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Author(s): D. P. Taggart, S. E. Betts, J. J. Vigil

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LANL'S MOBILE NONDESTRUCTIVE ASSAY AND EXAMINATION SYSTEMS FOR RADIOACTIVE WASTES

D. P. Taggart
Los Alamos National Laboratory
P.O. Box 1663, MS J594
Los Alamos, NM 87545
(505)665-6149

S. E. Betts
Los Alamos National Laboratory
P.O. Box 1663, MS J594
Los Alamos, NM 87545
(505)665-6149

J. J. Vigil
Los Alamos National Laboratory
P.O. Box 1663, MS J594
Los Alamos, NM 87545
(505)665-6149

R. J. Estep, E. F. Martinez, J. Mendez, T.H. Prettyman, and C. D. Rael, all from Los Alamos National Laboratory

ABSTRACT

The ability to accurately and rapidly measure nuclear material within drums and examine their contents without having to unpack the drums saves time, reduces characterization costs and minimizes radiation exposure. Over the past two years, Los Alamos National Laboratory (LANL) has developed and fielded a suite of mobile nondestructive assay and examination systems for use primarily on its own transuranic (TRU) waste but that also have application to low level, mixed and hazardous wastes. It has become obvious that systems like these are generally useful and have applications at other Department of Energy (DOE) production and environmental technology sites. Mobile capabilities present a potential cost savings where waste drums have to be transported to a fixed NDA facility. In other cases they fill a void where there is no fixed facility available because construction costs are prohibitive (as in the case of small quantity sites) or the available facilities may not meet current or evolving safety standards. Rather than bringing waste to a facility to be characterized, one can bring the characterization capability to the waste.

Three systems are described:

- Mobile Radiography System (M-RS): including Real Time Radiography (RTR) and digital radiography for noninvasive examination of waste package contents.
- Mobile Segmented/Tomographic Gamma Scanner (M-S/TGS): for determining the amount of gamma emitting radioisotopes in waste packages
- Mobile Passive/Active Neutron (M-PAN) Assay System: for determining the amount of neutron emitting and fissile material in waste packages.

I. MOBILE SYSTEM DESCRIPTIONS

A. Mobile Radiography System (M-RS)

A 450-keV M-RS has been custom designed and constructed by V.J. Technologies (Bohemia, N.Y.) to inspect containers of radioactive waste produced at LANL. It has the capability of inspecting waste containers sized from 5-gal. cans up to standard waste boxes (SWB, dimensions 54.5 in. x 71 in. x 37 in.). This 37 ton system is housed on a triple-axle, 51-ft. semi trailer (Figure 1). The trailer contains an operator control room (Figure 2), a lead shielded x-ray inspection chamber (Figure 3), storage rooms and compartments, an AC power generator, a climate control system, an automatic fire suppression system, and container handling equipment. Three axles are needed because of the added lead shielding required to shield the operators and public to cabinet x-ray standards (<0.5 mR/hr, 5 cm from outside surface of radiation protective enclosure at full beam power). It has three imaging capabilities; an image intensifier (12"), linear diode array and an open system.

The image intensifier (II) is mechanically linked to the x-ray tube and travels with the tube to view any area of a waste container in real time. The II output to a CCD TV camera is a video format that is fed to operator-selected image enhancement circuits then to both display monitors and video tape recorders. The image intensifier also is provided with an operator-selected magnification mode enlarging the image in the selected area.

The Linear Diode Array (LDA) consists of a single 36" long, 588-pixel LDA, analog/conversion/buffering electronic packages, host acquisition computer interface cards; and associated cabling. Waste containers are placed between the x-ray source and the LDA. As the manipulator passes the LDA across the container, the computer receives scan-line data from the conversion/interface electronics. The computer assembles each consecutive scan line into memory for subsequent display on the operator monitor and/or subsequent image processing operations. Raw or image processed data can also be stored in the computer's optical storage subsystem for later recall, or further analysis. Unlike the image intensifier and open system, the LDA is not a real time imaging system.

The open system consists of a 33-in. by 27-in. fluorescent screen, a mirror, and a TV camera all enclosed in a steel box. This system allows the operator to view an entire 891-in^2 area of the contents inside the container at once (an entire 55 gallon waste drum can be viewed at once in real time).

B. Mobile Segmented/Tomographic Gamma Scanner (S/TGS)

The mobile S/TGS was developed to assay radionuclides in low-level, transuranic, and mixed waste in containers ranging in size from 2 ft boxes to 83-gallon overpacks (Figures 4 and 5). The tomographic imaging capability provides a complete correction for source distribution and matrix attenuation effects, enabling accurate assays of Pu and other gamma-ray emitting isotopes. In addition, the system can reliably detect self-absorbing material such as plutonium metal shot, and can correct for bias caused by self-absorption. The system can be quickly configured to execute far-field scans, segmented gamma-ray scans, and a host of intermediate scanning protocols, enabling higher throughput (up to 20 drums per 8-hour shift).

The mobile S/TGS uses low-resolution transmission and emission tomography to minimize bias due to nonuniformity in the matrix and in the distribution of gamma-ray emitting material (for example, Pu and U). It also supports traditional scanning techniques such as segmented gamma scanning (SGS). High resolution gamma-ray spectroscopy (HRGS) is used to identify radionuclides within the drum and to provide accurate measurements of gamma-ray intensities. Because nonuniform matrix attenuation and source position effects are accounted for, the mobile S/TGS is accurate over a wide density range.

The high-resolution gamma-ray spectroscopy system measures gamma rays emitted from and transmitted through the waste package. This system consists of a collimated intrinsic germanium detector and associated spectroscopy electronics. The collimator shape depends on the type of scan. For example, segmented gamma scanning requires a rectangular collimator. A diamond-shaped collimator is used for tomographic gamma scanning. Currently, tungsten inserts are used to change the shape of the collimator.

Based on the results of a recent demonstration at Rocky Flats[1] , measurements of TRU waste at Los Alamos, and an experimental evaluation of the technique using a wide variety of mock waste matrices and source configurations, the demonstrated advantages of the mobile S/TGS technology include:

- Accuracy: From an accuracy standpoint, TGS outperforms all other conventional gamma-ray assay techniques for drum-sized waste packages with heterogeneous contents by a considerable margin[2].

- Completeness: the mobile S/TGS system is capable of identifying and assaying most gamma-ray emitting radionuclides.

- Self-attenuation corrections: the mobile S/TGS is able to reliably detect the presence of self-attenuating material or lumps. Gamma-ray assay techniques other than TGS cannot reliably correct for lumps because the effect of lumps can be obscured by other factors.

- Complementarity: the mobile S/TGS can provide accurate assays of drums for which other techniques such as passive neutron counting are invalid.

C. Mobile Passive/Active Neutron Assay

Over the past 18 months (approximately) we have received, refurbished, reactivated and calibrated a mobile second generation Los Alamos PAN assay system[3] (figures 6 and 7) given to us by the Carlsbad Area Office (CAO).

The mobile PAN assay system can be operated in an "active" mode which uses a DT neutron generator (figure 8) to produce interrogating neutrons to detect and quantify fissile material (Pu, U). It can also be operated in a "passive" mode, simply counting neutrons emerging from a waste drum as a result of spontaneous fissions (from ^{238}Pu, ^{240}Pu). In routine operation both modes must be used to measure the waste matrix neutron moderating and absorbing characteristics as part of the assay process.

In an idealized PAN system, the number of neutrons counted during an assay would be proportional to the amount of fissile material in the waste drum and independent of where the fissile material is located in it. In reality, because the neutrons we need to count can interact with all the drum's contents, the exact location of the fissile material, even in a homogeneous mock waste matrix drum, can affect the assay result. Because of this, assay results have to be "corrected" to compensate for the moderating and absorbing characteristics of the waste matrix. For heterogeneous waste forms, these spatial variations suggest that the outcome of a PAN assay can depend on where source material is in a waste drum. A mechanism such as imaging[4] may be needed to "locate" source material in the drum as part of the assay process.

III. MOBILE SYSTEMS APPLICATION

One of the first applications of all our mobile systems together was in support of a National Transuranic Program Office (NTPO) effort to determine the RCRA characteristics of 4 LANL waste streams. The information will be used in support of the Waste Isolation Pilot Plant's (WIPP) no migration variance petition to the Environmental Protection Agency (EPA). This characterization project is discussed in greater detail elsewhere at this conference[5]. The wastes were "homogeneous" matrices of Portland cement, gypsum cement and granular to rock-like salt blocks contaminated with weapons grade plutonium, uranium and americium.

Because of the high americium content and low-Z materials in the waste matrix, PAN assay results were inconclusive. Our PAN assay system, operated in a passive counting mode, was not able to provide reliable assays of all of the drums because of the resulting high (α,n) neutron production rate. In fact, the singles neutron count rate averaged about 14 times higher than would have been expected if the declared value of weapons grade (WG) plutonium was accurate and often was larger than would be expected if the waste drum contained 200 grams of WG Pu as metal or dry oxide. This result is shown in Figure 9.

The mobile S/TGS was used for the measurement of record and was able to separately quantify the ^{239}Pu and ^{241}Am content of each drum (even though some weighed up to 980 pounds). Results of the S/TGS scans of these drums are plotted in Figure 10. The S/TGS scans also showed that non-equilibrium amounts of ^{241}Am were present in drums even when it was not manifested. Finally, the summed gamma spectrum resulting from the S/TGS scans often showed radiation from ^{22}Na, a product of the $^{19}F\ (\alpha,n)^{22}Na^*$ reaction. This is an indication that fluorinated compounds were present in the waste, and not explicitly indicated in the waste description. It is not possible, at this time, to determine how much fluorine was in the waste, but if it is present in significant amounts, it could be responsible for the very large (α,n) signals observed in the PAN system.

IV. SUMMARY AND FUTURE PLANS

We have reported on a suite of mobile nondestructive assay and examination systems developed and fielded by LANL over the past two years, primarily for use on its own TRU waste but that also have application to low level, mixed and hazardous wastes. These systems or systems like them are generally useful and have applications at other DOE production and environmental technology sites

We have also reported on a first application of all our mobile systems together in an assay and examination effort supporting RCRA characterization of several LANL homogenous waste stream to support WIPP's no migration variance petition to the EPA. This application indicated how important it is, in general, to have the capability for both neutron and gamma assay. In this case, neutron assay was complicated by very high (α,n) neutron production rates in the waste and occasionally incomplete information regarding isotopics. Without the mobile S/TGS, assay would not have been possible.

The primary near term application for our mobile systems will be to support the Transuranic Waste Inspectable Storage Project (TWISP) at LANL. This project, scheduled to begin in the summer of 1996, is to retrieve TRU waste from under earthen cover at LANL and place it in inspectable arrays to come into compliance with regulations for storage of RCRA regulated wastes in the State of New Mexico. They will also be used to characterize wastes which will subsequently undergo intrusive analysis for RCRA components, as we continue to characterize LANL waste stream for shipment to WIPP when it opens in April 1998.

While this will occupy much of our time we intend to pursue potential improvements, innovations and new applications including the following.

A. Mobile Systems Integration

Improvements in the results of assays can be achieved by:

- combining information from segmented gamma scanning, drum weight, and real time radiography to increase overall system throughput
- use of the S/TGS lump-correction capability to identify cases where the active, thermal neutron

PAN assay of fissile material is biased due to the presence of self-shielded material

- using the mobile S/TGS emission images as a position correction for enhanced accuracy of active neutron assays (PAN or ^{252}Cf shuffler)

- using the mobile S/TGS to flag and assay wastes with a high (α,n) background which cannot be assayed reliably using passive neutron counting.

B. Remote Handled Wastes

For drums that must be remotely handled or that may result in an unacceptable dose to the operators, the mobile S/TGS can be operated by remote control.

C. Repackaging

The combined information from a digital radiograph and a mobile S/TGS image can be used to positively identify "hot" objects in waste drums to assess the benefit of repackaging. This could aid in reducing the volume of TRU waste in storage by enabling "hot" objects to be segregated, rendering the remainder of a waste drum low level waste.

ACKNOWLEDGMENTS

Funding for the M-PAN and M-RS systems came from the U.S. Department of Energy (EM-30) through direct baseline funding of waste management activities at LANL (ADS 4172). Funding for the development of tomographic gamma scanning (TGS) and research on quantitative computerized tomography was provided by the Department of Energy (DOE) Office of Safeguards and Security. The mobile S/TGS was subsequently developed in a collaborative effort that included the Chemical Science and Technology (CST) and Nonproliferation and International Security (NIS) divisions of Los Alamos National Laboratory again funded through the U.S. Department of Energy (EM-30) for waste management activities at LANL (ADS 4172).

We would like to acknowledge the valuable assistance of Bill Weston (Westinghouse - WIPP), Joe Lippis (NTPO) and Dan Menkhaus (INEL) in acquiring the mobile PAN. We also must thank Larry East (INEL), Earl Marwil (ScienTech) and Dan Menkhaus (INEL) for providing the Windows-based operating software for the mobile PAN.

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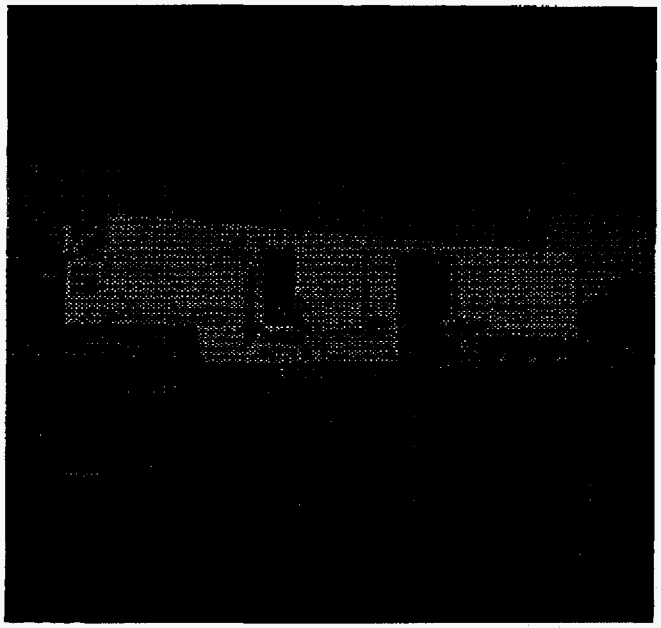

Figure 1- LANL's 450 kV mobile radiography system (custom built by V.J. Technologies, Bohemia, NY).

Figure 2 - The control room has TV monitors for real time images, controls for the x-ray source, drum movement, dual video recorders, hardcopy capability and an optical disc based system for archiving of digital radiographs.

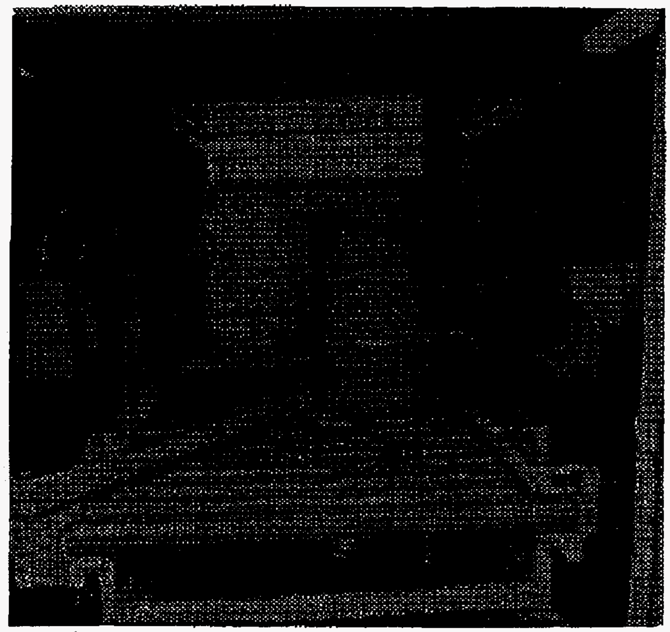

Figure 3 - View of the x-ray inspection chamber. The x-ray source is at the left. The linear diode array is mounted just in front of the 12" image intensifier at the right for this photo. This system will be used routinely for 55 and 85 gallon waste drums but can accommodate an object up to the size and weight of a Standard Waste Box (SWB).

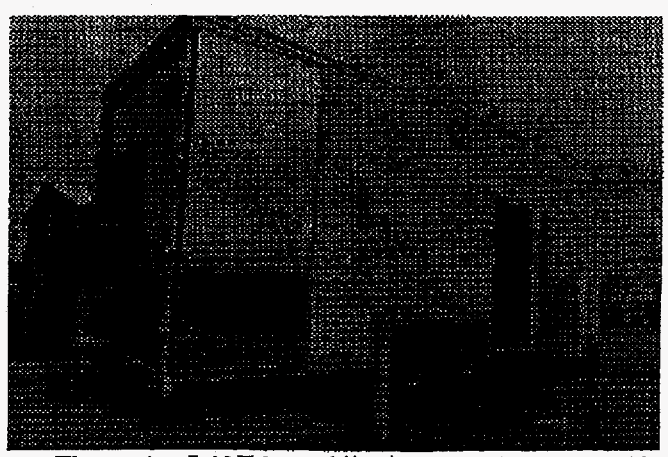

Figure 4 - LANL's mobile Segmented/Tomographic Gamma Scanner (S/TGS). "Fifth wheel" trailer custom built by E.G.&G., Las Vegas.

Figure 6 - LANL's Passive/Active Neutron (PAN) assay system for 55 gallon drums of TRU waste. PAN assay system and control room are in a transportainer mounted on a 45 foot trailer.

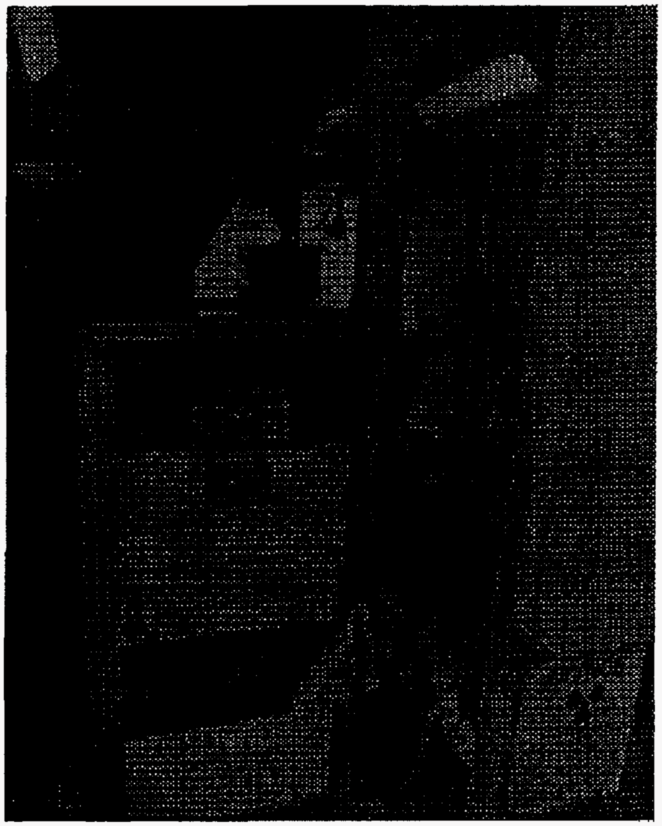

Figure 5 - View from the control room to the assay system on board the mobile S/TGS. A 55 gallon drum is loaded on the transfer table (just loaded or ready to unload).

Figure 7 - Mobile PAN control room. Operating software is a Windows-based package from Idaho National Engineering Laboratory (INEL).

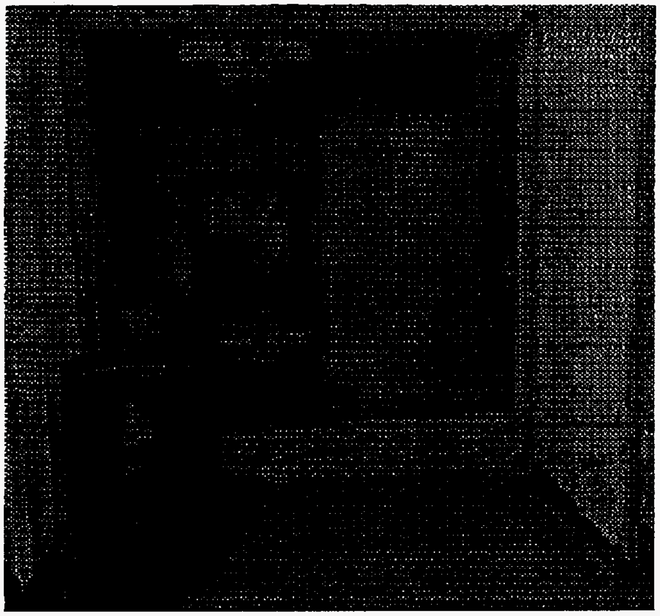

Figure 8 - The mobile PAN system. A second generation PAN assay system is mounted in the back end of a transportainer. A DT neutron source is located in the back right hand corner of the exposed assay chamber. When the sliding door is closed, a 55 gallon waste drum is completely surrounded by ^{3}He neutron detector tubes.

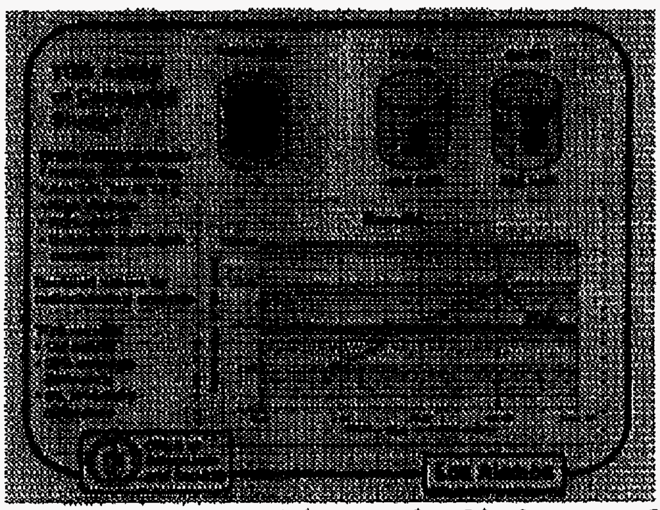

Figure 9 - The waste drums analyzed in the course of the NTPO effort often had a large neutron signal resulting from (a,n) reactions in the waste.

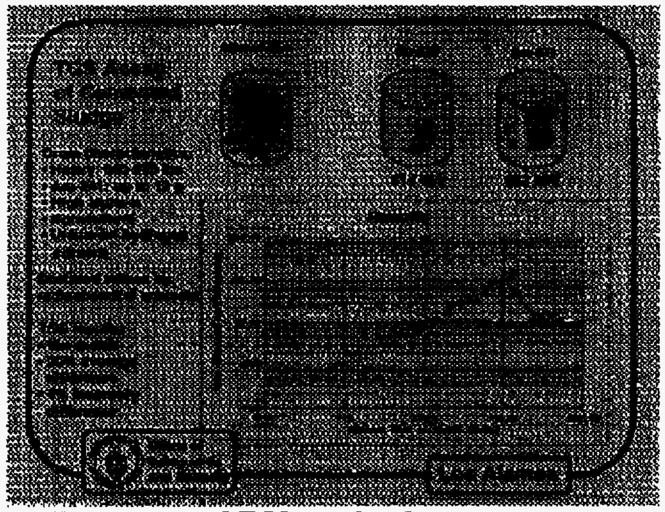

Figure 10 - S/TGS results for one waste stream analyzed in the course of the NTPO effort. The TGS results track the declared values (based on radiochemistry) well and reveal that there are ^{241}Am hot spots separated from ^{239}Pu. These drums are particularly dense.

← This is a place holder.