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Gamma Ray Scanner Systems for Nondestructive Assay of Heterogeneous Waste Barrels

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DISCLAIMER

GAMMA-RAY SCANNER SYSTEMS FOR NONDESTRUCTIVE ASSAY OF HETEROGENEOUS WASTE BARRELS †

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1. INTRODUCTION

Traditional gamma safeguards measurements have usually been performed using a segmented gamma scanning (SGS) system. The accuracy of this technique relies on the assumption that the sample matrix and the activity are both uniform for a segment. Waste barrels are often highly heterogeneous, span a wide range of composition and matrix type. The primary sources of error are all directly or indirectly related to a non-uniform measurement response associated with unknown radioactive source spatial distribution and heterogeneity of the matrix. These errors can be significantly reduced by some imaging techniques that measure exact spatial locations of sources and attenuation maps.

In this paper we describe a joint R&D effort between the Lawrence Livermore National Laboratory (LLNL) and the Institute of Nuclear Techniques (INT) of the Technical University, Budapest, to compare results obtained by two different gamma-ray nondestructive assay (NDA) systems used for imaging waste barrels. The basic principles are the same, but the approaches are different. Key factors to judge the adequacy of a method are the detection limit and the accuracy. Test drums representing waste to be measured are used to determine basic parameters of these techniques.

2. GAMMA-RAY NDA MEASUREMENTS AT LLNL

LLNL is developing an emerging gamma-ray NDA technology that we call active (A) and passive (P) computed tomography (CT) [1]. We have implemented our A&PCT technology at LLNL and into a mobile Waste Inspection Tomography (WIT) trailer [2]. These A&PCT technologies have been used to inspect waste containers at 3 waste-barrel storage sites, LLNL, Rocky Flats Environmental Technology Site, and Idaho National Engineering Laboratory. A&PCT can be used to characterize waste barrels up to 416-liters (110-gals.) with weights up to 725 kg (1600 lbs.), and containers up to 92-cm (3 ft.) diameter and 122 cm (3-4-ft.) tall.

A&PCT uses a single, highly-collimated HPGe detector and a ^{166m}Ho external radioactive source. The detector/source can be operated in two different modes: (1) collimated gamma-ray scanner (CGS) or (2) active and passive CT. The CGS mode is very similar to SGS except the detector is much more collimated. CGS is used to determine the height and isotopics of source(s) within a barrel. A&PCT is used to identify, localize and determine an accurate NDA of the barrel's radioactive content.

The active data acquisition for both CGS and A&PCT measures the attenuated gamma-ray spectrum emitted from a ^{166m}Ho source. For CGS the data is integrated while the barrel is continuously rotated. In ACT the data is obtained using first-generation CT, i.e., the barrel is translated and rotated discretely for each slice.

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To obtain passive CGS or CT images, the ^{166m}Ho source is shuttered; and the barrel is scanned in the same fashion used to obtain the active CGS or ACT data, respectively. In the passive mode, the detector records only gamma-rays emitted from within the barrel.

The active scans generate attenuation data at each significant gamma-ray energy identified in the passive barrel scan. Thus, the active scans provide energy-specific attenuation data (one value per slice for CGS and maps or cross-sectional images for ACT) so that attenuation corrections can be made for each internal gamma-ray energy identified.

3. COMBINED SGS-LOW RESOLUTION TOMO SCANNER AT INT

INT`s effort is aimed at modifying an existing SGS to employ tomographic imaging principles to assay heterogeneous waste. Significant improvement can be obtained when tomographic principles are used for measurement of unknown barrels [3]. An economically feasible solution is to build an array of small size, room-temperature detectors to an existing SGS. Without increasing the scanning time, it provides:

- the spatial distribution of attenuation coefficients (density) of any section of a barrel, using a transmission imaging;
- the gross distribution of radioactivity concentration of any section in a barrel, using emission imaging–this is limited by the detector energy resolution.

These two important distributions provide means to choose the operational mode and to estimate the error of a measurement. The high-energy resolution gamma detector can serve as a detector for SGS mode of operation and imaging selected isotopes. Accuracy of measurements depends on image resolution capability of the scanner. An array of 10 detectors ensures an accuracy level of about 5% independent of the heterogeneity of the waste. The measurement time and sensitivity are nearly the same as for an SGS scanner.

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