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Title: Benchmarking Data for the Proposed Signature of Used Fuel Casks

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Benchmarking Data for the Proposed Signature of Used Fuel Casks

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INTRODUCTION

A set of benchmarking measurements to test facets of the proposed extended storage signature was conducted on May 17, 2016.

SET UP

The measurements were designed to test the overall concept of how the proposed signature can be used to identify a used fuel cask based only on the distribution of neutron sources within the cask. To simulate the distribution, 4 Cf-252 sources were chosen and arranged on a 3x3 grid in 3 different patterns and raw neutron totals counts were taken at 6 locations around the grid. This is a very simplified test of the typical geometry studied previously in simulation with simulated used nuclear fuel.

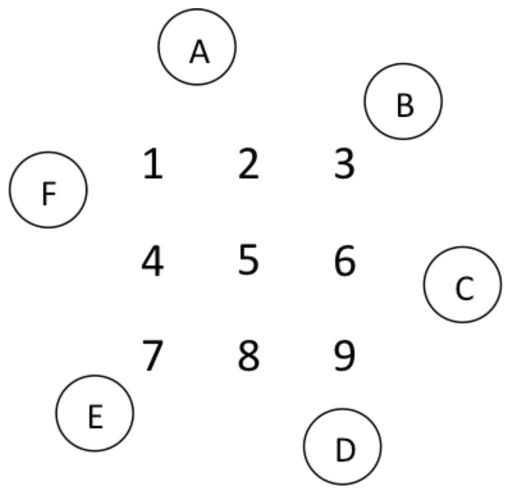

Figure 1: Testing layout

Figure 1 shows a not to scale layout used for testing. The numbered positions are the possible source locations and the lettered circles represent where the detector locations should be. During the testing, the 3x3 grid had a 4" pitch, while the detector location were placed on a 9" radius circle that was centered on source position #5.

The detectors used were 16" active length, 4 atm He-3 tubes made by Reuter Stokes. These were connected to PDT20A-HN amplifiers and controlled by an HH-MR system. According to the manufacturer provided data sheets, the high voltage plateau range ran from 1680-1750V, and the voltage was set at 1699V and reported as such by the HH-MR. The gate was set to 6.4 μs with a predelay of 0.04 μs and a total count time of 299 seconds. During testing, the tubes were laid flat on the table with the midpoint of the active length at the specified point for that tube. The tubes were set to be perpendicular to the radius of the circle they were placed on.

The four Cf-252 sources were selected due to their representation of different source strengths. Cf-252 is a good substitute for the energy spectrum of used nuclear fuel neutrons as well.

Table 1: Sources used and their neutron emission rate

Source Name	Neutron Emission Rate (n/s)
CF-5	3.09E+03
CF-6	6.21E+03
M7-622	4.07E+03
M7-624	1.39E+04

Table 1 provides all of the information on the sources used for testing. The sources were chosen to be close in activity, but not exactly the same. A range of source strengths is needed to accurately mimic the differences in neutron production between used fuel assemblies.

DATA ACQUISITION

The HH-MR can only read 3 detectors at one time, so each pattern had to be measured twice, moving the tubes between measurements to their alternate positions. Initially, 2 measurements with all of the sources in one position only were conducted. The sources were arranged in a north-south, east-west position when looking at Figure 1, where north was at the top of the figure. Cf-6 was placed just north of the source position, with CF-5 just south, M7-622 to the east and M7-624 to the west. The two measurements were made at source position 5 and 3 with the same arrangement of sources at both locations.

Table 2: Results from preliminary measurements

Measurement #1			Measurement #2		
Sources surrounding pos 5, Cf-5 North, CF-6 South, 622 East, 624 West			Sources surrounding pos 3, Cf-5 North, Cf-6 South, 622 East, 624 West		
Det:	Counts:	stdev	Det:	Counts	stdev
A	8298	91.09	A	7583	87.08
B	7900	88.88	B	26357	162.35
C	6885	82.98	C	8568	92.56
D	7591	87.13	D	5134	71.65
E	7431	86.20	E	4130	64.27
F	7740	87.98	F	4436	66.60

Table 2 shows the results of the two preliminary measurements made with sources. As it should be expected, the counts from measurement#1 were very similar to each other, which should be the case if the source is equidistant from each detector. When the source is moved closer to the edge, there is a significant spike in counts near that location with a corresponding drop in the detectors furthest away. These

2 measurements were meant to test the method of data acquisition and the equipment.

TESTING THE SIGNATURE

To test the signature, 3 arrangements of the sources were formulated.

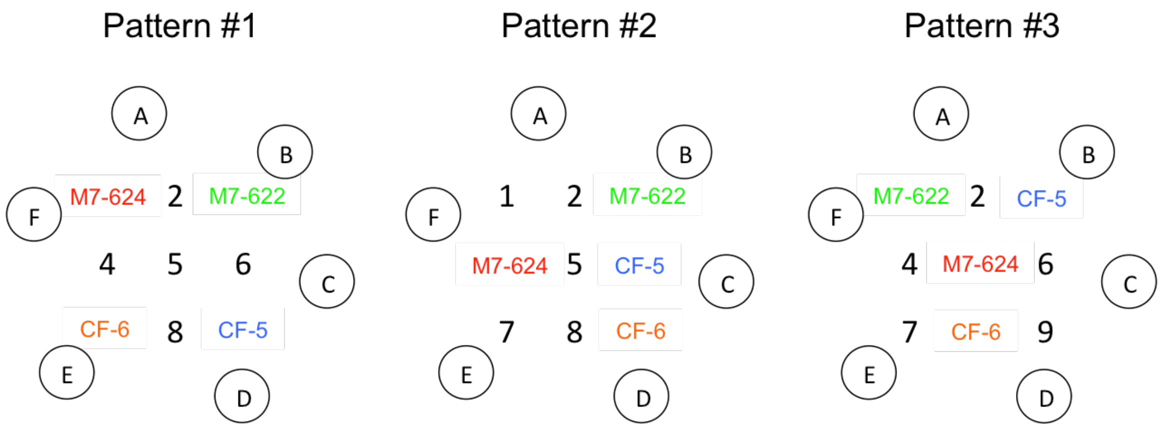

Figure 2: Source positions during testing

Each pattern was measured 3 times for 299 seconds each. The color coding in Figure 2 indicates the relative strength of the source, with blue being the weakest and red being the strongest.

Table 3: Results from the 3 patterns of source positions

	Pattern 1		Pattern 2		Pattern 3	
	Average	stdev	Average	stdev	Average	stdev
A	14761	258	6877	159	9440	237
B	9052	42	7995	44	5735	192
C	4120	64	4440	40	5159	53
D	3411	30	4081	27	4759	55
E	4786	139	7777	54	5796	232
F	10870	43	10125	76	8090	134

The patterns were chosen semi-randomly during testing, and are meant to induce different fluctuations between the detectors in neutron counts. With each pattern, there are spikes that correspond to the locations of the stronger sources.

DRAWING PARALLELS

While the results from these tests show what was expected behavior from point sources, how does it help inform the proposed method for identifying casks through this signature? Essentially, these tests show that a distribution of differing source strengths produces a varying amount of neutrons that can be measured at a boundary near the source locations. The counts change as the distribution of sources and their strengths is changed. This would be akin to moving used fuel assemblies around the cask.

Two of the sources were encased in polyethylene, which provided some moderation to those sources, however extra moderation was not available during testing. Shielding materials also were not used as the source strengths were relatively weak. However, the proposed signature has already been shown to be immune to the amount of shielding and moderation present in cask designs. The shielding in casks is almost entirely limited to the fuel basket, with a few designs incorporating a thin shield on the exterior. Because the shielding is uniform and because the shielding is never enough to stop all neutron leakage from the cask, there is always a signature that can be found. Moderation is similarly lacking in the design, and most moderation in casks comes in the form of concrete. There is not enough moderation to muddle the signature enough to be unusable in all casks simulated so far.

CONCLUSIONS

The tests performed during this effort and recorded here indicate that a distribution of sources in a pattern like that found in a used fuel cask will generate a varying signature around the circumference of that pattern. When the arrangement of sources changes, the signature will also change in a predictable manner.