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OAK RIDGE NATIONAL LABORATORY
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FOR THE DEPARTMENT OF ENERGY

# NMIS WITH IMAGING AND GAMMA RAY SPECTROMETRY FOR PU, HEU, HE, CHEMICAL AGENTS, AND DRUGS

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# NMIS WITH IMAGING AND GAMMA RAY SPECTROMETRY FOR PU, HEU, HE, CHEMICAL AGENTS, AND DRUGS

The concept for this system is a Nuclear Materials Identification System (NMIS) time-dependent coincidence system[1] that incorporates transmission tomographic imaging and gamma ray spectrometry and utilizes a small, lightweight (30 lbs), portable DT neutron (14.1 MeV) generator ($5 \times 10^7$ neutrons/second)[2], proton recoil scintillation detectors, a gamma ray detector (HPGe) with multichannel analyzer, and a fast (1GHz) time correlation processor. The proton recoil scintillators are 24 small 2.5x2.5x15.2-cm.-thick plastic scintillators for imaging and two 2x2 arrays of 25x25x8-cm.-thick liquid scintillators with online digital pulse shape discrimination to distinguish neutrons from gamma rays. A computer controlled scanner moves the small detectors and the source appropriately for scanning a target object for imaging. The system is based on detection of transmitted 14.1 MeV neutrons, fission neutrons and gamma rays from spontaneous inherent source fission of the target, fission neutrons and gamma rays induced by the external DT source, gamma ray from natural emissions of uranium and Pu, and induced gamma ray emission by the interaction of the 14.1 MeV neutrons from the DT source. This system is uniquely suited for detection of shielded highly enriched uranium (HEU), plutonium, and other special nuclear materials, and detection of high explosives (HE), chemical agents, and in some cases, drugs[3]. It will be adapted to utilize a trusted processor that incorporates information barrier and authentication techniques using open software and then be useful in some international applications for materials whose characteristics may be classified. The proposed information barrier version of the NMIS system would consist of detectors and cables, the red (classified side) system which processes the data, and the black (unclassified side) computer which handles the computer interface. The system could use the "IB wrapper" concept proposed by LANL and the software integrity (digital signatures) system proposed by Sandia. Since it is based entirely on commercially available components, the entire system, including the NMIS data acquisition boards, can be built with commercial off the shelf components. This system will incorporate the Portable Isotopic Neutron Spectrometer technology of A. J. Caffrey of the Idaho National Engineering and Environmental Laboratory for HE[4], chemical agents[4], and drug detection.

The system hardware and software can be configured to obtain the following: Pu presence, Pu mass, Pu 240/239 ratio, Pu geometry, Pu metal vs. non-metallic compound (absence of metal), time (age) since processing for Pu (or last purification), U presence, U mass, U enrichment, U geometry, U metal vs. non-metallic compound (absence of metal), high explosives, chemical weapons, and, in some cases, drugs. A matrix of the quantities determined, the method of determination, whether active (external neutron source) or passive, and the measurement equipment involved is given in the following table. Some of these attributes can be obtained by multiple data analysis methods. The gamma-ray spectrometry methods for Pu, HE, and drugs have been developed by other laboratories, are well-known and will be incorporated. In addition, the imaging capability allows warhead authentication and traceability of weapons parts and weapons components through dismantlement and can be used to verify the destruction or change in form of special nuclear material, HE, and other essential non-fissile components. The imaging data will provide geometric configurations for GADRAS-like codes[5]. Imaging and GADRAS complement each other for material determinations since both gamma-ray spectrometry interpretations and neutron transmission depend upon materials and configuration. In addition, the data imaging measurements and MCNP-PoliMi calculations of the NMIS time correlation signatures can be used to obtain fissile shape and mass without calibration. Very good initial estimates of the configuration of materials from imaging can be provided to both these codes for further refined analyses. The system will be modularly constructed with the RF shielded modules connected to the processor by appropriate control and signal cables in metal conduit. The system hardware and software modules may also be configured to estimate a selected subset of these attributes. In addition, signatures for fissile material can be used for template matching such as has been implemented for confirmation of inventories and receipts for weapons components at the Y-12 National Security Complex in Oak Ridge since 1996. Y-12 personnel were trained and have been operating three NMIS systems at the Y-12 complex.

This system has the advantage of combining multiple technologies into a single system for a variety of applications and thus is cost effective.

[1]A variant of this system was described in the following reference which is included as Appendix A: J. A. Mullens, J. E. Breeding, R. B. Perez, J. T. Mihalczo, T. E. Valentine, and J. A. McEvers, "A Multipurpose Processor for Arms Control and Nonproliferation and NMC&A," Institute of Nuclear Materials Management Annual Conference, July 1999, J. T. Mihalczo, J. K. Mattingly, J. A. Mullens, J. A. McEvers, J. S, Neal, R. B. Oberer, J. D. White, "Oak Ridge Multiple Attribute System (ORMAS) For Pu, HEU, HE, Chemical Agents, and Drugs," ORNL/TM-2001/175 (2001).

[2]While the active source is operational at $5 \times 10^7$ n/sec, the radiation dose is ~15 mrem/hr at 3 meters with the source unshielded; the source is turned off when not in use.

[3]Personnel communication, INEEL, July 2001.

[4]A. J. Caffrey, J. D. Cole, R. J. Gehrke, and R. C. Greenwood, "Chemical Warfare Agent and High Explosive Identification by Spectroscopy of Neutron-Induced Gamma Rays," IEEE Transactions of Nuclear Science, 39, p. 1422-1426 (1992)

[5]Dean J. Mitchell, GADRAS-95 User's Manual, Sandia National Laboratories Systems Research Center 5900 Report (1995)

## 10 – 15 Minute Time Constraint for Weapons Inspection
## Matrix of ORMAS Attribute Measurements

| Material | Attribute | | Method (Option, Implementation, Basis) | | Active or Passive | Measurement Equipment |
|---|---|---|---|---|---|---|
| plutonium | presence | 1 | time-dependent coincidence | detect internal spontaneous fission | active/passive | DT neutron source (if active), scintillation detectors, time-correlator |
| | | 2 | gamma spectrometry | detect Pu spectral lines | passive | high-resolution gamma detector, multi-channel analyzer |
| | age | 1 | gamma spectrometry | Measure in-growth of $^{241}Am$ | passive | high-resolution gamma detector, multi-channel analyzer |
| | metal / non-metal | 1 | neutron-initiated gamma spectrometry | detect 6129 KeV gamma from 14.1 MeV neutron interactions with O & F | active | DT neutron source, high-resolution gamma detector, multi-channel analyzer |
| | | 2 | time-dependent coincidence | measure density from neutron transmission | active | DT neutron source, scintillation detectors, time-correlator |
| | | 3 | time-dependent coincidence | attenuation of gammas emitted and multiplication depending on density | active | DT neutron source scintillation detectors, time-correlator |
| | geometry | 1 | time-dependent coincidence | imaging | active | DT neutron source, scintillation detectors, time-correlator |
| | relative $^{240}Pu$-content | 1 | time-dependent coincidence | compare spontaneous and induced fission rates | active | DT neutron source, scintillation detectors, time-correlator |
| | | 2 | gamma spectrometry | Compare $^{240}Pu$ and $^{239}Pu$ spectral lines | passive | high-resolution gamma detector, multi-channel analyzer |
| | fissile mass | 1 | time-dependent coincidence | measure induced fission rate enhanced by imaging | active | DT neutron source, scintillation detectors, time-correlator |
| | | 2 | time-dependent coincidence | measure spontaneous fission rate | passive | scintillation detectors, time-correlator |
| | disposition or conversion of | 1 | time-dependent coincidence | transmission imaging tomography | active | DT neutron source scintillation detectors, time-correlator |

| Material | Attribute | | Method (Option, Implementation, Basis) | | Active or Passive | Measurement Equipment |
|---|---|---|---|---|---|---|
| uranium | **presence** | 1 | time-dependent coincidence | detect induced fission and absence of internal spontaneous fission | active | DT neutron source, scintillation detectors, time-correlator |
| | **metal / non-metal** | 1 | neutron-initiated gamma spectrometry | detect 6129 KeV gamma from 14.1 MeV neutron interactions with O & F | active | DT neutron source, high-resolution gamma detector, multi-channel analyzer |
| | | 2 | time-dependent coincidence | measure density from neutron transmission | active | DT neutron source, scintillation detectors, time-correlator |
| | | 3 | time-dependent coincidence | attenuation of gamma emitted and multiplication depend on density | active | DT neutron source, scintillation detectors, time-correlator |
| | **geometry** | 1 | time-dependent coincidence | imaging | active | DT neutron source, scintillation detectors, time correlation |
| | **$U^{235}$-enrichment** | 1 | time-dependent coincidence | Compare induced fission rates and neutron transmission for simple parts | active | DT neutron source, scintillation detectors, time-correlator, HPGe |
| | | 2 | Gamma spectrometry corrected for imaging using field of view, volume, shielding | HPGe * | active | DT neutron source, scintillation detectors, time-correlator |
| | **fissile mass** | 1 | time-dependent coincidence | measure induced fission rate complemented by imaging | active | DT neutron source, scintillation detectors, time-correlator |
| | **Disposition or conversion of** | 1 | time-dependent coincidence | transmission imaging tomography | active | DT neutron source, scintillation detectors, time-correlator |
| **fissile** | **spatial distribution** | 1 | time-dependent coincidence | imaging plus DT source pixel correlated multiplicities | active | DT neutron source, scintillation detectors, time-correlator |

| Material | Attribute | | Method (Option, Implementation, Basis) | Active or Passive | Measurement Equipment | Material |
|---|---|---|---|---|---|---|
| dismantlement | **warhead authentication** | 1 | time dependent coincidence | transmission imaging tomography | active | DT neutron source, scintillation detectors, time-correlator |
| | **traceability of weapons/parts** | 1 | time dependent coincidence | transmission imaging tomography | active | DT neutron source, scintillation detectors, time-correlator |
| | **destruction of nuclear warhead casings** | 1 | time dependent coincidence | transmission imaging tomography | active | DT neutron source, scintillation detectors, time-correlator |
| | **destruction of essential non-nuclear parts** | 1 | time dependent coincidence | transmission imaging tomography | active | DT neutron source, scintillation detectors, time-correlator |
| high explosive | **presence** | 1 | gamma spectrometry | N presence and ratios of N/C, H/C, and O/C | active | DT neutron source, HPGe or BGO |
| | **geometry** | 1 | time dependent coincidence | Imaging | active | DT neutron source, scintillation detectors, time-correlator |
| | **separation from fissile** | 1 | time dependent coincidence | transmission imaging tomography | active | DT neutron source, scintillation detectors, time-correlator |
| | **destruction of** | 1 | time dependent coincidence | transmission imaging tomography | active | DT neutron source, scintillation detectors, time-correlator |
| **chemical weapon** | **presence** | 1 | gamma spectrometry | ratios of N/C, H/C, and O/C | active | DT neutron source, HPGe or BGO |
| **drugs** | **presence** | 1 | gamma spectrometry | ratios of N/C, H/C, and O/C | active | DT neutron source, HPGe or BGO |

* Measure 185.7 for gamma, use correction factor for shielding and volume from imaging.