PASSIVE NONDESTRUCTIVE ASSAY OF NUCLEAR MATERIALS

2007 ADDENDUM

DOUGLAS REILLY – Technical Editor

The nondestructive assay reference; ***Passive Nondestructive Assay of Nuclear Material***; Reilly, Ensslin, Smith, and Kreiner, was published in 1991 although the major technical writing was completed by 1987. This book has become widely known by the acronym ***PANDA***. Although much of the material contained therein is still valid, there has been considerable development in the field during the intervening twenty years. The two remaining editors/authors of the original book felt that it would be valuable to produce an Addendum to cover some of the more recent developments and some of the measurement technology omitted from ***PANDA***.

In 2002, Norbert Ensslin proposed a project to the US Department of Energy that would develop an appropriate set of additional chapters to complement the original ***PANDA***. The DOE agreed to fund this effort and work began on the Addendum early in 2003, when Doug Reilly returned to Los Alamos from the IAEA Safeguards Training Section.

As the writing project neared its conclusion, it was decided that the materials would be issued as Los Alamos National Laboratory reports on a compact disk and as .pdf files available on the internet website of the Safeguards Science and Technology Group, N-1, at LANL. The CD is available by contacting N-1.

Chapter 1, "Gamma-Ray Detectors for Nondestructive Analysis," LA-UR-05-3813, was written by Phyllis Russo and Duc Vo. Whereas ***PANDA*** treated only high-purity germanium and NaI(Tl) detectors, this chapter treats other alkali-halide detectors, scintillator-photodiode detectors, lanthanum scintillators, non-cryogenic semiconductor detectors, high-pressure Xe detectors, Pb-loaded scintillators, and micro-calorimeters, in addition to advances in NaI and HpGe.

Chapter 2, "Plutonium Isotopic Analysis Using PC/FRAM," LA-UR-03-4403, was written by Thomas Sampson. It covers the theory and operation of the PC/FRAM code and its performance in interlaboratory comparisons and various actual applications. It also covers the analysis of uranium spectra.

Chapter 3, "Measurement of Plutonium and Uranium Isotopics with MGA/MGAU," is being written by staff at Lawrence Livermore National Laboratory and is not yet available. These codes are extensively used internationally and the chapter covers theory, operation, and applications.

Chapter 4, "Tomographic Gamma-Ray Scanning of Uranium and Plutonium," LA-UR-07-5150, was written by Steven Hansen. This covers first the basic principles of tomography with simple examples of how tomographic images are formed and how voxel (volume element) mass and opacity are calculated. It then describes the design and operation of TGS systems and the performance of a system to characterize waste sent to the Waste Isolation Pilot Project (WIPP) in New Mexico. The chapter ends with a discussion of lump-correction techniques and an innovative technique for U lump correction.

Chapter 5, "Nondestructive Assay of Holdup," LA-UR-07-5149, was written by Douglas Reilly. This is an extension of ***PANDA*** chapter 20 that covers new corrections developed by Phyllis Russo for the Generalized Geometry Holdup (GGH) method and new applications and performance results.

Chapter 6, "Passive Neutron Multiplicity Counting," LA-UR-07-1402, was written by Norbert Ensslin, Merlyn Krick, Mark Pickrell, Doug Reilly, and Jim Stewart. ***PANDA*** covered neutron coincidence counting, but multiplicity counting was under development when it was published. The chapter covers the mathematical theory of triple coincidence counting, detector design, existing detectors and electronics, the multiplicity shift register, and multiplicity applications and performance.

Chapter 7, "Active Neutron Multiplicity Counting," LA-UR-07-1403, was written by Norbert Ensslin, Bill Geist, Merlyn Krick, and Mark Pickrell. Active multiplicity counting was developed to supplement active coincidence counting for ^{235}U materials. It does not have a "closed" solution as does passive multiplicity counting, but it may offer a promising technique for samples that are not amenable to coincidence counting. The chapter covers the theory and application of the technique.

Chapter 8, "Fast and Epithermal Neutron Multiplicity Counter," LA-UR-07-1602, was written by Mark Pickrell, Kevin Veal, and Norbert Ensslin. This chapter discusses the design and application of Epithermal Neutron (ENMC) and Fiber-Based Fast Neutron counters. Both of these counters address the problem of excessive accidentals from some samples by lowering the neutron die-away time of the counter. The ENMC is already in use and the Fiber-Based counter is still an experimental project.

Chapter 9, "Shufflers," LA-UR-03-4404, was written by Phillip Rinard. The Shuffler uses the principle of Delayed-Neutron Activation Analysis that was investigated using pulsed neutron generators in the very early days of the Los Alamos safeguards program. Instead of a neutron generator, the shuffler uses an intense ^{252}Cf neutron source that is moved close to the measured sample to induce fissions and quickly removed to a shield while delayed-neutrons from the fissions are counted. The chapter discusses basic theory, shuffler design, calibration, data analysis, and performance.

Chapter 10, "Principles and Applications of Calorimetric Assay," LA-UR-07-XXXX, was written by David Bracken and Clifford Rudy. This is a more comprehensive exposition of calorimetry than is given in ***PANDA*** chapters 21 and 22. The chapter covers heat-flow calorimeter theory, operation, calibration, and performance. Calorimetry applications to plutonium and tritium are covered, in addition to recent work on calorimetry of HEU.

Chapter 11, "Useful Nuclear Data," was compiled by Doug Reilly. This includes, among other things, a listing of nuclear data tables and figures in PANDA and Ray Gunnink's tabulation of x rays and γ rays from the principal isotopes of uranium and plutonium.

Index: A comprehensive topical index will be added at a later date. The following Table of Contents shows the contents of the Addendum.

Acknowledgements: I would like to acknowledge, especially, Norbert Ensslin for initiating this project and giving it his continued interest and support, even after his retirement from Los Alamos in 2005. Norbert obtained the necessary funding for the project and was a principal author of three of the chapters. This Addendum to PANDA would never exist were it not for Norbert's efforts. Next, I wish to recognize the support and funding of the U. S. Department of Energy, SO-13/20, and the project manager, Lynne Preston. Of course none of the chapters included herein could exist without the efforts of the fifteen principal authors. Lastly, I must recognize the support and encouragement received from the N-1 group management. Thank you everybody.

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