Gamma-Ray Analyzers

The general availability of the spontaneous fission radioisotope ^{252}Cf which emits high intensities of neutrons and the new intrinsic germanium gamma-ray detectors with their excellent resolution and ability to be temperature cycled without damage has greatly increased interest in the use of neutron capture prompt gamma-ray analysis. This principle of analysis can now be applied to a number of interesting problems including in-situ bore-hole logging for mineral prospecting purposes and the monitoring of the composition of large industrial process streams.

A program of research has been initiated by the Center to develop a Monte Carlo simulation of this measurement principle that could be used as a calibration relationship for eliminating sample matrix interferences.

SERVICES TO INDUSTRY

The Center is interested in providing services to industry involving the use of radioactive tracers, the design and use of radioisotope gauges, and the design and use of radioisotope excited analyzers. The primary interest of the Center in these areas is in the design, development, or one time use of a tracer method, radioisotope gauge, or radioisotope excited analyzer. Routine uses after initial development could be turned over to the industrial customer or perhaps to the Nuclear Services Group located within the Nuclear Engineering Department at North Carolina State University. The Nuclear Services Group presently provides neutron activation analysis services and routine energy-dispersive X-ray fluorescence analysis services.

EDUCATIONAL OPPORTUNITIES

Education and training of students and industrial personnel is one of the activities of the Center. Affiliation with the Departments of Nuclear and Chemical Engineering allows a student to obtain a Master's or Doctoral degree in either of these departments with their thesis research conducted at the Center. Generally, five to ten graduate students participate in ongoing research projects of the center.

Post-doctoral research in radioisotope applications is another possible activity within the Center. The funding for post-doctoral fellows may come from either research grants to the Center or from other sources such as the IAEA fellowship program.

Short courses on different aspects of radioisotope techniques can be presented by the Center. Such a course entitled, "Use of Radiotracer Techniques in Industry and Environmental Pollution" has been offered twice to groups of international scientists from 15 different countries under the sponsorship of the International Atomic Energy Agency. A laboratory manual based on this course has been published by the IAEA. It is also possible to produce professional-quality videotaped lectures on basic or specialized aspects of radioisotope applications. These videotapes and associated material may be made available either on loan or for purchase.

The Center staff are also active in publication of books and monographs. These include the following:

i) R. P. Gardner and R. L. Ely, "Radioisotope Measurement Applications in Engineering", Reinhold Publishing Corp. New York (1967).

ii) Laboratory Manual on the Use of Radiotracer Techniques in Industry and Environmental Pollution" International Atomic Energy Agency, Vienna (1975).

A monograph entitled, "Analysis and Design of Radioisotope Gauges" by R. P. Gardner and K. Verghese is in preparation.

EQUIPMENT AND FACILITIES

The laboratories and offices associated with the Center are located in the Burlington Engineering Laboratories. This building also houses a 1 MW nuclear reactor, a modern computerized neutron activation analysis facility and other engineering research facilities such as electron microscopes, an electron microprobe, and X-ray diffraction systems. Access to an IBM 370/170 digital computer is also available from this building. All of these facilities are available to Center personnel.

Equipment within the laboratories of the Center include modern radiation measurement systems for both laboratory and field use, a modern X-ray fluorescence analysis system, and various radioisotope sources for experiments. A modern high-speed data collecting system for field use has been acquired under a grant from the National Science Foundation.

For tracer studies of particulate processes various laboratory and pilot-plant scale comminution systems, comminution systems, flotation systems, and crystallization units are available. Close cooperation is maintained with the Minerals Research Laboratories of the University where pilot-plant studies of mineral processes are carried out routinely.

PERSONNEL

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