

Using the Nuclide Report Function to Perform Enrichment Estimates with the ORTEC digiDART™

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ABSTRACT

The Technical & Measurement Support (T&MS) section of the Nuclear Materials Control and Accountability (NMC&A) Organization began researching commercially available stand-alone portable multichannel analyzers (PMCA) to replace the Davidson PMCA, which was no longer manufactured and had become obsolete. The ORTEC digiDART™ was chosen as the replacement for the Davidson PMCA. The digiDART™, however, did not come with on-board enrichment estimate software. This paper describes a method developed by Y-12 NMC&A of using the Nuclide Report function of the digiDART™ to perform enrichment estimates of sufficiently thick materials in the field, using sodium iodide NaI(Tl) detectors.

BACKGROUND

In NMC&A, the Davidson PMCA was used with NaI(Tl) detectors as standard equipment by the T&MS group to regularly perform passive gamma Nondestructive Assay (NDA) confirmation measurements on internal and external Special Nuclear Material (SNM) transfers, non-SNM checks to verify that there was no unauthorized transfer of unshielded enriched uranium from one area to another, holdup measurements, and inventory verification/confirmation measurements, among other functions. Many of these measurements required enrichment estimates, and most required that some aspect of the spectrum be scrutinized as part of the field analysis. The Davidson PMCA internal software included a program that used the Infinite-Sample Gamma Measurement Technique to calculate enrichment in real time as well as an onscreen spectrum during the sample acquisition.

Production of the Davidson PMCA ceased in 1998, but it had become obsolete years earlier because of new NDA technology. Its continued use by the NMC&A T&MS group long past its era was largely due to its ability to provide a view of the spectrum in the field, which was used to help determine if a measurement met predefined acceptance criteria, and the unit's internal enrichment estimate capability.

Most of the new NDA equipment that the T&MS group researched to replace the Davidson PMCA was more ergonomically advantageous than the Davidson and had much better data storage capability. One common drawback of the new equipment, however, was the need for computers or some other interface equipment to run the software for job control and the viewing of the spectra. Also, none of the commercially available PMCA researched included a stand-alone unit with both internal enrichment estimate capability and real time spectrum display. Because of field measurements in contaminated areas, measurements in inconvenient locations, and the need for a system that one person could control, the systems that required computers or other interfaces were not feasible as replacements for the Davidson.

The T&MS section decided on the ORTEC digiDART™ as a replacement for the Davidson PMCA. The digiDART™ is a stand-alone system that can be interfaced with other equipment if desired. It has a screen that displays spectra in real time, and a keypad that gives the user full control of the NDA measurement process. The data collected from the assigned Regions of

Interest (ROI) may be used in standard enrichment estimate algorithms that can be calculated by hand or programmed into calculators and spreadsheets.

In spite of the benefits of the digiDART™, there remained a need for a faster, more convenient way for the NDA professional to obtain a good enrichment estimate from the spectra collected without having to carry extra equipment into the field. The Nuclide Report function of the digiDART™ was investigated as a possible solution.

NUCLIDE REPORT FUNCTION

The Nuclide Report displays the activity of up to 9 user-selected peaks. The calculated value is computed by multiplying the net peak count rate by a user-defined constant. The digiDART™ Operator Manual states that if the constant includes the efficiency and branching ratio, the displayed value will be activity. The task was to derive a method of determining a constant k that when used with net peak count rate would yield a value for enrichment.

All of the uranium sources used for the research of the Nuclide Report function were metal and infinitely thick for reasons of gamma ray measurement. By the Fundamental Enrichment Relation presented in the Nondestructive Assay Techniques for Safeguards Practitioners course taught at Los Alamos National Laboratory and discussed in *Passive Nondestructive Assay of Nuclear Materials* (PANDA), it was known that the area of the 186 keV ROI was proportional to the enrichment of the standards being measured. The fact that the Nuclide Report function could be used to display activity implied a mathematical relationship between detector efficiency, activity, and enrichment. Correlating digiDART™ Nuclide Report output to the Fundamental Enrichment Relation yielded Equation 1 as a mathematical solution that has proven to be consistent for producing a user-defined constant k to input to the Nuclide Report setup for field enrichment estimates of infinitely thick material.

$$\text{Equation 1: } k = \frac{(\text{Source Enrichment}) \times (\text{Count Time})}{(\text{Net Counts})}$$

where Source Enrichment is in percentage form (12.34% as opposed to 0.1234), Count Time is in seconds, and Net Counts is the net counts in the 186 keV ROI.

In the normal process of employing the digiDART™ Nuclide Report technique, only one enriched uranium source of known enrichment is needed to determine the enrichment constant. A spectrum is acquired from a source of known enrichment and the value for the Net Counts in the 186 keV ROI is used for input to the algorithm denominator. The k value computed is input to the digiDART™ when the unit prompts the user to input the Nuclide Report Constant.

Use of the Nuclide Report function for enrichment estimates requires that when the user is prompted to input the ROI Length parameter, the value must be equal to the right channel value of the 186 keV ROI minus the left channel value of the 186 keV ROI plus 1. This value differs from that of the ROI width as defined in the digiDART™ Operator Manual, which excludes the first three and the last three channels of the ROI in its calculations.

The Control Chart in Appendix A show actual data collected by 4 digiDART™s connected to different detectors measuring calibration sources of different enrichments.

INFINITE-SAMPLE GAMMA MEASUREMENT

With the Infinite-Sample Gamma Measurement Technique taught at Los Alamos National Laboratory and also discussed in PANDA, the basic measurement procedure involves viewing a uranium sample through a collimated channel with a gamma-ray detector. The enrichment is deduced from the intensity of the ^{235}U 186 keV gamma ray. If the depth of the sample along the collimation axis is much larger than the mean free path of the 186 keV photons in the sample material, all samples of the same physical composition would represent the same visible volume to the detector. This is called the “infinite thickness” criterion. In order for enrichments to be meaningful for the entire sample, the material must be isotopically uniform. Typically, two or more uranium sources of known enrichment are used for calibration to determine enrichment constants **A** and **B** for Equation 2.

$$\text{Equation 2: } E_n = AR_{n1} + BR_{n2}$$

where A and B are enrichment constants determined using at least two sources of known and different enrichments, and R_{n1} and R_{n2} are the count rates for the 186 keV and Compton ROI, respectively.

A program which employed the Infinite-Sample Gamma Measurement Technique was available in the internal software of the Davidson PMCA.

NUCLIDE REPORT FUNCTION METHOD RESULTS

While the Davidson PMCA displays enrichment values to 3 decimal places, the digiDART™ Nuclide Report enrichment method as discussed in this paper displays a total of only three digits. Such estimates are accurate enough for real time enrichment estimates in the field. It is recommended that in addition to employing the Nuclide Report method, the user will store the spectra acquired so that the data can be downloaded and verified by other methods if more accuracy is needed for official record after returning from the field. The user would need to set up the digiDART™ for the enrichment estimate method desired and transfer or input the raw data into the software or calculation process after returning from the field. Care should also be taken in the field to view the displayed spectrum to check for interfering isotopes if they are potentially present.

The stability of the method has been demonstrated by hundreds of measurements under controlled conditions in the laboratory as well as hundreds of measurements in the field. Appendix B shows the result of 100 measurements of a calibration source in the laboratory. The system performance was within the control limits for the measurement.

Further testing of the method revealed that, as the equation implies, the enrichment of the calibration source does not cause a significant difference in the measurement result. The digiDART™ Nuclide Report was set up for 3 ROI reports. The ROI 0 report was set up using the constant determined by calibrating with Src1, the ROI 1 report was set up using the constant determined by calibrating with Src2, and the ROI 2 report was set up using the constant determined by calibrating with Src3. The control chart for data from 110 field measurements is represented in Figure 3 in Appendix C.

Appendix A

Control Charts Comparing Percent Relative Enrichment Estimates for Four Different digiDART™ Systems using Calibration Sources of Different Enrichment

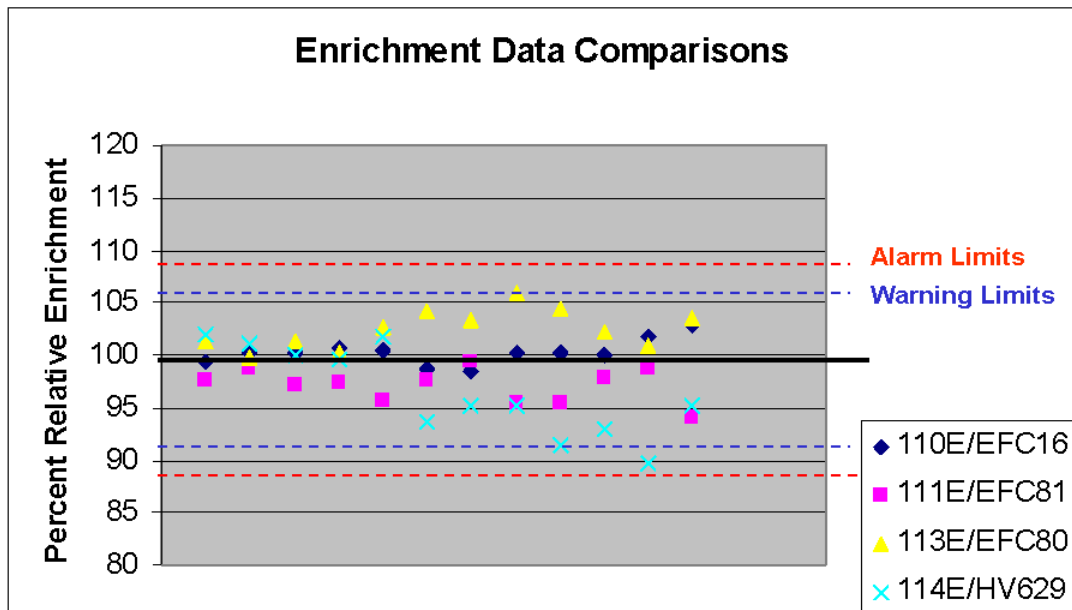


FIGURE 1

Appendix B:

Percent Relative Enrichment Values from an Enriched Uranium Calibration Source

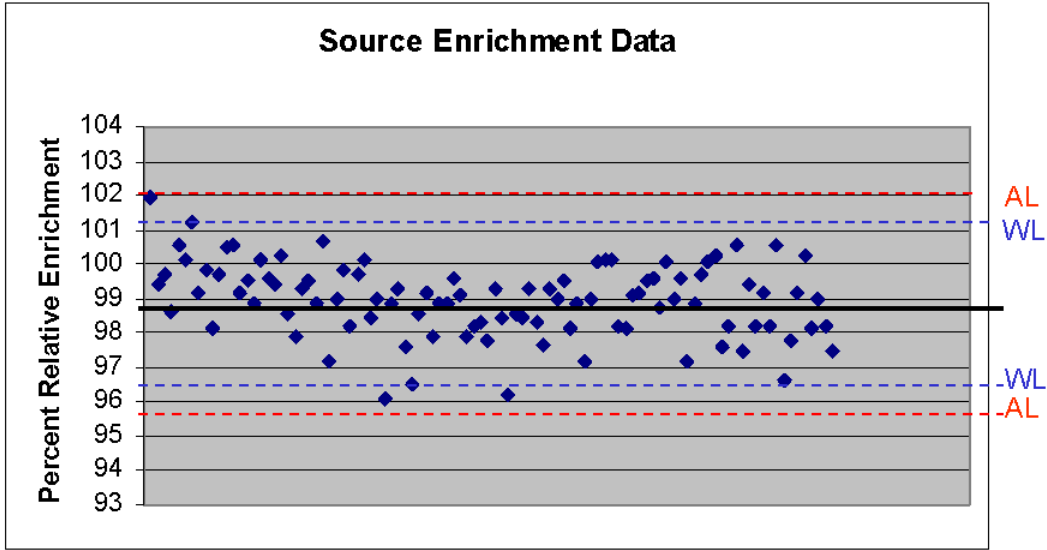


FIGURE 2

Appendix C:

Comparisons of Measured Related Enrichment Values with digiDART™
Calibrated with Sources of Different Enrichments

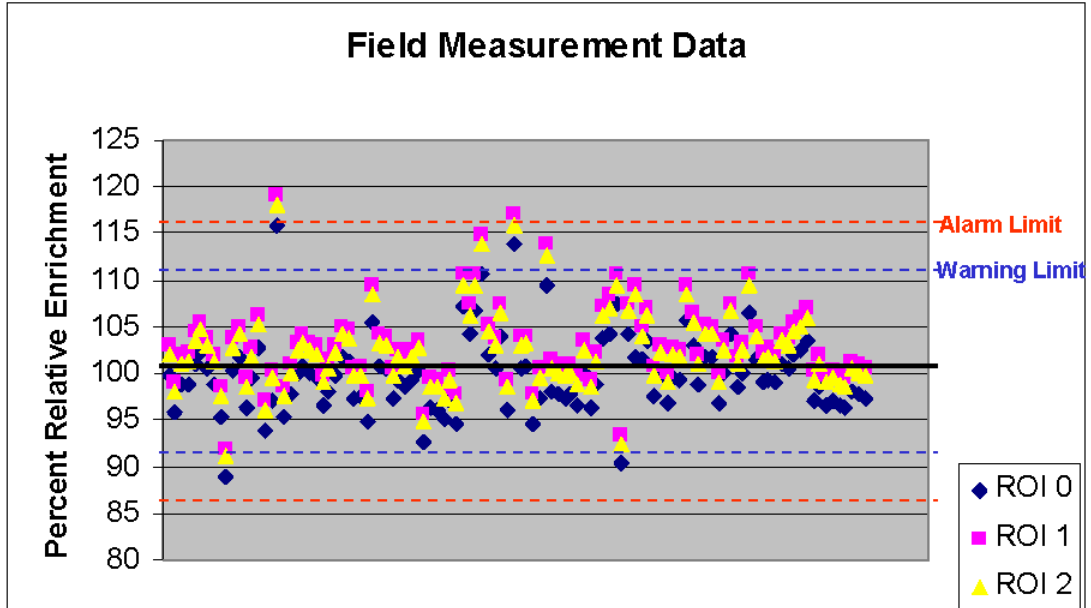


Figure 3

References:

Doug Reilly, Norbert Ensslin, Hastings Smith, Jr., and Sarah Kreiner, Passive Nondestructive Assay of Nuclear Materials, United States Nuclear Regulatory Commission, Washington, D.C, 1991 pp. 202-204.

DigiDART Portable MCA Operators Manual

Davidson Portable Multichannel Analyzer Operators Manual