RECENT IMAGING MEASUREMENTS WITH NMIS AT ORNL

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INTRODUCTION

This brief report summarizes the status of imaging with the Nuclear Materials Identification System (NMIS) at ORNL. The imaging is based on time of flight transmission measurements with a time tagged source of radiation and a simple array of detectors. The conclusion from this work is that imaging can enhance nuclear material control and accountability (NMC&A) by providing the detailed configuration of the fissile and non fissile materials of an item undergoing non destructive assay.

RESULTS

The following photograph shows the set up of the DT generator with an alpha particle detector in a laboratory at ORNL with the set of eight 1x1x6-in.-thick plastic scintillators for imaging measurements. The DT generator is spaced ~ 90 cm from the detectors. The object to be imaged is between the DT generator and the array of plastic scintillation detectors. From the inside out the object consists of a 1-in.-diameter polyethylene rod, air, a 2 3/8 -in.-diam. steel pipe with a wall thickness of ~0.16 in., air, another steel pipe with diameter of 4 ¾ in and wall thickness of ~0.27 in., polyethylene beads with density of 0.57

Figure 1. Photograph of the DT generator, array of detectors, and object to be imaged between the DT generator and the detector array.

g/cc, and a standard 7 3/8-in-diam. polyethylene bottle with the top cut off.

Figure 2 is a photograph of this same object in an AT 400 container. The photograph was taken looking down into the container. In this case, a measurement was also performed with the container empty to remove the effects of the container. The source and detectors were located at the vertical centerline of the object. In the measurements the detectors were moved 1 and 2 in. along an arc with respect to the position of the DT source. This resulted in data from 24 transmission measurements at one elevation to be used in reconstruction of the image.

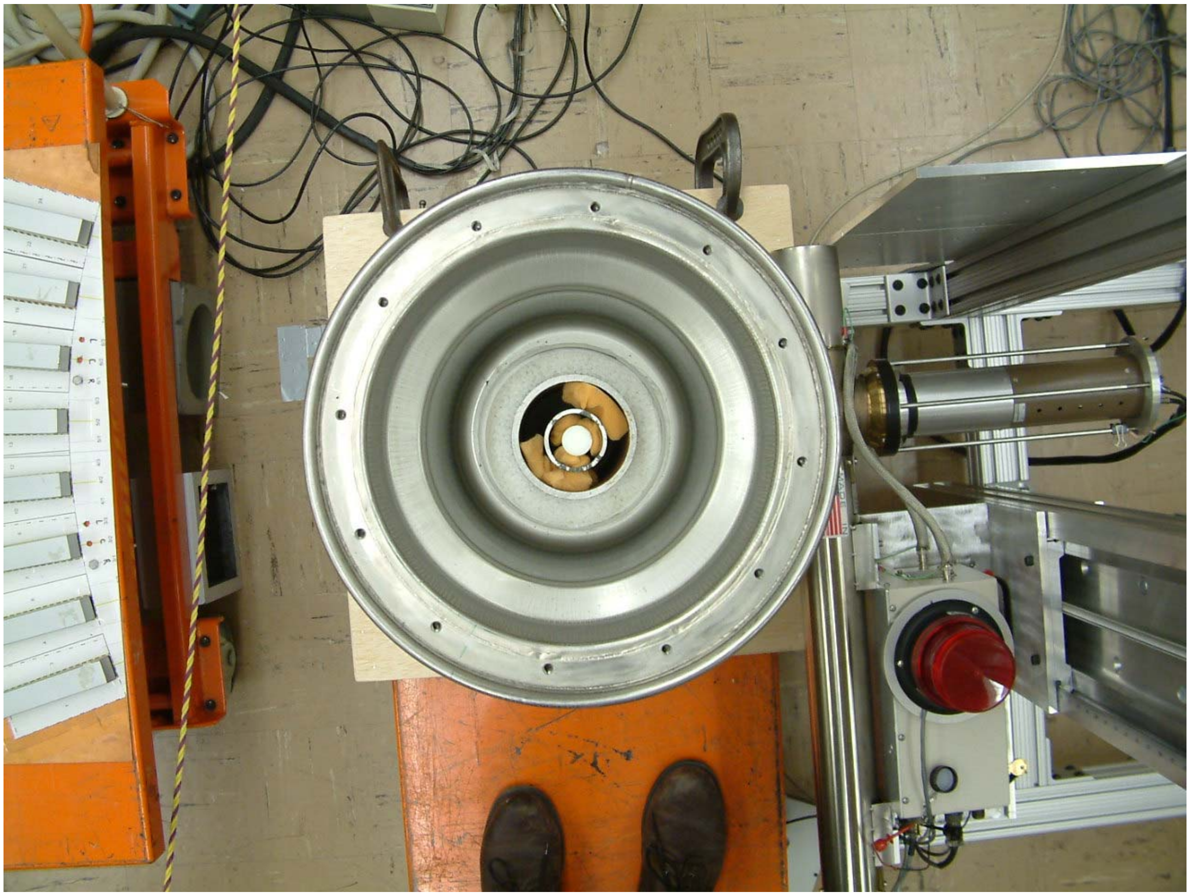

Figure 2. Object to be imaged in an AT 400 container between the DT source on the right and the array of detectors on the left.

Figure 3 shows a sketch of the cross section of the actual object and the object reconstructed from the data from the imaging measurements. The cylindrical symmetry of the object simplifies the measurement in that the object need not be rotated and the measurements could be performed at one elevation only. It is clear from sketch that the full detail of the object is obtained from the data and perhaps the thicknesses of the different materials could also be obtained. The analyses model varies the thickness and the attenuation coefficients to best fit the data.

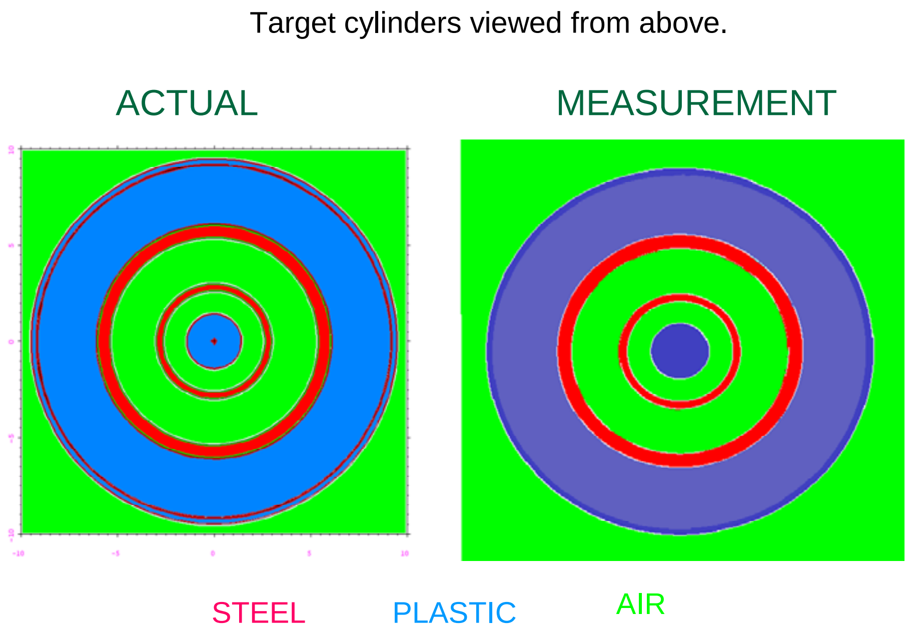

Figure 3 Object: Actual and Reconstructed Using Parametric Reconstruction

The next photograph (Figure 4) is the two steel pipes and poly rod removed from the object and placed on a rotating table. When this section was removed by hand, maintaining the concentricity was attempted but obviously failed (see photo) and the iron pipes are not concentric.

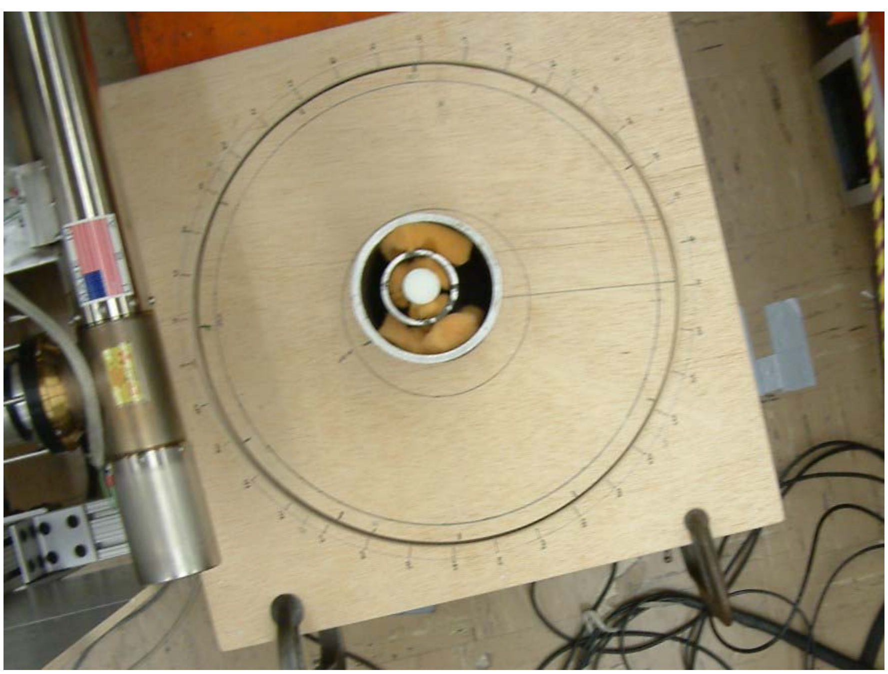

Figure 4 Central steel pipes and polyethylene removed from the object and located on a rotating table.

The next sketch (Figure 5.) is the previous photo with the center section consisting of the polyethylene rod and steel pipes extracted from the object. The imaging measurements were interpreted in two ways: 1) with the source modeled as a point (lower sketch) and 2) as the actual spot size of 11 mm of the target (upper sketch). Modeling which included the actual target spot size produced the better image. Note that the reconstructed image with the actual spot size of the target showed the pipes were not concentric. The photo of the target in the Fig.5 was rotated to correspond properly with the reconstructed images.

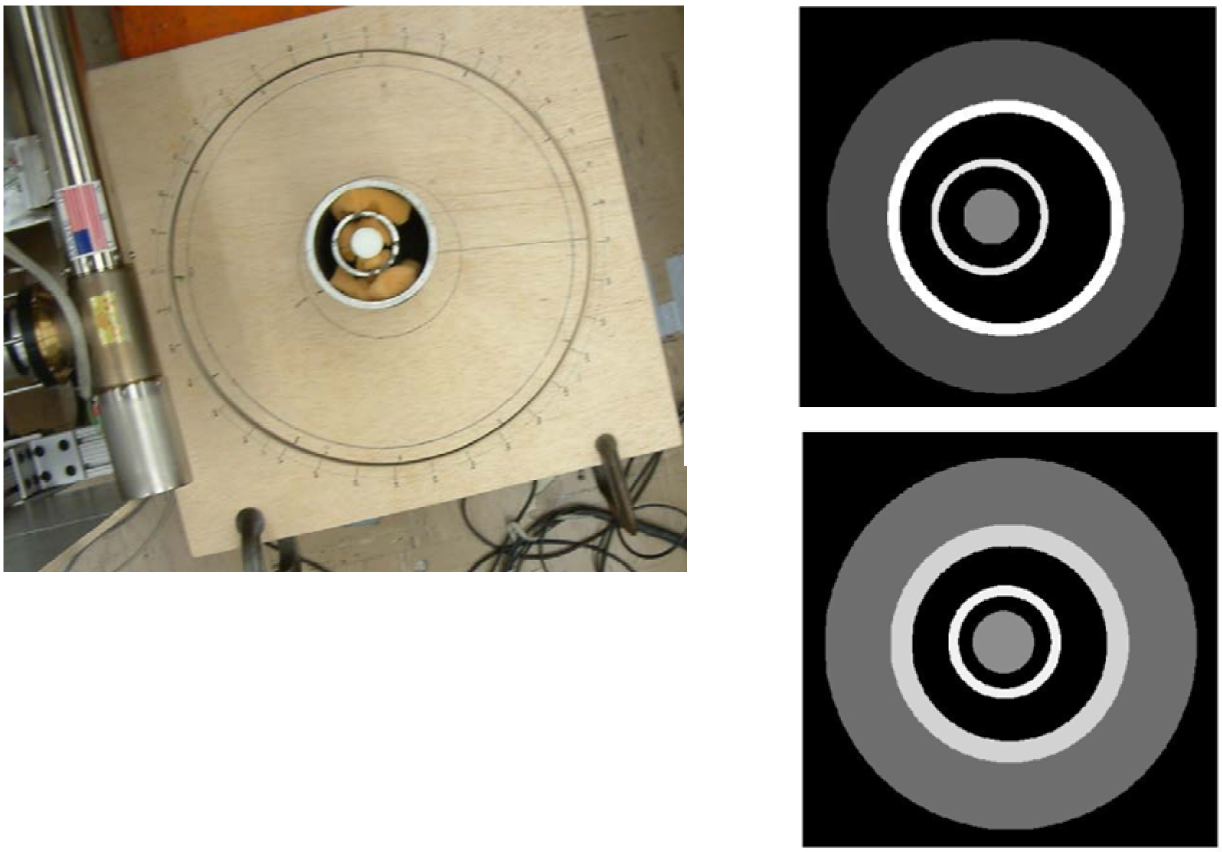

Figure 5 Comparison of the removed central section's image from the data with 2 assumptions about the target spot size: a point (lower sketch) and the actual 11 mm diameter circular area (upper sketch)

MEASUREMENT TIME

The measurement time was less than 3 minutes for each radial position for the measurement in the container and ~ 1 minute for the steel and polyethylene out of the container. The total time for the 3 radial positions is then ~9 and 3 minutes. Of course, this is for a single elevation. Thus, more complicated objects requiring more elevations would require more time. This depends on the distance between the source and detectors (which for these measurements it was 90 cm), detection efficiency, the source intensity, and the attenuation. The source intensity was ~ 2 E+7 n/s. Both too much and too little attenuation increases the measurement time. For these measurements the detection efficiency for neutrons hitting the front face (1x1-in.-square) was ~ 70% per incident 2 Mev neutron.

AUTOMATED SCANNING

A scanner for cylindrical drums has been constructed that moves the detectors automatically along an arc of 15 degrees and moves the source (DT or Cf) and detectors vertically. A sketch of the drum scanner looking down from the top is given in Figure 6. The photograph shows the amplifier for the Cf source on the left and the detectors on the right with some lead between them. This scanner had three options for the radius of the arc from the source depending on the size of the container. An additional part of this scanner not yet fabricated is an apparatus for rotating the object for measurements on three dimensional objects. A photograph of the scanner as it now exists at ORNL is given in Figure 7. The base and vertical support is welded steel. Future drum scanners will be bolted together for ease of shipment and assembly. Obviously, for smaller object such as HEU storage cans, smaller scanners could be designed.

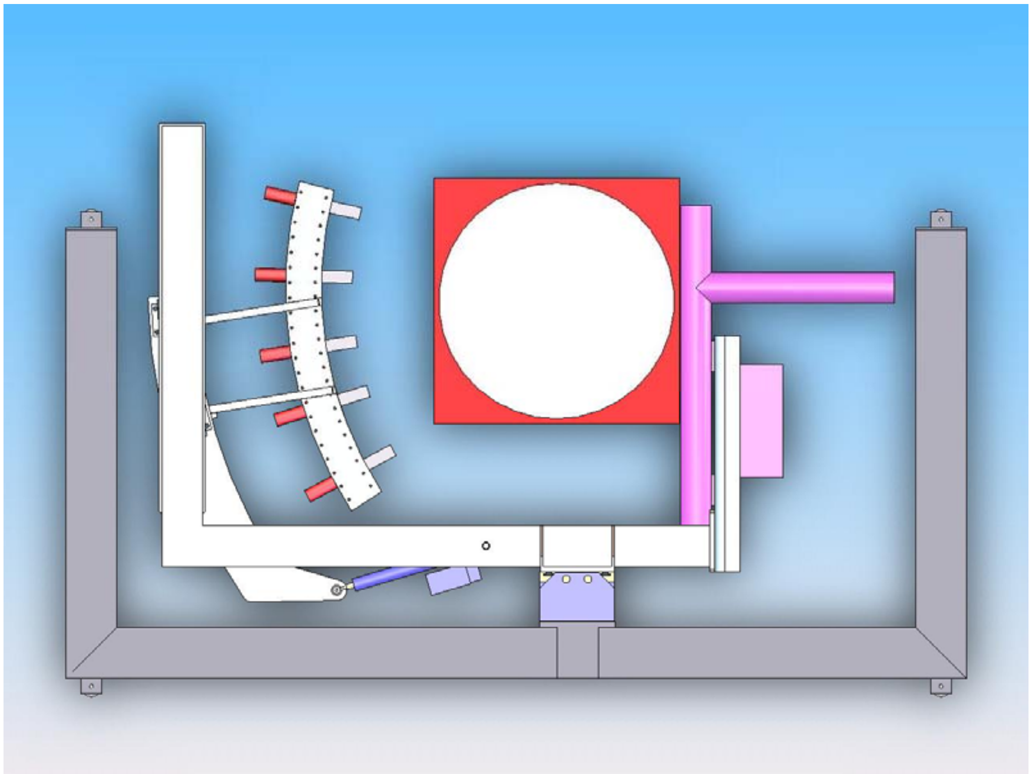

Figure 6 Sketch of the drum scanner with a DT generator

Figure 7 Photograph of the drum scanner as it now exists with detector array installed

CHOICE OF INTERROGATING SOURCE

NMIS imaging measurements have been also been performed with a Cf source. Both a DT generator with an alpha detector and a time tagged Cf source can be used for imaging. Choice is based on convenience and measurement time considerations. The Cf source provides both a neutron and gamma ray image. The gamma ray image preferentially shows high density materials and the neutron transmission preferentially shows the lower density materials. Combined they show the total image. The DT generator from the above data shows both types of materials.

CONCLUSIONS

The imaging capability of NMIS can enhance nuclear material control and accountability by providing the detailed configuration of the fissile and non fissile components of an item under interrogation. Since this imaging is based on transmission, a limitation is that imaging will not distinguish HEU from depleted uranium but other features of NMIS signatures can differentiate between them.