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^{252}CF-SOURCE-DRIVEN NOISE ANALYSIS MEASUREMENTS WITH ANNULAR HIGH ENRICHED URANIUM METAL CASTINGS

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^{252}Cf-Source-Driven Noise Analysis Measurements with Annular High Enriched Uranium Metal Castings

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This summary describes measurements performed on four annular uranium metal castings of different enrichments to investigate the use of ^{252}Cf-source-driven noise analysis measurements[1] as a means to quantify the amount of special nuclear material (SNM) in the casting. Previous measurements[2] and calculational studies[3] have shown that many of the signatures obtained from the source-driven measurement are sensitive to fissile mass. Measurements were performed to assess the applicability of this method to standard annular uranium metal castings at the Oak Ridge Y-12 plant under verification by the International Atomic Energy Agency (IAEA) using the Nuclear Weapons Identification System (NWIS) processor[4]. The sensitivity of the measured parameters to fissile mass was investigated using four castings each with a different enrichment. Preliminary results are presented that demonstrate the sensitivity of the measured parameter to fissile mass. However, these preliminary results do not represent an optimized measurement configuration but are intended to demonstrate possible applications of this method.

The measurements were performed with standard annular uranium metal castings of four different enrichments (80.09 wt% ^{235}U, 84.97 wt% ^{235}U, 90.03 wt% ^{235}U, and 93.15 wt% ^{235}U). All of the annular castings were geometrically the same having an 8.89-cm ID and a 12.7-cm OD. All castings were contained in stainless steel cans that had 15.6-cm OD and were 22.4 cm tall with a 0.15-cm wall thickness as shown in Fig. 4.2. The density of the 93.15 wt% ^{235}U enriched casting is 18.76 g/cm^3, and the density of the other castings will be slightly more due to the increased amount of ^{238}U in the casting. These castings are comprised almost entirely of uranium but do have a small amount of impurities such as oxygen, nitrogen, carbon, and silicon. Each of these castings contains about the same amount of impurities. The enrichment was essentially the only parameter that was changed from one casting to another. The annular castings were placed inside a 7.62-cm thick polyethylene reflector with the source on one side of the casting and four detectors located on the opposite side as shown in Fig. 1. A solid 7.62-cm thick polyethylene reflector was placed on the top and the bottom of the U-shaped polyethylene reflector.

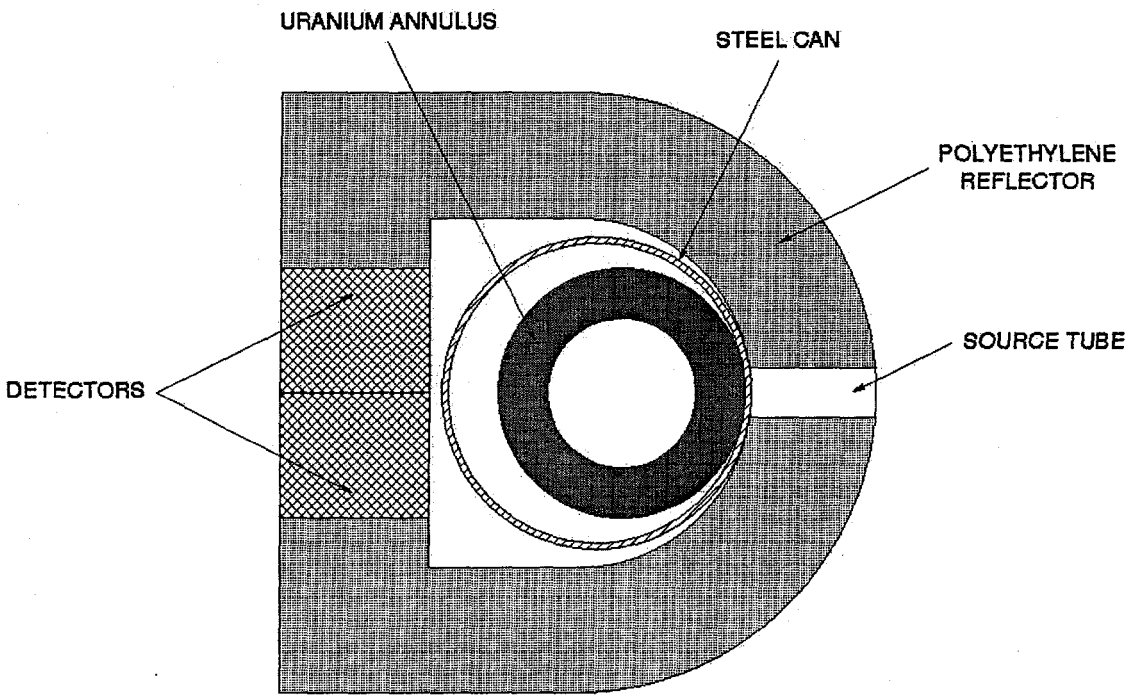

Figure 1 Sketch of top view of the measurement configuration with annular casting.

The source was located 7.62 cm from the bottom of the casting and was in contact with the casting container. The ^{252}Cf source had a mass of ~0.7 μg and more than 99% of the source spontaneous fission events were counted. The four detectors used in these measurements were fast plastic scintillators that are sensitive to both gamma rays and neutrons and were positioned in a 2x2 array. Detectors *#4* and *#5* were positioned above detectors *#2* and *#3* respectively. These detectors are 7.62-cm wide and tall and 10.16-cm thick and had a 0.635-cm thick lead shield on the sides with no shielding on the front face of the detectors. The thresholds for these detectors were set such that only gamma rays above 320 keV energy and neutrons above 1.5 MeV would be detected. Additional measurements were performed with the casting removed from the moderator to obtain a reference measurement for the neutron time of flight.

In the measurements, both auto and cross correlation functions are generated from the measured time responses. The detector auto correlation functions should be sensitive to fissile mass. The detector auto-correlation functions were integrated over time to obtain the total correlated counts for the detectors and are presented in Table 1 along with the sensitivity coefficient for the integrals. The integral of the total correlated counts increases as fissile mass increases. The integral of the auto correlation functions increases approximately 13% from 13.97 to 16.43 kg of ^{235}U.

Table 1 Integral of Detector Auto Correlation Functions and Sensitivity Coefficients For Annular Uranium Metal Castings				
^{235}U Mass (kg)	R_{22}	R_{33}	R_{44}	R_{55}
13.97	8.25E-02	8.36E-02	7.68E-02	7.64E-02
14.83	8.70E-02	8.43E-02	8.09E-02	7.67E-02
15.90	9.17E-02	9.41E-02	8.47E-02	8.52E-02
16.43	9.59E-02	9.72E-02	8.83E-02	8.78E-02
Sensitivity Coefficient	0.0580	0.0665	0.0538	0.0613

The source-detector cross correlation function is also sensitive to fissile mass. The directly transmitted gamma rays are not very sensitive to the fissile mass because gamma ray attenuation is predominately due to atomic rather than nuclear interactions and should not be sensitive to the enrichment. On the other hand the predominantly neutron peak is sensitive to the amount of fissile material. The source-detector correlation values increase as fissile mass increases. The integrals of the source-detector correlation functions over time are given in Table 2. The integral of the source-detector correlation function changes approximately 12% from 13.97 to 16.43 kg of ^{235}U.

Table 2 Integral of Source-Detector Correlation Functions and Sensitivity Coefficients for Annular Uranium Metal Castings				
^{235}U Mass (kg)	R_{12}	R_{13}	R_{14}	R_{15}
13.97	1.57E-02	1.58E-02	1.42E-02	1.42E-02
14.83	1.60E-02	1.53E-02	1.43E-02	1.34E-02
15.90	1.72E-02	1.77E-02	1.56E-02	1.57E-02
16.43	1.79E-02	1.80E-02	1.61E-02	1.60E-02
Sensitivity Coefficient	0.0549	0.0658	0.0555	0.0629

The detector-detector correlation functions are also sensitive to fissile mass. The detector-detector correlation function values increase as fissile mass increases due to the increase in fission in the system as fissile mass increases. The detector-detector correlation functions were integrated over time and the results are presented in Table 3. The integral of the detector-detector cross correlation function increases approximately 25% to 27% as the ^{235}U mass increases from 13.97 to 16.43 kg. The sensitivity coefficient for the integral of the detector-detector correlation function as a function of mass is approximately 0.13 which is twice as large as the sensitivity for the detector auto correlation and the source-detector correlation.

Table 6.3 Integral of Detector-Detector Cross Correlation Functions and Sensitivity Coefficients for Annular Uranium Metal Castings						
^{235}U Mass (kg)	R_{23}	R_{24}	R_{25}	R_{34}	R_{35}	R_{45}
13.97	3.11E-03	2.94E-03	2.18E-03	2.21E-03	2.95E-03	2.64E-03
14.83	3.37E-03	3.36E-03	2.36E-03	2.39E-03	3.05E-03	2.88E-03
15.90	3.97E-03	3.64E-03	2.80E-03	2.83E-03	3.79E-03	3.30E-03
16.43	4.28E-03	3.96E-03	3.01E-03	3.06E-03	3.98E-03	3.53E-03
Sensitivity Coefficient	0.132	0.113	0.134	0.135	0.133	0.118

These measurements have demonstrated the sensitivity of several of the measured parameters obtained from the source-driven noise analysis measurement. This measurement method can be used to quantify the amount of fissile material for uranium components. The detector auto correlation functions, the source-detector cross correlation functions, and the detector-detector cross correlation functions can be related directly to fissile mass. The detector-detector cross correlation functions are a factor of two more sensitive to fissile mass than the detector auto spectra or the source-detector cross spectra. These measurements were with a very limited number of reference components and additional measurements are required. Additional measurements can be used to obtain calibration curves and to optimize the measurement configuration for highest sensitivity.

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