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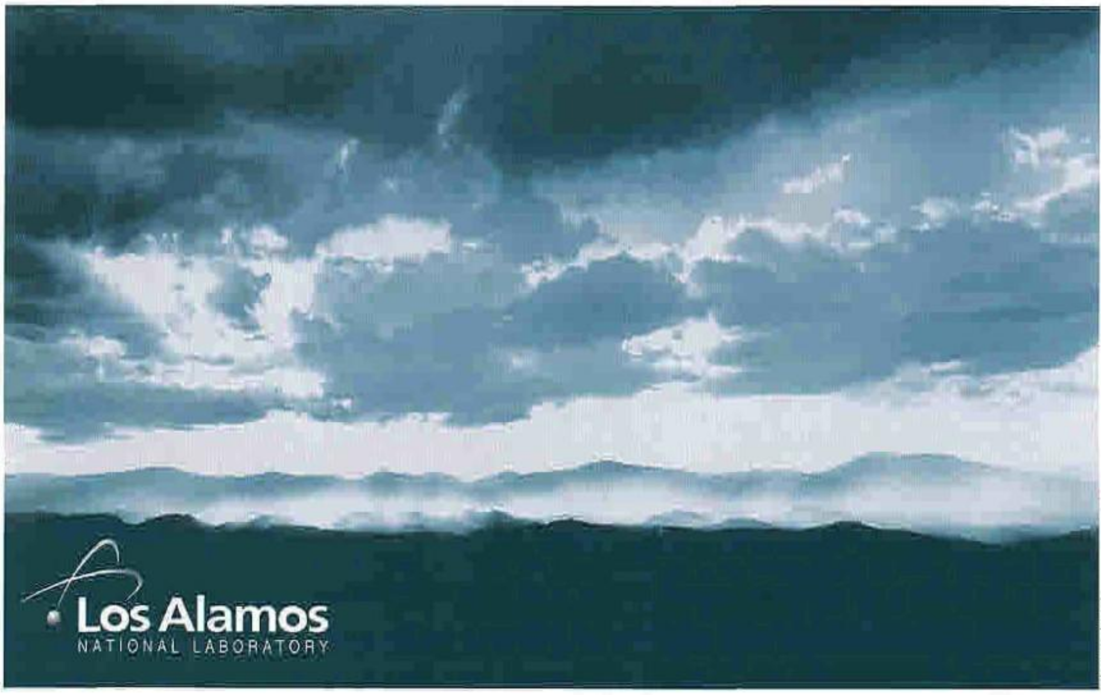

Chris J. Lindberg

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ABSTRACT
An attribute verification system (AVNG) with information barriers for mass and isotopics measurements has been designed and its fabrication is nearly completed. The AVNG is being built by scientists at the Russian Federal Nuclear Center-VNIIEF, with support of Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL). Such a system could be used to verify the presence of several unclassified attributes of classified material with no classified information release. The system is comprised of a neutron multiplicity counter and gamma-spectrometry system based on a high purity germanium gamma detector (nominal relative efficiency @ 1332 keV 50%) and digital gamma-ray spectrometer DSPEC^{PLUS}. The neutron multiplicity counter is a three ring counter with 164 ^{3}He tubes. The system was designed to measure prototype containers 491 mm in diameter and 503 mm high. This paper provides a brief history of the project and documents the progress of this effort with drawings and photographs.

INTRODUCTION
The development, manufacture, testing and demonstration of the plutonium attribute verification system are carried out within the framework of the Agreement № 37713-000-02-35 made between the Los Alamos National Laboratory (LANL) managed by the University of California, USA, and the Russian Federal Nuclear Center-VNIIEF, Russia. The parties have developed a system with Information Barriers for containers with plutonium.

The measurement procedure involves the examination of a sealed AT-400R container; whose radiation signatures are obtained and the following attributes are verified:

- Plutonium presence in the container;
- Plutonium 240/239 isotope ratio exceeds established threshold value;
- Plutonium mass exceeds an agreed to threshold value.

THE SYSTEM DESIGN

The AVNG system consists of the following elements:

- a gamma-spectrometry system based on a high-purity germanium (HPGe) detector and a digital gamma-ray spectrometer DSPEC^{PLUS};
- a neutron multiplicity counter based on ^{3}He-tubes in polyethylene moderator;
- an instrument rack with measuring and control equipment;
- a control/indicator panel built into the operator's control panel; and
- protection circuits to prevent unauthorized access;

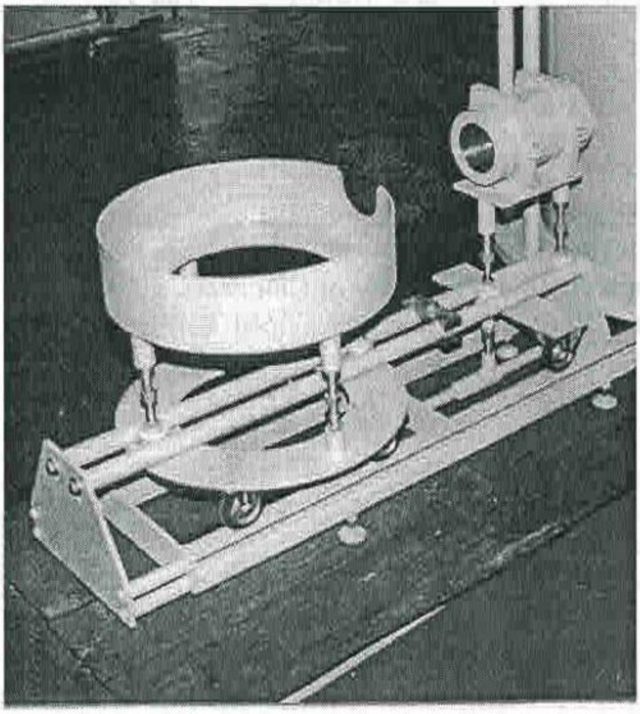
All the system's elements are located in a shielded module. The exception is a shielded control/indication panel mounted outside the module. Below the system basic components are briefly described.

GAMMA-SPECTROMETRY COMPONETS

Gamma-ray spectrometry is used to establish plutonium presence and determine the ^{240}Pu/^{239}Pu ratio from the analysis of plutonium gamma-ray radiation detected. The gamma-ray spectrometer is developed on the basis of commercially available elements:

- HPGe detector SGD-GEM-50180 Plus with streamlined side-looking cryostat (ORTEC).
- Digital spectrometer DSPEC^{PLUS} (ORTEC).

The digital spectrometer being used allows for operation at very high count rates with no degradation in energy resolution. The HPGe detector cryostat is inserted in a tungsten shield with a capability of changing the diameter of the collimator. The detector itself is placed on a movable support that allows the distance between the neutron multiplicity detector wall and the HPGe detector head face to be varied within certain limits. Figure 1. shows the manufactured support for the HPGe detector and the collimator. Figure 2. shows the collimator and adjustable opening.



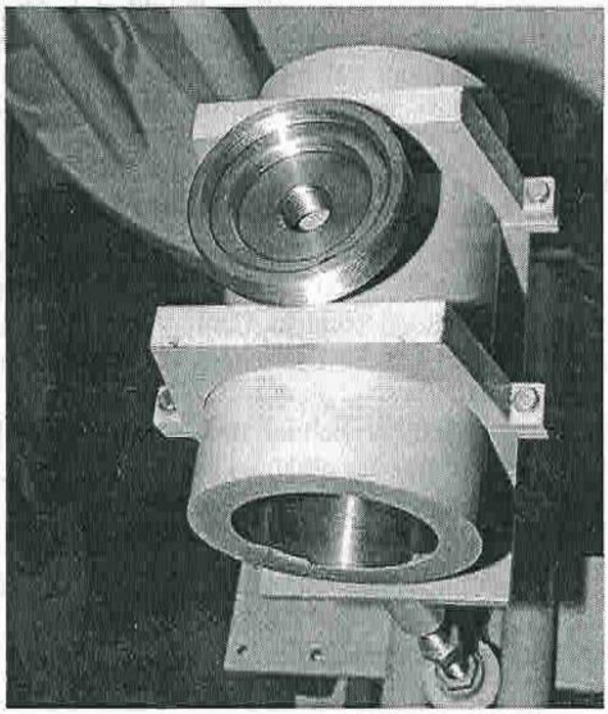


Fig. 1 Fig. 2

NEUTRON MULTIPLICITY COUNTER

A neutron multiplicity counter is used to determine the threshold mass value of plutonium in the sealed container. The cavity's inner dimensions were specified according to the AT-400R container dimensions: outer diameter - 491 mm, height - 503 mm. Outer dimensions were determined from condition of maximum detection efficiency.
When considering different neutron multiplicity counter design options, two configurations of the moderator block were analyzed; cylindrical and hexagonal shapes. The modeling simulations have shown the neutron detection efficiency for detectors with cylindrical and hexagonal moderator blocks to be practically the same. The cylindrical configuration was preferred as more compact and preferred for manufacturing. In addition, modeling was performed to evaluate the influence of the end reflector material and thickness on the detector efficiency. As a result, polyethylene was chosen as the moderator, and graphite was chosen for the end reflector material. According to the modeling results the detection efficiency of the neutron multiplicity counter for plutonium placed inside an AT-400R container is approximately 30%.

For the neutron counter helium tubes, CANBERRA EURISYS 192HN90 1005 mm long have been selected; the tube outer diameter is 25 mm. The helium pressure in the tubes is 10 atm. Tubes in the neutron multiplicity counter are positioned in concentric circles. The geometry of the helium tubes positioned in the body is shown in Fig.3.

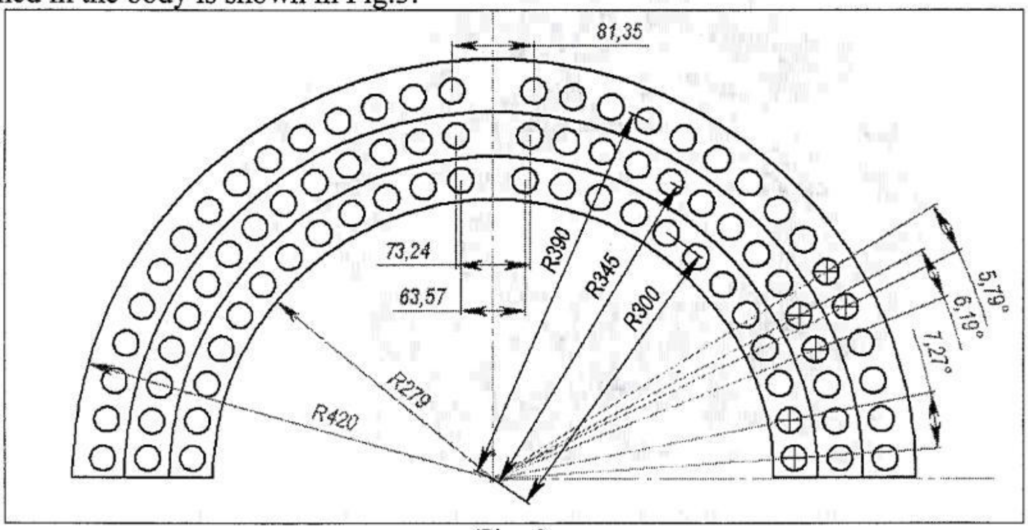


Fig. 3.

The following considerations were taken into account as the ^{3}He-tubes position within the detector was determined:

- the necessity for container position sensors installed within the moderator body (sensors capable of determining container type – working/testing);
- restrictions due to the door hinge area.

The helium tubes were positioned on three radii as follows:

- circle I (radius is 300 mm), 48 tubes;
- circle II (radius is 345 mm), 56 tubes;

- circle III (radius is 390 mm), 60 tubes.

The total number of helium tubes in the neutron multiplicity counter is 164.

There are 28 groups of tubes; 24 of them are the complete (6 tubes in each group, 2 tubes in each circle) and 4 are incomplete (5 tubes in each group, 2 tubes on circle II and three on circle III). As a result, there are six groups consisting of six tubes and one group consisting of five tubes in each of the neutron multiplicity counter doors. In the neutron multiplicity counter body there are twelve groups consisting of six tubes and two groups consisting of five tubes.

In the upper portion of the neutron multiplicity counter body, amplifier/shapers are installed, intended to provide high-voltage for the tubes and to amplify and shape the signal from the tubes. In all, 28 amplifier/shaper units are installed. For each group of the neutron tubes one amplifier/shaper unit is used. The amplifier/shaper circuit is implemented based on the hybrid chip Amptek A111, as well as the MAX267 (Maxim) and 74123 (Texas Instruments) chips. To highlight the indicator LED a multi-vibrator is installed with pulse duration of 0.5 μs. An RLC-filter is mounted on the amplifier/shaper high voltage input. The amplifier/shaper is mounted within a metal box (junction box) providing electromagnetic shielding for the printed board placed inside the body.

Fig. 4 presents a general view of the neutron multiplicity counter upper portion to give an idea of the helium tubes and amplifier/shapers location.

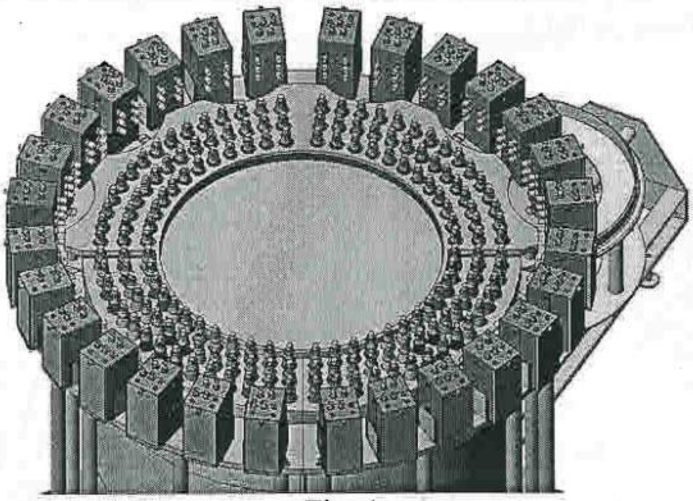


Fig. 4

In all, there are eight high-voltage SHV-connectors on the junction box body, six of them connected by cables with the group of six ^{3}He-tubes of the neutron detector and the remaining two provide working voltage supply to/from the adjacent counter groups. In addition to HV connectors there are two BNC-connectors on the body to supply working voltage to/from the amplifier/shaper board and two BNC-connectors to the signal line as well. An outline of the amplifier/shaper body is shown in Fig 5.

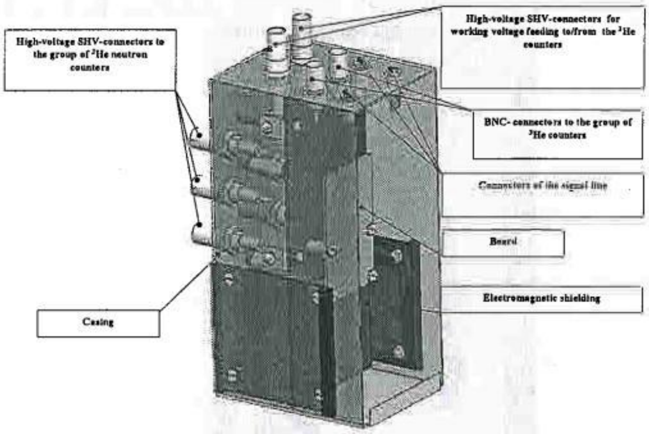


Fig. 5.

Each junction box is mechanically fastened to the upper graphite reflector casing and to the door flanges providing both free access to the connectors and visual control over the junction box operation through LEDs brought through the window in the casing. For tubes on the door openings, the junction boxes (the amplifier/shaper units) are fastened to the doors and move with them. Fig.6 presents a general appearance of the neutron multiplicity counter with the doors opened.

Fig. 6

A general view of the amplifier/shaper unit with removed cover is shown in Fig 7.

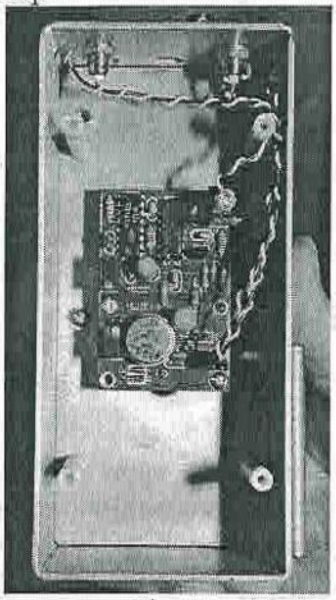


Fig. 7

To record pulses, an ORTEC AMSR-150 shift register will be used. As mentioned above, a controlled high-voltage power supply built into this device is employed to supply the neutron tubes and a built-in low-voltage power supply is used to supply the preamplifiers/shapers. In addition to the shift register, two ANTECH 1081 de-randomizers will be used to allow for the expected high-count rates,

To calibrate and test the system, a set of well-proven test samples is needed consisting of plutonium placed in specially modified AT-400R containers. The containers with these test samples have been modified to contain two circular grooves (see fig. 8). Because work with such containers implies full access to all of the measured data, when such modified containers are installed in the measurement cavity, the system automatically switches into the unclassified mode of operation.

Fig. 8

To recognize the container type (test/normal), six pairs of photoelectric sensors are used to identify the grooves associated with the modified control container. In addition to these tangentially located sensors in the neutron multiplicity counter body, two additional sensors are mounted to reveal the presence of a container of an appropriate diameter. Fig. 9 shows the sensors disposition within the detector body.

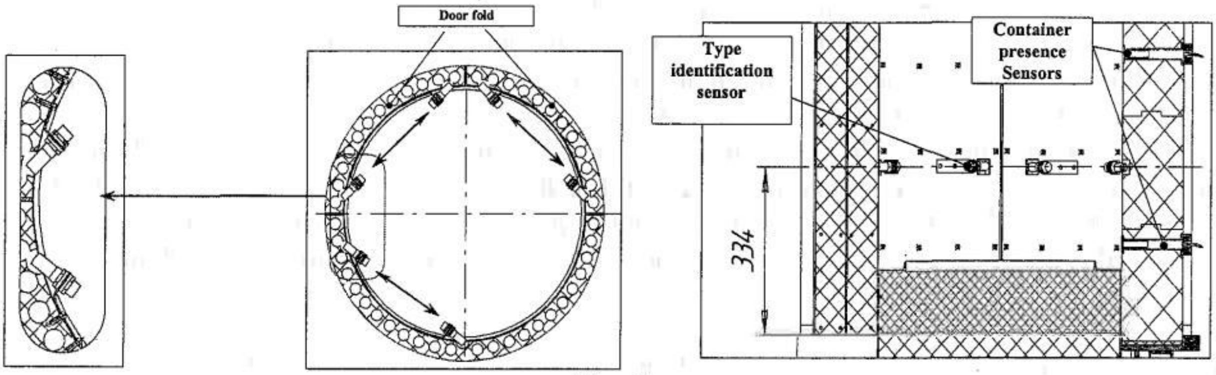


Fig. 9

THE SYSTEM CONTROL

The system's computer portion consists of two microcomputers. They are used for measurement and control. The measurement microcomputer performs the entire set of procedures for measurment device control, conducting measurements, data analysis, and decision assessment for attribute verification of fissile material within a controlled container. To prevent potential information release during measurements a scheme of interface communications using serial exchange lines between the measuring and control microcomputers is used. When measurements are being performed the lines of exchange between the control microcomputer are physically broken. This eliminates the potential for information transmission from the devices to the environment through the control microcomputer. After calculations have been completed and compared to predefined parameters, the data is deleted in the memory. The measuring microcomputer then engages a relay switch and initiates a data exchange with the control microcomputer.

The control microcomputer's function is to provide for a regular order of operations execution in the system, to accept commands from the control panel, and to display the operation results and system status codes. The control microcomputer's functions also include a set of procedures to impede unauthorized access to the system. To process gamma-spectrometry data the LLNL- PU-600 v.1.1 code has been adapted and is used. Information from the neutron multiplicity counter is processed with the use of an adapted INCC code provided by LANL.

SYSTEM LOCATION

The system will be located in a module providing electromagnetic shielding in the radio-frequency range up to 100 MHz. Overall dimensions of this module are 3700×2550×2200 mm. The box is divided by a screening barrier into detection and measuring compartments. The communications between these compartments are provided by a set of cables placed in shielded conduit. This module was incorporated into the system to fulfill two main functions:

- to provide protection against unauthorized access to the system;
- to provide an additional electromagnetic screen (information barrier).

In all, two levels of electromagnetic screening are envisioned in AVNG system. The external level is an isolated module and the inner level is a protected rack for the measuring/control electronics, cable communication barriers, and metal cases protecting the detectors and preamplifiers. The neutron multiplicity counter and the germanium detector are located in detector section of the isolated module. The protected cable channel provides the connection between module sections. Additionally, unauthorized access prevention sensors – infrared sensors – are situated in the detector section (as well as in the measuring section).For these sensors, an ADEMCO firm of 998 type passive sensor will be used. This sensor in regular operation mode has no "dead" space and provides overall control over the compartment space. The doors to the module are locking using electromagnetic door latches.

The isolation module is constructed with sliding doors in both sections. Both doors contain electromagnetic latches to exclude unauthorized entering inside the compartments and emergency disconnection of power supply. The doors are supported using metal frames (angle channel).

To provide cooling for the internal volume, suction-and-exhaust ventilators of SHROFF-HOFFMAN with electromagnetic shielding are built in each compartment. These do not reduce the electromagnetic shielding level to 300 MHz. In addition, inside the detection compartment of the isolation module a frame is provided to fix the detector unit frame. When the doors are opened the lighting in the compartments automatically switches on. A layout of the equipment in the isolation module is shown in fig. 11.

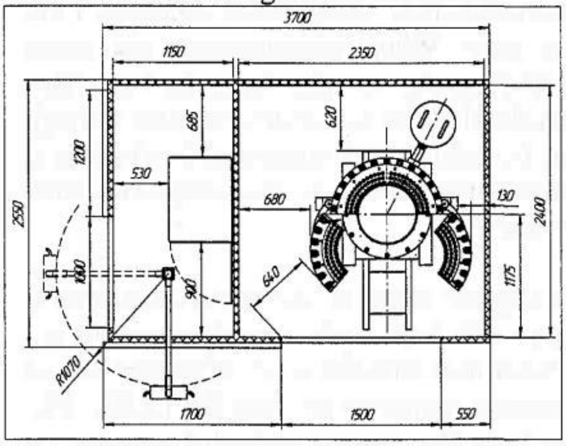


Fig. 10

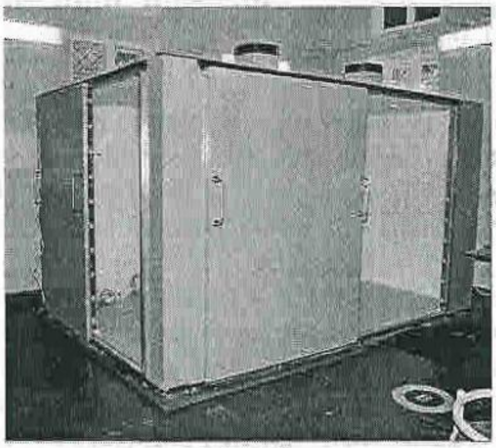


Fig. 11

CONCLUSION

The AVNG measurement system has been designed and now is being manufactured to provide an plutonium isotopic ratio threshold and mass threshold evaluation. The measurement system basic components are a neutron multiplicity counter and a gamma-ray spectrometric system. To date, the main units have been manufactured. Including, the isolation module to house the hardware, the neutron multiplicity counter casing, collimating system for the gamma-spectrometer, and the cases to hold the boards for the amplifier/shaper. With the use of two prototypes systems the majority of software has been debugged. Once LANL exports the measuring equipment, VNIIEF will finalize the system installation, begin testing and software debugging. The system certification will be performed using a set of unclassified test samples. A joint American-Russian test protocol is being planned.

The AVNG is created by scientists of the Russian Federal Nuclear Center - VNIIEF with the support of Los Alamos National Laboratory and with the assistance of Lawrence Livermore National Laboratory. The given project exemplifies how persevering joint efforts of experts of the two countries can overcome arising difficulties and reach the formulated object. It should be noted that the presented list of Russian authors does not include the names of all the project participants. We would therefore like to thank all the persons not named here, but who contributed to the system creation through their efforts.

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