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OAK RIDGE
Y-12
PLANT

Report No.: Y/LB-16,061

PLUTONIUM TEST PLAN
ORNL-VNIIEF COLLABORATION

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Storage Program Office

June 6, 2000

MANAGED BY
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SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Prepared by the
Oak Ridge Y-12 Plant
Oak Ridge, Tennessee 37831
managed by
Lockheed Martin Energy Systems, Inc.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

1 Test Objective

The goal of this test is to collect the cross correlation and HOS signatures from four detectors, arranged in a tetrahedron about different plutonium objects during the ORNL/VNIIEF collaborative measurements in Sarov, Russia. The four detectors will be arranged in a tetrahedron as shown in Figure 1. (The plutonium object is not shown for clarity but would be in the center of the tetrahedron.) The following constraints about the detector geometry should be adhered to

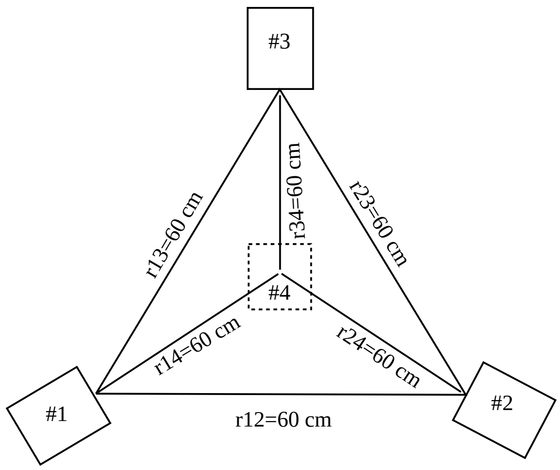

Figure 1: Top View of 4 Detectors in a Tetrahedron

if possible.

- the base of the tetrahedron (detectors #1, #2, and #3) should have 3 identical detectors (preferably 4 in. x 4 in., plastic scintillators) placed in an equilateral triangle,
- the length of one side of the base should 60 cm ($R_{12} = R_{23} = R_{13} = 60\ cm$)
- the ideal height of the fourth detector above the base is $\sqrt{2/3}$ of the side of the equilateral triangle ($height = \sqrt{2/3}\ (60\ cm) = 49\ cm$), and finally,
- any *mismatched* detector should be placed at the apex of the tetrahedron (i.e. top position).

The collected signatures will be processed later. In order to perform the post processing, the peak efficiencies and neutron thresholds for each detector must be obtained by performing a standard Time-of-Flight measurement. Secondly, the response matrix data must be benchmarked for each detector/object configuration. This benchmark is determined by collecting the NMIS signatures in active mode for a californium source at two different points inside the tetrahedral volume of detectors.

2 Test Matrix

The test matrix shown in Table 1 summarizes the series of measurements that need to be performed, assuming that the four detectors are arranged in a regular tetrahedron with sides of 60 cm. Runs 2 and 3 need only be performed once per geometrical configuration. Run 1 should only be performed once per day or if detector drift is suspected.

Table 1: Test Matrix for Regular Tetrahedron, $side = 60\ cm$

Run	Configuration	Mode	Blocks	Parameters to Record
1	Time-of-Flight	Active, HOS	10×10^8	peak eff., thresholds
2	Point Source #1	Active, HOS	200×10^8	voxel location
3	Point Source #2	Active, HOS	200×10^8	voxel location
4	Pu Shell #1 [a]	Passive, HOS	1000×10^8	detector geometry
5	Pu Shell #2 [b]	Passive, HOS	1000×10^8	detector geometry

[a] $R_i = 1.0, R_o = 4.02$ cm, see *Preliminary Draft, Typical Measurements Sequence for Joint ORNL-VNIIEF Collaboration*

[b] $R_i = 5.35, R_o = 6.00$ cm, see *Preliminary Draft,Typical Measurements Sequence for Joint ORNL-VNIIEF Collaboration*

The objects in Runs 4 & 5 were selected because they exhibit the largest relative difference in size yet have nearly identical masses.

2.1 Time-of-Flight

The setup for the time-of-flight run is shown in Figure 2. This is the standard setup and all detector efficiencies should be within 2 % of each other. If this configuration is not convenient, then place the source at Voxel Location (1,1,1) and use the setup as described in Section 2.2.

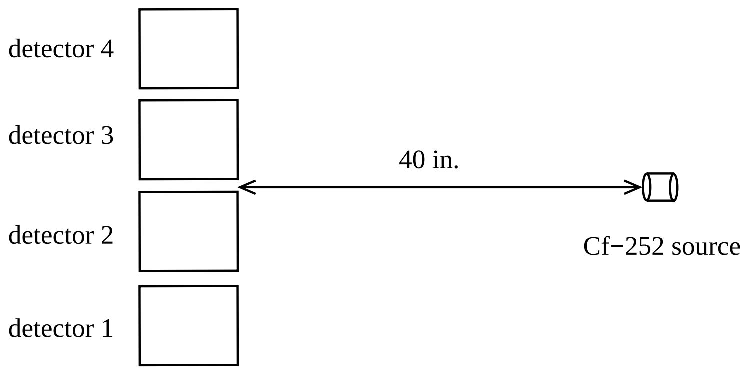

Figure 2: Time-of-Flight Setup

2.2 Point Source Calibrations (Runs 2-3)

Place the ^{252}Cf source at the two voxel locations whose coordinates are given in Table 2 and collect the NMIS signatures using active mode. All X, Y, and Z coordinates are referenced to the center of the front face of detector #1 (X=0,Y=0,Z=0). Detectors #1 through #3 lie in the X-Y plane and Detector #4 is located above the X-Y plane, in the positive Z-direction as shown in Figure 3.

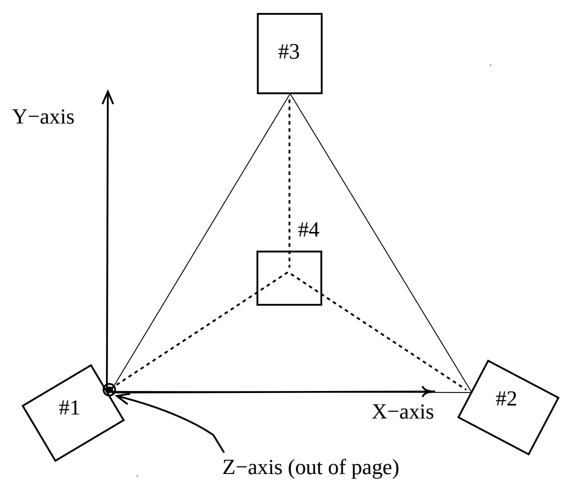

Figure 3: X-Y-Z Coordinate System

The parameters R_1, R_2, R_3, and R_4 indicate the distances from the voxel to the center of the front face of their respective detector. (R_1 is the distance from the voxel to Detector #1.)

Table 2: Voxel Coordinates

Voxel Location (i,j,k)	X (cm)	Y (cm)	Z (cm)	R_1 (cm)	R_2 (cm)	R_3 (cm)	R_4 (cm)
(1,1,1)	30.0	17.3	12.3	36.7	36.7	36.7	36.7
(0,1,0)	7.5	13.0	0.0	15.0	54.1	45.0	54.1

For Voxel (1,1,1), the source is positioned in the geometric center of the tetrahedral configuration of detectors such that the radial distance from the source to each detector is equal as shown in Figure 4. Note that the LOS (line-of-sight) vectors shown in the drawing run from the center of the source to the center of the front faces of each detector. Detector 4 is above the

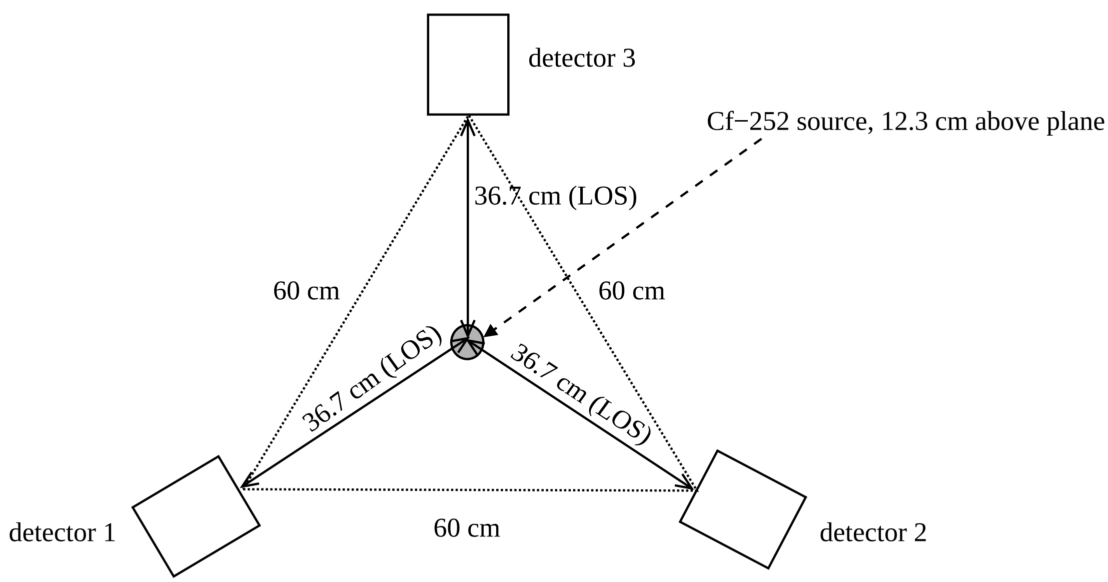

Figure 4: Top view of ^{252}Cf Source and Detectors, (Det #4 not shown)

source and is not shown for clarity.

Figure 5 shows a side view of this source/detector configuration. Note that the source height is 1/4 of the height of the tetrahedron. Record all the detector-to-detector ranges and the source-to-detector ranges.

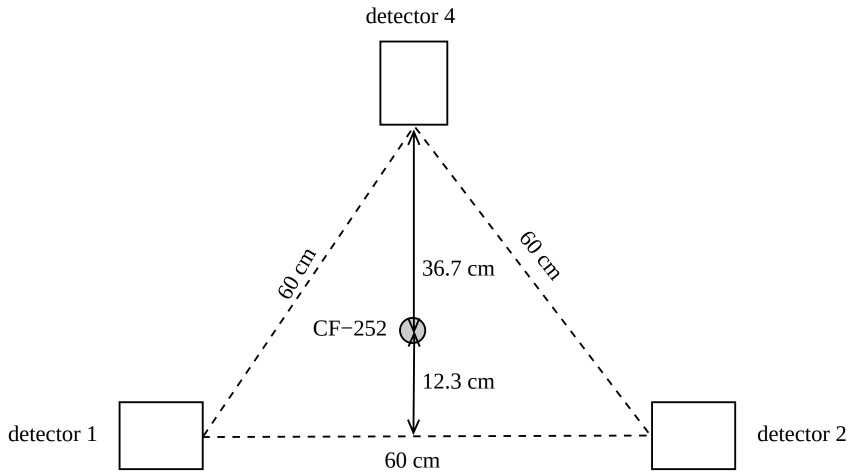

Figure 5: Side view of ^{252}Cf Source and Detectors

For Voxel (0,1,0) the source is placed in the interior of the tetrahedron at the coordinates indicated in Table 2. (Note that since Z=0, the source is in the same plane as the base of the tetrahedron.) Record all the detector-to-detector ranges and the source-to-detector ranges.

2.3 Plutonium Shells (Runs 4 & 5)

Both of these tests use the recommended detector configuration - a tetrahedron with all sides equal to 60 cm. The plutonium object is placed in the geometric center of the tetrahedron as shown in Figures 6 and 7. After placing the object inside the tetrahedron, record the detector-to-detector ranges and the object-to-detector ranges. In passive mode, collect cross correlations for the number of blocks indicated in the test matrix.

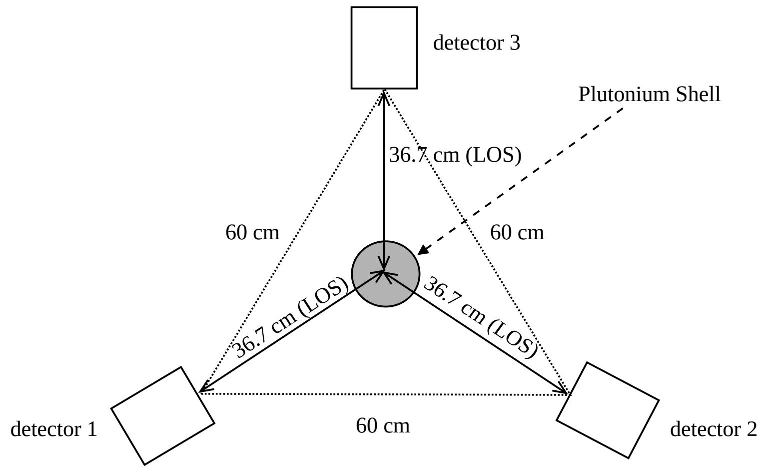

Figure 6: Top view of Pu Shell Inside Tetrahedron of Detectors

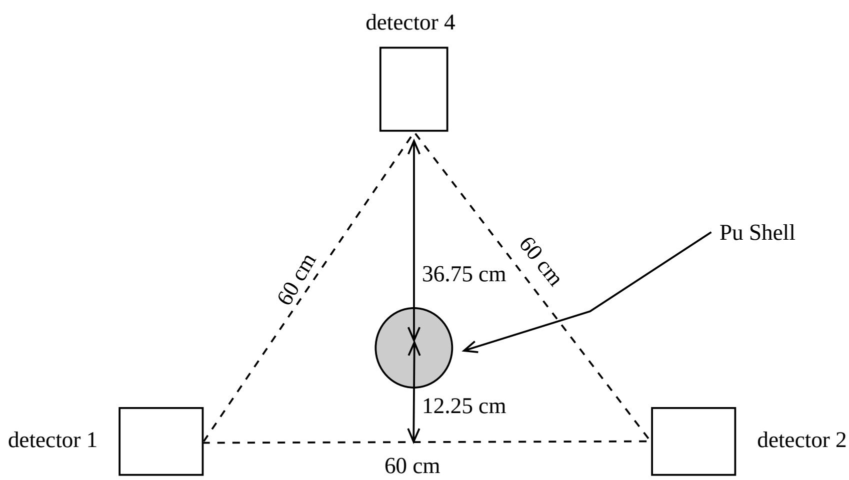

Figure 7: Side view of Pu Shell Inside Tetrahedron of Detectors

3 Appendix

3.1 Geometry of Equilateral Triangle

The geometric center of an equilateral triangle can be graphically determined by drawing vectors from each vertex to the middle of the opposite side. The intersection will be the geometric center. Alternativley, the geometric center can be computed by using Equation 1 to compute the height, of the equilateral triangle.

$$h = \frac{\sqrt{3}}{2} side \tag{1}$$

Then, the X and Y coordinates are computed using Equations 2 and 3. Again, the origin is the center of the front face of Detector #1.

$$X = \frac{side}{2} \tag{2}$$

$$Y = \frac{h}{3} = \frac{side}{2\sqrt{3}} \tag{3}$$

Using these equations and Figure 8, for an equilateral triangle of 60 cm, the height is 52 cm, X = 30 cm, and Y = 17.3 cm.

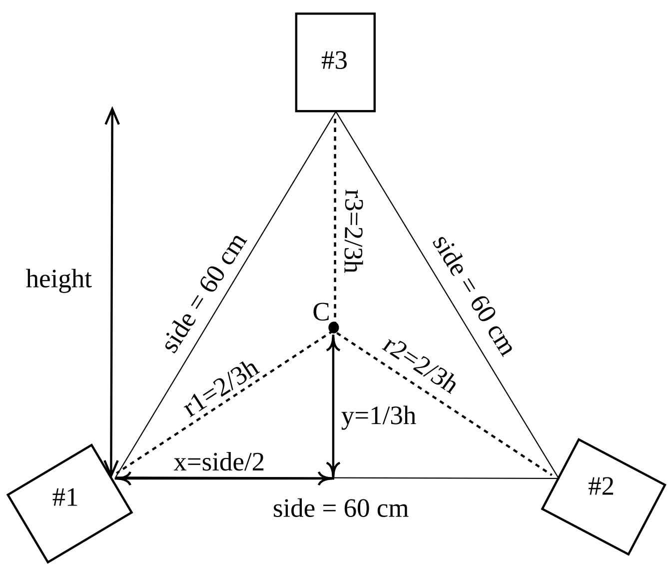

Figure 8: Center (pt C) of an Equilateral Triangle

3.2 Geometry of Tetrahedrons

For a regular tetrahedron, i.e., all sides of the tetrahedron are equal, the height of the tetrahedron can be found using Equation 4.

$$height = side \times \sqrt{\frac{2}{3}} \tag{4}$$

The height of the *geometric* center of any tetrahedron (measured from it's base) can be computed using Equation 5.

$$center = \frac{height}{4} \tag{5}$$

It is **NOT** $height/2$; that is the vertical center. The radial distance or the length of the line-of-sight vector from the geometric center to each vertex can be computed using Equation 6.

$$LOS = \frac{side}{2}\sqrt{\frac{3}{2}} \tag{6}$$

The X, Y, and Z coordinates of the voxels (1,1,1) and (0,1,0) and their ranges to the four detectors can be computed for different size tetrahedrons by simply scaling the coordinates of a regular tetrahedron with a 1 cm side. For example, for a tetrahedron with a side of 60 cm, the ranges from Voxel (1,1,1) to each detector can be computed as follows: $R_1 = R_2 = R_3 = R_4 = .612\ cm \times 60 = 36.7\ cm$.

Table 3: Voxel Coordinates for a Tetrahedron, Side = 1 cm

Voxel (i,j,k)	X (cm)	Y (cm)	Z (cm)	R_1 (cm)	R_2 (cm)	R_3 (cm)	R_4 (cm)
(1,1,1)	.50000	.28868	.20412	.61237	.61237	.61237	.61237
(0,1,0)	.12500	.21651	.00000	.25000	.90139	.75000	.90139

3.3 Spontaneous Fission Data

Table 4: Spontaneous Fission Data

Isotope	Spontaneous Fission Specific Activity (n/s-g)	Spontaneous Fission Multiplicity ν	Induced Thermal Fission Multiplicity ν
^{239}Pu	2.18×10^{-2}	2.16	2.88
^{240}Pu	1.02×10^{3}	2.16	2.8
^{252}Cf	2.34×10^{12}	3.757	4.06