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FORMS OF PLUTONIUM IN THE TRILATERAL INITIATIVE**

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Abstract

A team of technical experts from the Russian Federation, the International Atomic Energy Agency (IAEA), and the United States has been working since December 1997 to develop a toolkit of instruments that could be used to verify plutonium-bearing items that have classified characteristics in nuclear weapons states. This suite of instruments is similar in many ways to standard safeguards equipment and includes high-resolution gamma-ray spectrometers, neutron multiplicity counters, gross neutron counters, and gross gamma-ray detectors. In safeguards applications, this equipment is known to be robust and authentication methods are well understood. However, this equipment is very intrusive, and a traditional safeguards application of such equipment for verification of materials with classified characteristics would reveal classified information to the inspector. Several enabling technologies have been or are being developed to facilitate the use of these trusted, but intrusive safeguards technologies. In this paper, these new technologies will be described.

1. INTRODUCTION

The verification of plutonium-bearing items that have classified characteristics presents new challenges relative to traditional safeguards. First and foremost the classified information cannot be disclosed to the inspector. However, the inspector must have confidence that the measurements are robust and are providing authentic results. These two requirements, seemingly in opposition to each other, have motivated a novel technical approach to this kind of verification. To protect classified information, an attribute measurement approach has been adopted. In this approach, attributes of the materials are identified and measured using familiar, nondestructive assay methods. A filter is then applied to transform the attribute measurement into a simple pass or fail unclassified answer that the inspector may have access to. The agreed upon attributes for the Trilateral Initiative are: the presence of plutonium, the

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presence of plutonium with a ^{240}Pu to ^{239}Pu ratio less than 0.1, and the presence of a plutonium mass that is greater than some agreed upon threshold. For this latter mass attribute, the threshold has yet to be defined and will most likely be inventory specific.

The data that are acquired to deduce the attribute information are classified and also must be protected. Thus, a new technology called an information barrier has been developed. This technology, described further below, consists of technological and administrative methods to protect the information from unauthorized access by the inspector while protecting the data collection equipment and analysis computers from unauthorized access by the host.

Another challenge to the development of a verification approach for materials with classified characteristics is to select measurement methods that do not require representative standards for calibration and authentication. For an inspector to trust the verification technology, he or she must be able to reach independent conclusions that the system is operating as it is supposed to. Trusted reference materials that have been independently verified are usually used for this purpose. The best source of these trusted, reference materials is the inventory to be verified. However, for materials with classified characteristics, the inspector cannot independently verify reference materials drawn from the inventory because to do so would reveal classified information. Only unclassified reference materials can be made available to the inspector, and these cannot truly represent the inventory of materials to be verified. Thus, any measurement method selected also must satisfy the requirement that it can be calibrated and authenticated using unclassified reference materials that may be quite unlike the inventory to be verified.

To meet these challenges, a team of technical experts representing all three parties to the Initiative has met for the last four years to discuss and develop technical methods to address these challenges. As a result of these discussions, the technical experts have provisionally agreed to general technical requirements (GTR and functional specifications (FS))[1] for an attribute measurement system called “Atttribute Verification System with an Information Barrier Utilizing Neutron Multiplicity Counting and High-Resolution Gamma-Ray Spectrometry” or AVNG. Certain other ancillary equipment also has been discussed that might be used to provide additional confidence in a Trilateral Initiative verification approach. Below we will describe this equipment. We will also describe the status of the work and plans for future development.

2. THE AVNG

A schematic diagram of the AVNG can be found in Fig. 1. The radiation measurement components of the AVNG consist of a combined neutron multiplicity counter and high-resolution gamma-ray spectroscopy system. The components of the system are specified to have sufficient detection efficiency to produce timely results. Timeliness is driven both by facility requirements and by sample packaging. The latter is an issue because facilities that have been discussed as potential sites for Trilateral Initiative verifications will store plutonium in highly shielded containers that can dramatically reduce and change their emissions.

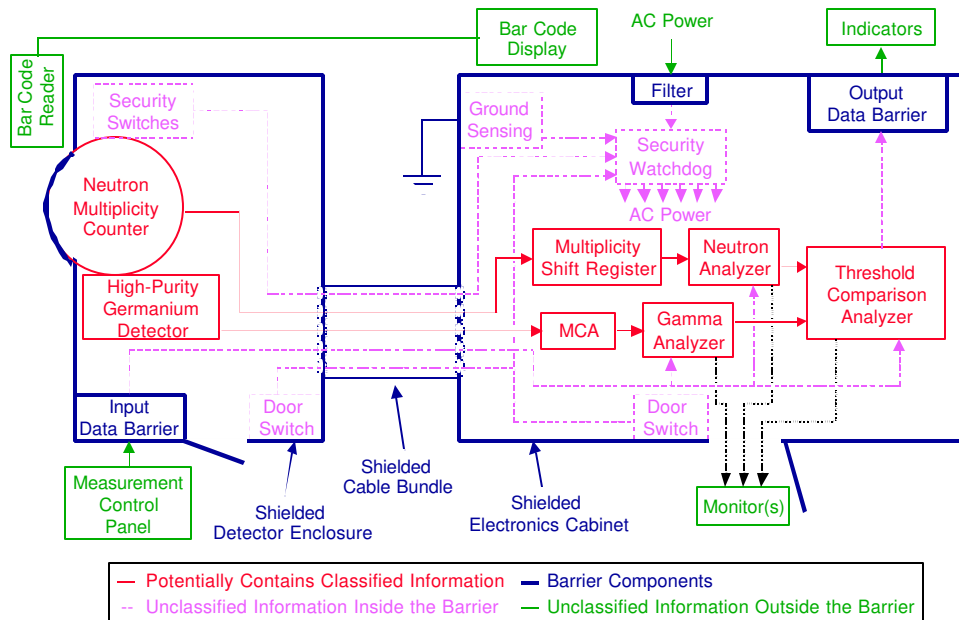


Fig. 1. Conceptual schematic of AVNG measurement system. This system is composed of standard neutron and gamma measurement systems surrounded by an information barrier.

Preferably the AVNG will obtain all data simultaneously. Because both neutron and gamma ray data must be used to deduce plutonium mass, some classified information needs to be stored for a short period. Simultaneous data collection is specified in order to reduce the amount of time that classified data must be stored in computer memory.

The measurement data are analyzed by software that has similar functionality to standard IAEA nondestructive assay software, but all unnecessary functionality is specified to be removed. System software is specified to be as minimal as possible. Minimizing software reduces the opportunity for classified data to be mishandled by the system and makes the job of authentication easier.

The computers that analyze the data are specified to be very simple and contain an absolute minimum of non-volatile memory. All classified data are stored in volatile memory. Software resides on non-rewritable programmable read-only memory. There are no hard drives or other mechanical drives in the computers. This is specified to increase their robustness as well as to protect the classified information.

All measurements are controlled by simple switches. These switches can be of the push-button variety or sensors that tell the system what type of measurement to make depending on a container type. These switches provide the only possible operator input. Four types of measurements are possible and a specific sequence of measurements is required on system start-up. Start-up includes a gamma-ray calibration, a background measurement, and a ^{252}Cf measurement to verify correct operation of the neutron multiplicity counter. The fourth measurement type is a verification measurement.

Output from the system consists of a simple yes/no reporting system. Because this information is unclassified, a means of archival storage is allowed by the specification but the details have not been developed.

The most enabling part of the AVNG is the information barrier. This barrier is specified to include appropriate shields and other devices to prevent the transmission of any

electromagnetic (EM) signals into or out of the system. Other means may be applied to prevent the transmission of other forms of signals for these purposes, e.g., infrared or audio. Shielded cabinets and administrative/physical security measures can be part of the information barrier. All cabinets that protect the measurement equipment and computers are specified to have tamper indicating features consistent with normal IAEA safeguards practice.

All input and output communication with the AVNG is specified to use as few communication lines as absolutely necessary for the minimum amount of data bits transmitted. Data transmissions—such as those made with security switches, measurement selection switches, and output display or archival storage device—are protected by means of a data barrier that insures that only the allowed, unidirectional communication can take place and that it can only be unidirectional.

The system is designed to operate in two modes: a secure mode and an open mode. The mode is specified to be controlled by simple, non-operator controlled switches. These switches may be container controlled. The default state of the system is secure. All measurement types are possible in either security mode. In open mode, an inspector can have access to raw data and results. These can be viewed via monitors or printers attached to the system. Secure mode operation is intended for the verification of materials with classified characteristics. In secure mode, no output other than yes/no answers are available, and no output devices can be physically attached to the system.

A “ security watchdog” oversees the modes of operation. This device, together with an emergency “scram” switch, controls all power to the system. If there is any intrusion into the system when it is in secure mode, the watchdog disconnects the power and all information in volatile memory is lost. The security watchdog prevents the power from coming back on until the system is taken out of the secure state and placed in open mode. Once in open mode, the system’s power is restored after an appropriate time-out period has elapsed.

An important advantage to the AVNG concept, as shown schematically in Fig. 1, is the distinct separation of the system security functions from the measurement functions. Except for power, no direct communication takes place between the security watchdog and the security switches to the measurement equipment or computers that analyze the results. Thus, in a sense, the measurement equipment does not “know” whether the data being taken is classified or not. This gives assurance to the inspector that the equipment will behave the same whether the system is in open mode or the system is in secure mode.

3. ATTRIBUTE MEASUREMENT EQUIPMENT PROTOTYPES

Two prototype attribute measurement systems with information barriers have been built in the U. S. The first was demonstrated during a Trilateral Initiative Technical Workshop held at Los Alamos in June 1999.[2] The U.S. technical experts built the system, shown in Fig. 2, based on technical discussions up to that time, but used several possible technical solutions in the prototype to stimulate further discussion. They employed a variety of solutions ranging from standard IAEA software running on a desktop computer platform to a customized microcomputer running minimal software. As a result of this demonstration, the technical experts were tasked to develop the FS and GTR referenced above.



Fig. 2. *The first prototype attribute measurement system with an information barrier for the Trilateral Initiative.*

A second prototype, shown in Fig. 3, was built and demonstrated the following summer.[3] Although this demonstration was not done within the auspices of the Trilateral Initiative, many of the same technical experts from the U.S. and from the Russian Federation were involved. In addition, to the extent possible for a demonstration system, the Trilateral Initiative GTR and FS were included in this second prototype. In particular, this system allowed for simultaneous neutron and gamma ray measurements. This prototype measured six attributes including the three used in the Trilateral Initiative and thus also demonstrated the versatility of the information barrier concept.

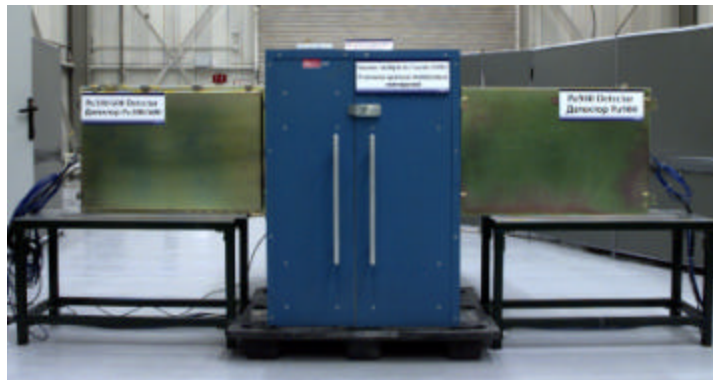


Fig. 3. *The second attribute verification system with information barrier.*

4. LESSONS LEARNED AND OTHER EQUIPMENT

In the FS and GTR for the AVNG, the technical experts anticipated the need for robustness and a self-diagnostic capability for the equipment. These are important features of standard safeguards equipment. Much investment has been spent over the years in developing user-friendly, interactive interfaces so that an IAEA inspector can judge when equipment is malfunctioning and what is wrong. Such interfaces, however, are considered non-essential functionality from an information protection perspective for the AVNG. And in secure mode, only an OK/ NOT OK status is allowed.

An important lesson learned from the development of the two prototype systems is the importance of having diagnostic capability to detect the cause of failures when the system is in secure mode. In the two prototypes, no such capability existed and much time was expended trying to track down the causes of intermittent problems that would occur in secure mode, but not in open mode—when diagnostic information was available. A modification to the GTR and FS may need to include an allowance for a “private” access by the host to obtain diagnostic error codes when the self-diagnostics of the system detect a failure when in secure mode. This access may need to be through the information barrier via a data barrier to a host access only display. The data barrier assures the inspector that the host is not “tampering” with the system when error codes are being read.

Another lesson learned is that to understand and establish confidence in the performance of a complex system like the AVNG requires a great deal of testing using a variety of reference materials. The complexity of this task is not only linked to the number of components in the system, but also to the difficulty in obtaining an adequate variety of reference materials that represent what the system might measure. In building the two prototype systems, simulations were not used to the extent they could have been to ease this process. The limited simulations were valuable. More simulations would have made the integration easier and could have helped provide greater confidence in these systems. For future field-able systems, simulations will be even more important to understand performance when representative reference materials cannot be available.

One of the greatest challenges of an information barrier verification is gaining confidence that the system is operating as it is supposed to. Another challenge to verifications envisaged under the Trilateral Initiative is to maintain this confidence for a very large inventory of material. These challenges have generated discussions between the technical experts concerning what other types of equipment or methods could be used to overcome these challenges.

The equipment that has been discussed includes in-site probes, authentication/simulation tools, signal splitters,[4] and lower-level measurement equipment that could “screen” a larger fraction of the inventory than might be possible with the AVNG. *In-situ* probes are simple gross radiation measurement devices that could be used to provide confidence that an item placed in a storage position has remained in storage. Monte Carlo simulations of their use to measure gamma-ray or neutron emissions from samples in storage indicate that they may provide a valuable way to add confidence that materials put into long-term storage arrays have remained in place. Tools such as this probe reduce the need to remove materials from their storage locations. Reducing the movement of these materials reduces the opportunity to divert them to some other use.

The authentication/simulation tool is an electronic pulse simulator that mimics the output of a radiation measurement device. With this tool, an inspector can exercise a system that has an information barrier independent of host controlled reference materials. This tool has also been identified as being potentially very useful in training inspectors, exercising electronics packages, and safeguards applications.

Signal splitters are devices that allow for signal sharing while insuring that the information is not being degraded or changed by the splitting. The AVNG system contains some expensive components that may also be of use to a facility's domestic safeguards needs. Signal splitters would enable the same equipment to be used for both domestic and IAEA use, thus saving resources.

Lower-level measurement equipment might include systems like the Russian Passport System or an AVNG system that has less measurement precision capability. Efforts have been undertaken to analyze what type of lower-level measurement equipment might be useful and how this type of equipment might be applied to inventories of materials that might come under the Trilateral Initiative.

5. CURRENT STATUS AND THE FUTURE

Currently work is ongoing to develop contracts that would allow an AVNG prototype and reference materials to be produced in Russia. At the most recent meeting of the Trilateral Initiative Principals this past September, this contract work was reaffirmed. The prototype's goal is to produce an instrument that could be fielded at the Russian Fissile Material Storage Facility.

Work in the U.S. is ongoing to develop *in-situ* probes, authentication/simulation tools, and signal splitters. This work will be showcased during a Trilateral Initiative workshop on lower-level support measurements and verification equipment to be held at the Joint Research Center in Ispra, Italy. At this workshop, the technical experts will also mockup a lower-level measurement system and compare simulation calculations to what is measured for well-characterized reference materials in shielded storage containers. Facilitated discussions on equipment authentication and demonstrations of some novel monitoring and surveillance capabilities will also be held.

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