RFP--4464

DE91 015987

A NEW APPROACH TO PERFORMING HOLDUP MEASUREMENTS ON GLOVE BOX EXHAUSTS

J. Bruce Glick, Francis X. Haas, and Albert G. Garrett
EG&G Rocky Flats, Inc.,
Golden, Colorado 80402

G. A Sheppard, P. A. Russo, M. C. Miller, E. C. Piquette, and T. R. Wenz
Los Alamos National Laboratory
Los Alamos, New Mexico 87544

ABSTRACT

A new measurement technique has been developed for quantifying plutonium holdup in process glove box exhausts. This technique has been implemented at Rocky Flats with a shielded, collimated bismuth germanate (BGO) gamma-ray detector. Measurements along the duct are made in pairs. The detector is positioned for an upward view of the deposit from two inches below the duct, and for a downward view from two inches above it. The plutonium is assumed to be uniformly deposited in the bottom of the duct and to fill the detector's field of view when it is in the lower position. A model has been developed that relates the deposit width to the ratio of the count rates measured at two positions, above and below the duct. Once a deposit width has been deduced, it is multiplied by the area-source assay result from the bottom measurement to yield a mass-per-unit-length at that duct location. Total plutonium (Pu) mass is then determined by multiplying the duct length by the average of the mass-per-unit-length assays performed along the duct. The technique's applicability is presented in a comparison of field measurement data to analysis results on material removed from the ducts.

INTRODUCTION

Glovebox exhaust systems are used to evacuate the glovebox atmosphere and to isolate it from the workplace. These systems carry the glovebox exhaust to plenums where High Efficiency Particulate Air (HEPA) filters are employed to remove particulates from the air. Many glovebox operations, specifically dry processes such as burning and grinding, often cause small particles to be drawn into the exhaust system. These particles, including the nuclear material being processed, then accumulate in areas of lesser or poor circulation within the closed exhaust systems. Measurement of this nuclear material accumulation (holdup) is essential when addressing criticality safety; employee health and safety; public risk; and nuclear materials control and accountability programs in process areas.

Prior to an assessment of criticality safety at the Rocky Flats Plant (RFP) during the summer of 1989, non-quantitative gamma surveys were accomplished primarily for the purpose of radiation protection. SCIENTECH Inc., under contract to the Department of Energy, performed the criticality safety assessment (CSA) at RFP from July through September of 1989. The (CSA) Team utilized non-destructive assay (NDA) equipment to perform surveys of selected glovebox exhaust systems to estimate plutonium holdup. In response to recommendations resulting from the CSA Team assessment, the Safeguards Measurements organization was chartered to develop and implement a measurement program to evaluate nuclear material holdup in glovebox exhaust systems at RFP.

Non-destructive assay, specifically gamma-ray detection, is the measurement method of choice for plutonium holdup when it is contained in a structure of relatively uniform cross-section, such as glovebox exhaust ductwork. Safeguards Measurements personnel conferred with the Safeguards Technology Group N-1 at Los Alamos National Laboratory (LANL) who had developed a high resolution gamma-ray detection system specifically for holdup measurements. The methodology and computer software for data acquisitions utilizing point, line, and area source models to quantify holdup material was transferred to RFP. Rocky Flats then procured the appropriate instrumentation to fabricate high resolution measurement systems using this technology.

These systems, employing the proven technique of far-field-line-geometry measurements, worked well. However, utilization of this equipment and technique was restricted due to the physical layout of the glovebox exhaust systems. Ducts to be measured could not be isolated from surrounding systems using the far-field method. Since these restraints existed in a majority of the process areas, a smaller, more transportable detector system had to be developed. Safeguards Measurements, in conjunction with the RFP Nuclear Instrumentation Development group, developed a bismuth germanate (BGO) detector system for use in the restrictive confines of the process areas.

DETECTOR SYSTEM

The BGO gamma-ray measurement system was designed to be totally portable. It utilizes a hand-held BGO scintillation detector connected to a portable multi-channel analyzer and computer. The BGO scintillation material offers roughly four times the efficiency of a comparably sized Sodium Iodide crystal with only a moderate decrease in resolution. Hence, a smaller crystal size requiring less shielding was used to fabricate a small, efficient, and extremely portable detector for performing holdup measurements.

The BGO crystal used for the RFP duct holdup measurement program is a 0.5 inch by 0.5 inch cylinder. The crystal is mounted on a 0.5 inch diameter photomultiplier (PM) tube and is collimated and shielded with lead. The lead collimator is a 1 inch thick cylinder with a 0.5 inch aperture. The sides of the detector crystal and PM tube are concentrically shielded with 0.66 inches of lead. Additionally, the probe has a 0.5 inch backshield. The detector, PM tube, and shielding are packaged in an aluminum tube 1.85 inches in diameter and 7.5 inches long.

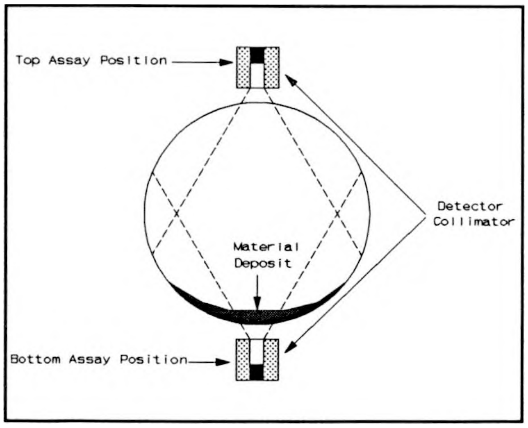
CALIBRATION

The BGO detector system is calibrated using a certified plutonium 'point source' standard, as described in the LANL Safeguards Technology Training Program [1]. The point source self absorption and encapsulation attenuation correction factors were determined by correlating the point source calibration data to data obtained measuring a set of well characterized 'line source' standards. The line standards consisted of plutonium oxide tightly packed in 18 inch long pieces of 3/16 inch aluminum tubing. The data for both the line standards and the point source were acquired using a high purity germanium detector. The 129, 203, 345, 375, and 414 keV gamma-ray energies from the decay of ^{239}Pu were analyzed. The corresponding correction factors for the point source were determined by comparing the attenuation corrected calibration for the line standards to the calibration for the point source. Since the 345, 375, and 414 keV gamma-rays fall within the region of interest assigned to the low resolution BGO system, a weighted average of these correction factors is applied. The point source is then used to generate an Area Calibration Constant (ACC) [1]. This constant is then used with the bottom assay position measurement data (described below) to calculate the concentration of Pu at the location measured.

DATA ACQUISITION

Using an area source model, the BGO system is positioned to acquire pairs of measurements at specific intervals along the duct. The detector is positioned for an upward view of the deposit two inches below the duct, and for a downward view two inches above it (Figure 1). The two inch space, from the detector crystal to the duct surface, was chosen to accommodate the collimator and a one inch space for a lead background shield. The lead shield is used to determine the background at both the top and bottom measurement positions. This detector placement technique ensures that the detector position is consistent for each measurement location, is easily reproducible, and is independent of the duct diameter.

Figure 1: Duct Cross-Section

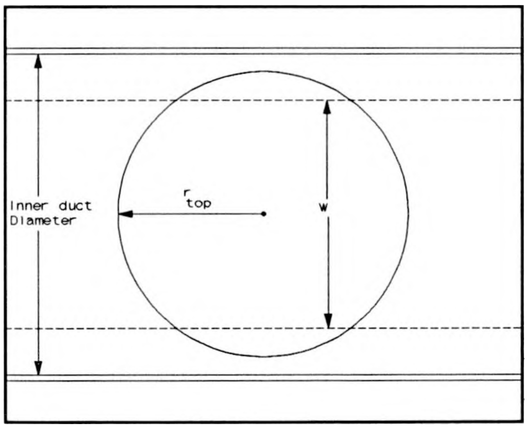


The data acquisition process is carried out using an integrated software package that directs the operator through the measurement process. Normal data acquisition time for each of the four measurements (top background, top assay, bottom background, bottom assay) per location is 100 seconds live time. Typical spacing between locations is 1 foot, for ducts less than 14 inches in diameter; and 2 feet, for ducts greater than 14 inches in diameter.

DATA ANALYSIS

The assumption used is, that for most horizontal ductwork, the majority of holdup material rests along the bottom of the duct. This assumption has been verified by field measurements and by a remote video camera used inside ducts targeted for clean-out. When the detector is placed in the bottom assay position, the area of the holdup material is assumed to extend beyond the field of view of the detector. When the detector is placed in the top assay position, the holdup material is assumed to fall within the detector field of view (Figure 2).

Figure 2: Top Position Detector Field-of-View



By using a ratio of the top count rate to the bottom count rate, the width of the holdup material may be estimated using a mathematical model developed jointly by RFP and LANL personnel[2] (Equation 1). The width (W) of the holdup material is defined as the extent (i.e. arc length) of material extending from side to side along the bottom of the duct transverse to the duct axis.

Equation (1)

$$\frac{C_T}{C_B} = \frac{2}{\Pi}\left[\sin^{-1}(X) + 2X\sqrt{1-X^3} + X^3\ln\left(\frac{1-\sqrt{1-X^2}}{X}\right)\right]$$

Where:

$X = W/2r_{top}$

$2r_{top}$ = Detector field-of-view projected on duct surface

This equation is applicable for cases where C_B is greater than C_T. In cases where the ratio of the top to bottom count rates is not statistically different from 1, the holdup is assumed to be uniformly deposited around the inner surface of the duct, and the inner circumference of the duct is substituted for the width (W). In the case of a vertical duct, the inner circumference of the duct is also substituted for the width (W).

Once the data has been collected for a duct section, a final holdup value is calculated by the software. For each measurement location, a point assay (PA) in grams per unit length of duct is calculated based on the net count rates, area calibration constant, material width, and a correction factor for attenuation by the duct wall (Equation 2).

Equation (2)

$$PA\ (Gm/Cm) = NCR \times ACC \times W \times CF_{Pipe}$$

Where:

NCR = *Net Count Rate in counts per second.*

ACC = *Area calibration constant in grams-seconds per square centimeter.*

W = *Width of holdup material in centimeters using model.*

CF_{PIPE} = *Attenuation correction factor for the intervening pipe material.*

The point assay calculation is repeated for each measurement location along a duct. Each location can be described in terms of its relative position from the starting point. Each value is then graphed versus its relative position. The plutonium mass (in grams) in the ductwork assayed is given by the area under the "curve" (Equation 3).

Equation (3)

$$Pu\ (gms) = \sum_{i=1}^{n-1} \frac{(y_{i+1}+y_i)}{2} \times (x_{i+1}-x_i)$$

Where:

n = *number of assay locations*
y = *point assay (gram/cm)*
x = *position of each point assay (cm) along the length of the duct*

DATA COMPARISON

Typically NDA measurements are validated by measuring standards representative of process material. This validation method is not easily accomplished for duct holdup measurements due to the number and varying matrices of holdup material. As an alternative, in areas where ducts are cleaned out, a comparison of before- and after-remediation holdup measurements can be made to proven NDA methods (calorimetry/gamma-spectroscopy) or destructive analysis of the material removed.

RFP personnel have cleaned several sections of ductwork and the removed material has been assayed by calorimetry/gamma-spectroscopy to ascertain the nuclear material content. Two examples of the comparison between the before- and after-remediation holdup measurements (delta) and those measured by calorimetry/gamma-spectroscopy are detailed below.

In the cleaned-out section of one glovebox exhaust system, which included 10, 12 and 14 inch diameter ducts, the delta between the holdup measurements is 307 grams. This data compares favorably to the calorimetry/gamma-spectroscopy assay of 302 grams Pu in the 1947 grams of material removed. In another, totally separate exhaust system, which included 10 and 12 inch diameter ducts, the holdup measurements delta on the cleaned section is 124 grams. This data also compares favorably to the calorimetry/gamma-spectroscopy assay of 122 grams Pu in the 774 grams of material cleaned out.

SUMMARY

These comparisons have exceeded expectations. The limited data available provides an indication that the BGO detector top/bottom contact measurement technique is valid. As additional data is accumulated, the overall effectiveness of the applicability of the top/bottom ratio model will be assessed.

Contact holdup measurements on glovebox exhaust ducts, employing the top/bottom width model is a viable method. It is especially useful in areas where pipe configuration is not conducive to the far-field line approximation method.

1. Los Alamos National Laboratory, Group N-1, Safeguards Technology Training Program; "Nondestructive Assay of Special Nuclear Material Holdup"; February 1991.

2. G. A. Sheppard, et al; "Models For Gamma-Ray Holdup Measurements at Duct Contact"; To be presented at the INMM 32nd Annual Meeting; New Orleans, LA, July 28-31, 1991.

A New Approach to Performing Holdup Measurements On Glovebox Exhausts

J. BRUCE GLICK
EG&G Rocky Flats, Inc.

INMM 32[ND] ANNUAL MEETING

JULY 29, 1991

A New Approach to Performing Holdup Measurements On Glovebox Exhausts

- Introduction
- Detector System
- Detector Calibration
- Data Acquisition
- Data Analysis
- Data Comparison
- Summary

Introduction

- How it All Started

  - Criticality Safety Assessment

  - Ducts Identified as a Potential Concern

  - Chartered to Develop and Implement a Program

Detector System

- Difficulties with Duct Configuration
- Contact Measurements Feasible
- Bismuth Germanate (BGO) Detectors Selected
- Collimated, Shielded System Very Portable

Calibration

- Applied LANL Calibration Technique
- 5 gram Plutonium 'Point Source'
- Correction Factors - Using 'Line Source' Standards
- Correlated to BGO ROI
- Area Calibration Constant Generated

Data Acquisition

- Assumption: Majority of Holdup in Bottom of Duct

- Confirmed With
  - Field Measurements
  - Video Characterization

- Measurements Performed Above and Below Duct

Data Analysis

- Material Width Model
  - Vertical Ducts
  - Top/Bottom Ratio Approaching Unity
- Point Assay (gm/cm) Calculated at Each Location
- Total Pu in Duct Section

Data Comparison

- Pre- and Post-Clean Out Measurements (Delta)

- Delta Measurements Comparison

Section 1		Section 2	
Delta:	307 Grams	Delta:	124 Grams
Calorimetry:	302 Grams	Calorimetry:	122 Grams

Summary

- Contact Top/Bottom Technique Viable

- Continuing Validation
  - Remediation (Delta)
  - Comparison to 'Far-Field' Method