PORTABLE X-RAY, K-EDGE HEAVY METAL DETECTOR

TECHNOLOGY NEED

Cleanup of many DOE facilities requires dismantling equipment that has been used to process hazardous materials such as uranium, plutonium, and mercury. Examples include plutonium processing glove boxes at Los Alamos National Laboratory (LANL) and Rocky Flats Environmental Technology Site (RFETS) and uranium processing facilities at Oak Ridge National Laboratory (ORNL) and the Savannah River Site (SRS). Using existing techniques, such as passive neutron and gamma measurements, and neutron activation analysis, it is difficult and time consuming to detect and quantify these hazardous materials when they are contained within pipes, ducts, and equipment. Quantitative uncertainty can be ±100% in some cases. Rapid *in situ* analysis of equipment for hazardous elements is needed to improve the efficiency and safety of deactivation and decommissioning efforts. Similar needs are found for characterization of mixed waste and spent nuclear fuel. Examples of applicable Site Technology Coordination Groups (STCG) need statements include:

AL-07-01-11-MW: Waste Sorting and Characterization
AL-07-01-14-MW: Characterization of Transuranic Waste to Meet Waste Isolation Pilot Plant Waste Acceptance Criteria
ID-1.1.10: Nondestructive Determination of Fissile Material Content in Spent Nuclear Fuel
ID-3.2.13: Non-Invasive Resource Conservation and Recovery Act Analysis of Drums
ID-6.1.02: Real-Time Field Instrumentation for Characterization of Radioactive and Metal Contamination in Soil
RF-WM12: Bulk Debris Characterization

TECHNOLOGY DESCRIPTION

The approach to this problem is based on observing the K-edge absorption transition in X-ray transmission measurements. The object to be inspected is located between an X-ray source and an energy-sensitive X-ray detector. The transmission spectrum is analyzed to determine the type and quantity of different elements present in the sample. Each element in the sample is identified by the unique energy at which the K-edge occurs. The amount of each element present is determined from the magnitude of the intensity change at the corresponding absorption edge. This method provides accurate quantification of heavy metals regardless of container material or geometry.

BENEFITS

A fast *in situ* method for quantifying the presence of uranium, plutonium, and Resource Conservation and Recovery Act (RCRA)-listed heavy metals inside closed containers greatly enhances the safety and efficiency of deactivation and decommissioning efforts. Not having to dispose of process equipment as radioactive waste will yield significant savings. Accurate determination of the level of the hazardous metals present enhances the safety of dismantling operations.

CAPABILITIES/LIMITATIONS

K-edge densitometry can be used to quantify heavy elements ranging from cadmium to plutonium found in a range of matrix materials. The sensitivity achievable will depend on the specific combination of materials as well as on the data collection time. A typical precision of 10 percent for 10 mg/cm^2 of thorium, uranium, or plutonium in one inch of steel (100 PPM) is achievable within a few minutes. For lighter elements, such as lead or mercury in a matrix of aluminum or soil, sensitivity of 200 PPM can be obtained within a few minutes measurement time. Greater sensitivity is possible with longer data collection times.

Unlike passive nondestructive assay (NDA) techniques, K-edge analysis generally does not require correction for matrix effects. Little prior knowledge of sample composition or geometry is required.

Initial capital cost of the system will range from $80-150K depending on the selection of X-ray source and detector.

K-edge densitometry requires access to both sides of a sample. The current state of technology for X-ray sources and detectors requires about one foot clearance on either side of the sample. Special training for operation of the X-ray source is required, and personnel cannot work in the area around the inspection point during operation of the X-ray source.

COLLABORATION/TECHNOLOGY TRANSFER

This project is currently being carried out at Ames Laboratory and Iowa State University taking advantage of the existing expertise at the Center for Nondestructive Evaluation. The K-edge data acquisition and analysis software developed for this project is available for licensing.

ACCOMPLISHMENTS

- A prototype K-edge detector was assembled and tested in FY 1996.
- A K-edge data acquisition and analysis software package and Windows-based user interface program were developed and are available for licensing.
- New algorithms were developed to handle cases of relatively thick contamination (>1000 mg/sq. cm of heavy metal), thus extending the range of applicability of K-edge analysis.
- The prototype was successfully demonstrated at the Oak Ridge K-25 Site in February 1997. The Materials and Chemistry Lab hosted the demonstration and provided samples of one-inch ID monel pipes with uranium holdup to be inspected. Operation of the K-edge detector was demonstrated for uranium contamination ranging from 10 mg/sq. cm to 6,000 mg/sq cm and results from the K-edge measurements were found to agree very well with baseline nondestructive assay measurements of passive gamma rays. The following report details the results of this demonstration.

  T. Jensen, T. Aljundi, C. Whitmore, H. Zhong, and J.N. Gray, "Field Demonstration of a Portable, X-Ray, K-Edge Heavy-Metal Detector", Ames Laboratory internal report IS-5131 (March 31, 1997).
- From August 1997 to January 1998 a demonstration was carried out at the Iowa State University Nuclear Engineering Lab (POC: S. Wendt). Aluminum-clad uranium fuel plates were inspected to determine the feasibility of using K-edge analysis in determining properties of spent nuclear fuel. This was in response to needs from INEEL (POC: C. L. Bendixsen) and Savannah River (POCs: T. Andes and A. Brewer). The K-edge measurements agreed very well with predictions for uranium concentrations expected for stored spent nuclear fuel assemblies under a variety of matrix conditions. Trent Andes visited ISU in January 1998 and observed the operation of the K-edge detector. The following report details the results of this demonstration.

  T. Jensen, T. Aljundi, C. Whitmore, H. Zhong, and J.N. Gray, "X-Ray, K-Edge Measurement of Uranium Concentration in Reactor Fuel Plates", Ames Laboratory internal report IS-5129 (November 26, 1997).

TECHNICAL TASK PLAN (TTP) INFORMATION

TTP No./Title: CH15C251 - Portable X-Ray, K-Edge Heavy Metal Detector

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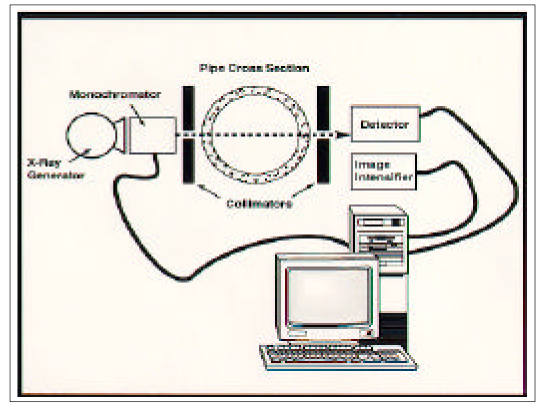
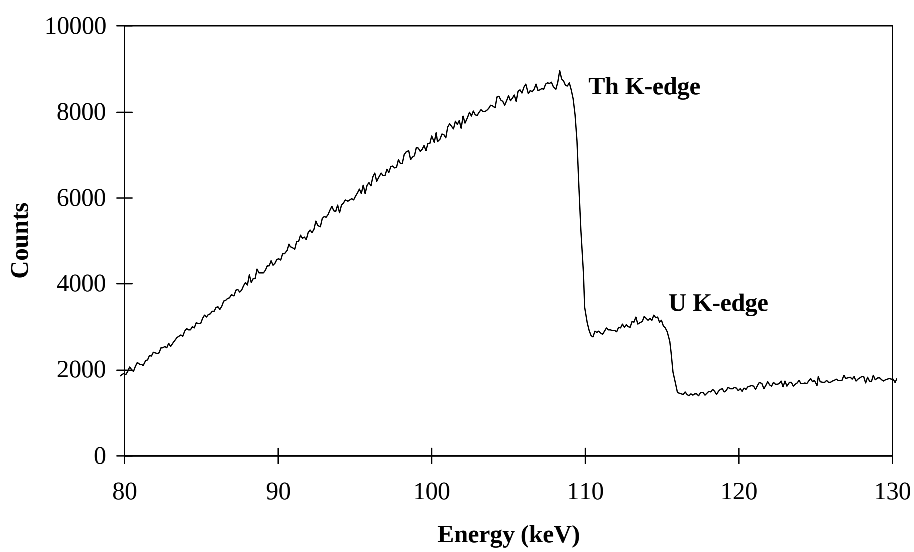


The innovative heavy metal detector illustrated above delivers a beam of X-rays through solid structures and analyzes the absorption of the X-rays having energies near the K-edge energies of various elements.



X-ray transmission spectrum for a sample consisting of foils of thorium and uranium. (The foils were each approximately 0.25 millimeters thick.)