Y-12

OAK RIDGE
Y-12
PLANT

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ACTIVE NEUTRON INTERROGATION FOR VERIFICATION OF STORAGE OF WEAPONS COMPONENTS AT THE OAK RIDGE Y-12 PLANT

J. T. Mihalczo
T. E. Valentine
J. K. Mattingly
J. A. Mullens
S. S. Hughes

Nuclear Materials Management and
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Oak Ridge National Laboratory
P.O.Box 2008
Oak Ridge, TN 37831-6004 USA
(423) 574-5577

A nuclear weapons identification system (NWIS), under development since 1984 at the Oak Ridge Y-12 Plant and presently in use there, uses active neutron interrogation with low-intensity ^{252}Cf sources in ionization chambers to provide a timed source of fission neutrons from the spontaneous fission of ^{252}Cf.[1] The particles from the source enter the weapon and/or component, and induce fission in the fissile material. One or more detectors on the opposite side of the weapon/ component detect the emitted radiation, which consists of three components: directly transmitted, scattered, and fission induced radiation. Data from the source ionization chamber and the two detectors are processed using conventional time and frequency analysis methods to yield a very robust signature consisting of 19 functions of frequency and time for a system consisting of a source and two detectors.[2] Some of these signatures are not sensitive to background radiation from nearby materials or sources. Until 1996, the extensive use of this method has been limited by cumbersome hardware (bulky, low sampling rates, low processing rate, long measurement times). The new prototype NWIS processor[2] has made improvements of greater than a factor of 1000 in size, sampling rate, processing rate, and measurements times over that available just 10 years ago. For some systems, measurements can be completed in less than one minute. Since late 1996, development of a laptop-based version of the processor was initiated.

Advantages of NWIS are (1) high sensitivity {small changes in configurations produce large changes in signatures}; (2) insensitivity of some signatures to background radiation, {useful for storage configurations or for tracking of secondaries through the first stage of dismantlement since the presence of the primary on the assembled system does not affect some signatures for the secondary}; (3) can be nonintrusive {does not reveal design information, which makes it useful for bilateral treaties or by the International Atomic Energy Agency (IAEA)}; and (4) very difficult to deceive. To date, measurements have been performed on ~15 different weapons systems in a variety of configurations both in and out of containers. Those systems included pits and fully assembled systems ready for deployment at the Pantex Plant in Amarillo, Texas, and weapons components at the Oak Ridge Y-12 Plant. These measurements have shown that NWIS can identify nuclear weapons and/or components; nuclear weapons/components can be distinguished from mockups where fissile material has been replaced by nonfissile material; omissions of small amounts (4%) of fissile material can be detected; changes in internal configurations can be determined; trainer parts can be identified as was demonstrated by verification of 512 containers with B33 components at the Y-12 Plant[4] (as many as 32 in one 8-hour shift); and nonfissile components can be identified.

The current NWIS activities at the Oak Ridge Y-12 Plant include: (1) further development of the system for more portablity and lower power consumption, (2) collection of reference signatures for all weapons components in containers, and (3) confirmation of a particular weapons component in storage and confirmation of receipts. This paper describes the recent measurements with NWIS for a particular weapons component in storage (Fig. 1) that have resolved an Inspector General (IG's) audit finding with regard to performance of confirmation of inventory.

The signatures for the unknown containers were compared to those for a reference container. Signatures were obtained with NWIS for the reference container in a variety of conditions. The reference container was opened (of course this can't be done in a bilateral inspection and other means of confirming the reference can be used) and the HEU content of the component verified by measurements with the source and detector adjacent to the component. Other measurements or MCNP-DSP[5,6] calculations of the measurement are used to determine the sensitivity of the signatures to the HEU content of the component. Measurements are then performed with the component in its storage container and again MCNP-DSP calculations are used to obtain the sensitivity of the signatures to the presence of HEU. This process is repeated for all types of storage containers. For the particular component measured here, it was stored in three containers: DT99, DT1, and DT103. Therefore, three sets of reference signatures were obtained. A step in this process is of course obtaining the statistical precision of the signature and deciding on a measurement time. Before comparisons can be made between unknowns and the reference signatures, the variation in the signatures about the reference must be established. These variations are: (1) statistical, (2) variations from source-detector locations, (3) variations in the components themselves, and (4) variations resulting from location of the component in the container and packaging. The source-detector placement variations were obtained from repeated measurements with the three reference components in their containers where the source and detectors are removed and relocated several times around the container and the variations measured. The composite of variations three and four are obtained by measurements with several containers and include rotation of containers. With these data, if all items match the reference, an average signature and its acceptable variation is established and used for all subsequent confirmations. To display the signatures without revealing design information, the signatures for the unknown components in containers were divided by those for the reference and the results subsequently displayed. Since there are such a large number of signatures (19 for 3 channels), pattern recognition algorithms need to be developed to automate the decision process.

The signature that was used for the resolution of the IG's finding was the cross power spectral density (CPSD12) between detector 2 and the Cf source ionization chamber 1. This signature is a measurements of the common information in both signals. This signature was chosen because, for frequencies >0 Hz it is not affected by the background.[7,8] This was verified by measurements with the reference container located in a variety of storage configurations: (1) single container on pallet on concrete floor, (2) container on pallet with three other containers, (3) container on pallet of four with one and two full pallets above it, (4) container on pallet of four with one and two pallets below, and (5) container on pallet of four with one pallet above and one pallet below. Configuration 5 is shown in Fig. 2. All CPSD12 values as a function of frequency up to 100 MHz were within the acceptable band of signatures thus confirming the fact that the CPSD12 does not depend on background.

Now that the reference signatures have been established and an acceptable variation in the signatures has been defined from measurements, the confirmation process proceeded. The confirmations had to be performed without moving any of the containers in the storage array (Fig. 1) in which the containers were stacked four to a pallet, up to three pallets high. The confirmatory measurements proceeded by placing the source on one side of the container and the detectors on the other side 180° from the source for which the reference signatures were acquired. Typical results for this weapons component in the three types of containers used for storage are shown in Fig. 3 where the CPSD12 (the primary signature for confirmation) for a particular container divided by that of the reference set is plotted (solid line) as a function of frequency up to 100 MHz. The solid lines which are the ratios for the particular three containers shown are within the acceptable variation (shaded band) of the reference signatures of the component in each type of container. This type of comparison for each unknown container was used to identify the components.

The fact that some of the signatures from NWIS are not sensitive to changes in background radiation makes NWIS very useful for storage configurations. These confirmations have shown that NWIS is practical for use in large storage arrays and has resolved an Inspector General's audit finding with regard to confirmation of items in storage arrays at the Oak Ridge Y-12 Plant. Further development of NWIS for increased portability and lower power consumption will make it more useful for these applications.

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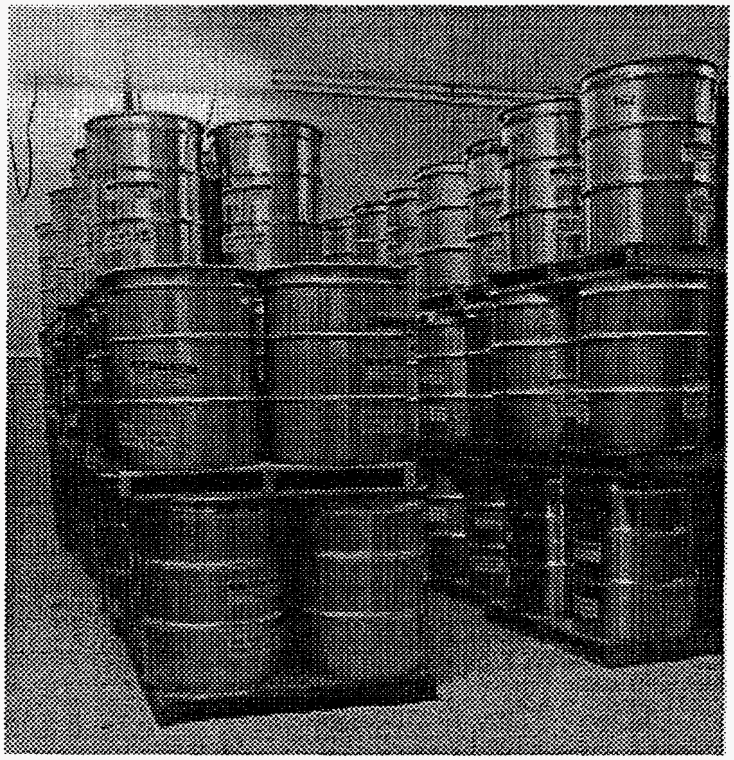

Fig. 1. Storage Array

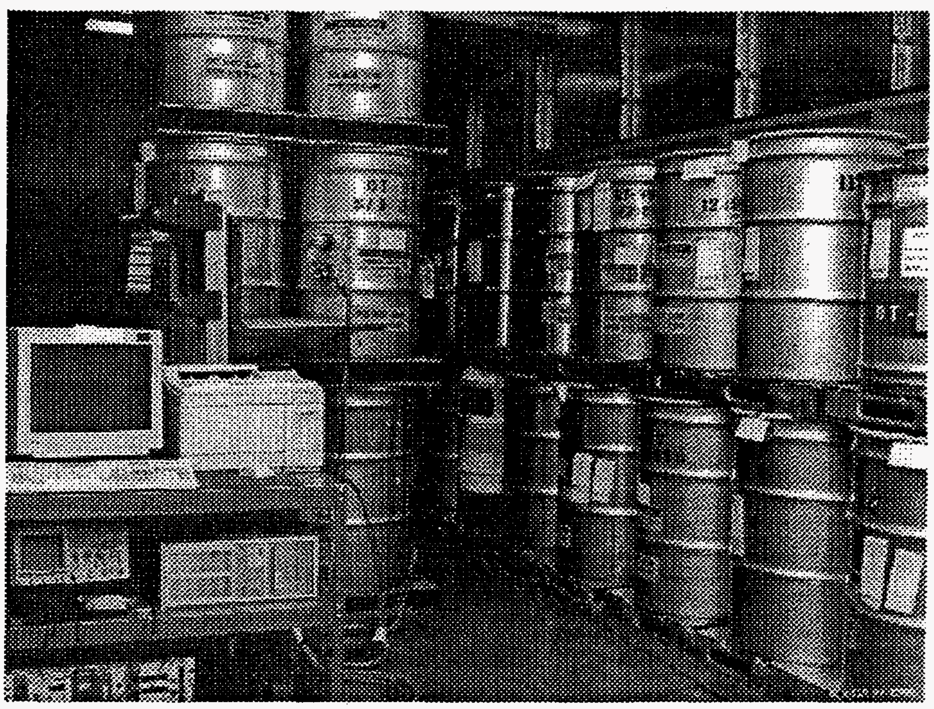

Fig. 2. Configuration of NWIS in Use at Y-12 Storage Facility

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