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Moisture Measurement Perturbations of the Surface Neutron Probe Resulting from Waste Material Properties and Arrangements

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Abstract: Experimental tests and computer simulations of a surface neutron moisture measurement probe have been performed to determine the effects that different material variations and arrangements are expected to have upon probe moisture measurement error. This work supplements the existing probe calibration to changes in waste moisture concentration and should aid in the selection of the best in-tank measurement locations.

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1.0 SUMMARY

Experimental tests and computer simulations of a surface neutron moisture measurement probe have been completed to determine the effects that different material variations and arrangements are expected to have upon probe moisture measurement error. Many possible tank waste material anomalies, including variations in material composition, density and geometric arrangement, may be encountered. Some of these anomalies may significantly affect the probe moisture measurement accuracy. If the anomaly can be visually identified, recommendations have been made that provide guidance for avoiding these situations during in-tank probe deployment. For anomalies that can not be visually identified, the effect upon the moisture measurement error has been partially characterized and possible plans for potentially correcting the data to compensate for the anomaly are discussed. It is expected that there will be in-tank locations that are suitable for moisture measurement and that, for those cases, a moisture concentration, gradient with depth, and uncertainty bound can be established. To more accurately determine moisture measurement interpretations for cases where an anomaly is indicated, additional simulation analyses may be required.

2.0 INTRODUCTION

The surface moisture measurement system (SMMS) has been developed to deploy a neutron moderation-based moisture measurement probe to the tank waste surface (Stokes et al, 1995). This SMMS neutron probe has been tested, computer simulated, and calibrated to changes in moisture concentration of underlying materials (Watson and Bussell 1996). The calibration tests and simulations have focussed upon the simplest material arrangement and composition. The arrangement considered for these tests had the probe resting on a flat smooth material surface where the material contained no non-water hydrogen and little presence of strong thermal neutron absorbing elements. It is known that the response of the probe may be altered by changes in the surrounding waste geometry and composition. The in-tank waste surface geometry is known to be more irregular than the moisture standards used in the probe calibration. The waste composition is generally understood, but is not well characterized. This report is intended to document experimental tests and computer simulations performed to assess the effects of potential in-tank waste anomalies, deviations from the idealized calibration, upon the response of the probe. This information will be used both to avoid obtaining in-tank measurements in locations that would be likely to yield moisture data that is significantly compromised and to aid in data interpretation and uncertainty analyses.

The probe is mechanically housed within a nearly cylindrical stainless steel container (WHC 1996) with an outer diameter in the sensor region of about 3.3 inches. The main sensor portion of the probe consists of three detectors, each of which is at least partially shielded with cadmium and or polyethylene, and a californium-252 neutron source. Figure 2-1 shows a sketch, not to scale, identifying the major components of the sensor portion of the probe. The housing is designed to be deployed upright on the surface being investigated with the flat bottom in firm contact with the material. Detector 1 is positioned horizontally in the bottom of the housing

nearest to the neutron source and is surrounded with a thick (0.16 cm) outer cadmium shield and a partial inner layer of polyethylene. This detector is designed to detect epithermal neutrons returning to the probe. Epithermal neutrons will have, on average, undergone fewer collisions than lower energy neutrons and, therefore, will have traveled less deep in the media. Detector 2 is surrounded with a very thin (0.01 cm) cadmium shield and a polyethylene wrap and is vertically positioned near the probe bottom opposite the source. This detector detects a mix of thermal and epithermal neutrons that have, on average, traveled more deeply into the material than those detected by detector 1. Detector 3 is not surrounded with shielding, but rather is placed directly centered above a thick cadmium disk. This detector captures mainly thermalized neutrons that have traveled, on average, most deeply in the waste and exited the waste a short distance outside the probe housing.

3.0 WASTE MATERIAL PROPERTIES AND ARRANGEMENTS

3.1 BULK DENSITY

The neutron probe measures moisture by obtaining a measure of the average neutron moderation properties of the medium. In general, increasing the bulk density of the medium will decrease the neutron path length between collisions, thereby more quickly moderating the neutrons. An increase in the bulk density of the material under the probe is expected to provide the probe with an increased signal, equivalent to some change in moisture concentration. Computer simulations, using the radiation transport code Monte Carlo N-Particle (MCNP), were performed to assess the expected magnitude of this effect (LANL 1993). Throughout this report the model predictions have been scaled by a multiplicative calibration constant determined during calibration tests for each detector (Watson and Bussell 1996). Model input files and difference files comparing similar cases may be found in Appendix B. Analyses of tank waste salt cake samples and estimates of the waste density in the 20 Organic Watch-List tanks indicates that the expected density of waste near the surface of single shell tanks is about 1.5 g/cm^3 (WASTREN 1993) (Agnew 1996). Figure 3-1 shows the predicted response of each of the three detectors in the neutron probe to changes in waste bulk density at a constant moisture concentration of 15 weight percent (wt%) water. The error bars shown on individual points in this figure are representative of the stochastic precision for each value. In general, model predicted responses were calculated throughout this report with precision uncertainties of less than 2 to 3 percent. To obtain the best understanding of how the deviations in detector responses presented in Figure 3-1 relate to uncertainty in the moisture measurement the responses should be compared with those expected for changes in moisture at a constant density. Figure 3-2 shows the waste moisture as a function of the computer model predicted detector responses. A polynomial least-square fit to the data (presented in Appendix A) for each detector was produced to obtain the moisture as a function of response rate for each detector:

$$\text{Detector 1: Moisture} = -14.615 + 0.4194 \cdot (\text{response})$$

$$\text{Detector 2: Moisture} = -4.44 + 0.1254 \cdot (\text{response}) + 0.0006 \cdot (\text{response})^2$$

$$\text{Detector 3: Moisture} = 0.6047 + 0.0955 \cdot (\text{response}) + 0.0023 \cdot (\text{response})^2$$

If the density perturbation detector responses from Figure 3-1 are substituted in the above equations, then the equations will give apparent moisture concentration values that would be calculated if the waste were assumed to have a density of 1.5 g/cm^3 . If this apparent moisture is averaged for the three detectors a simple indication of the effect of density upon the moisture measurement may be obtained. Over the density range from about 1 to 2 g/cm^3 , it is expected that the moisture prediction will be in error about 1.5 wt% moisture for each 0.1 g/cm^3 that the actual density deviates from an assumed density of 1.5 g/cm^3 . If, for instance, the actual waste bulk density is 1.7 g/cm^3 , then the moisture prediction from the probe data will likely be about 3 wt% higher than the actual moisture concentration. Given information about the waste bulk density, the interpretation of the data could easily be corrected to eliminate this error.

3.2 HYDROCARBONS

The moderation properties of the waste are strongly dependant upon its hydrogen concentration. Because the probe measures the moderation properties of the waste and the data interpretation assumes that nearly all hydrogen is from water, the presence of significant hydrogen from sources other than water will affect the moisture interpretation. Hydrocarbons are known to have been present in the tank waste streams. While there is no way for the neutron probe to distinguish between hydrogen from various mixed sources, it is important to understand the expected magnitude of the effects caused by non-water hydrogen.

The waste composition in the computer simulation was varied by adding a mixture of equal amounts (by weight) of 6 organic compounds to the standard waste composition while maintaining the moisture concentration. The six organic compounds, intended to be representative of those used in the waste streams, are hexone, dibutyl phosphate, tributyl phosphate, trisodium citrate, hexadecanoic acid, and sodium ethylenediaminetetraacetic acid. Figure 3-3 shows the computer model predicted detector responses to changing total organic concentration at a constant moisture concentration of 15 wt%. Using the moisture response equations presented in section 3.1, an indication of the apparent moisture interpretation was derived and is shown in figure 3-4. From figure 3-4 one can conclude that each weight percent of total additional organic is expected to increase the apparent moisture concentration by about one weight percent. This result will vary according to the chosen mix of hydrocarbons. Hydrocarbons that have a smaller weight or atom fraction of hydrogen will contribute a reduced offset signal to the detectors.

Figure 2-1. Sketch of the Sensor/Source Portion of the Neutron Probe (Cross-Sectional View).

Figure 3-1. Computer model predicted response of each detector as a function of tank waste bulk density at 15 wt% moisture.

Figure 3-2. Simulant matrix moisture concentration as a function of model predicted detector responses (probe 3).

Figure 3-3. Model predicted detector responses as a function of organic concentration at 15 wt% moisture concentration.

Figure 3-4. Apparent moisture concentration as a function of organic concentration at actual 15 wt% moisture.

3.3 STRONG THERMAL NEUTRON ABSORBERS

Since the neutron probe detectors primarily detect thermal and epithermal neutrons, the presence of significant quantities of strong thermal neutron absorbers in the waste could reduce flux of the measurable portion of the neutron spectrum returning to the probe. Cadmium and or boron, two strong thermal neutron absorbers, are expected to be present in relatively low quantities in some of the tank wastes (WASTREN 1993). The response from detector 1 is expected to be nearly unaffected by the presence of strong thermal neutron absorbers in the waste. Detector 1 is shielded with thick layers of polyethylene and cadmium that adsorb nearly all thermal neutrons incident upon the probe.

Approximately 30 Hanford Site waste tanks, on a critical list for surface moisture inspection, were researched to determine the amount of neutron absorbing material within the tanks. Of these tanks, tank S-111 is expected to contain the greatest amount of neutron-absorbing material (WASTREN 1993). The neutron absorption properties of the waste in this tank are dominated by nitrogen and very small amounts of cadmium. Nitrogen is a weak thermal neutron absorber, but large concentrations of this element are present. Less than one-tenth of the neutron absorber concentration found in S-111 is expected for about 50% of the tanks, and less than about one-half of the S-111 absorber concentration is expected for 80% of the tanks. During the calibration of the neutron probe, two moisture standards were constructed that were spiked with boron concentrations typical of those that are expected in these tank wastes (Watson and Bussell 1996). One of these standards contained 0.0018 wt% boron and the other contained 0.0036 wt% boron uniformly mixed into the matrix. Both of the standards contained approximately 19 wt% moisture so that the response of the probe to these standards could be compared with one another and with the response to a 19 wt% moisture standard that contained no added boron. The bulk density of these standards varied slightly so that a correction was needed to directly compare the responses obtained from them. The bulk density of the standard without boron was $1.636 \pm 0.006 \text{ g/cm}^3$, while the density of the added boron standards was $1.601 \pm 0.005 \text{ g/cm}^3$ and $1.603 \pm 0.015 \text{ g/cm}^3$. Using the results from section 3.1, a correction was applied to the experimentally measured responses from the added boron standards. In order to relate the observed changes in detector response to apparent changes in moisture concentration, relationships giving the responses as functions of moisture for each detector in each probe are needed. Data presented in Figures 5-6 through 5-14 of the calibration report (Watson and Bussell 1996) were used to derive such relationships by performing polynomial least-square fits to the experimental data measured on moisture standards 1-6. These six moisture standards contain uniform moisture in a range from about 4 to 35 wt% water. Using these moisture/detector response relationships the fractional differences in the measured moisture concentrations between the added boron standards and the control standard were determined and are presented in table 3-1.

For in-tank data interpretation, the best estimate waste compositions will be used to determine the moisture concentrations. This moisture interpretation could be corrected, if needed, given better available characterization data. The results in table 3-1 indicate that only small effects upon the moisture interpretation would be expected unless the concentration of strong thermal neutron absorbers near the waste surface was greatly underestimated. For

example, if the surface waste contains 15 wt% moisture and contains strong neutron absorbers in quantities equivalent to the presence of an additional 0.0018 wt% boron, then the moisture concentrations predicted by detectors 1 through 3 would be about 14.9, 14.5 and 13.6 wt%, respectively. The average error, in this example, is only 0.7 wt% moisture. Detectors 1, 2, and 3 are designed to investigate different average depths into the underlying waste with detector 1 investigating the shallowest and detector 3 the deepest. Because detectors 1 and 2 are less affected by the presence of absorbers, the interpretation of data taken in a region with unexpectedly high concentrations of neutron absorbers will be that the moisture concentration decreases with depth in the waste. Primarily because of gravity induced liquid drainage, the waste, in general, is not expected to contain less moisture with increasing depth. If the data interpretation indicates that the waste has a moist layer above a more dry layer, the presence of an increased concentration of strong thermal neutron absorbers will be suspected. While there is no simple way to confirm this suspicion, the data can be reanalyzed not considering the data from detector 3, whose response is most affected by the absorbers. The moisture analyses would likely contain both results as possible interpretations.

Table 3-1. Average estimated fractional change in the moisture measurement for each detector using the boron containing moisture standards.

	Fractional Error Introduced into Moisture Concentration	
	0.0018 wt% Boron	0.0036 wt% Boron
Detector 1	-0.0045	-0.035
Detector 2	-0.033	-0.095
Detector 3	-0.093	-0.12

3.4 PHYSICAL GEOMETRIC WASTE ARRANGEMENT

The in-tank waste surface will, in general, be irregular in shape. However, because the wastes were substantially liquid at one time, the waste surface is expected to have some small areas where the surface is somewhat flat. Because the SMMS neutron probe will be deployed with an in-tank camera, operations will be able to visually select the probe measurement locations. The SMMS deployment arm allows the probe to be placed anywhere within a 1.8 m radius of the deployment riser centerline. The information in this section will be used by scientists to provide guidance in selecting the best measurement locations where the probe signals are likely to be least affected by the waste geometry and arrangement.

While an almost infinite number of possible variations in the waste surface may be encountered, we have consolidated these variations into a few major categories. In these major categories of possible waste variations, only a few, relatively simple examples have been evaluated here. These simple cases should be representative of more complicated, but similar, types of waste arrangements expected in the waste tank.

These scenarios were evaluated both by making some experimental measurements and/or by performing MCNP calculations to determine the effects of the geometry variations. The experimental arrangements all utilized the same moisture standard filled with a mixture of silica sand and hydrate alumina containing 19.1 wt% water uniformly distributed throughout and chemically bound to the mixture. A thin aluminum lid, which had been sealed on top of the moisture standard after it was constructed, was removed for these anomaly experiments. For the experimental measurements, the responses from each detector are compared with those obtained when no material anomaly was present. The difference in the response rate is then related to the moisture error introduced by the anomaly. This error is calculated using linear least-square fit equations produced from the final moisture calibration data for probe 2, found in figures 5-16, 5-17, and 5-18 of the calibration report (Watson and Bussell 1996). These simple linear relationships provide constants of proportionality, listed in Table 3-2, between the change in detector response and the change in moisture interpretation for each detector. These same constants are applicable for converting the changes in MCNP predicted detector responses to the these same anomalies for the experimentally measured configurations. For some cases only a model prediction of the expected magnitude of the effect is available. This modeling work was completed prior to the completion of the probe calibration and used a slightly different model of the SMMS neutron probe. This model also utilized best estimate salt cake waste composition rather than moisture standard simulant for the material matrix and modeled a larger volume of waste matrix. The trends and results from these calculations should be accurate predictions of the effects of these anomalies, but these results require different constants (provided in Table 3-3) to obtain estimates of the effects upon the moisture measurement.

Table 3-2. The constants used to convert experimental changes in detector responses to estimate moisture errors for each detector. These constants are also applied to computer model prediction of the experimental arrangements.

Detector	$\frac{\Delta \text{Moisture}}{\Delta \text{Detector Response}} \text{ (wt\% - s)}$
1	0.27
2	0.20
3	0.33

Table 3-3. The constants used to convert computer modeled (older probe model) changes in detector responses to estimate moisture errors for each detector.

Detector	$\frac{\Delta \text{Moisture}}{\Delta \text{Detector Response}}$ (wt% - s)
1	0.32
2	0.20
3	0.14

3.4.1 Surface Cracks

The surface of the waste may have large or small cracks or air-filled gaps. Many small cracks in the surface are expected to effect the probe response much like that predicted for a reduced bulk density of the waste (section 3.1). Large cracks, on the order of several centimeters or larger, will be readily visible and may be avoided or will cause effects similar to those discussed in section 3.4.2. Here we investigate cracks with widths in the range from about 0.3 to 1 cm.

One experimental arrangement was used to obtain an estimate of the effects of multiple cracks directly beneath the probe. Three aluminum slats (30.5 x 0.32 x 5.1 cm) were placed in the moisture matrix spaced about 2.8 cm apart and level with the matrix surface. The aluminum excludes the moisture containing matrix from the volume it occupies and provides very little perturbation of the matrix moderation properties. The slats were oriented to simulate vertical surface cracks 0.32 cm wide and 5.1 cm deep. The probe was placed in the center of the slats as sketched in figure 3-5. The experimental data was processed using the Curvecut code (Version 1.0) to produce detector count rates that are included in Appendix A (Finfrock 1996). Based upon the differences in these count rates from those obtained without the anomaly, the estimated experiment-based moisture measurement error was:

$$\begin{aligned} \text{detector 1 } \Delta M &= -1.1 \text{ wt\%} \\ \text{detector 2 } \Delta M &= -1.8 \text{ wt\%} \\ \text{detector 3 } \Delta M &= -3.0 \text{ wt\%} \end{aligned}$$

while the computer model predicted moisture measurement error for this arrangement was:

$$\begin{aligned} \text{detector 1 } \Delta M &= -2.6 \text{ wt\%} \\ \text{detector 2 } \Delta M &= -2.2 \text{ wt\%} \\ \text{detector 3 } \Delta M &= -0.8 \text{ wt\%} \end{aligned}$$

As expected, multiple small cracks beneath the probe will lower the probe moisture prediction by a couple of weight percent, much like a small reduction in the overall bulk density of the waste.

In addition to this single experimental arrangement, computer modeling of several arrangements of a single but wider crack was completed. The crack (1 cm wide) was located either under the probe source or under detector 1 and crack depths of both 5 and 10 cm were used. Figure 3-6 shows a diagram of the modeled arrangements. For all of these modeled arrangements the length of the crack was essentially infinite and the crack was filled with air. The waste matrix was modeled containing 10 wt% moisture. The results of this modeling, summarized in table 3-4, indicated that a single, medium sized crack in the waste surface under the probe is expected to cause the moisture measurement to have a negative error of about 1 wt%.

Table 3-4. Summary of modeled predicted moisture measurement error for a 1 cm wide air crack under the probe for two crack locations and two crack depths.

Detector	Crack Under Detector 1		Crack Under Neutron Source	
	Depth: 5 cm	Depth: 10 cm	Depth: 5 cm	Depth: 10 cm
	ΔM (wt%)	ΔM (wt%)	ΔM (wt%)	ΔM (wt%)
1	-0.5	-0.8	-0.8	-0.9
2	-0.1	-0.1	-0.3	-0.3
3	-0.3	-0.4	0.0	-0.1

3.4.2 Large Holes

In addition to smaller cracks, the waste surface is expected to have some locations with larger holes or wider, deeper depressions. Such holes are expected to be visually identified and avoided. Experimental tests and computer modeling were performed to obtain estimates of how far the probe should be placed from holes of different sizes so that the detector signals are no longer significantly affected.

The experimental arrangements utilized rectangular aluminum baking pans to form a hole in the moisture matrix next to the probe. One or two of these baking pans were inserted into the moisture matrix level with the surface and the standard was mechanically vibrated to recompact the matrix around the pan. The vibration technique was similar to that used to assemble all moisture standards as described in the calibration report (Watson and Bussell 1996). The pans were about 23 cm long, 12 cm wide, and 6.6 cm high with a wall thickness of about 0.06 cm. The width and length of the pans was slightly tapered toward the base. For the first arrangement, a

Figure 3-5. Sketch of the experimental multiple surface crack simulation arrangement (top and side views).

Figure 3-6. Sketch of two modeled surface crack arrangements (side views).

single pan was submerged at a location near the center of the standard so that when the probe was centered on the standard its outer casing would be tangent to the side of the long axis of the pan. The probe was rotated to place the neutron source opposite the side tangent to the pan. For the second experimental arrangement, two pans were inserted in the waste, end to end, so that the probe would be tangent to their edge at the ends where the pans touched. Figure 3-7 shows a diagram of the two experimental arrangements. The estimated experiment-based moisture measurement errors and computer model predicted moisture measurement errors for these two arrangements are compared in Table 3-5. In general, the experimental results indicate that the response of detector 3 is most affected by the large hole very close to the probe, while the response of detector 1 has not been significantly affected.

Table 3-5. Comparison of the experimental and model predicted moisture measurement errors resulting from the two experimental surface hole arrangements.

Detector	Single Pan Hole		Double Pan Hole	
	Experiment ΔM (wt%)	Model ΔM (wt%)	Experiment ΔM (wt%)	Model ΔM (wt%)
1	0.3	-2.0	-1.1	-2.1
2	-2.6	-3.7	-3.8	-5.4
3	-5.0	-2.4	-6.9	-3.2

The effects of similar large holes more distant from the probe were investigated by computer simulation for waste containing 10 wt% moisture. Rectangular holes or canyons were modeled both 20 and 40 cm away from the probe. The canyons were 10 cm deep and 10 cm wide with a length of either 50 cm or 10 cm. The computer model predicted moisture measurement errors for these arrangements are summarized in Table 3-6. A 50 cm long hole that is 40 cm away from the probe is not expected to be detectable, while the same sized hole 20 cm from the probe will perturb the overall moisture measurement by only about 1 wt%. It appears that about a 20 cm or greater spacing is desired between the probe and large surface holes to minimize the effects upon the moisture measurement. Shorter spacings will cause the probe, primarily detector 3, to underestimate the waste moisture.

Figure 3-7. Sketches of Experimental Hole Arrangements.

Table 3-6. Summary of computer model predictions of moisture measurement error caused by large surface hole located far from the probe.

Detector	20 cm away, 10 cm long	20 cm away, 50 cm long	40 cm away, 50 cm long
	ΔM (wt%)	ΔM (wt%)	ΔM (wt%)
1	-0.1	-0.3	0.0
2	-0.1	-0.4	0.0
3	-0.1	-1.4	0.0

3.4.3 Hills or Protrusions Above Surrounding Waste Level

The settling of the waste as the liquids were removed from many tanks caused the waste surface to buckle or slump in various locations, leaving hills or waste protrusions above the general level of the waste surface. Experimental arrangements were devised to determine the spacing required between the probe and different sized hills to nearly eliminate the effects of these hills upon the moisture measurement.

The hills were experimentally arranged by filling rectangular aluminum pans, identical to those used in the surface hole tests, with 19 wt% moisture simulant. The volume of each pan was measured by weighing the water required to completely fill each pan. The weight of simulant added to each pan was measured so that the bulk density of the contents of each pan could be determined. The probe was placed at the center of the moisture standard and one or more pan filled with simulant were placed at a given distance from the probe and oriented so that the long side of the pan was parallel to a line tangent to the nearest point on the probe housing. Measurements were taken for six different arrangements of 1, 2, or 4 simulant-filled pans, shown in figure 3-8. Comparisons of the experimental and computer modeled moisture errors introduced by these hill arrangements for each detector are summarized in table 3-7. In general, the measured and modeled results are in agreement. The modeled results for the change in response of detectors 2 and 3 to the hill 6 arrangement are the only results that are beyond acceptable agreement. Given the experimental increase in detector responses between hill 3 and hill 5, one would have expected the measured responses from hill 6 (additional filled pans at the same distance from the probe) to have been greater. The lack of agreement is likely from some experimental anomaly that might be corrected by repeating the measurement. The overall results seem to indicate that for a small hill (single pan) the probe should be placed about 20 cm or more from the hill to reduce the moisture measurement error below 1 wt%. It is expected that for larger hills (equivalent to 2 or more pans) the probe will need to be placed 30-40 cm from these hills to reduce the effect upon all detector responses below about 1 wt%. To confirm this expectation, the probe responses to a large rectangular hill (10cm high, 10 cm wide, 50 cm long)

Figure 3-8. Sketches of Experimental Hill Arrangements.

placed 40 cm from the probe were computer modeled for 10 wt% moisture throughout the waste matrix. For this arrangement the predicted detector moisture errors were 0.9 wt% (detector 1), 0.9 wt% (detector 2), and 0.5 wt% (detector 3). Hills are usually expected to affect the response of the detector 3 the greatest.

Table 3-7. Summary of the experimental and model predicted detector moisture measurement errors obtained for six experimental hill arrangements (see figure 3-8).

Arrangement Description (Hill Number)	Experiment ΔM (wt%)			Model ΔM (wt%)		
	1	2	3	1	2	3
pan next to probe on source side (1)	10.1	12.6	25.6	15.8	18.3	29.3
pan next to probe, side opposite source (2)	3.1	20.6	10.4	5.7	27.2	12.7
pan 13 cm from probe, side opposite source (3)	0.1	1.8	2.8	0.3	2.2	2.6
pan 20 cm from probe, side opposite source (4)	0.7	0.6	0.8	0.1	0.4	1.0
2 pans 13 cm from probe, opposite source (5)	1.2	4.8	6.1	0.4	2.8	4.2
4 pans 13 cm from probe, opposite source (6)	0.4	2.0	1.8	1.0	6.0	9.1

3.4.4 Dished Depressions

Large scale or small scale depressions in the waste surface or areas where the waste has slumped slightly below the general surrounding waste level will affect the probe detector responses. The effects of large scale depressions were investigated with experimental measurements. The effects of shallow, small scale (about the diameter of the probe) depressions were only investigated using computer modeling.

Large scale depressions were experimentally arranged using different diameter cylindrical aluminum pans that were inserted below the level of the moisture matrix. The pan inner diameters were 15.2, 20.3, and 25.4 cm and the wall thickness of each was 0.06 cm. Each pan was inserted about 1.9 cm into the matrix at the center of the moisture standard and then the probe was placed inside the pan at its center. These arrangements essentially placed the probe at the center of shallow, cylindrical depressions in the matrix surface. With the probe more fully surrounded by the moisture matrix, the detector responses were expected to increase. Table 3-8 summarizes the experimental and computer model predicted error in the moisture from these arrangements. The results show that placing the probe in a large depression with diameter less than about 40 cm will have significant effects upon the probe responses, especially detectors 2 and 3. This arrangement is similar to completely surrounding the probe with a small height hill. Very large diameter surface depressions or very shallow surface depressions are expected to cause little perturbation upon the moisture measurement.

Table 3-8. Summary of the experimental and model predicted detector moisture measurement errors obtained for the three cylindrical pan depression arrangements.

Cylindrical Pan Inner Diameter (cm)	Experiment ΔM (wt%)			Model ΔM (wt%)		
	1	2	3	1	2	3
15.2	3.2	10	23	4	9.6	17
20.3	0.8	6.4	21	2.3	6.9	15
25.4	-2.2	4.0	25	1.1	4.2	12

Small scale depressions in the surface that might exist under the probe but be too small to allow the probe to fit inside the depression were computer simulated. The two arrangements were modeled: a spherical shaped dished depression with surface diameter equal to the probe diameter and maximum depth equal to 1.27 cm, and a cylindrical depression with side equal to the probe diameter and with a depth of 1.27 cm. For both arrangements, sketched in figure 3-9, the probe was modeled directly over, but not submerged into the depressions. These arrangements are similar to having large cracks beneath the probe and were expected to result in negative moisture errors. The computer model predicted moisture measurement errors from these arrangements are summarized in table 3-9. Detector 1 is most affected by shallow depressions beneath the probe because it is designed to investigate the smallest volume and shortest depth into the underlying medium. Small shallow depressions directly under the probe are not expected to have a significant effect upon the overall probe moisture measurement.

Table 3-9. Summary of the model predicted detector moisture measurement errors obtained for the small surface depression arrangements.

Arrangement Description	Model ΔM (wt%)		
	1	2	3
Spherical dished depression 1.27 cm deep	-1.5	-0.4	-0.2
Cylindrical depression 1.27 cm deep	-1.7	-0.6	-0.1

Figure 3–9. Sketch of two modeled small surface depressions underneath the probe (side views).

Cylindrical Depression Under Probe

Dished Depression Under Probe

3.4.5 Irregular Surface

The surface of the waste is irregular to some degree in most areas. Even if no large hills or canyons are present, there is likely to be some variation or roughness to the surface. In an effort to quantify the probes sensitivity to this irregularity a computer model was constructed with alternating bands of higher and lower surfaces. The area under the probe, and in a surrounding 5.0 cm wide annulus, was level. This was surrounded by an annulus 5.0 cm wide and 2.54 cm high filled with waste. There followed another 5.0 cm annulus of level surface and then another waste annulus. The results of this calculation are shown in Table 3-10.

Table 3-10. Summary of the model predicted detector moisture measurement errors obtained for the irregular surface arrangements.

Arrangement Description	Model ΔM (wt%)		
	1	2	3
Alternating annuli of waste, 2.54 cm high	2.6	3.0	4.0

3.4.6 Waste Surface to Probe Suspension or Submersion

The probe will be lowered to the surface by a cable on the SMMS deployment system. Although the waste surface is expected to often be firm enough to support the probe, if the surface yields under the probe weight, the deployment operator will need to attempt to raise the probe so that its bottom is even with and just touching the waste surface. Horizontal stripes have been painted on the probe base to visually facilitate this operation. It is possible that the probe may be slightly submerged below the level of the waste or even slightly suspended above the waste level during this positioning. Although it is expected that the probe can be positioned within a very small distance (less than 0.5 cm) of the waste surface, the effects of probe standoff and submersion were investigated by experimental arrangements and or modeling.

Both experimental measurements and modeling were performed to assess the effects of standoff (probe suspension above the surface) upon probe responses. The probe is placed upon the simulant surface using an aluminum deployment stand. This stand grasps the probe from its top using an arm that has a pivot. The arm can be used to raise or lower the probe to a fixed height in relationship to the simulant surface. Measurements were taken with the probe resting on the moisture simulant surface and with the probe suspended 1.3, 2.5, and 3.8 cm above the surface. Table 3-10 summarizes the moisture errors for the experimental standoff arrangements and computer predictions of the errors for those arrangements. For the large measured standoff distances the effect upon probe responses is significant.

Table 3-10. Summary of the experimental and model predicted detector moisture measurement errors obtained for probe standoff arrangements.

Probe Distance Above Matrix (cm)	Experiment ΔM (wt%)			Model ΔM (wt%)		
	1	2	3	1	2	3
1.3	-6.8	-7.8	-9.6	-6.4	-6.3	-6.7
2.5	-11	-12	-16	-8.9	-10	-12
3.8	-14	-15	-21	-11	-13	-14

The computer modeling of the experimental liftoff arrangements was extended to predict the moisture measurement errors as a function of probe submersion in the 19wt% moisture matrix. Figure 3-10 shows the model predicted moisture error as a function of probe height above (or below) the moisture matrix surface. The modeled response data for each detector was fitted by a polynomial using the least-square method. Realistic standoff or submersion distances are expected to be very small because of the quality camera surveillance system used to deploy the probe. Table 3-11 provides the model predicted moisture measurement error for small standoff and submersion distances calculated using the polynomial fits shown in figure 3-10. Except for detector 1, slight standoffs seem to perturb the moisture signals less than equal distance submersions of the probe. The overall moisture error is expected to be lower if the probe is slightly above the surface than if it is slightly submerged below the surface.

Table 3-11. Model predicted detector moisture measurement errors obtained for realistic probe standoff and submersion distances. (Calculated from polynomial fit to modeled data, Figure 3-10)

Probe Distance Above Matrix (cm)	Detector Moisture Errors ΔM (wt%)		
	Detector 1	Detector 2	Detector 3
0.3	-1.9	-1.6	-1.6
0.2	-1.4	-1.0	-0.8
0.1	-1.0	-0.3	0.0
-0.1	-0.1	1.0	1.8
-0.2	0.4	1.6	2.7
-0.3	0.8	2.3	3.8

Figure 3-10. Estimated moisture error from model predicted detector responses to changes in the probe distance relative to the moisture matrix surface. (polynomial curve fits are plotted)

3.4.7 Probe Tilt

The surface of the tank waste is not always level. Because the probe is deployed from a hanging cable, the probe will tilt so that the base of the probe may be parallel to the waste surface at the deployment location. If the surface is far from level (greater than about 10°), then the deployment operator will likely need to adjust the probe height, thereby adjusting the angle that the probe bottom makes with the waste surface. Because the deployment camera only has one view of the probe it is difficult to visually confirm that the probe bottom is parallel to an inclined surface. Deployment tests with a probe on irregular surfaces inclined between 5 and 30 degrees demonstrated that the probe would be placed, on average, about 2 degrees from and almost always less than 5 degrees from perpendicular to the surface (Ritter 1996). These tests were performed using the actual deployment system, probe, and by only viewing the probe placement from the deployment camera video monitors.

Experimental tests were performed to determine the effect of probe inclination with respect to the matrix surface upon moisture measurement error. The probe placement fixture was used to hold the probe at a given angle with respect to the simulant surface and a digital inclinometer, attached to the side of the probe housing, was used to measure the angle of inclination. The angle of inclination of the probe housing was measured to be 89.8 degrees when the probe rested flat upon the matrix surface. For the measurements, the probe was tilted about an axis parallel to the longitudinal axis of detector 1 so that for positive tilt angles the portion of the probe below the neutron source remained in contact with the surface. Figure 3-11 shows a graph of the predicted detector moisture measurement errors as a function of the angle between the probe base and the matrix surface. For tilt angles less than or equal to about 2 degrees, the moisture measurement error for all detectors will likely be below 1 wt%. For tilt angles between 2 and 5 degrees, the expected moisture measurement error rises to between 1 and 3 wt% for the different detectors.

3.5 MOISTURE DISTRIBUTION

It is expected that the moisture will not necessarily be uniformly distributed throughout the volumes investigated by the probe detectors. Gravitational and capillary forces and surface air exposure make it likely that the moisture concentration of the waste will increase as a function of depth in the waste. Because no validated model of the moisture concentration currently exists, we plan to assume that the moisture concentration as a function of depth is a zero or positive linear gradient near the waste surface. This assumption allows us to obtain computer model predictions of the detector responses as a function of moisture gradient for boundary surface moistures ranging from 0 to at least 40 wt%.

Figure 3-11. Experimentally determined moisture measurement error as a function of the angle between the probe base and matrix surface.

The assumption of a linear moisture gradient will introduce uncertainty into the moisture interpretation of the data. This uncertainty will primarily come from how the shape of the moisture gradient differs from linear. A computer code, TMAD, has been developed that will aid scientists in determining the surface moisture concentration and moisture gradient from the measured in-tank data (Finrock 1995). This code will compare the measured detector count rates with those predicted by computer modeling for different moisture concentrations and gradients to determine a best fit. Allowing only for uniform moisture or increasing moisture with depth may make it easier for some type of anomalies to be identified. For instance, the responses that would be obtained from the presence of unexpectedly large quantities of strong thermal neutron absorbers would yield moisture interpretations with very large errors.

4.0 PLANNED MOISTURE INTERPRETATION AND UNCERTAINTY BOUNDS

The moisture interpretation of in-tank data will be accomplished using the aid of the TMAD code. This code will compare the measured data with libraries of predicted detector responses for different moisture concentrations and gradients. The initial libraries will be created using a flat waste surface geometry (no anomaly), at a single assumed bulk density, and for a single waste matrix composition. The TMAD code provides the user with an estimate of the uncertainty in the moisture interpretation based solely upon how well the measured data agrees with the best-fit modeled response set.

If the TMAD moisture uncertainty is low (less than about 3 wt% moisture) then one might assume that data unaffected by anomalies was obtained and that the moisture interpretation is valid. It is also possible that, even though TMAD found a good fit modeled response set, the data has been compromised by a tank waste anomaly. An anomaly might produce detector signals similar to those expected from legitimate non-anomaly moisture arrangements. During the deployment process, in-tank video of each probe deployment will be taken. Also, notes should be maintained by test personnel describing any concerns about observed evidence of material anomalies near each deployment measurement location. While the TMAD code provides an automated moisture interpretation based upon available data libraries, each individual measurement location and corresponding moisture interpretation will need to be carefully evaluated by a scientist. While the moisture interpretation provided by the TMAD code may be the best available, the scientist will need to estimate additional uncertainty or identify any suspected bias in the results based upon consideration of the data and the in-tank video of each deployment.

In cases where the TMAD moisture uncertainty is high (greater than about 5 wt% moisture) it is likely that either a material anomaly was present or that an assumption made in the moisture analyses, such as waste composition, density, or moisture gradient description, does not accurately describe reality. In some cases, the response of one of the detectors may be eliminated from consideration in the moisture interpretation. This elimination could be based upon visual evidence of a given type of anomaly. As shown in this document, many anomaly types will more significantly affect the response of one of the three detectors, leaving the moisture prediction based upon the remaining two detectors reasonably accurate. The solution for obtaining the most

accurate moisture interpretation may be to individually analyze each measurement location using available information or indications of an anomaly. This solution, while desirable, would require significant time and effort to perform the needed computer simulations of each individual situation. Available resources may limit the ability to better analyse data that may have been influenced by an anomaly. Information presented in this report may be used to apply rough corrections to the data assuming a given anomaly type and magnitude. These data are being collected to help determine whether some Hanford wastes meet available moisture concentration criteria for safe storage. If the measurement, even given the large uncertainty, strongly indicates that the moisture concentration is either well above or below established safety criteria, then more analyses may not be warranted.

5.0 CONCLUSIONS

Experimental tests and simulation modeling have been performed for the SMMS neutron probe. The results indicate that different anomalies or variations in the waste composition or arrangement are expected to affect the accuracy of the moisture concentration interpretation derived from data acquired with the probe. Because many of the physical waste arrangements that might affect the probe response should be observable using the in-tank camera system during deployment, it should often be possible to place the probe to avoid these anomalies. The results in this report indicate that placing the probe a great enough distance from large hole or hill shaped anomalies will eliminate their effects upon the measured probe signals. Many other possible types of material anomalies, such as small cracks or shallow depressions in the waste surface are expected to have very small effects upon the measured probe signal.

6.0 REFERENCES

- Agnew, S. F., 1996, *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 3*, LA-UR-96-858, Los Alamos National Laboratory, Los Alamos, New Mexico.
- Finfrock, S. H., 1996, *The CURVECUT Neutron Spectrum Processing Code*, WHC-SD-WM-CSUG-011, Westinghouse Hanford Company, Richland, Washington.
- Finfrock, S. H., 1995, *System Design Description for the TMAD Code*, WHC-SD-WM-CSRS-028, Westinghouse Hanford Company, Richland, Washington.
- LANL, 1993, *MCNP - A General Monte Carlo N-Particle Transport Code, Version 4A*, LA-12625, (J. F. Briesmeister, Ed.), Los Alamos National Laboratory, Los Alamos, New Mexico.
- Ritter, G. A., 1996, *Surface Moisture Measurement System Hardware Acceptance Test Report*, WHC-SD-WM-ATR-153, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Stokes, T. I., W. T. Watson, M. Gimera, J. H. Bussell, A. Dabiri, D. T. Holslin, F. Johansen, 1995, *Design Requirements Document (DRD) for Surface Moisture Measurement System (SMMS)*, WHC-SD-WM-DRD-002, Rev. 0., Westinghouse Hanford Company, Richland, Washington.
- WASTREN, Inc., 1993, *Radionuclide and Chemical Inventories for the Single-Shell Tanks*, WHC-SD-WM-TI-565, Rev 1, Westinghouse Hanford Company, Richland, Washington.
- Watson, W. T. and J. H. Bussell, 1996, *Results of Experimental Tests and Calibrations of the Surface Neutron Moisture Probe*, WHC-SD-WM-TRP-260, Rev. 0., Westinghouse Hanford Company, Richland, Washington.
- WHC, 1996, *SMMS Neutron Probe Assembly*, Rev 0., May 1996, drawing H-14-100483, Westinghouse Hanford Company, Richland, Washington.

Appendix A. Model predicted and experimentally measured detector response data.

Table A-1. Model predicted response of each detector as a function of tank waste bulk density at a moisture concentration of 15 wt% (Figure 3-1).

Density (g/cm ³)	Detector 1 (s ⁻¹)	Detector 2 (s ⁻¹)	Detector 3 (s ⁻¹)
1.1	52.9	72.6	46.1
1.2	57.2	82.8	45.9
1.3	60.8	85.4	50.4
1.4	67.1	93.9	53.1
1.5	72.1	100	58.1
1.6	78.5	107	62.1
1.7	81.9	111	64.6
1.8	87.4	115	68.0

Table A-2. Model predicted responses for different matrix simulant moisture concentrations (Figure 3-2).

Moisture Concentration (wt%)	Detector 1 (s ⁻¹)	Detector 2 (s ⁻¹)	Detector 3 (s ⁻¹)
0	29.7	33.5	9.7
5	44.5	57.3	25.7
10	58.3	79.5	42.3
15	72.2	101	57.6
20	85.1	121	70.7
25	97.5	138	85.7
30	110	156	99.5
40	135	187	114
50	153	208	132
65	183	247	145

Table A-3. Model predicted detector responses for different total waste organic concentrations at 15 wt% moisture (Figure 3-3)

Total Organic Concentration (wt%)	Detector 1 (s^{-1})	Detector 2 (s^{-1})	Detector 3 (s^{-1})
0	72.1	100	58.1
1	74.5	100	60.3
2	75.3	105	65.0
3	78.7	109	64.6
4	80.2	110	68.0
6	83.4	121	70.7
8	88.1	125	75.4

One experimental arrangement was used to obtain an estimate of the effects of multiple cracks directly beneath the probe. The Curvecut-derived experimental detector count rates and model predicted count rates are listed in Table A-4.

Table A-4. Comparison of base (no anomaly) case and multiple crack case experimental and model predicted detector responses (probe 3)

Data Source	Base (No Anomaly) Case (s^{-1})			Multiple Crack Case (s^{-1})		
	Det 1	Det 2	Det3	Det 1	Det 2	Det3
Experiment	106	160	128	102	151	119
Modeled	124	169	95	114	158	92

Table A-5. Model predicted detector responses (count rates) for a 1 cm wide air crack under the probe for two crack locations and crack depths.

Detector	Crack Under Detector 1			Crack Under Neutron Source		
	none	5 cm depth	10 cm depth	none	5 cm depth	10 cm depth
1	62	61	60	62	59	59
2	68	68	67	70	68	68
3	93	90	90	93	93	92

Table A-6. Comparison of the experimental and model predicted detector responses resulting from the two experimental surface hole arrangements.

Detector	Exp. No Anomaly	Single Pan Hole		Double Pan Hole	
		Experiment (s^{-1})	Model (s^{-1})	Experiment (s^{-1})	Model (s^{-1})
1	106	107	72.9	102	72.3
2	160	147	112	141	104
3	128	113	88.4	113	86.0

Table A-7. Summary of computer model predictions of detector responses to arrangements with a large surface hole located far distances from the probe.

Detector	No Anomaly	Hole 20 cm away, 10 cm long	Hole 20 cm away, 50 cm long	Hole 40 cm away, 50 cm long
1	62	62	61	62
2	69	69	67	69
3	93	92	83	93

Table A-8. Summary of the experimental and model predicted detector responses obtained for six experimental hill arrangements using probe 1 (see figure 3-8).

Pan (Hill) Arrangement Description	Experiment (s ⁻¹)			Model (s ⁻¹)		
	1	2	3	1	2	3
No anomaly	126	169	87.5	124	169	94.8
next to probe on source side	163	232	165	182	261	184
next to probe, opposite source	137	272	119	145	306	133
13 cm from probe, opposite source	126	178	96	125	180	103
20 cm from probe, opposite source	128	172	90	124	172	97.7
2 pans 13 cm from probe, opposite source	130	193	106	125	183	107
4 pans 13 cm from probe, opposite source	127	179	93	128	199	122

Table A-9. Summary of the experimental and model predicted detector count rates obtained for the three cylindrical pan depression arrangements.

Cylindrical Pan Inner Diameter (cm)	Experiment (s ⁻¹)			Model (s ⁻¹)		
	1	2	3	1	2	3
No Anomaly	100	146	98	80.2	130	95.6
15.2	112	197	168	95.0	179	146
20.3	103	178	162	88.6	165	142
25.4	92	166	174	84.1	151	132

Table A-10. Summary of the model predicted detector responses obtained for the small surface depression arrangements.

Arrangement Description	Modeled Detector Responses (s ⁻¹)		
	1	2	3
No Anomaly	62	70	92
Spherical dished depression 1.27 cm deep	58	68	93
Cylindrical depression 1.27 cm deep	57	67	91

Table A-11. Summary of the model predicted detector responses obtained for the irregular surface arrangement.

Arrangement Description	Modeled Detector Responses (s ⁻¹)		
	1	2	3
No Anomaly	61	70	93
Concentric annuli of waste, 2.54 cm high	70	85	122

Table A-11. Summary of the experimental and model predicted detector responses obtained for the probe standoff distances.

Probe Distance Above Matrix (cm)	Experiment Detector Responses (s ⁻¹)			Model Detector Responses (s ⁻¹)		
	1	2	3	1	2	3
No Anomaly	106	160	128	80.2	130	95.6
1.3	81	121	99	56.4	98.9	78.4
2.5	66	99	78	47.2	78.4	60.5
3.8	55	84	65	40.6	65.4	53.1

Table A-12. Summary of the experimental and model predicted detector responses obtained for different probe tilt angles.

Probe Tilt Angle (degree)	Experiment Detector Responses (s^{-1})			Model Detector Responses (s^{-1})		
	1	2	3	1	2	3
-12.7	79	139	80	58.8	112	76.7
-8.4	87	141	85	64.0	116	78.3
-4	99	148	104	68.2	123	87.3
0 (no anomaly)	108	160	118	80.2	130	95.6
4.5	106	150	121	75.3	123	94.3
8.5	98	141	131	71.4	112	99.7

Appendix B. Computer model (MCNP) input files

input file for base case for hole under probe:

message:

Vert Surface Neutron (t18 geom) modified importances

```
c      10% water saltcake, surface test: none
c
c
1 1 -8.0      75 -72 -15 imp:n=100 $ Cf-252 source
3 13 -1.138e-3 70 -68 -40 imp:n=300 $ det 2 air
4 13 -1.138e-3 67 -71 -43 imp:n=250 $ det 2 air
9 3 -.96 67 -70 -40 43 imp:n=290 $ det 2 poly
10 6 -.9833e-4 92 -.93 -42 imp:n=300 $ det 1
11 6 -.9833e-4 71 -70 -43 imp:n=650 $ det 2
12 6 -.9833e-4 91 -90 -44 imp:n=350 $ det 3
13 8 -.865 (62 -69 -41) (40:68:-67) imp:n=190 $ det 2 cad
14 8 -.865 (96 -97 -46 45);(-45 96 -99);(-45 98 -97) imp:n=110 $ det 1 cad
15 3 -.96 99 -98 -45 42 50 imp:n=220 $ det 1 poly
16 13 -1.138e-3 -93 92 -45 42 -50 imp:n=100 $ det 1 air
17 13 -1.138e-3 -.98 93 -45 #15 imp:n=120 $ det 1 air
18 13 -1.138e-3 -.92 99 -.45 #15 imp:n=120 $ det 1 air
21 19 -7.8    9 -8 1 -62 imp:n=100 $ steel housing
22 19 -7.8    9 1 -62 #1 imp:n=100 $ steel housing bottom
23 19 -7.8    9 -8 62 -60 imp:n=100 $ steel housing
48 15 -1.50    2 -1 -8 imp:n=100 $saltcake
49 15 -1.50    3 -2 -8 imp:n=100 $saltcake
50 15 -1.50    #48 #49 -1 -100 imp:n=100 $saltcake
51 15 -1.50    #48 #49 -1 100 -101 imp:n=90 $saltcake
52 15 -1.50    -1 101 -102 imp:n=80
53 15 -1.50    -1 102 -103 imp:n=70
54 15 -1.50    -1 103 -104 imp:n=60
55 15 -1.50    -1 104 -105 imp:n=50
56 15 -1.50    -1 105 -106 imp:n=40
57 15 -1.50    -1 106 -107 imp:n=30
58 15 -1.50    -1 107 -108 imp:n=15
59 15 -1.50    -1 108 -109 imp:n=8
60 15 -1.50    -1 109 -110 imp:n=4
70 13 -1.138e-3 1 8 -103 imp:n=60 $ air
71 13 -1.138e-3 1 103 -105 imp:n=25 $ air
72 13 -1.138e-3 1 105 -107 imp:n=15 $ air
73 13 -1.138e-3 1 107 -109 imp:n=4 $air
74 13 -1.138e-3 1 109 -110 imp:n=1 $air
75 13 -1.138e-3 74 -77 -9 -60 #200 #12 imp:n=220
76 13 -1.138e-3 62 -9 -77 -74 (-96:97:46) #1 #100 imp:n=100 $ air next to source & det 1
77 13 -1.138e-3 62 -60 -9 77 #11 #9 #13 #3 #4 #200 imp:n=140 $ air next to det 2
78 13 -1.138e-3 60 -103 -8 #12 imp:n=60 $ air above probe
100 19 -7.8 (-80 -75 -9);(-83 75) -81 -9 62 #1 imp:n=100 $ source enclosure
200 8 -.865    -13 -82 74 43 #13 #3 #3 imp:n=95 $cadmium
500 0
      110 imp:n=0

1 pz 0.00    $ top of saltcake
2 pz -1.00
3 pz -2.00
8 c/z 1.7 4.22 4.214 $ outer steel housing x y R .125 in thick wall
9 c/z 1.7 4.22 3.896 $ outer steel housing x y R 3.068 in ID
13 c/z 1.5 4.22 3.6 $ cadmium x y R
15 c/y -1.409 0.643 0.216 $ source radius x z R
16 pz 15.0    $ top of air
40 c/z 4.38 4.22 1.2 $ cad inner/poly outer 2.05 mm thick poly
41 c/z 4.38 4.22 1.205 $ detector 2 cad 0.005 cm thick
```

42 c/y 1.65 1.837 0.79 \$ detector 1 radius (.62"OD) x z R
 43 c/z 4.38 4.22 0.79 \$ detector 2 radius (.62"OD) x y R
 44 c/z 1.75 4.22 1.27 \$ detector 3 radius (.62"OD) x y R
 45 c/y 1.65 1.837 1.29 \$ det 1 poly
 46 c/y 1.65 1.837 1.455 \$ det cad
 50 p 1.1 4.22 1.05 1.1 5 1.05 1.2 4.22 1.9 \$ det 1 poly
 60 pz 14.5 \$ imp plane
 62 pz 0.381 \$ top of housing bottom
 67 pz 0.386 \$ top of det 2 Cd 0.005 cm thick
 68 pz 5.4818 \$ top of det 2 Cd
 69 pz 5.4868 \$ top of det 2 Cd 0.005 cm thick
 70 pz 4.5284 \$ top of det 2
 71 pz 1.3484 \$ bottom of det 2
 72 py 4.220001 \$ top of source
 74 pz 4.8 \$ bottom of cadmium disk
 75 py 4.219999 \$ bottom of source
 77 px 3.12 \$ left side of iron block
 80 px -.479 \$ source enclosure (side)
 81 pz 1.65 \$ source enclosure (top)
 82 pz 4.965 \$ top of cadmium
 83 px -.873 \$ thin side of source enclosure
 90 pz 11.569 \$ end of top det 3
 91 pz 6.489 \$ end of top det 3
 92 py 2.93 \$ end of det 1
 93 py 6.11 \$ end of det 1
 96 py 1.5 \$ cad/air
 97 py 7.6924 \$ cad/air
 98 py 7.5324 \$ cad/air
 99 py 1.66 \$ cad/air
 100 s 1.0 4.22 0.0 5.0
 101 s 1.0 4.22 0.0 10.0
 102 s 1.0 4.22 0.0 15.0
 103 s 1.0 4.22 0.0 20.0
 104 s 1.0 4.22 0.0 25.0
 105 s 1.0 4.22 0.0 30.0
 106 s 1.0 4.22 0.0 35.0
 107 s 1.0 4.22 0.0 40.0
 108 s 1.0 4.22 0.0 45.0
 109 s 1.0 4.22 0.0 50.0
 110 s 1.0 4.22 0.0 100.0

 c idum 4j -7
 mode n
 phys:n 20 20
 sdef cel d1 pos cel d2 axs 0 1 0 ext cel d3
 rad cel d4 wgt=2.3e7 erg d5
 sc1 source cell is Cf-252 source in cell 1 : 10 micrograms
 si1 1 1
 sp1 d 1.0
 sc2 source location is centered in cell 1
 ds2 1 -1.409 4.22 0.643
 sc3 source extent
 ds3 s 6
 sc4 source radius
 ds4 s 7
 sc5 energy distribution: Cf-252 Watt Spontaneous Fission Spectrum
 sp5 -3 1.025 2.926
 sc6 source extent is 1.0 centimeter total length
 si6 0.000001
 sp6 -21 0
 sc7 source radius is .216 centimeters
 si7 0.0 0.216

```

sp7 -21 1
f4:n 10 $ detector regions
fm4 8.489e-6 9 207 $ (n,alpha) interactions
f14:n 11 $ detector regions
fm14 8.489e-6 9 207 $ (n,alpha) interactions
f24:n 12 $ detector regions
fm24 8.489e-6 9 207 $ (n,alpha) interactions
m1 98252.35c 2 $ Cf-252
    8016.50c 6
    16032.50c 1
m3 1001.50c 2.000000 $ Polyethylene
    6000.50c 1.000000
m3t poly.01t
m6 5010.50c 0.24 $ BF3 gas (2.99 g/l at 1 atm)
    5011.50c 0.01 $ Ref: HCP-62ed B-84
    9019.50c 0.75 $ 96% enriched in B-10
m8 48000.50c -1.00 $ cadmium
m9 5010.50c 1.00 $ B-10 used for tallying
m13 7014.50c 0.8000 $ LOW air (1.138e-3 g/cc)
    8016.50c 0.2000
m15 1001.50c -0.011596 $ BY-104 Saltcake Simulant 10% H2O
    7014.50c -0.1307
    8016.50c -0.5748
    11023.50c -0.2611
    12000.50c -0.0003
    13027.50c -0.0133
    14000.50c -0.0033
    15031.50c -0.0013
    20000.50c -0.0009
    25055.50c -0.0006
    26000.55c -0.0022
m15t lwtr.01t $ hydrogen in water 300 K
m19 6000.50c -0.003 $ 4130 carbon steel
    25055.50c -0.005
    15031.50c -0.00035
    16032.50c -0.0004
    14000.50c -0.002
    24000.50c -0.01
    42000.50c -0.002
    26000.55c -0.97725
totnu
nps 50000000
ctme 5000
prdmp 5000000 10000000 1 1
print 60 120 126 140

```

diff file showing differences between base case input and input for
1.27cm cylindrical hole under probe:

```

4c4
< c      10% water saltcake, surface test: none
--
> c      10% water saltcake, surface test: 1.27 cm air
23c23
< 48 15 -1.50      2 -1 -8      imp:n=100 $saltcake
--
> 48 13 -1.138e-8  2 -1 -8      imp:n=100 $air
50c50
< 2 pz -1.00
--
> 2 pz -1.27

```

diff file showing differences between base case input and input for
1.27cm dish under probe:

```
4c4
< c      10% water saltcake, surface test: none
--
> c      10% water saltcake, surface test: dish under
23,26c23,24
< 48 15 -1.50      2 -1 -8      imp:n=100 $saltcake
< 49 15 -1.50      3 -2 -8      imp:n=100 $saltcake
< 50 15 -1.50 #48 #49 -1      -100 imp:n=100 $saltcake
< 51 15 -1.50 #48 #49 -1      100 -101 imp:n=90 $saltcake
--
> 50 15 -1.50 #69      -1      -100 imp:n=100 $saltcake
> 51 15 -1.50 #69      -1      100 -101 imp:n=90 $saltcake
35a34
> 69 13 -1.138e-3      -1      -4 imp:n=60      $ air
51a51
> 4 s      1.7 4.22 9.2075 10.4775
```

diff file showing differences between base case input for hole under probe
and base case for crack under probe:

```
4c4
< c      10% water saltcake, surface test: none
--
> c      10% water saltcake, surface test: none (crack)
23,24c23,24
< 48 15 -1.50      2 -1 -8      imp:n=100 $saltcake
< 49 15 -1.50      3 -2 -8      imp:n=100 $saltcake
--
> 48 15 -1.50 4 -5 2 -1 -8      imp:n=100 $saltcake
> 49 15 -1.50 4 -5 3 -2 -8      imp:n=100 $saltcake
27c27
< 52 15 -1.50      -1      101 -102 imp:n=80
--
> 52 15 -1.50 #48 #49 -1      101 -102 imp:n=80
50,51c50,53
< 2 pz      -1.00
< 3 pz      -2.00
--
> 2 pz      -5.00
> 3 pz      -10.00
> 4 px      1.20
> 5 px      2.20
```

diff file showing differences between base case (no crack) input
and 5 cm crack case

```
4c4
< c      10% water saltcake, surface test: none (crack)
--
> c      10% water saltcake, surface test: 5x1 crack
23,24c23,24
< 48 15 -1.50 4 -5 2 -1 -8      imp:n=100 $saltcake
< 49 15 -1.50 4 -5 3 -2 -8      imp:n=100 $saltcake
```

```

--
> 48 13 -1.138e-8 4 -5 2 -1 -8 imp:n=100 $air
> 49 15 -1.50 4 -5 3 -2 -8 imp:n=100 $saltcake

```

```

*****
diff file showing differences between base case (no crack) input
and 10 cm crack case

```

```

4c4
< c      10% water saltcake, surface test: none (crack)
--
> c      10% water saltcake, surface test: 10x1 crack
23,24c23,24
< 48 15 -1.50 4 -5 2 -1 -8 imp:n=100 $saltcake
< 49 15 -1.50 4 -5 3 -2 -8 imp:n=100 $saltcake
--
> 48 13 -1.138e-8 4 -5 2 -1 -8 imp:n=100 $air
> 49 13 -1.138e-8 4 -5 3 -2 -8 imp:n=100 $air

```

```

*****
diff file showing differences between base case (hole) input
and base case (no crack under source) input:

```

```

4c4
< c      10% water saltcake, surface test: none
--
> c      10% water saltcake, surface test: none (crack under source)
23,24c23,24
< 48 15 -1.50      2 -1 -8 imp:n=100 $saltcake
< 49 15 -1.50      3 -2 -8 imp:n=100 $saltcake
--
> 48 15 -1.50 4 -5 2 -1 -8 imp:n=100 $saltcake
> 49 15 -1.50 4 -5 3 -2 -8 imp:n=100 $saltcake
27c27
< 52 15 -1.50      -1 101 -102 imp:n=80
--
> 52 15 -1.50 #48 #49 -1 101 -102 imp:n=80
50,51c50,53
< 2 pz -1.00
< 3 pz -2.00
--
> 2 pz -5.00
> 3 pz -10.00
> 4 px -2.00
> 5 px -1.00

```

```

*****
diff file showing differences between base case (no crack) input
and 5 cm crack under source

```

```

4c4
< c      10% water saltcake, surface test: none (crack under source)
--
> c      10% water saltcake, surface test: 5x1 crack under source
23,24c23,24
< 48 15 -1.50 4 -5 2 -1 -8 imp:n=100 $saltcake
< 49 15 -1.50 4 -5 3 -2 -8 imp:n=100 $saltcake
--
> 48 13 -1.138e-8 4 -5 2 -1 -8 imp:n=100 $air
> 49 15 -1.50 4 -5 3 -2 -8 imp:n=100 $saltcake

```

```

*****

```

diff file showing differences between base case (no crack) input
and 10 cm crack under source

```
4c4
< c      10% water saltcake, surface test: none (crack under source)
---
> c      10% water saltcake, surface test: 10x1 crack under source
23,24c23,24
< 48 15 -1.50 4 -5 2 -1 -8      imp:n=100 $saltcake
< 49 15 -1.50 4 -5 3 -2 -8      imp:n=100 $saltcake
---
> 48 13 -1.138e-8 4 -5 2 -1 -8      imp:n=100 $air
> 49 13 -1.138e-8 4 -5 3 -2 -8      imp:n=100 $air

*****
diff file showing differences between base case (hole) input
and base case (no canyon) input:
```

```
4c4
< c      10% water saltcake, surface test: none
---
> c      10% water saltcake, canyon geometry
23,26c23,24
< 48 15 -1.50      2 -1 -8      imp:n=100 $saltcake
< 49 15 -1.50      3 -2 -8      imp:n=100 $saltcake
< 50 15 -1.50 #48 #49 -1      -100 imp:n=100 $saltcake
< 51 15 -1.50 #48 #49 -1 100 -101 imp:n=90 $saltcake
---
> 50 15 -1.50      -1      -100 imp:n=100 $saltcake
> 51 15 -1.50      -1 100 -101 imp:n=90
29,40c27,42
< 54 15 -1.50      -1 103 -104 imp:n=60
< 55 15 -1.50      -1 104 -105 imp:n=50
< 56 15 -1.50      -1 105 -106 imp:n=40
< 57 15 -1.50      -1 106 -107 imp:n=30
< 58 15 -1.50      -1 107 -108 imp:n=15
< 59 15 -1.50      -1 108 -109 imp:n=8
< 60 15 -1.50      -1 109 -110 imp:n=4
< 70 13 -1.138e-3 1      8 -103 imp:n=60 $air
< 71 13 -1.138e-3 1      103 -105 imp:n=25 $air
< 72 13 -1.138e-3 1      105 -107 imp:n=15 $air
< 73 13 -1.138e-3 1      107 -109 imp:n=4 $air
< 74 13 -1.138e-3 1      109 -110 imp:n=1 $air
---
> 54 15 -1.50 #61      -1 103 -104 imp:n=60
> 55 15 -1.50 #61      -1 104 -105 imp:n=50
> 56 15 -1.50 #62      -1 105 -106 imp:n=40
> 57 15 -1.50 #62      -1 106 -107 imp:n=30
> 58 15 -1.50 #63      -1 107 -108 imp:n=15
> 59 15 -1.50 #63      -1 108 -109 imp:n=8
> 60 15 -1.50 #64      -1 109 -110 imp:n=4
> 61 15 -1.50      -1 28 26 -27 103 -105 -110 imp:n=50 $canyon (sc)
> 62 15 -1.50      -1 28 26 -27 105 -107 -110 imp:n=30 $canyon (sc)
> 63 15 -1.50      -1 28 26 -27 107 -109 -110 imp:n=8 $canyon (sc)
> 64 15 -1.50      -1 28 26 -27 109      -110 imp:n=4 $canyon (sc)
> 70 13 -1.138e-3 1      8 -103 imp:n=60 $air
> 71 13 -1.138e-3 1      103 -105 imp:n=25 $air
> 72 13 -1.138e-3 1      105 -107 imp:n=15 $air
> 73 13 -1.138e-3 1      107 -109 imp:n=4 $air
> 74 13 -1.138e-3 1      109 -110 imp:n=1 $air
50,51d51
```

```
< 2 pz -1.00
< 3 pz -2.00
56a57.59
> 26 py -25.0
> 27 py 25.0
> 28 pz -10.0
```

```
*****
diff file showing differences between base case (no canyon) input
and near canyon input:
```

```
4c4
< c 10% water saltcake, canyon geometry
~
> c 10% water saltcake, canyon geometry, near
34c34
< 61 15 -1.50 -1 28 26 -27 103 -105 -110 imp:n=50 $canyon (sc)
~
> 61 13 -1.138e-3 -1 28 26 -27 103 -105 -110 imp:n=50 $canyon (air)
```

```
*****
diff file showing differences between base case (no canyon) input
and far canyon input:
```

```
4c4
< c 10% water saltcake, canyon geometry
~
> c 10% water saltcake, canyon geometry, far
37c37
< 64 15 -1.50 -1 28 26 -27 109 -110 imp:n=4 $canyon (sc)
~
> 64 13 -1.138e-3 -1 28 26 -27 109 -110 imp:n=4 $canyon (air)
```

```
*****
diff file showing differences between base case (no canyon) input
and near, short canyon input:
```

```
4c4
< c 10% water saltcake, canyon geometry
~
> c 10% water saltcake, canyon geometry, near, short
34c34
< 61 15 -1.50 -1 28 26 -27 103 -105 -110 imp:n=50 $canyon (sc)
~
> 61 13 -1.138e-3 -1 28 26 -27 103 -105 -110 imp:n=50 $canyon (air)
57,58c57,58
< 26 py -25.0
< 27 py 25.0
~
> 26 py -5.0
> 27 py 5.0
```

surf15_t11.inp (base case for density and organic parameter studies, density=1.5 g/cm³, no organic)

As-Built Surface Neutron Probe 1/22/96, Rev 0

c Det#1 B-10 TALLY REGION 80-100%

1 6 -2.34 31 -30 27 -28 imp:n=300

c DET#2 B-10 TALLY REGION 80-100%

2 6 -2.34 67 -66 70 -71 imp:n=310

c DET#3 B-10 TALLY REGION 80-100%

3 6 -2.34 78 -77 80 -82 imp:n=300

c narrow part of source housing

4 4 -8.02 (9 7 -2 -5 4) (6:14) imp:n=100

c entrance slot to source cavity

5 13 -.000114 ((16 (-86:87));(-18 -87 86))
 (3 -17 -1 -15) # (107 -106) imp:n=100
 c probe housing bottom
 6 4 -8.02 -4 3 -1 6 #5 #55 imp:n=100
 c Ar/CO2 Det#1
 7 9 -.001 (-29 26 -31);(153 -30 31 -29);(-30 31 -152 26) imp:n=300
 c SS Cathode Det# 1
 8 4 -8.02 26 -29 -23 30 imp:n=225
 c Polyethylene Det#1
 9 3 -0.96 (-21 22 -34 26)(59 :24 :.25) imp:n=200
 c main cadmium Det#1
 10 8 -8.65 (-34 35 21 -20) imp:n=100
 c top cadmium washer det#1
 11 8 -8.65 (-36 35 -21 38 39) imp:n=100
 c bottom cadmium hat det#1
 12 8 -8.65 ((34 -33 -20 22 40);(34 -32 22 -37);(-32 29 -22)) imp:n=100
 c ss clip around det#1
 13 4 -8.02 (20 -19 -33 60) imp:n=100
 c ss plate screwed to cad shield
 14 4 -8.02 (-51 49 -52 95 41 93) imp:n=90
 c cad shield under det#3
 15 8 -8.65 (50 -49 -52 53 41 88 89 90 91 92 93) #53 imp:n=90
 c Aluminum in poly insert of det#1
 16 5 -2.6989 -24 25 22 -21 26 -34 -59 imp:n=150
 c sides of probe housing (bottom third)
 17 4 -8.02 ((-1 2 4 -11);(-4 -6 -1 14)) #5 #54 #55 imp:n=100
 c Ar/CO2 Det#2
 18 9 -.001 (69 -72 -67);(155 67 -66 -72);(-154 67 -66 69) imp:n=310
 c Cathode Det#2
 19 4 -8.02 66 -58 69 -72 imp:n=300
 c ss top Det#2
 20 4 -8.02 -58 72 -73 imp:n=100
 c bottom ss Det#2
 21 4 -8.02 -58 68 -69 imp:n=100
 c Polyethylene Det#2
 22 3 -0.96 58 -56 65 -74 imp:n=200
 c SS mounting sleeve det#2
 23 4 -8.02 (56 -61 65 -74);(64 -65 -61) imp:n=200
 c polyimide bottom det#2
 24 7 1.4 -58 65 -68 imp:n=100
 c polyimide on cadmium plating
 26 7 1.4 62 -63 44 -74 imp:n=100
 c cadmium det#2
 25 8 -8.65 (61 -62 -74 64);(44 -64 -62) imp:n=140
 c SS mounting sleeve
 27 4 -8.02 ((45 63 -41 -75 44);(-44 43 -41 45);
 (4 -43 -41 63 45)) #13 imp:n=110
 c wide part of probe source housing
 28 4 -8.02 (-9 8 -2 4 -5 6) #5 #55 imp:n=100
 c Ar+CO2 gas det#3
 29 9 -.001 (81 -83 -78);(157 -83 78 -77);(-156 81 78 -77) imp:n=300
 c Cathode wall det#3
 30 4 -8.02 77 -76 81 -83 imp:n=200
 c bottom ss det#3
 31 4 -8.02 -76 79 -81 imp:n=100
 c top ss wall det#3
 32 4 -8.02 83 -84 -76 imp:n=100
 c polyimide det#3
 33 7 1.4 (76 -47 -84 79);(51 -79 -47) imp:n=200
 c ss mounting sleeve det#3
 34 4 -8.02 (47 -46 -85 51) imp:n=150
 c polyimide around det#1

35 7 1.4 (23 -22 26 -29) imp:n=200
c air space below cad in probe
36 13 -.000114 (-50 4 -2 41 19 60)(5:-8:(-7 9)) 95 #53 imp:n=100
37 13 -.000114 (-50 4 -2 41 20 -60)(5:-8:(-7 9)) #53 imp:n=100
38 13 -.000114 (37 -2 33 -19):(-37 -2 32) imp:n=100
39 13 -.000114 (-20 -2 -35) imp:n=100
40 13 -.000114 (63 -41 4 -75 -45 -2):(-63 4 -43):(-63 -45 43 -44) imp:n=100
41 13 -.000114 (36 -21 -26):(-38 35 -36):(-21 -39 35 -36) imp:n=100
c ss screws in cad shield
42 4 -8.02 -88 50 -49 imp:n=100
43 4 -8.02 -89 50 -49 imp:n=100
44 4 -8.02 -90 50 -49 imp:n=100
45 4 -8.02 -91 50 -49 imp:n=100
46 4 -8.02 95 -53 50 -49 imp:n=100
47 4 -8.02 -92 50 -49 imp:n=100
c #10 threaded rod
48 4 -8.02 (-129 51 -97):(-51 -95 5) imp:n=100
c main thick wall portion of housing
49 4 -8.02 -12 2 11 -130 imp:n=100
c air above cad plate below top of det#3
50 13 -.000114 (-2 51 -85)((46 41 97):(63 75 -41)
:(58 -63 74):(-73 -58)) 90 88 imp:n=100
c around around cad/ss plate
51 13 -.000114 (-2 52 50 -51 41) imp:n=100
c slot in cad/ss plate for wire pass through
52 13 -.000114 (-93 -51 50) #51 imp:n=100
c det#1 stiffener
53 4 -8.02 98 -99 100 -49 101 -102 imp:n=100
c source holder grab hole
54 13 -.000114 107 -15 -104 imp:n=100
c source holder nut
55 4 -8.02 -106 104 107 -15 imp:n=100
c source holder threads/body
56 4 -8.02 -6 15 -108 imp:n=100
c source capsule
57 4 -8.02 (-109 108 -112 105):(110 -109 -105):
(108 -111 -105) imp:n=100
c air around source capsule
58 13 -.000114 (112 -6 108 -14):(-14 109 -112) imp:n=100
c Pd-Cf2O3 NEUTRON SOURCE
59 1 -10.0 -113 115 -114 imp:n=100
c air around source
60 13 -.000114 -105 111 -110 #59 imp:n=100
c electrical board #1
61 10 -1.21 116 -117 -2 97 90 88 imp:n=100
c threaded rod
62 4 -8.02 51 -129 -90 imp:n=90
c threaded rod
63 4 -8.02 51 -129 -88 imp:n=100
c electrical board #2
64 10 -1.21 120 -121 -2 97 90 88 imp:n=100
c electrical board #3
65 10 -1.21 122 -123 -2 97 90 88 imp:n=100
c electrical board #4
66 10 -1.21 126 -127 -2 97 90 88 imp:n=100
c air above top of det#3 below first electrical board
67 13 -.000114 (-2 85 -116 90 88 97 47):(-47 84 -116) imp:n=90
c air between board 1 and ss plate 40
68 13 -.000114 (-2 117 -118 90 88 97) imp:n=90
c air between ss plate 40 and board #2
69 13 -.000114 (-2 119 -120 90 88 97) imp:n=90
c air between board #2 and board #3

70 13 -.000114 (-2 121 -122 90 88 97) imp:n=90
c SS ground Plane #40
71 4 -8.02 118 -119 -2 97 90 88 imp:n=90
c SS ground Plane #41
72 4 -8.02 124 -125 -2 97 90 88 imp:n=90
c SS ground Plane #39
73 4 -8.02 128 -129 -2 97 90 88 imp:n=90
c air between board #3 and SS plate #41
74 13 -.000114 (-2 123 -124 90 88 97) imp:n=90
c air between SS plate #41 and board #4
75 13 -.000114 (-2 125 -126 90 88 97) imp:n=90
c air between board #4 & SS plate #39
76 13 -.000114 (-2 127 -128 90 88 97) imp:n=90
c bottom of cablehead
77 4 -8.02 103 -130 -12 131 #49 imp:n=70
c air between board #4 & SS plate #39
78 13 -.000114 -2 129 -103 imp:n=70
c cablehead nut
79 4 -8.02 130 -132 131 -12 imp:n=50
c cablehead neck
80 4 -8.02 132 -133 131 -134 imp:n=50
c air around cablehead neck
81 13 -.000114 132 -133 134 -12 imp:n=40
c cable
82 13 -.000114 103 -133 -131 imp:n=50
C air around probe
83 13 -.000114 -200 3 ((1 -11):(12 11):133) imp:n=100
84 14 -1.5 -200 -10 -3 54 imp:n=100
85 14 -1.5 -200 -10 -54 55 imp:n=60
86 14 -1.5 -200 -10 -55 imp:n=30
87 14 -1.5 -200 10 -3 54 imp:n=90
88 14 -1.5 -200 10 -54 55 imp:n=50
89 14 -1.5 -200 10 -55 imp:n=20
c extended B10 coating bottom of det#1
104 6 -2.34 31 -30 152 -27 imp:n=300
c extended B10 coating top of det#1
105 6 -2.34 31 -30 28 -153 imp:n=300
c extended B10 coating bottom of det#2
106 6 -2.34 67 -66 154 -70 imp:n=300
c extended B10 coating top of det#2
107 6 -2.34 67 -66 71 -155 imp:n=300
c extended B10 coating bottom of det#2
108 6 -2.34 78 -77 156 -80 imp:n=300
c extended B10 coating top of det#2
109 6 -2.34 78 -77 82 -157 imp:n=300
110 13 -.000114 -40 -20 22 34 -33 37 imp:n=90
c temp outside
150 0 200 imp:n=0

1 cz 4.2138599
2 cz 3.8963599
3 pz 0.0000000
10 cz 25.00
54 pz -34.000
55 pz -69.000
4 pz 0.3175000
5 pz 1.5367000
c outer source hole
6 c/y 3.0480000 0.6604000 0.3568700
7 px 2.5400000
8 px 2.1844000
9 py -0.7112000

c top of thin wall section of probe housing
11 pz 10.426700
c outer diameter of thick part (upper 2/3) of probe housing
12 cz 4.3815
13 pz 44.754799
14 py 1.5240000
15 py -1.7780000
16 px 2.3368000
17 pz 1.2954000
18 c/y 2.9718000 0.6604000 0.6350000
19 c/y 0.0000000 1.7578 1.41478
20 c/y 0.0000000 1.76000 1.28778
21 c/y 0.0000000 1.76000 1.1480800
22 c/y 0.0000000 1.76000 0.6400800
23 c/y 0.0000000 1.76000 0.6350000
24 p 0.3400000 0.0000000 1.0000000 2.3825200
25 p 0.3400000 0.0000000 1.0000000 1.0833100
26 py -2.1285200
27 py -0.6299200
28 py 2.3164800
29 py 3.5864799
30 c/y 0.0000000 1.76000 0.5588000
c Inner B-10 lining 0.4 mg/cm2
31 c/y 0.0000000 1.76000 0.5586265
32 py 3.72618
33 py 2.77622
34 py 2.6365200
35 py -3.05562
36 py -2.9159200
37 c/y 0.0000000 1.76000 0.77978
38 c/y 0.0000000 1.76000 0.3175000
39 c/y 0.0000000 2.73260 0.3175000
40 c/y 0.822 1.41 0.3175
c Hole in Cad under Det#3 for support rod
41 c/z -2.6974800 0.0000000 1.26492
43 pz 0.47498
44 pz 0.62738
45 px -3.3400999
46 cz 0.7937500
47 cz 0.6489700
48 pz 11.772900
49 pz 4.5084999
50 pz 4.3433999
c top of ss plate below det#3
51 pz 4.6659799
c radius of cad/SS shield
52 cz 3.8353999
53 c/z 3.0162500 0.0000000 0.5041900
c inner polyethylene inner Det#2
c poly outer Det#2
56 c/z -2.6974800 0.0000000 1.0096500
c poly inner Det#2
57 c/z -2.6974800 0.0000000 0.6489700
58 c/z -2.6974800 0.0000000 0.6350000
59 p -16.436870 0.0000000 1.0000000 2.3825200
60 py -0.8970000
c inner ss cad-plated peice for det#2
c SS plated piece outer det#2
61 c/z -2.6974800 0.0000000 1.1112500
c 0.003" Cad outer Det#2
62 c/z -2.6974800 0.0000000 1.11379
c polyimide outer

63 c/z -2.6974800 0.0000000 1.11887
c Inner bottom cadmium Det#2
64 pz 0.62992
c Inside bottom ss plated peice det#2
65 pz 0.71882
c inner cathode det#2
66 c/z -2.6974800 0.0000000 0.5588000
c inner B-10 coating det#2
67 c/z -2.6974800 0.0000000 0.5586265
c inner top polyimide det#2
68 pz 0.7239
c inner bottom ss cathode det#2
c Bottom Active Region DET#2
69 pz 0.8001
70 pz 2.1590000
c top active region det#2
71 pz 6.4769999
c Inside top Det#2
72 pz 7.8993999
c Top of Det#2
73 pz 7.9755999
c top of polyethylene det#2
74 pz 7.7165199
c top of ss mounting sleeve det#2
75 pz 7.2008999
c Inner polyimid det#3
76 cz 0.6438900
c inner cathode Det#3
77 cz 0.5676900
c Inner B-10 lining Det#3
78 cz 0.5675165
c bottom Det#3
79 pz 4.6710599
c bottom active region det#3
80 pz 6.1696599
c inside bottom det#3
81 pz 4.7472599
c top active region det#3
82 pz 10.487660
c inside top det#3
83 pz 11.910060
c det#3
84 pz 11.986260
c top mounting sleeve det#3
85 pz 11.650980
c through source slot
86 pz 0.6604
c through source slot
87 px 2.9718
c screw in cad shield X Y R
88 c/z -1.51 -2.6 0.18669
c screw in cad shield X Y R
89 c/z -2.41 -1.82 0.18669
c screw in cad shield X Y R
90 c/z -1.51 2.6 0.18669
c screw in cad shield X Y R
91 c/z -0.37 2.99 0.18669
c screw in cad shield X Y R
92 c/z 2.78 -1.18 0.18669
c slot in cad shield X Y R
93 c/z -.45 -3.40 0.4572
c #10 threaded rod OD

95 c/z 3.01625 0.0.2413
 c top of thick walled outer housing (17.875 in.)
 96 pz 45.4025
 c standoff around #10 threaded rod
 97 c/z 3.01625 0.0.3937
 c left side of det#1 stiffener
 98 px 1.44028
 c right side of det#1 stiffener
 99 px 1.51648
 c bottom of det#1 stiffener
 100 pz 1.5367
 c front edge of det#1 stiffener
 101 py -1.27
 c back edge of det#1 stiffener
 102 py 1.27
 c bottom of cable head
 103 pz 41.529
 c source holder threaded grab hole radius
 104 c/y 3.0480000 0.6604000 0.207
 c source capsule ID
 105 c/y 3.0480000 0.6604000 0.196
 c source holder nut radius
 106 c/y 3.0480000 0.6604000 0.40
 c source holder nut end
 107 py -2.16
 c source holder thread/capsule interface
 108 py -0.686
 c source holder capsule end
 109 py 0.686
 c source capsule inner bottom end
 110 py 0.450
 c source capsule inner top end
 111 py -0.165
 c source capsule/holder OD
 112 c/y 3.0480000 0.6604000 0.3175
 c source OD
 113 c/y 3.0480000 0.6604000 0.00935
 c source top
 114 py 0.15185
 c source bottom
 115 py 0.13315
 c bottom (#1) electrical board (bottom)
 116 pz 16.756
 c bottom (#1) electrical board (top)
 117 pz 16.914
 c (#40) electrical SS ground plane (bottom)
 118 pz 18.971
 c (#40) electrical SS ground plane (top)
 119 pz 19.129
 c (#2) electrical board (bottom)
 120 pz 20.551
 c (#2) electrical board (top)
 121 pz 20.708
 c (#3) electrical board (bottom)
 122 pz 24.188
 c (#3) electrical board (top)
 123 pz 24.345
 c (#41) electrical SS ground plane (bottom)
 124 pz 28.307
 c (#41) electrical SS ground plane (top)
 125 pz 28.460
 c (#4) electrical board (bottom)

126 pz 29.882
 c (#4) electrical board (top)
 127 pz 30.04
 c (#39) electrical SS ground plane (bottom)
 128 pz 31.462
 c (#39) electrical SS ground plane (top)
 129 pz 31.615
 c top shoulder of cable head
 130 pz 43.74
 c cable OD
 131 cz 1.06
 c approx top cable head nut
 132 pz 46.92
 c top of cable head
 133 pz 52.73
 c OD of cable head neck
 134 cz 1.4
 c extension of B10 coating at bottom of det#1
 152 py -1.430
 c extension of B10 coating at top of det#1
 153 py 3.116
 c extension of B10 coating at bottom of det#2
 154 pz 1.245
 c extension of B10 coating at top of det#2
 155 pz 7.391
 c extension of B10 coating at bottom of det#3
 156 pz 5.256
 c extension of B10 coating at top of det#3
 157 pz 11.402
 c inner B-10 coating 70% det#1
 160 c/y 0.0 1.76 0.558679
 c inner B-10 coating 60% det#1
 161 c/y 0.0 1.76 0.558696
 c inner B-10 coating 50% det#1
 162 c/y 0.0 1.76 0.558713
 c inner B-10 coating 40% det#1
 163 c/y 0.0 1.76 0.558731
 c inner B-10 coating 30% det#1
 164 c/y 0.0 1.76 0.558748
 c inner B-10 coating 20% det#1
 165 c/y 0.0 1.76 0.558766
 c inner B-10 coating 10% det#1
 166 c/y 0.0 1.76 0.558783
 c inner B-10 coating 70% det#2
 167 c/z -2.69748 0.0 0.558679
 c inner B-10 coating 60% det#2
 168 c/z -2.69748 0.0 0.558696
 c inner B-10 coating 50% det#2
 169 c/z -2.69748 0.0 0.558713
 c inner B-10 coating 40% det#2
 170 c/z -2.69748 0.0 0.558731
 c inner B-10 coating 30% det#2
 171 c/z -2.69748 0.0 0.558748
 c inner B-10 coating 20% det#2
 172 c/z -2.69748 0.0 0.558766
 c inner B-10 coating 10% det#2
 173 c/z -2.69748 0.0 0.558783
 c inner B-10 coating 70% det#3
 174 cz 0.567569
 c inner B-10 coating 60% det#3
 175 cz 0.567586
 c inner B-10 coating 50% det#3

```

176 cz 0.567603
c inner B-10 coating 40% det#3
177 cz 0.567621
c inner B-10 coating 30% det#3
178 cz 0.567638
c inner B-10 coating 20% det#3
179 cz 0.567656
c inner B-10 coating 10% det#3
180 cz 0.567673
c outside sphere
200 so 100

mode n
c phys:n 20 20
c idum 4j -7
c 15.0 micrograms Cf-252
sdef cel d1 pos fcel d2 axs 0 1 0 ext fcel d3
rad fcel d4 wgt=3.47e7 erg d5
sc1 source cell is Cf-252 source in cell 59
sil 1 59
sp1 d 1.0
sc2 source location is centered in cell 59
ds2 1 3.048 0.1425 0.6604
sc3 source extent
ds3 s 6
sc4 source radius
ds4 s 7
sc5 energy distribution: Cf-252 Watt Spontaneous Fission Spectrum
sp5 -3 1.025 2.926
sc6 source extent is 0.0187 centimeter total length
si6 0.00935
sp6 -21 0
sc7 source radius is .00935 centimeters
si7 0.0 0.00935
sp7 -21 1
f4:n 1 $ detector regions
c 0.1409 (B-10 atoms)/(barn-cm)
fm4 0.1409 6 207 $(n,alpha) interactions
f14:n 2 $ detector regions
fm14 0.1409 6 207 $(n,alpha) interactions
f24:n 3 $ detector regions
fm24 0.1409 6 207 $(n,alpha) interactions
c Cf-252 - Pd-Cf2O3
m1 98252.35c -0.119
98250.35c -0.069
8016.50c -0.018
46105.50c -0.363
46108.50c -0.431
c UHMW Polyethylene (0.96 g/cm3)
m3 1001.50c 2.000000
6000.50c 1.000000
m3t poly.01t
c 304 stainless steel (8.02 g/cm3)
m4 6000.50c -0.08
25055.50c -2.0
15031.50c -0.045
16032.50c -0.03
14000.50c -0.75
24000.50c -19.0
26000.55c -68.245
7014.50c -0.1
28000.50c -9.75

```

```

c          6061 Aluminum (2.6989 g/cm3)
m5  13027.50c -97.92
    14000.50c -0.6
    29000.50c -0.28
    12000.50c -1.0
    24000.50c -0.2
c          B-10 92% enriched (2.34g/cm3)
m6  5010.50c -.92
    5011.50c -0.08
c          polyimide (1.4 g/cm3)
m7  6000.50c 22
    1001.50c 14
    8016.50c 7
    7014.50c 2
m7t poly.01t
c          cadmium (8.65 g/cm3)
m8  48000.50c -1.00
c          90%Ar + 10%CO2
m9  6000.50c -0.027
    8016.50c -0.073
    18000.35c -0.900
c          fiberglass/copper electrical boards
m10 1001.50c -0.0453
    5010.50c -0.00228    $ 8.1 wt% B2O3, 50 wt% fiber, 50 wt% epoxy
    5011.50c -0.010206
    6000.50c -0.282
    8016.50c -0.4107
    11023.50c -0.0103
    12000.50c -0.0225
    13027.50c -0.0337
    14000.50c -0.1178
    16032.50c -0.000399
    20000.50c -0.0737
    22000.50c -0.00686
    26000.55c -0.00412
m10t poly.01t    $ hydrogen in poylethylene 300 K
c          air (1.138e-3 g/cm3)
m13 7014.50c 0.8000
    8016.50c 0.2000
m14 1001.50c -1.6979
    7014.50c -12.5009
    8016.50c -59.4129
    11023.50c -24.1771
    12000.50c -0.0316
    13027.50c -1.2297
    14000.50c -0.2886
    15031.50c -0.1276
    20000.50c -0.1178
    25055.50c -0.0592
    26000.55c -0.3564
m14t lwtr.01t
totnu
nps 80000000
print 60 120 126 140

```

```

surfab15-1.1_t11.inp (waste density =1.1 g/cm³)
162,167c162,168
< 84 14 -1.5 -200 -10 -3 54 imp:n=100
< 85 14 -1.5 -200 -10 -54 55 imp:n=60

```



```

< 86 14 -1.5 -200 -10 -55 imp:n=30
< 87 14 -1.5 -200 10 -3 54 imp:n=90
< 88 14 -1.5 -200 10 -54 55 imp:n=50
< 89 14 -1.5 -200 10 -55 imp:n=20
--
> c tank waste
> 84 14 -1.10 -200 -10 -3 54 imp:n=100
> 85 14 -1.10 -200 -10 -54 55 imp:n=60
> 86 14 -1.10 -200 -10 -55 imp:n=30
> 87 14 -1.10 -200 10 -3 54 imp:n=90
> 88 14 -1.10 -200 10 -54 55 imp:n=50
> 89 14 -1.10 -200 10 -55 imp:n=20
559c560
< nps 80000000
--
> nps 28000000

```

surfab15-1.2_t11.inp (waste density =1.2 g/cm³)
162,167c162,168

```

< 84 14 -1.5 -200 -10 -3 54 imp:n=100
< 85 14 -1.5 -200 -10 -54 55 imp:n=60
< 86 14 -1.5 -200 -10 -55 imp:n=30
< 87 14 -1.5 -200 10 -3 54 imp:n=90
< 88 14 -1.5 -200 10 -54 55 imp:n=50
< 89 14 -1.5 -200 10 -55 imp:n=20
--
> c tank waste
> 84 14 -1.20 -200 -10 -3 54 imp:n=100
> 85 14 -1.20 -200 -10 -54 55 imp:n=60
> 86 14 -1.20 -200 -10 -55 imp:n=30
> 87 14 -1.20 -200 10 -3 54 imp:n=90
> 88 14 -1.20 -200 10 -54 55 imp:n=50
> 89 14 -1.20 -200 10 -55 imp:n=20
559c560
< nps 80000000
--
> nps 28000000

```

surfab15-1.3_t11.inp (waste density =1.3 g/cm³)
162,167c162,168

```

< 84 14 -1.5 -200 -10 -3 54 imp:n=100
< 85 14 -1.5 -200 -10 -54 55 imp:n=60
< 86 14 -1.5 -200 -10 -55 imp:n=30
< 87 14 -1.5 -200 10 -3 54 imp:n=90
< 88 14 -1.5 -200 10 -54 55 imp:n=50
< 89 14 -1.5 -200 10 -55 imp:n=20
--
> c tank waste
> 84 14 -1.30 -200 -10 -3 54 imp:n=100
> 85 14 -1.30 -200 -10 -54 55 imp:n=60
> 86 14 -1.30 -200 -10 -55 imp:n=30
> 87 14 -1.30 -200 10 -3 54 imp:n=90
> 88 14 -1.30 -200 10 -54 55 imp:n=50
> 89 14 -1.30 -200 10 -55 imp:n=20
559c560
< nps 80000000
--
> nps 28000000

```

surfab15-1.4_t11.inp (waste density =1.4 g/cm³)

162,167c162,168

```
< 84 14 -1.5 -200 -10 -3 54 imp:n=100
< 85 14 -1.5 -200 -10 -54 55 imp:n=60
< 86 14 -1.5 -200 -10 -55 imp:n=30
< 87 14 -1.5 -200 10 -3 54 imp:n=90
< 88 14 -1.5 -200 10 -54 55 imp:n=50
< 89 14 -1.5 -200 10 -55 imp:n=20
```

—

> c tank waste

```
> 84 14 -1.40 -200 -10 -3 54 imp:n=100
> 85 14 -1.40 -200 -10 -54 55 imp:n=60
> 86 14 -1.40 -200 -10 -55 imp:n=30
> 87 14 -1.40 -200 10 -3 54 imp:n=90
> 88 14 -1.40 -200 10 -54 55 imp:n=50
> 89 14 -1.40 -200 10 -55 imp:n=20
```

559c560

< nps 80000000

—

> nps 28000000

surfab15-1.6_t11.inp (waste density =1.6 g/cm³)

162,167c162,168

```
< 84 14 -1.5 -200 -10 -3 54 imp:n=100
< 85 14 -1.5 -200 -10 -54 55 imp:n=60
< 86 14 -1.5 -200 -10 -55 imp:n=30
< 87 14 -1.5 -200 10 -3 54 imp:n=90
< 88 14 -1.5 -200 10 -54 55 imp:n=50
< 89 14 -1.5 -200 10 -55 imp:n=20
```

—

> c tank waste

```
> 84 14 -1.60 -200 -10 -3 54 imp:n=100
> 85 14 -1.60 -200 -10 -54 55 imp:n=60
> 86 14 -1.60 -200 -10 -55 imp:n=30
> 87 14 -1.60 -200 10 -3 54 imp:n=90
> 88 14 -1.60 -200 10 -54 55 imp:n=50
> 89 14 -1.60 -200 10 -55 imp:n=20
```

559c560

< nps 80000000

—

> nps 28000000

surfab15-1.7_t11.inp (waste density =1.7 g/cm³)

162,167c162,168

```
< 84 14 -1.5 -200 -10 -3 54 imp:n=100
< 85 14 -1.5 -200 -10 -54 55 imp:n=60
< 86 14 -1.5 -200 -10 -55 imp:n=30
< 87 14 -1.5 -200 10 -3 54 imp:n=90
< 88 14 -1.5 -200 10 -54 55 imp:n=50
< 89 14 -1.5 -200 10 -55 imp:n=20
```

—

> c tank waste

```
> 84 14 -1.70 -200 -10 -3 54 imp:n=100
> 85 14 -1.70 -200 -10 -54 55 imp:n=60
> 86 14 -1.70 -200 -10 -55 imp:n=30
> 87 14 -1.70 -200 10 -3 54 imp:n=90
> 88 14 -1.70 -200 10 -54 55 imp:n=50
> 89 14 -1.70 -200 10 -55 imp:n=20
```

559c560

```
< nps 80000000
---
> nps 28000000
```

```
surfab15-1.8_t11.inp (waste density =1.8 g/cm³)
162,167c162,168
```

```
< 84 14 -1.5 -200 -10 -3 54 imp:n=100
< 85 14 -1.5 -200 -10 -54 55 imp:n=60
< 86 14 -1.5 -200 -10 -55 imp:n=30
< 87 14 -1.5 -200 10 -3 54 imp:n=90
< 88 14 -1.5 -200 10 -54 55 imp:n=50
< 89 14 -1.5 -200 10 -55 imp:n=20
```

```
---
> c tank waste
> 84 14 -1.80 -200 -10 -3 54 imp:n=100
> 85 14 -1.80 -200 -10 -54 55 imp:n=60
> 86 14 -1.80 -200 -10 -55 imp:n=30
> 87 14 -1.80 -200 10 -3 54 imp:n=90
> 88 14 -1.80 -200 10 -54 55 imp:n=50
> 89 14 -1.80 -200 10 -55 imp:n=20
```

```
559c560
< nps 80000000
---
> nps 28000000
```

```
surfab15-1.9_t11.inp (waste density =1.9 g/cm³)
162,167c162,168
```

```
< 84 14 -1.5 -200 -10 -3 54 imp:n=100
< 85 14 -1.5 -200 -10 -54 55 imp:n=60
< 86 14 -1.5 -200 -10 -55 imp:n=30
< 87 14 -1.5 -200 10 -3 54 imp:n=90
< 88 14 -1.5 -200 10 -54 55 imp:n=50
< 89 14 -1.5 -200 10 -55 imp:n=20
```

```
---
> c tank waste
> 84 14 -1.90 -200 -10 -3 54 imp:n=100
> 85 14 -1.90 -200 -10 -54 55 imp:n=60
> 86 14 -1.90 -200 -10 -55 imp:n=30
> 87 14 -1.90 -200 10 -3 54 imp:n=90
> 88 14 -1.90 -200 10 -54 55 imp:n=50
> 89 14 -1.90 -200 10 -55 imp:n=20
```

```
559c560
< nps 80000000
---
> nps 28000000
```

```
*****
surfab0_t11.inp (base case for moisture dependence cases: 0 wt% water)
```

As-Built Surface Neutron Probe 1/22/96, Rev 0

```
c Det#1 B-10 TALLY REGION 80-100%
  1 6 -2.34 31 -30 27 -28 imp:n=300
c DET#2 B-10 TALLY REGION 80-100%
  2 6 -2.34 67 -66 70 -71 imp:n=310
c DET#3 B-10 TALLY REGION 80-100%
  3 6 -2.34 78 -77 80 -82 imp:n=300
c narrow part of source housing
  4 4 -8.02 (9 7 -2 -5 4) (6:14) imp:n=100
```

c entrance slot to source cavity
5 13 -.000114 ((16 (-86:87));(-18 -87 86))
(3 -17 -1 -15) # (107 -106) imp:n=100

c probe housing bottom
6 4 -8.02 -4 3 -1 6 #55 imp:n=100

c Ar/CO2 Det#1
7 9 -.001 (-29 26 -31);(153 -30 31 -29);(-30 31 -152 26) imp:n=300

c SS Cathode Det# 1
8 4 -8.02 26 -29 -23 30 imp:n=225

c Polyethylene Det#1
9 3 -0.96 (-21 22 -34 26)(59 :24 :-25) imp:n=200

c main cadmium Det#1
10 8 -8.65 (-34 35 21 -20) imp:n=100

c top cadmium washer det#1
11 8 -8.65 (-36 35 -21 38 39) imp:n=100

c bottom cadmium hat det#1
12 8 -8.65 ((34 -33 -20 22 40);(34 -32 22 -37);(-32 29 -22)) imp:n=100

c ss clip around det#1
13 4 -8.02 (20 -19 -33 60) imp:n=100

c ss plate screwed to cad shield
14 4 -8.02 (-51 49 -52 95 41 93) imp:n=90

c cad shield under det#3
15 8 -8.65 (50 -49 -52 53 41 88 89 90 91 92 93) #53 imp:n=90

c Aluminum in poly insert of det#1
16 5 -2.6989 -24 25 22 -21 26 -34 -59 imp:n=150

c sides of probe housing (bottom third)
17 4 -8.02 ((-1 2 4 -11);(-4 -6 -1 14)) #5 #54 #55 imp:n=100

c Ar/CO2 Det#2
18 9 -.001 (69 -72 -67);(155 67 -66 -72);(-154 67 -66 69) imp:n=310

c Cathode Det#2
19 4 -8.02 66 -58 69 -72 imp:n=300

c ss top Det#2
20 4 -8.02 -58 72 -73 imp:n=100

c bottom ss Det#2
21 4 -8.02 -58 68 -69 imp:n=100

c Polyethylene Det#2
22 3 -0.96 58 -56 65 -74 imp:n=200

c SS mounting sleeve det#2
23 4 -8.02 (56 -61 65 -74);(64 -65 -61) imp:n=200

c polyimide bottom det#2
24 7 1.4 -58 65 -68 imp:n=100

c polyimide on cadmium plating
26 7 1.4 62 -63 44 -74 imp:n=100

c cadmium det#2
25 8 -8.65 (61 -62 -74 64);(44 -64 -62) imp:n=140

c SS mounting sleeve
27 4 -8.02 ((45 63 -41 -75 44);(-44 43 -41 45);
(4 -43 -41 63 45)) #13 imp:n=110

c wide part of probe source housing
28 4 -8.02 (-9 8 -2 4 -5 6) #5 #55 imp:n=100

c Ar+CO2 gas det#3
29 9 -.001 (81 -83 -78);(157 -83 78 -77);(-156 81 78 -77) imp:n=300

c Cathode wall det#3
30 4 -8.02 77 -76 81 -83 imp:n=200

c bottom ss det#3
31 4 -8.02 -76 79 -81 imp:n=100

c top ss wall det#3
32 4 -8.02 83 -84 -76 imp:n=100

c polyimide det#3
33 7 1.4 (76 -47 -84 79);(51 -79 -47) imp:n=200

c ss mounting sleeve det#3
34 4 -8.02 (47 -46 -85 51) imp:n=150

c polyimide around det#1
 35 7 1.4 (23-22 26 -29) imp:n=200

c air space below cad in probe
 36 13 -.000114 (-50 4 -2 41 19 60)(5:-8:(-7 9)) 95 #53 imp:n=100
 37 13 -.000114 (-50 4 -2 41 20 -60)(5:-8:(-7 9)) #53 imp:n=100
 38 13 -.000114 (37 -2 33 -19);(-37 -2 32) imp:n=100
 39 13 -.000114 (-20 -2 -35) imp:n=100
 40 13 -.000114 (63 -41 4 -75 -45 -2);(-63 4 -43);(-63 -45 43 -44) imp:n=100
 41 13 -.000114 (36 -21 -26);(-38 35 -36);(-21 -39 35 -36) imp:n=100

c ss screws in cad shield
 42 4 -8.02 -88 50 -49 imp:n=100
 43 4 -8.02 -89 50 -49 imp:n=100
 44 4 -8.02 -90 50 -49 imp:n=100
 45 4 -8.02 -91 50 -49 imp:n=100
 46 4 -8.02 95 -53 50 -49 imp:n=100
 47 4 -8.02 -92 50 -49 imp:n=100

c #10 threaded rod
 48 4 -8.02 (-129 51 -97);(-51 -95 5) imp:n=100

c main thick wall portion of housing
 49 4 -8.02 -12 2 11 -130 imp:n=100

c air above cad plate below top of det#3
 50 13 -.000114 (-2 51 -85)((46 41 97);(63 75 -41);
 (58 -63 74);(73 -58)) 90 88 imp:n=100

c around around cad/ss plate
 51 13 -.000114 (-2 52 50 -51 41) imp:n=100

c slot in cad/ss plate for wire pass through
 52 13 -.000114 (-93 -51 50) #51 imp:n=100

c det#1 stiffener
 53 4 -8.02 98 -99 100 -49 101 -102 imp:n=100

c source holder grab hole
 54 13 -.000114 107 -15 -104 imp:n=100

c source holder nut
 55 4 -8.02 -106 104 107 -15 imp:n=100

c source holder threads/body
 56 4 -8.02 -6 15 -108 imp:n=100

c source capsule
 57 4 -8.02 (-109 108 -112 105);(110 -109 -105);
 (108 -111 -105) imp:n=100

c air around source capsule
 58 13 -.000114 (112 -6 108 -14);(-14 109 -112) imp:n=100

c Pd-Cf2O3 NEUTRON SOURCE
 59 1 -10.0 -113 115 -114 imp:n=100

c air around source
 60 13 -.000114 -105 111 -110 #59 imp:n=100

c electrical board #1
 61 10 -1.21 116 -117 -2 97 90 88 imp:n=100

c threaded rod
 62 4 -8.02 51 -129 -90 imp:n=90

c threaded rod
 63 4 -8.02 51 -129 -88 imp:n=100

c electrical board #2
 64 10 -1.21 120 -121 -2 97 90 88 imp:n=100

c electrical board #3
 65 10 -1.21 122 -123 -2 97 90 88 imp:n=100

c electrical board #4
 66 10 -1.21 126 -127 -2 97 90 88 imp:n=100

c air above top of det#3 below first electrical board
 67 13 -.000114 (-2 85 -116 90 88 97 47);(-47 84 -116) imp:n=90

c air between board 1 and ss plate 40
 68 13 -.000114 (-2 117 -118 90 88 97) imp:n=90

c air between ss plate 40 and board #2
 69 13 -.000114 (-2 119 -120 90 88 97) imp:n=90

c air between board #2 and board #3
70 13 -.000114 (-2 121 -122 90 88 97) imp:n=90
c SS ground Plane #40
71 4 -8.02 118 -119 -2 97 90 88 imp:n=90
c SS ground Plane #41
72 4 -8.02 124 -125 -2 97 90 88 imp:n=90
c SS ground Plane #39
73 4 -8.02 128 -129 -2 97 90 88 imp:n=90
c air between board #3 and SS plate #41
74 13 -.000114 (-2 123 -124 90 88 97) imp:n=90
c air between SS plate #41 and board #4
75 13 -.000114 (-2 125 -126 90 88 97) imp:n=90
c air between board #4 & SS plate #39
76 13 -.000114 (-2 127 -128 90 88 97) imp:n=90
c bottom of cablehead
77 4 -8.02 103 -130 -12 131 #49 imp:n=70
c air between board #4 & SS plate #39
78 13 -.000114 -2 129 -103 imp:n=70
c cablehead nut
79 4 -8.02 130 -132 131 -12 imp:n=50
c cablehead neck
80 4 -8.02 132 -133 131 -134 imp:n=50
c air around cablehead neck
81 13 -.000114 132 -133 134 -12 imp:n=40
c cable
82 13 -.000114 103 -133 -131 imp:n=50
C air around probe
83 13 -.000114 -200 3 ((1 -11):(12 11):133) imp:n=100
84 14 -1.5 -200 -10 -3 54 imp:n=100
85 14 -1.5 -200 -10 -54 55 imp:n=60
86 14 -1.5 -200 -10 -55 imp:n=30
87 14 -1.5 -200 10 -3 54 imp:n=90
88 14 -1.5 -200 10 -54 55 imp:n=50
89 14 -1.5 -200 10 -55 imp:n=20
c extended B10 coating bottom of det#1
104 6 -2.34 31 -30 152 -27 imp:n=300
c extended B10 coating top of det#1
105 6 -2.34 31 -30 28 -153 imp:n=300
c extended B10 coating bottom of det#2
106 6 -2.34 67 -66 154 -70 imp:n=300
c extended B10 coating top of det#2
107 6 -2.34 67 -66 71 -155 imp:n=300
c extended B10 coating bottom of det#2
108 6 -2.34 78 -77 156 -80 imp:n=300
c extended B10 coating top of det#2
109 6 -2.34 78 -77 82 -157 imp:n=300
110 13 -.000114 -40 -20 22 34 -33 37 imp:n=90
c temp outside
150 0 200 imp:n=0

1 cz 4.2138599
2 cz 3.8963599
3 pz 0.0000000
10 cz 25.00
54 pz -34.000
55 pz -69.000
4 pz 0.3175000
5 pz 1.5367000
c outer source hole
6 c/y 3.0480000 0.6604000 0.3568700
7 px 2.5400000
8 px 2.1844000

9	py	-0.7112000		
c top of thin wall section of probe housing				
11	pz	10.426700		
c outer diameter of thick part (upper 2/3) of probe housing				
12	cz	4.3815		
13	pz	44.754799		
14	py	1.5240000		
15	py	-1.7780000		
16	px	2.3368000		
17	pz	1.2954000		
18	c/y	2.9718000	0.6604000	0.6350000
19	c/y	0.0000000	1.7578	1.41478
20	c/y	0.0000000	1.76000	1.28778
21	c/y	0.0000000	1.76000	1.1480800
22	c/y	0.0000000	1.76000	0.6400800
23	c/y	0.0000000	1.76000	0.6350000
24	p	0.3400000	0.0000000	1.0000000 2.3825200
25	p	0.3400000	0.0000000	1.0000000 1.0833100
26	py	-2.1285200		
27	py	-0.6299200		
28	py	2.3164800		
29	py	3.5864799		
30	c/y	0.0000000	1.76000	0.5588000
c Inner B-10 lining 0.4 mg/cm2				
31	c/y	0.0000000	1.76000	0.5586265
32	py	3.72618		
33	py	2.77622		
34	py	2.6365200		
35	py	-3.05562		
36	py	-2.9159200		
37	c/y	0.0000000	1.76000	0.77978
38	c/y	0.0000000	1.76000	0.3175000
39	c/y	0.0000000	2.73260	0.3175000
40	c/y	0.822 1.41 0.3175		
c Hole in Cad under Det#3 for support rod				
41	c/z	-2.6974800	0.0000000	1.26492
43	pz	0.47498		
44	pz	0.62738		
45	px	-3.3400999		
46	cz	0.7937500		
47	cz	0.6489700		
48	pz	11.772900		
49	pz	4.5084999		
50	pz	4.3433999		
c top of ss plate below det#3				
51	pz	4.6659799		
c radius of cad/SS shield				
52	cz	3.8353999		
53	c/z	3.0162500	0.0000000	0.5041900
c inner polyethylene inner Det#2				
c poly outer Det#2				
56	c/z	-2.6974800	0.0000000	1.0096500
c poly inner Det#2				
57	c/z	-2.6974800	0.0000000	0.6489700
58	c/z	-2.6974800	0.0000000	0.6350000
59	p	-16.436870	0.0000000	1.0000000 2.3825200
60	py	-0.8970000		
c inner ss cad-plated peice for det#2				
c SS plated piece outer det#2				
61	c/z	-2.6974800	0.0000000	1.1112500
c 0.003" Cad outer Det#2				
62	c/z	-2.6974800	0.0000000	1.11379

c polyimide outer
 63 c/z -2.6974800 0.0000000 1.11887
 c Inner bottom cadmium Det#2
 64 pz 0.62992
 c Inside bottom ss plated peice det#2
 65 pz 0.71882
 c inner cathode det#2
 66 c/z -2.6974800 0.0000000 0.5588000
 c inner B-10 coating det#2
 67 c/z -2.6974800 0.0000000 0.5586265
 c inner top polyimide det#2
 68 pz 0.7239
 c inner bottom ss cathode det#2
 c Bottom Active Region DET#2
 69 pz 0.8001
 70 pz 2.1590000
 c top active region det#2
 71 pz 6.4769999
 c Inside top Det#2
 72 pz 7.8993999
 c Top of Det#2
 73 pz 7.9755999
 c top of polyethylene det#2
 74 pz 7.7165199
 c top of ss mounting sleeve det#2
 75 pz 7.2008999
 c Inner polyimid det#3
 76 cz 0.6438900
 c inner cathode Det#3
 77 cz 0.5676900
 c Inner B-10 lining Det#3
 78 cz 0.5675165
 c bottom Det#3
 79 pz 4.6710599
 c bottom active region det#3
 80 pz 6.1696599
 c inside bottom det#3
 81 pz 4.7472599
 c top active region det#3
 82 pz 10.487660
 c inside top det#3
 83 pz 11.910060
 c top det#3
 84 pz 11.986260
 c top mounting sleeve det#3
 85 pz 11.650980
 c through source slot
 86 pz 0.6604
 c through source slot
 87 px 2.9718
 c screw in cad shield X Y R
 88 c/z -1.51 -2.6 0.18669
 c screw in cad shield X Y R
 89 c/z -2.41 -1.82 0.18669
 c screw in cad shield X Y R
 90 c/z -1.51 2.6 0.18669
 c screw in cad shield X Y R
 91 c/z -0.37 2.99 0.18669
 c screw in cad shield X Y R
 92 c/z 2.78 -1.18 0.18669
 c slot in cad shield X Y R
 93 c/z -.45 -3.40 0.4572

c #10 threaded rod OD
 95 c/z 3.01625 0 0.2413
 c top of thick walled outer housing (17.875 in.)
 96 pz 45.4025
 c standoff around #10 threaded rod
 97 c/z 3.01625 0 0.3937
 c left side of det#1 stiffener
 98 px 1.44028
 c right side of det#1 stiffener
 99 px 1.51648
 c bottom of det#1 stiffener
 100 pz 1.5367
 c front edge of det#1 stiffener
 101 py -1.27
 c back edge of det#1 stiffener
 102 py 1.27
 c bottom of cable head
 103 pz 41.529
 c source holder threaded grab hole radius
 104 c/y 3.0480000 0.6604000 0.207
 c source capsule ID
 105 c/y 3.0480000 0.6604000 0.196
 c source holder nut radius
 106 c/y 3.0480000 0.6604000 0.40
 c source holder nut end
 107 py -2.16
 c source holder thread/capsule interface
 108 py -0.686
 c source holder capsule end
 109 py 0.686
 c source capsule inner bottom end
 110 py 0.450
 c source capsule inner top end
 111 py -0.165
 c source capsule/holder OD
 112 c/y 3.0480000 0.6604000 0.3175
 c source OD
 113 c/y 3.0480000 0.6604000 0.00935
 c source top
 114 py -0.15185
 c source bottom
 115 py 0.13315
 c bottom (#1) electrical board (bottom)
 116 pz 16.756
 c bottom (#1) electrical board (top)
 117 pz 16.914
 c (#40) electrical SS ground plane (bottom)
 118 pz 18.971
 c (#40) electrical SS ground plane (top)
 119 pz 19.129
 c (#2) electrical board (bottom)
 120 pz 20.551
 c (#2) electrical board (top)
 121 pz 20.708
 c (#3) electrical board (bottom)
 122 pz 24.188
 c (#3) electrical board (top)
 123 pz 24.345
 c (#41) electrical SS ground plane (bottom)
 124 pz 28.307
 c (#41) electrical SS ground plane (top)
 125 pz 28.460

c (#4) electrical board (bottom)
 126 pz 29.882
 c (#4) electrical board (top)
 127 pz 30.04
 c (#39) electrical SS ground plane (bottom)
 128 pz 31.462
 c (#39) electrical SS ground plane (top)
 129 pz 31.615
 c top shoulder of cable head
 130 pz 43.74
 c cable OD
 131 cz 1.06
 c approx top cable head nut
 132 pz 46.92
 c top of cable head
 133 pz 52.73
 c OD of cable head neck
 134 cz 1.4
 c extension of B10 coating at bottom of det#1
 152 py -1.430
 c extension of B10 coating at top of det#1
 153 py 3.116
 c extension of B10 coating at bottom of det#2
 154 pz 1.245
 c extension of B10 coating at top of det#2
 155 pz 7.391
 c extension of B10 coating at bottom of det#3
 156 pz 5.256
 c extension of B10 coating at top of det#3
 157 pz 11.402
 c inner B-10 coating 70% det#1
 160 c/y 0.0 1.76 0.558679
 c inner B-10 coating 60% det#1
 161 c/y 0.0 1.76 0.558696
 c inner B-10 coating 50% det#1
 162 c/y 0.0 1.76 0.558713
 c inner B-10 coating 40% det#1
 163 c/y 0.0 1.76 0.558731
 c inner B-10 coating 30% det#1
 164 c/y 0.0 1.76 0.558748
 c inner B-10 coating 20% det#1
 165 c/y 0.0 1.76 0.558766
 c inner B-10 coating 10% det#1
 166 c/y 0.0 1.76 0.558783
 c inner B-10 coating 70% det#2
 167 c/z -2.69748 0.0 0.558679
 c inner B-10 coating 60% det#2
 168 c/z -2.69748 0.0 0.558696
 c inner B-10 coating 50% det#2
 169 c/z -2.69748 0.0 0.558713
 c inner B-10 coating 40% det#2
 170 c/z -2.69748 0.0 0.558731
 c inner B-10 coating 30% det#2
 171 c/z -2.69748 0.0 0.558748
 c inner B-10 coating 20% det#2
 172 c/z -2.69748 0.0 0.558766
 c inner B-10 coating 10% det#2
 173 c/z -2.69748 0.0 0.558783
 c inner B-10 coating 70% det#3
 174 cz 0.567569
 c inner B-10 coating 60% det#3
 175 cz 0.567586

```

c inner B-10 coating 50% det#3
176 cz 0.567603
c inner B-10 coating 40% det#3
177 cz 0.567621
c inner B-10 coating 30% det#3
178 cz 0.567638
c inner B-10 coating 20% det#3
179 cz 0.567656
c inner B-10 coating 10% det#3
180 cz 0.567673
c outside sphere
200 so 100

mode n
c phys:n 20 20
c idum 4j -7
c 15.0 micrograms Cf-252
sdef cel d1 pos fcel d2 axs 0 1 0 ext fcel d3
rad fcel d4 wgt=3.47e7 erg d5
sc1 source cell is Cf-252 source in cell 59
sil 1 59
sp1 d 1.0
sc2 source location is centered in cell 59
ds2 1 3.048 0.1425 0.6604
sc3 source extent
ds3 s 6
sc4 source radius
ds4 s 7
sc5 energy distribution: Cf-252 Watt Spontaneous Fission Spectrum
sp5 -3 1.025 2.926
sc6 source extent is 0.0187 centimeter total length
si6 0.00935
sp6 -21 0
sc7 source radius is .00935 centimeters
si7 0.0 0.00935
sp7 -21 1
f4:n 1 $ detector regions
c 0.1409 (B-10 atoms)/(barn-cm)
fm4 0.1409 6 207 $(n,alpha) interactions
f14:n 2 $ detector regions
fm14 0.1409 6 207 $(n,alpha) interactions
f24:n 3 $ detector regions
fm24 0.1409 6 207 $(n,alpha) interactions
c Cf-252 - Pd-Cf2O3
m1 98252.35c -0.119
98250.35c -0.069
8016.50c -0.018
46105.50c -0.363
46108.50c -0.431
c UHMW Polyethylene (0.96 g/cm3)
m3 1001.50c 2.000000
6000.50c 1.000000
m3i poly.01t
c 304 stainless steel (8.02 g/cm3)
m4 6000.50c -0.08
25055.50c -2.0
15031.50c -0.045
16032.50c -0.03
14000.50c -0.75
24000.50c -19.0
26000.55c -68.245
7014.50c -0.1

```

```

28000.50c -9.75
c      6061 Aluminum (2.6989 g/cm3)
m5    13027.50c -97.92
      14000.50c -0.6
      29000.50c -0.28
      12000.50c -1.0
      24000.50c -0.2
c      B-10 92% enriched (2.34g/cm3)
m6    5010.50c -.92
      5011.50c -0.08
c      polyimide (1.4 g/cm3)
m7    6000.50c 22
      1001.50c 14
      8016.50c 7
      7014.50c 2
m7t   poly.01t
c      cadmium (8.65 g/cm3)
m8    48000.50c -1.00
c      90%Ar + 10%CO2
m9    6000.50c -0.027
      8016.50c -0.073
      18000.35c -0.900
c      fiberglass/copper electrical boards
m10   1001.50c -0.0453
      5010.50c -0.00228    $ 8.1 wt% B2O3, 50 wt% fiber, 50 wt% epoxy
      5011.50c -0.010206
      6000.50c -0.282
      8016.50c -0.4107
      11023.50c -0.0103
      12000.50c -0.0225
      13027.50c -0.0337
      14000.50c -0.1178
      16032.50c -0.000399
      20000.50c -0.0737
      22000.50c -0.00686
      26000.55c -0.00412
m10t  poly.01t    $ hydrogen in poylethylene 300 K
c      air (1.138e-3 g/cm3)
m13   7014.50c 0.8000
      8016.50c 0.2000
m14   1001.50c -0.0229
      7014.50c -14.707
      8016.50c -54.2252
      11023.50c -28.4437
      12000.50c -0.0372
      13027.50c -1.4467
      14000.50c -0.3395
      15031.50c -0.1501
      20000.50c -0.1386
      25055.50c -0.0697
      26000.55c -0.4194
m14t  lwtr.01t
totnu
nps   50000000
print 60 120 126 140

```

surfab5_t11.inp (moisture dependance case: 5 wt% water)

```

546,556c546,556
< m14 1001.50c -0.0229
<    7014.50c -14.707
<    8016.50c -54.2252

```

```

< 11023.50c -28.4437
< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
---
> m14 1001.50c -0.5812
> 7014.50c -13.9716
> 8016.50c -55.9544
> 11023.50c -27.0215
> 12000.50c -0.0353
> 13027.50c -1.3744
> 14000.50c -0.3225
> 15031.50c -0.1426
> 20000.50c -0.1317
> 25055.50c -0.0662
> 26000.55c -0.3984
559c559
< nps 50000000
---
> nps 70000000

```

surfab10_t11.inp (moisture dependance case: 10 wt% water)

```

546,556c546,556
< m14 1001.50c -0.0229
< 7014.50c -14.707
< 8016.50c -54.2252
< 11023.50c -28.4437
< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
---
> m14 1001.50c -1.1396
> 7014.50c -13.2363
> 8016.50c -57.6837
> 11023.50c -25.5993
> 12000.50c -0.0335
> 13027.50c -1.3021
> 14000.50c -0.3056
> 15031.50c -0.1351
> 20000.50c -0.1248
> 25055.50c -0.0627
> 26000.55c -0.3774
559c559
< nps 50000000
---
> nps 40000000

```

surfab15_t11.inp (moisture dependance case: 15 wt% water)

```

546,556c546,556
< m14 1001.50c -0.0229
< 7014.50c -14.707

```

```

< 8016.50c -54.2252
< 11023.50c -28.4437
< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
—
> m14 1001.50c -1.6979
> 7014.50c -12.5009
> 8016.50c -59.4129
> 11023.50c -24.1771
> 12000.50c -0.0316
> 13027.50c -1.2297
> 14000.50c -0.2886
> 15031.50c -0.1276
> 20000.50c -0.1178
> 25055.50c -0.0592
> 26000.55c -0.3564
559c559
< nps 50000000
—
> nps 80000000

```

surfab20_t11.inp (moisture dependance case: 20 wt% water)

```

546,556c546,556
< m14 1001.50c -0.0229
< 7014.50c -14.707
< 8016.50c -54.2252
< 11023.50c -28.4437
< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
—
> m14 1001.50c -2.2563
> 7014.50c -11.7656
> 8016.50c -61.1422
> 11023.50c -22.7550
> 12000.50c -0.0298
> 13027.50c -1.1574
> 14000.50c -0.2716
> 15031.50c -0.1201
> 20000.50c -0.1109
> 25055.50c -0.0558
> 26000.55c -0.3355
559c559
< nps 50000000
—
> nps 70000000

```

surfab25_t11.inp (moisture dependance case: 25 wt% water)

```

546,556c546,556
< m14 1001.50c -0.0229
< 7014.50c -14.707
< 8016.50c -54.2252

```

```
< 11023.50c -28.4437
< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
```

```
—
> m14 1001.50c -2.8146
> 7014.50c -11.0302
> 8016.50c -62.8714
> 11023.50c -21.3328
> 12000.50c -0.0279
> 13027.50c -1.0851
> 14000.50c -0.2546
> 15031.50c -0.1126
> 20000.50c -0.1040
> 25055.50c -0.0523
> 26000.55c -0.3145
```

559c559

```
< nps 50000000
```

```
—
> nps 70000000
```

surfab30_t11.inp (moisture dependance case: 30 wt% water)

546,556c546,556

```
< m14 1001.50c -0.0229
< 7014.50c -14.707
< 8016.50c -54.2252
< 11023.50c -28.4437
< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
```

```
—
> m14 1001.50c -3.3730
> 7014.50c -10.2949
> 8016.50c -64.6007
> 11023.50c -19.9106
> 12000.50c -0.0260
> 13027.50c -1.0127
> 14000.50c -0.2377
> 15031.50c -0.1051
> 20000.50c -0.0970
> 25055.50c -0.0488
> 26000.55c -0.2935
```

559c559

```
< nps 50000000
```

```
—
> nps 35000000
```

surfab40_t11.inp (moisture dependance case: 40 wt% water)

546,556c546,556

```
< m14 1001.50c -0.0229
< 7014.50c -14.707
< 8016.50c -54.2252
< 11023.50c -28.4437
```

```

< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
—
> m14 1001.50c -4.4897
> 7014.50c -8.8242
> 8016.50c -68.0592
> 11023.50c -17.0662
> 12000.50c -0.0223
> 13027.50c -0.8680
> 14000.50c -0.2037
> 15031.50c -0.0901
> 20000.50c -0.0832
> 25055.50c -0.0418
> 26000.55c -0.2516
559c559
< nps 50000000
—
> nps 30000000

```

surfab50_t11.inp (moisture dependance case: 50 wt% water)

```

546.556c546.556
< m14 1001.50c -0.0229
< 7014.50c -14.707
< 8016.50c -54.2252
< 11023.50c -28.4437
< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
—
> m14 1001.50c -5.6064
> 7014.50c -7.3535
> 8016.50c -71.5177
> 11023.50c -14.2218
> 12000.50c -0.0186
> 13027.50c -0.7234
> 14000.50c -0.1698
> 15031.50c -0.0751
> 20000.50c -0.0693
> 25055.50c -0.0348
> 26000.55c -0.2097
559c559
< nps 50000000
—
> nps 25000000

```

surfab65_t11.inp (moisture dependance case: 65 wt% water)

```

546.556c546.556
< m14 1001.50c -0.0229
< 7014.50c -14.707
< 8016.50c -54.2252
< 11023.50c -28.4437

```



```

< 12000.50c -0.0372
< 13027.50c -1.4467
< 14000.50c -0.3395
< 15031.50c -0.1501
< 20000.50c -0.1386
< 25055.50c -0.0697
< 26000.55c -0.4194
—
> m14 1001.50c -7.2814
> 7014.50c -5.1474
> 8016.50c -76.7054
> 11023.50c -9.9553
> 12000.50c -0.013
> 13027.50c -0.5064
> 14000.50c -0.1188
> 15031.50c -0.0525
> 20000.50c -0.0485
> 25055.50c -0.0244
> 26000.55c -0.1468
559c559
< nps 50000000
—
> nps 25000000

```

surfab15_t11-org1.inp (total organic concentration: 1 wt%)

```

546,556c546,557
< m14 1001.50c -1.6979
< 7014.50c -12.5009
< 8016.50c -59.4129
< 11023.50c -24.1771
< 12000.50c -0.0316
< 13027.50c -1.2297
< 14000.50c -0.2886
< 15031.50c -0.1276
< 20000.50c -0.1178
< 25055.50c -0.0592
< 26000.55c -0.3564
—
> m14 1001.50c -1.7822
> 6000.50c -0.518
> 7014.50c -12.3661
> 8016.50c -59.1276
> 11023.50c -23.9776
> 12000.50c -0.0312
> 13027.50c -1.2153
> 14000.50c -0.2852
> 15031.50c -0.1700
> 20000.50c -0.1164
> 25055.50c -0.0585
> 26000.55c -0.3523
559c560
< nps 80000000
—
> nps 40000000

```

\$ 15% H2O, 1% organic

surfab15_t11-org2.inp (total organic concentration: 2 wt%)

```

546,556c546,557
< m14 1001.50c -1.6979
< 7014.50c -12.5009
< 8016.50c -59.4129
< 11023.50c -24.1771

```

```

< 12000.50c -0.0316
< 13027.50c -1.2297
< 14000.50c -0.2886
< 15031.50c -0.1276
< 20000.50c -0.1178
< 25055.50c -0.0592
< 26000.55c -0.3564
--
> m14 1001.50c -1.8664 $ 15% H2O, 2% organic
> 6000.50c -1.0352
> 7014.50c -12.2314
> 8016.50c -58.8422
> 11023.50c -23.778
> 12000.50c -0.0309
> 13027.50c -1.2008
> 14000.50c -0.2818
> 15031.50c -0.2125
> 20000.50c -0.1151
> 25055.50c -0.0578
> 26000.55c -0.3481
559c560
< nps 80000000
--
> nps 40000000

```

surfab15_t11-org3.inp (total organic concentration: 3 wt%)
546.556c546.557

```

< m14 1001.50c -1.6979
< 7014.50c -12.5009
< 8016.50c -59.4129
< 11023.50c -24.1771
< 12000.50c -0.0316
< 13027.50c -1.2297
< 14000.50c -0.2886
< 15031.50c -0.1276
< 20000.50c -0.1178
< 25055.50c -0.0592
< 26000.55c -0.3564
--
> m14 1001.50c -1.9506 $ 15% H2O, 3% organic
> 6000.50c -1.553
> 7014.50c -12.0966
> 8016.50c -58.5568
> 11023.50c -23.5784
> 12000.50c -0.0305
> 13027.50c -1.1863
> 14000.50c -0.2784
> 15031.50c -0.2549
> 20000.50c -0.1137
> 25055.50c -0.0571
> 26000.55c -0.3439
559c560
< nps 80000000
--
> nps 40000000

```

surfab15_t11-org4.inp (total organic concentration: 4 wt%)
546.556c546.557

```

< m14 1001.50c -1.6979
< 7014.50c -12.5009

```

```
< 8016.50c -59.4129
< 11023.50c -24.1771
< 12000.50c -0.0316
< 13027.50c -1.2297
< 14000.50c -0.2886
< 15031.50c -0.1276
< 20000.50c -0.1178
< 25055.50c -0.0592
< 26000.55c -0.3564
```

```
—
> m14 1001.50c -2.0349 $ 15% H2O, 4% organic
> 6000.50c -2.0704
> 7014.50c -11.9618
> 8016.50c -58.2714
> 11023.50c -23.3788
> 12000.50c -0.0301
> 13027.50c -1.1719
> 14000.50c -0.2750
> 15031.50c -0.2974
> 20000.50c -0.1123
> 25055.50c -0.0565
> 26000.55c -0.3397
```

```
559c560
< nps 80000000
—
> nps 30000000
```

surfab15_t11-org6.inp (total organic concentration: 6 wt%)
546,556c546,557

```
< m14 1001.50c -1.6979
< 7014.50c -12.5009
< 8016.50c -59.4129
< 11023.50c -24.1771
< 12000.50c -0.0316
< 13027.50c -1.2297
< 14000.50c -0.2886
< 15031.50c -0.1276
< 20000.50c -0.1178
< 25055.50c -0.0592
< 26000.55c -0.3564
```

```
—
> m14 1001.50c -2.2034 $ 15% H2O, 6% organic
> 6000.50c -3.1055
> 7014.50c -11.6922
> 8016.50c -57.7006
> 11023.50c -22.9797
> 12000.50c -0.0294
> 13027.50c -1.1429
> 14000.50c -0.2682
> 15031.50c -0.3823
> 20000.50c -0.1095
> 25055.50c -0.0551
> 26000.55c -0.3313
```

```
559c560
< nps 80000000
—
> nps 28000000
```

surfab15_t11-org8.inp (total organic concentration: 8 wt%)
546,556c546,557

```

< m14 1001.50c -1.6979
< 7014.50c -12.5009
< 8016.50c -59.4129
< 11023.50c -24.1771
< 12000.50c -0.0316
< 13027.50c -1.2297
< 14000.50c -0.2886
< 15031.50c -0.1276
< 20000.50c -0.1178
< 25055.50c -0.0592
< 26000.55c -0.3564
—
> m14 1001.50c -2.3718 $ 15% H2O, 8% organic
> 6000.50c -4.1407
> 7014.50c -11.4226
> 8016.50c -57.1298
> 11023.50c -22.5805
> 12000.50c -0.0286
> 13027.50c -1.1140
> 14000.50c -0.2614
> 15031.50c -0.4671
> 20000.50c -0.1067
> 25055.50c -0.0537
> 26000.55c -0.3229
559c560
< nps 80000000
—
> nps 25000000

*****
surfab4_113.inp (no anomaly base case for following material geometry/probe placement anomaly cases)
As-Built Surface Neutron, Cd d#1 .055", Cd d#2 .006", Stand#4 19wt%
c Det#1 B-10 TALLY REGION 80-100%
  1 6 -2.34 31 -160 27 -28 imp:n=300
c DET#2 B-10 TALLY REGION 80-100%
  2 6 -2.34 67 -167 70 -71 imp:n=310
c DET#3 B-10 TALLY REGION 80-100%
  3 6 -2.34 78 -174 80 -82 imp:n=300
c narrow part of source housing
  4 4 -8.02 (9 7 -2 -5 4) (6:14) imp:n=100
c entrance slot to source cavity
  5 13 -.000114 ((16 (-86:87));(-18 -87 86))
    (3 -17 -1 -15 ) # (107 -106) imp:n=100
c probe housing bottom
  6 4 -8.02 -4 3 -1 6 #55 imp:n=100
c At/CO2 Det#1
  7 9 -.001 (-29 26 -31);(153 -30 31 -29);(-30 31 -152 26) imp:n=300
c SS Cathode Det#1
  8 4 -8.02 26 -29 -23 30 imp:n=225
c Polyethylene Det#1
  9 3 -0.96 (-21 22 -34 26 )(59 :24 :-25 ) imp:n=200
c main cadmium Det#1
  10 8 -8.65 (-34 35 21 -20 ) imp:n=100
c top cadmium washer det#1
  11 8 -8.65 (-36 35 -21 38 39 ) imp:n=100
c bottom cadmium hat det#1
  12 8 -8.65 ((34 -33 -20 22 40);(34 -32 22 -37 );(-32 29 -22 )) imp:n=100
c ss clip around det#1
  13 4 -8.02 (20 -19 -33 60) imp:n=100
c ss plate screwed to cad shield
  14 4 -8.02 (-51 49 -52 95 41 93) imp:n=90

```

c cad shield under det#3
 15 8 -8.65 (50 -49 -52 53 41 88 89 90 91 92 93) #53 imp:n=90

c Aluminum in poly insert of det#1
 16 5 -2.699 -24 25 22 -21 26 -34 -59 imp:n=150

c sides of probe housing (bottom third)
 17 4 -8.02 ((-1 2 4 -11);(-4 -6 -1 14)) #5 #54 #55 imp:n=100

c Ar/CO2 Det#2
 18 9 -.001 (69 -72 -67);(155 67 -66 -72);(-154 67 -66 69) imp:n=310

c Cathode Det#2
 19 4 -8.02 66 -58 69 -72 imp:n=300

c ss top Det#2
 20 4 -8.02 -58 72 -73 imp:n=100

c bottom ss Det#2
 21 4 -8.02 -58 68 -69 imp:n=100

c Polyethylene Det#2
 22 3 -0.96 58 -56 65 -74 imp:n=200

c SS mounting sleeve det#2
 23 4 -8.02 (56 -61 65 -74);(64 -65 -61) imp:n=200

c polyimide bottom det#2
 24 7 1.4 -58 65 -68 imp:n=100

c polyimide on cadmium plating
 26 7 1.4 62 -63 44 -74 imp:n=100

c cadmium det#2
 25 8 -8.65 (61 -62 -74 64);(44 -64 -62) imp:n=140

c SS mounting sleeve
 27 4 -8.02 ((45 63 -41 -75 44);(-44 43 -41 45);
 (4 -43 -41 63 45)) #13 imp:n=110

c wide part of probe source housing
 28 4 -8.02 (-9 8 -2 4 -5 6) #5 #55 imp:n=100

c Ar+CO2 gas det#3
 29 9 -.001 (81 -83 -78);(157 -83 78 -77);(-156 81 78 -77) imp:n=300

c Cathode wall det#3
 30 4 -8.02 77 -76 81 -83 imp:n=200

c bottom ss det#3
 31 4 -8.02 -76 79 -81 imp:n=100

c top ss wall det#3
 32 4 -8.02 83 -84 -76 imp:n=100

c polyimide det#3
 33 7 1.4 (76 -47 -84 79);(51 -79 -47) imp:n=200

c ss mounting sleeve det#3
 34 4 -8.02 (47 -46 -85 51) imp:n=150

c polyimide around det#1
 35 7 1.4 (23 -22 26 -29) imp:n=200

c air space below cad in probe
 36 13 -.000114 (-50 4 -2 41 19 60);(5:-8;(-7 9)) 95 #53 imp:n=100
 37 13 -.000114 (-50 4 -2 41 20 -60);(5:-8;(-7 9)) #53 imp:n=100
 38 13 -.000114 (37 -2 33 -19);(-37 -2 32) imp:n=100
 39 13 -.000114 (-20 -2 -35) imp:n=100
 40 13 -.000114 (63 -41 4 -75 -45 -2);(-63 4 -43);(-63 -45 43 -44) imp:n=100
 41 13 -.000114 (36 -21 -26);(-38 35 -36);(-21 -39 35 -36) imp:n=100

c ss screws in cad shield
 42 4 -8.02 -88 50 -49 imp:n=100
 43 4 -8.02 -89 50 -49 imp:n=100
 44 4 -8.02 -90 50 -49 imp:n=100
 45 4 -8.02 -91 50 -49 imp:n=100
 46 4 -8.02 95 -53 50 -49 imp:n=100
 47 4 -8.02 -92 50 -49 imp:n=100

c #10 threaded rod
 48 4 -8.02 (-129 51 -97);(-51 -95 5) imp:n=100

c main thick wall portion of housing
 49 4 -8.02 -12 2 11 -130 imp:n=100

c air above cad plate below top of det#3

50 13 -.000114 (-2 51 -85) ((46 41 97):(63 75 -41)
 : (58 -63 74):(73 -58)) 90 88 imp:n=100
 c around around cad/ss plate
 51 13 -.000114 (-2 52 50 -51 41) imp:n=100
 c slot in cad/ss plate for wire pass through
 52 13 -.000114 (-93 -51 50) #51 imp:n=100
 c det#1 stiffener
 53 4 -8.02 98 -99 100 -49 101 -102 imp:n=100
 c source holder grab hole
 54 13 -.000114 107 -15 -104 imp:n=100
 c source holder nut
 55 4 -8.02 -106 104 107 -15 imp:n=100
 c source holder threads/body
 56 4 -8.02 -6 15 -108 imp:n=100
 c source capsule
 57 4 -8.02 (-109 108 -112 105):(110 -109 -105):
 (108 -111 -105) imp:n=100
 c air around source capsule
 58 13 -.000114 (112 -6 108 -14):(-14 109 -112) imp:n=100
 c Pd-Cf2O3 NEUTRON SOURCE
 59 1 -10.0 -113 115 -114 imp:n=100
 c air around source
 60 13 -.000114 -105 111 -110 #59 imp:n=100
 c electrical board #1
 61 10 -1.21 116 -117 -2 97 90 88 imp:n=90
 c threaded rod
 62 4 -8.02 51 -129 -90 imp:n=100
 c threaded rod
 63 4 -8.02 51 -129 -88 imp:n=100
 c electrical board #2
 64 10 -1.21 120 -121 -2 97 90 88 imp:n=100
 c electrical board #3
 65 10 -1.21 122 -123 -2 97 90 88 imp:n=100
 c electrical board #4
 66 10 -1.21 126 -127 -2 97 90 88 imp:n=100
 c air above top of det#3 below first electrical board
 67 13 -.000114 (-2 85 -116 90 88 97 47):(-47 84 -116) imp:n=90
 c air between board 1 and ss plate 40
 68 13 -.000114 (-2 117 -118 90 88 97) imp:n=90
 c air between ss plate 40 and board #2
 69 13 -.000114 (-2 119 -120 90 88 97) imp:n=90
 c air between board #2 and board #3
 70 13 -.000114 (-2 121 -122 90 88 97) imp:n=90
 c SS ground Plane #40
 71 4 -8.02 118 -119 -2 97 90 88 imp:n=90
 c SS ground Plane #41
 72 4 -8.02 124 -125 -2 97 90 88 imp:n=90
 c SS ground Plane #39
 73 4 -8.02 128 -129 -2 97 90 88 imp:n=90
 c air between board #3 and SS plate #41
 74 13 -.000114 (-2 123 -124 90 88 97) imp:n=90
 c air between SS plate #41 and board #4
 75 13 -.000114 (-2 125 -126 90 88 97) imp:n=90
 c air between board #4 & SS plate #39
 76 13 -.000114 (-2 127 -128 90 88 97) imp:n=90
 c bottom of cablehead
 77 4 -8.02 103 -130 -12 131 #49 imp:n=70
 c air between board #4 & SS plate #39
 78 13 -.000114 -2 129 -103 imp:n=70
 c cablehead nut
 79 4 -8.02 130 -132 131 -12 imp:n=50
 c cablehead neck

80 4 -8.02 132 -133 131 -134 imp:n=50
c air around cablehead neck
81 13 -.000114 132 -133 134 -12 imp:n=40
c cable
82 13 -.000114 103 -133 -131 imp:n=50
c air around probe above barrel lip
83 13 -.000114 142 -143 144 -145 139 -133 1 #49 #79 #81 imp:n=100
c top 0-3cm layer of hydrated alumina + sand (inner cylinder)
84 2 -1.605 -140 146 -135 -151 imp:n=100
c 3-6cm layer of hydrated alumina + sand (inner cylinder)
85 2 -1.605 -146 147 -135 -151 imp:n=100
c 6-9cm layer of hydrated alumina + sand (inner cylinder)
86 2 -1.605 -147 148 -135 -151 imp:n=90
c 9-20cm layer of hydrated alumina + sand (inner cylinder)
87 2 -1.605 -148 149 -135 -151 imp:n=75
c 20-30cm layer of hydrated alumina + sand (inner cylinder)
88 2 -1.605 -149 150 -135 -151 imp:n=60
c 30cm-bottom layer of hydrated alumina + sand (inner cylinder)
89 2 -1.605 -150 137 -135 -151 imp:n=50
c Aluminum barrel (upper sides)
90 5 -2.699 (-139 135 -136 149) imp:n=90
c Aluminum lid (top)
91 5 -2.699 -3 140 -135 imp:n=100
c Air inside barrel
92 13 -.000114 3 -139 -135 1 #49 imp:n=100
c poly under barrel (inner cylinder)
93 3 -0.96 141 -138 -151 imp:n=30
c air around barrel
94 13 -.000114 136 138 -139 142 -143 144 -145 imp:n=40
c Aluminum barrel (bottom)
95 5 -2.699 -135 138 -137 imp:n=40
c top 0-3cm layer of hydrated alumina + sand (outer ring)
96 2 -1.605 -140 146 -135 151 imp:n=100
c 3-6cm layer of hydrated alumina + sand (outer ring)
97 2 -1.605 -146 147 -135 151 imp:n=90
c 6-9cm layer of hydrated alumina + sand (outer ring)
98 2 -1.605 -147 148 -135 151 imp:n=80
c 9-20cm layer of hydrated alumina + sand (outer ring)
99 2 -1.605 -148 149 -135 151 imp:n=65
c 20-30cm layer of hydrated alumina + sand (outer ring)
100 2 -1.605 -149 150 -135 151 imp:n=50
c 30cm-bottom layer of hydrated alumina + sand (outer ring)
101 2 -1.605 -150 137 -135 151 imp:n=40
c poly under barrel (outer)
102 3 -0.96 141 -138 142 -143 144 -145 151 imp:n=20
c Aluminum barrel (bottom sides)
103 5 -2.699 (138 135 -136 -149) imp:n=50
c extended B10 coating bottom of det#1
104 6 -2.34 31 -30 152 -27 imp:n=300
c extended B10 coating top of det#1
105 6 -2.34 31 -30 28 -153 imp:n=300
c extended B10 coating bottom of det#2
106 6 -2.34 67 -66 154 -70 imp:n=300
c extended B10 coating top of det#2
107 6 -2.34 67 -66 71 -155 imp:n=300
c extended B10 coating bottom of det#2
108 6 -2.34 78 -77 156 -80 imp:n=300
c extended B10 coating top of det#2
109 6 -2.34 78 -77 82 -157 imp:n=300
c hole in cad det#1 for temp sensor
110 13 -.000114 -40 -20 22 34 -33 37 imp:n=90
c DET#1 B-10 TALLY REGION 70%

200 6 -2.34 160 -161 27 -28 imp:n=300
 c DET#1 B-10 TALLY REGION 60%
 201 6 -2.34 161 -162 27 -28 imp:n=300
 c DET#1 B-10 TALLY REGION 50%
 202 6 -2.34 162 -163 27 -28 imp:n=300
 c DET#1 B-10 TALLY REGION 40%
 203 6 -2.34 163 -164 27 -28 imp:n=300
 c DET#1 B-10 TALLY REGION 30%
 204 6 -2.34 164 -165 27 -28 imp:n=300
 c DET#1 B-10 TALLY REGION 20%
 205 6 -2.34 165 -166 27 -28 imp:n=300
 c DET#1 B-10 TALLY REGION 10%
 206 6 -2.34 166 -30 27 -28 imp:n=300
 c DET#2 B-10 TALLY REGION 70%
 207 6 -2.34 167 -168 70 -71 imp:n=310
 c DET#2 B-10 TALLY REGION 60%
 208 6 -2.34 168 -169 70 -71 imp:n=310
 c DET#2 B-10 TALLY REGION 50%
 209 6 -2.34 169 -170 70 -71 imp:n=310
 c DET#2 B-10 TALLY REGION 40%
 210 6 -2.34 170 -171 70 -71 imp:n=310
 c DET#2 B-10 TALLY REGION 30%
 211 6 -2.34 171 -172 70 -71 imp:n=310
 c DET#2 B-10 TALLY REGION 20%
 212 6 -2.34 172 -173 70 -71 imp:n=310
 c DET#2 B-10 TALLY REGION 10%
 213 6 -2.34 173 -66 70 -71 imp:n=310
 c DET#3 B-10 TALLY REGION 70%
 214 6 -2.34 174 -175 80 -82 imp:n=300
 c DET#3 B-10 TALLY REGION 60%
 215 6 -2.34 175 -176 80 -82 imp:n=300
 c DET#3 B-10 TALLY REGION 50%
 216 6 -2.34 176 -177 80 -82 imp:n=300
 c DET#3 B-10 TALLY REGION 40%
 217 6 -2.34 177 -178 80 -82 imp:n=300
 c DET#3 B-10 TALLY REGION 30%
 218 6 -2.34 178 -179 80 -82 imp:n=300
 c DET#3 B-10 TALLY REGION 20%
 219 6 -2.34 179 -180 80 -82 imp:n=300
 c DET#3 B-10 TALLY REGION 10%
 220 6 -2.34 180 -77 80 -82 imp:n=300
 c outside (void)
 150 0 -141:-142:143:-144:145:133 imp:n=0

 1 cz 4.2138599
 2 cz 3.8963599
 3 pz 0.0000000
 4 pz 0.3175000
 5 pz 1.5367000
 c outer source hole
 6 c/y 3.0480000 0.6604000 0.3568700
 7 px 2.5400000
 8 px 2.1844000
 9 py -0.7112000
 c top of thin wall section of probe housing
 11 pz 10.426700
 c outer diameter of thick part (upper 2/3) of probe housing
 12 cz 4.3815
 13 pz 44.754799
 14 py 1.5240000
 15 py -1.7780000
 16 px 2.3368000

17	pz	1.2954000		
18	c/y	2.9718000	0.6604000	0.6350000
19	c/y	0.0000000	1.7578	1.41478
20	c/y	0.0000000	1.76000	1.28778
21	c/y	0.0000000	1.76000	1.1480800
22	c/y	0.0000000	1.76000	0.6400800
23	c/y	0.0000000	1.76000	0.6350000
24	p	0.3400000	0.0000000	1.0000000
25	p	0.3400000	0.0000000	1.0000000
26	py	-2.1285200		
27	py	-0.6299200		
28	py	2.3164800		
29	py	3.5864799		
30	c/y	0.0000000	1.76000	0.5588000
c Inner B-10 lining 0.4 mg/cm2				
31	c/y	0.0000000	1.76000	0.5586265
32	py	3.72618		
33	py	2.77622		
34	py	2.6365200		
35	py	-3.05562		
36	py	-2.9159200		
37	c/y	0.0000000	1.76000	0.77978
38	c/y	0.0000000	1.76000	0.3175000
39	c/y	0.0000000	2.73260	0.3175000
40	c/y	0.822 1.41 0.3175		
c Hole in Cad under Det#3 for support rod				
41	c/z	-2.6974800	0.0000000	1.26492
43	pz	0.47498		
44	pz	0.62738		
45	px	-3.3400999		
46	cz	0.7937500		
47	cz	0.6489700		
48	pz	11.772900		
49	pz	4.5084999		
50	pz	4.3433999		
c top of ss plate below det#3				
51	pz	4.6659799		
c radius of cad/SS shield				
52	cz	3.8353999		
53	c/z	3.0162500	0.0000000	0.5041900
c inner polyethylene inner Det#2				
c poly outer Det#2				
56	c/z	-2.6974800	0.0000000	1.0096500
c poly inner Det#2				
57	c/z	-2.6974800	0.0000000	0.6489700
58	c/z	-2.6974800	0.0000000	0.6350000
59	p	-16.436870	0.0000000	1.0000000
60	py	-0.8970000		2.3825200
c inner ss cad-plated peice for det#2				
c SS plated piece outer det#2				
61	c/z	-2.6974800	0.0000000	1.1112500
c 0.003" Cad outer Det#2				
62	c/z	-2.6974800	0.0000000	1.11379
c polyimide outer				
63	c/z	-2.6974800	0.0000000	1.11887
c Inner bottom cadmium Det#2				
64	pz	0.62992		
c Inside bottom ss plated peice det#2				
65	pz	0.71882		
c inner cathode det#2				
66	c/z	-2.6974800	0.0000000	0.5588000
c inner B-10 coating det#2				

67 c/z -2.6974800 0.0000000 0.5586265
c inner top polyimide det#2
68 pz 0.7239
c inner bottom ss cathode det#2
c Bottom Active Region DET#2
69 pz 0.8001
70 pz 2.1590000
c top active region det#2
71 pz 6.4769999
c Inside top Det#2
72 pz 7.8993999
c Top of Det#2
73 pz 7.9755999
c top of polyethylene det#2
74 pz 7.7165199
c top of ss mounting sleeve det#2
75 pz 7.2008999
c Inner polyimid det#3
76 cz 0.6438900
c inner cathode Det#3
77 cz 0.5676900
c Inner B-10 lining Det#3
78 cz 0.5675165
c bottom Det#3
79 pz 4.6710599
c bottom active region det#3
80 pz 6.1696599
c inside bottom det#3
81 pz 4.7472599
c top active region det#3
82 pz 10.487660
c inside top det#3
83 pz 11.910060
c top det#3
84 pz 11.986260
c top mounting sleeve det#3
85 pz 11.650980
c through source slot
86 pz 0.6604
c through source slot
87 px 2.9718
c screw in cad shield X Y R
88 c/z -1.51 -2.6 0.18669
c screw in cad shield X Y R
89 c/z -2.41 -1.82 0.18669
c screw in cad shield X Y R
90 c/z -1.51 2.6 0.18669
c screw in cad shield X Y R
91 c/z -0.37 2.99 0.18669
c screw in cad shield X Y R
92 c/z 2.78 -1.18 0.18669
c slot in cad shield X Y R
93 c/z -.45 -3.40 0.4572
c #10 threaded rod OD
95 c/z 3.01625 0 0.2413
c top of thick walled outer housing (17.875 in.)
96 pz 45.4025
c standoff around #10 threaded rod
97 c/z 3.01625 0 0.3937
c left side of det#1 stiffener
98 px 1.44028
c right side of det#1 stiffener

99 px 1.51648
 c bottom of det#1 stiffener
 100 pz 1.5367
 c front edge of det#1 stiffener
 101 py -1.27
 c back edge of det#1 stiffener
 102 py 1.27
 c bottom of cable head
 103 pz 41.529
 c source holder threaded grab hole radius
 104 c/y 3.0480000 0.6604000 0.207
 c source capsule ID
 105 c/y 3.0480000 0.6604000 0.196
 c source holder nut radius
 106 c/y 3.0480000 0.6604000 0.40
 c source holder nut end
 107 py -2.16
 c source holder thread/capsule interface
 108 py -0.686
 c source holder capsule end
 109 py 0.686
 c source capsule inner bottom end
 110 py 0.450
 c source capsule inner top end
 111 py -0.165
 c source capsule/holder OD
 112 c/y 3.0480000 0.6604000 0.3175
 c source OD
 113 c/y 3.0480000 0.6604000 0.00935
 c source top
 114 py 0.15185
 c source bottom
 115 py 0.13315
 c bottom (#1) electrical board (bottom)
 116 pz 16.756
 c bottom (#1) electrical board (top)
 117 pz 16.914
 c (#40) electrical SS ground plane (bottom)
 118 pz 18.971
 c (#40) electrical SS ground plane (top)
 119 pz 19.129
 c (#2) electrical board (bottom)
 120 pz 20.551
 c (#2) electrical board (top)
 121 pz 20.708
 c (#3) electrical board (bottom)
 122 pz 24.188
 c (#3) electrical board (top)
 123 pz 24.345
 c (#41) electrical SS ground plane (bottom)
 124 pz 28.307
 c (#41) electrical SS ground plane (top)
 125 pz 28.460
 c (#4) electrical board (bottom)
 126 pz 29.882
 c (#4) electrical board (top)
 127 pz 30.04
 c (#39) electrical SS ground plane (bottom)
 128 pz 31.462
 c (#39) electrical SS ground plane (top)
 129 pz 31.615
 c top shoulder of cable head

130 pz 43.74
 c cable OD
 131 cz 1.06
 c approx top cable head nut
 132 pz 46.92
 c top of cable head
 133 pz 52.73
 c OD of cable head neck
 134 cz 1.4
 c ID Aluminum Barrel
 135 cz 38.1
 c OD Aluminum Barrel
 136 cz 38.58
 c inside bottom Al barrel *****
 137 pz -37.577
 c outside bottom Al barrel(18" - Hair) Barrel#4 Hair = 2.831 in. ****
 138 pz -38.053
 c top of Al barrel *****
 139 pz 7.191
 c top of top mixture
 140 pz -0.0794
 c polyethylene under barrel (bottom) *****
 141 pz -43.133
 c polyethylene under barrel (left side x)
 142 px -48.26
 c polyethylene under barrel (right side x)
 143 px 48.26
 c polyethylene under barrel (front side y)
 144 py -48.26
 c polyethylene under barrel (back side y)
 145 py 48.26
 c 3 cm below top of mixture
 146 pz -3.0794
 c 6 cm below top of mixture
 147 pz -6.0794
 c 9 cm below top of mixture
 148 pz -9.0794
 c 20 cm below top of mixture
 149 pz -20.0794
 c 30 cm below top of mixture
 150 pz -30.0794
 c cylindrical importance map in barrel
 151 cz 20.0
 c extension of B10 coating at bottom of det#1
 152 py -1.430
 c extension of B10 coating at top of det#1
 153 py 3.116
 c extension of B10 coating at bottom of det#2
 154 pz 1.245
 c extension of B10 coating at top of det#2
 155 pz 7.391
 c extension of B10 coating at bottom of det#3
 156 pz 5.256
 c extension of B10 coating at top of det#3
 157 pz 11.402
 c inner B-10 coating 70% det#1
 160 c/y 0.0 1.76 0.558679
 c inner B-10 coating 60% det#1
 161 c/y 0.0 1.76 0.558696
 c inner B-10 coating 50% det#1
 162 c/y 0.0 1.76 0.558713
 c inner B-10 coating 40% det#1

```

163  c/y 0.0 1.76 0.558731
c inner B-10 coating 30% det#1
164  c/y 0.0 1.76 0.558748
c inner B-10 coating 20% det#1
165  c/y 0.0 1.76 0.558766
c inner B-10 coating 10% det#1
166  c/y 0.0 1.76 0.558783
c inner B-10 coating 70% det#2
167  c/z -2.69748 0.0 0.558679
c inner B-10 coating 60% det#2
168  c/z -2.69748 0.0 0.558696
c inner B-10 coating 50% det#2
169  c/z -2.69748 0.0 0.558713
c inner B-10 coating 40% det#2
170  c/z -2.69748 0.0 0.558731
c inner B-10 coating 30% det#2
171  c/z -2.69748 0.0 0.558748
c inner B-10 coating 20% det#2
172  c/z -2.69748 0.0 0.558766
c inner B-10 coating 10% det#2
173  c/z -2.69748 0.0 0.558783
c inner B-10 coating 70% det#3
174  cz 0.567569
c inner B-10 coating 60% det#3
175  cz 0.567586
c inner B-10 coating 50% det#3
176  cz 0.567603
c inner B-10 coating 40% det#3
177  cz 0.567621
c inner B-10 coating 30% det#3
178  cz 0.567638
c inner B-10 coating 20% det#3
179  cz 0.567656
c inner B-10 coating 10% det#3
180  cz 0.567673
c outside sphere
200  cz 70

mode n
phys:n 20 20
c 15.0 micrograms Cf-252
sdef cel d1 pos fcel d2 axs 0 1 0 ext fcel d3
    rad fcel d4 wgt=3.47e7 erg d5
sc1 source cell is Cf-252 source in cell 59
si1 1 59
sp1 d 1.0
sc2 source location is centered in cell 59
ds2 1 3.048 0.1425 0.6604
sc3 source extent
ds3 s 6
sc4 source radius
ds4 s 7
sc5 energy distribution: Cf-252 Watt Spontaneous Fission Spectrum
sp5 -3 1.025 2.926
sc6 source extent is 0.0187 centimeter total length
si6 0.00935
sp6 -21 0
sc7 source radius is .00935 centimeters
si7 0.0 0.00935
sp7 -21 1
e0 4e-7 7e-7 1.5e-6 3e-6 1e-5 1e-4 .1 2.2 20
f4:n 1 200 201 202 203 204 205 206 t $ detector regions

```

```

c      0.1409 (B-10 atoms)/(barn-cm)
fm4    0.1409 6 207      $ (n,alpha) interactions
f14:n  2 207 208 209 210 211 212 213 t $ detector regions
fm14   0.1409 6 207      $ (n,alpha) interactions
f24:n  3 214 215 216 217 218 219 220 t $ detector regions
fm24   0.1409 6 207      $ (n,alpha) interactions
c      Cf-252 - Pd-Cf2O3
m1     98252.35c -0.119
      98250.35c -0.069
      8016.50c -0.018
      46105.50c -0.363
      46108.50c -0.431
c      hydrated alimina + sand (19.1 wt% water)
m2     1001.50c -0.0216
      8016.50c -0.5786
      11023.50c -0.0009
      13027.50c -0.1907
      14000.50c -0.2080
      26000.55c -0.0001
m2t    lwtr.01t
c      UHMW Polyethylene (0.96 g/cm3)
m3     1001.50c 2.000000
      6000.50c 1.000000
m3t    poly.01t
c      304 stainless steel (8.02 g/cm3)
m4     6000.50c -0.08
      25055.50c -2.0
      15031.50c -0.045
      16032.50c -0.03
      14000.50c -0.75
      24000.50c -19.0
      26000.55c -68.245
      7014.50c -0.1
      28000.50c -9.75
c      6061 Aluminum (2.699 g/cm3)
m5     13027.50c -97.92
      14000.50c -0.6
      29000.50c -0.28
      12000.50c -1.0
      24000.50c -0.2
c      B-10 92% enriched (2.34g/cm3)
m6     5010.50c -.92
      5011.50c -0.08
c      polyimide (1.4 g/cm3)
m7     6000.50c 22
      1001.50c 14
      8016.50c 7
      7014.50c 2
m7t    poly.01t
c      cadmium (8.65 g/cm3)
m8     48000.50c -1.00
c      90%Ar + 10%CO2
m9     6000.50c -0.027
      8016.50c -0.073
      18000.35c -0.900
c      fiberglass/copper electrical boards
m10    1001.50c -0.0453
      5010.50c -0.00228      $ 8.1 wt% B2O3, 50 wt% fiber, 50 wt% epoxy
      5011.50c -0.010206
      6000.50c -0.282
      8016.50c -0.4107
      11023.50c -0.0103

```

```

12000.50c -0.0225
13027.50c -0.0337
14000.50c -0.1178
16032.50c -0.000399
20000.50c -0.0737
22000.50c -0.00686
26000.55c -0.00412
m10t poly.01t $ hydrogen in poylethylene 300 K
c air (1.138e-3 g/cm3)
m13 7014.50c 0.8000
8016.50c 0.2000
totnu
nps 100000000
print 60 120 126 140

```

```

surfab3-25_t13.inp (single pan hole)
161a162
> 221 13 -.000114 -3 194 192 -193 -190 191 imp:n=100
163c164
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
--
> 84 2 -1.605 -3 146 -135 -151 #221 imp:n=100
165c166
< 85 2 -1.605 -146 147 -135 -151 imp:n=100
--
> 85 2 -1.605 -146 147 -135 -151 #221 imp:n=100
167c168
< 86 2 -1.605 -147 148 -135 -151 imp:n=90
--
> 86 2 -1.605 -147 148 -135 -151 #221 imp:n=90
177c178
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
185c186
< 96 2 -1.605 -3 146 -135 151 imp:n=100
--
> 96 2 -1.605 -3 146 -135 151 #221 imp:n=100
187c188
< 97 2 -1.605 -146 147 -135 151 imp:n=90
--
> 97 2 -1.605 -146 147 -135 151 #221 imp:n=90
189c190
< 98 2 -1.605 -147 148 -135 151 imp:n=80
--
> 98 2 -1.605 -147 148 -135 151 #221 imp:n=80
259a261,265
> 190 px -4.2139000
> 191 px -16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz -6.6040000

```

```

surfab4-25_t13.inp (double pan hole)
161a162,163
> 221 13 -.000114 -3 194 192 -193 -190 191 imp:n=100
> 222 13 -.000114 -3 194 -192 195 -190 191 imp:n=100
163c165
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
--
> 84 2 -1.605 -3 146 -135 -151 #221 #222 imp:n=100

```

```

165c167
< 85 2 -1.605 -146 147 -135 -151 imp:n=100
--
> 85 2 -1.605 -146 147 -135 -151 #221 #222 imp:n=100
167c169
< 86 2 -1.605 -147 148 -135 -151 imp:n=90
--
> 86 2 -1.605 -147 148 -135 -151 #221 #222 imp:n=90
177c179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
185c187
< 96 2 -1.605 -3 146 -135 151 imp:n=100
--
> 96 2 -1.605 -3 146 -135 151 #221 #222 imp:n=100
187c189
< 97 2 -1.605 -146 147 -135 151 imp:n=90
--
> 97 2 -1.605 -146 147 -135 151 #221 #222 imp:n=90
189c191
< 98 2 -1.605 -147 148 -135 151 imp:n=80
--
> 98 2 -1.605 -147 148 -135 151 #221 #222 imp:n=80
259a262,267
> 190 px -4.21390000
> 191 px -16.40590000
> 192 py 0.00000000
> 193 py 23.11400000
> 195 py -23.11400000
> 194 pz -6.60400000

```

```

surfab5_t13.inp (hill #1)
161a162
> 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
177c178
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 3 -139 -135 1 #49 #221 imp:n=100
259a261,265
> 190 px 4.21390000
> 191 px 16.40590000
> 192 py -11.55700000
> 193 py 11.55700000
> 194 pz 6.60400000

```

```

surfab6_t13.inp (hill #2)
161a162
> 221 2 -1.58 3 -194 192 -193 -190 191 imp:n=100
177c178
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 3 -139 -135 1 #49 #221 imp:n=100
259a261,265
> 190 px -4.21390000
> 191 px -16.40590000
> 192 py -11.55700000
> 193 py 11.55700000

```


> 194 pz 6.6040000

surfab10_t13.inp (hill #3)

161a162

> 221 2 -1.58 3 -194 192 -193 -190 191 imp:n=100

177c178

< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100

—

> 92 13 -.000114 3 -139 -135 1 #49 #221 imp:n=100

259a261.265

> 190 px -17.1679000

> 191 px -29.3599000

> 192 py -11.5570000

> 193 py 11.5570000

> 194 pz 6.6040000

surfab7_t13.inp (hill #4)

161a162

> 221 2 -1.58 3 -194 192 -193 -190 191 imp:n=100

177c178

< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100

—

> 92 13 -.000114 3 -139 -135 1 #49 #221 imp:n=100

259a261.265

> 190 px -23.9139000

> 191 px -36.1059000

> 192 py -11.5570000

> 193 py 11.5570000

> 194 pz 6.6040000

661c667

<nps 25000000

—

>nps 28000000

surfab8_t13.inp (hill #5)

161a162,163

> 221 2 -1.58 3 -194 192 -193 -190 191 imp:n=100

> 222 2 -1.46 3 -194 -192 195 -190 191 imp:n=100

177c179

< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100

—

> 92 13 -.000114 3 -139 -135 1 #49 #221 #222 imp:n=100

259a262.267

> 190 px -17.1679000

> 191 px -29.3599000

> 192 py 0.0000000

> 193 py 23.1140000

> 195 py -23.1140000

> 194 pz 6.6040000

surfab9_t13.inp (hill #6)

161c161,165

< 83 13 -.000114 142 -143 144 -145 139 -133 1 #49 #79 #81 imp:n=100

—

> 83 13 -.000114 142 -143 144 -145 139 -133 1 #49 #79 #81 #223 #224 imp:n=100

> 221 2 -1.46 3 -194 192 -193 -190 191 imp:n=100

> 222 2 -1.58 3 -194 -192 195 -190 191 imp:n=100

```
> 223 2 -1.54 194 -196 192 -193 -190 191 imp:n=100
> 224 2 -1.50 194 -196 -192 195 -190 191 imp:n=100
177c181
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
-
> 92 13 -.000114 3 -139 -135 1 #49 #221 #222 #223 #224 imp:n=100
259a264,270
> 190 px -17.1679000
> 191 px -29.3599000
> 192 py 0.0000000
> 193 py 23.1140000
> 195 py -23.1140000
> 194 pz 6.6040000
> 196 pz 13.2080000
```

surfabcp10_t13.inp (15.2 cm ID cylindrical pan depression)

```
161a162
> 221 13 -.000114 (1 -210 3 -212) imp:n=100
163c164
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
-
> 84 2 -1.605 (-212 146 -135 -151 210):(146 -3 -210) imp:n=100
177c178
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
-
> 92 13 -.000114 212 -139 -135 1 #49 #221 imp:n=100
185c186
< 96 2 -1.605 -3 146 -135 151 imp:n=100
-
> 96 2 -1.605 -212 146 -135 151 imp:n=100
259a261,267
> 210 cz 7.6200000
> 212 pz 1.9
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
```

surfabcp11_t13.inp (20.3 cm ID cylindrical pan depression)

```
161a162
> 221 13 -.000114 1 -210 3 -212 imp:n=100
163c164
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
-
> 84 2 -1.605 (-212 146 -135 -151 210):(146 -3 -210) imp:n=100
177c178
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
-
> 92 13 -.000114 212 -139 -135 1 #49 #221 imp:n=100
185c186
< 96 2 -1.605 -3 146 -135 151 imp:n=100
-
> 96 2 -1.605 -212 146 -135 151 imp:n=100
259a261,267
> 210 cz 10.1600000
> 212 pz 1.9
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
```

> 194 pz 6.6040000

surfabcpl2_t13.inp (25.4 cm ID cylindrical pan depression)

161a162

> 221 13 -.000114 1 -210 3 -212 imp:n=100

163c164

< 84 2 -1.605 -3 146 -135 -151 imp:n=100

> 84 2 -1.605 (-212 146 -135 -151 210);(146 -3 -210) imp:n=100

177c178

< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100

> 92 13 -.000114 212 -139 -135 1 #49 #221 imp:n=100

185c186

< 96 2 -1.605 -3 146 -135 151 imp:n=100

> 96 2 -1.605 -212 146 -135 151 imp:n=100

259a261,267

> 210 cz 12.700000

> 212 pz 1.9

> 190 px 4.2139000

> 191 px 16.4059000

> 192 py -11.5570000

> 193 py 11.5570000

> 194 pz 6.6040000

661c669

< nps 25000000

> nps 28000000

surfabsub2_t13.inp (probe bottom submerged 2 cm below surface)

162,163c162

< c top 0-3cm layer of hydrated alumina + sand (inner cylinder)

< 84 2 -1.605 -3 146 -135 -151 imp:n=100

> 84 2 -1.605 (-195 146 -151 1);(-3 -1 146) imp:n=100

177c176

< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100

> 92 13 -.000114 195 -139 -135 1 #49 imp:n=100

185c184

< 96 2 -1.605 -3 146 -135 151 imp:n=100

> 96 2 -1.605 -195 146 -135 151 imp:n=100

259a259,264

> 190 px 4.2139000

> 191 px 16.4059000

> 192 py -11.5570000

> 193 py 11.5570000

> 194 pz 6.6040000

> 195 pz 2.0

661c666

< nps 25000000

> nps 25000000

surfabsub1.5_t13.inp (probe bottom submerged 1.5 cm below surface)

162,163c162

< c top 0-3cm layer of hydrated alumina + sand (inner cylinder)

< 84 2 -1.605 -3 146 -135 -151 imp:n=100

```

--
> 84 2 -1.605 -195 146 -151 1);(-3 -1 146) imp:n=100
177c176
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 195 -139 -135 1 #49 imp:n=100
185c184
< 96 2 -1.605 -3 146 -135 151 imp:n=100
--
> 96 2 -1.605 -195 146 -135 151 imp:n=100
259a259,264
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
> 195 pz 1.5
661c666
< nps 25000000
--
> nps 25000000

```

```

surfabsub1_t13.inp (probe bottom submerged 1 cm below surface)
162,163c162
< c top 0-3cm layer of hydrated alumina + sand (inner cylinder)
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
--
> 84 2 -1.605 (-195 146 -151 1);(-3 -1 146) imp:n=100
177c176
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 195 -139 -135 1 #49 imp:n=100
185c184
< 96 2 -1.605 -3 146 -135 151 imp:n=100
--
> 96 2 -1.605 -195 146 -135 151 imp:n=100
259a259,264
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
> 195 pz 1.0
661c666
< nps 25000000
--
> nps 25000000

```

```

surfabsub.5_t13.inp (probe bottom submerged .5 cm below matrix surface)
162,163c162
< c top 0-3cm layer of hydrated alumina + sand (inner cylinder)
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
--
> 84 2 -1.605 (-195 146 -151 1);(-3 -1 146) imp:n=100
177c176
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 195 -139 -135 1 #49 imp:n=100
185c184
< 96 2 -1.605 -3 146 -135 151 imp:n=100

```

```

--
> 96 2 -1.605 -195 146 -135 151 imp:n=100
259a259,264
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
> 195 pz 0.5
661c666
< nps 25000000
--
> nps 25000000

surfab7-25_t13.inp (probe bottom suspended 1.3 cm above matrix surface)
161a162
> c 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
163c164
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
--
> 84 2 -1.605 -201 146 -135 -151 imp:n=100
177c178,179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
> 192 13 -.000114 -3 201 -135 imp:n=100
185c187
< 96 2 -1.605 -3 146 -135 151 imp:n=100
--
> 96 2 -1.605 -201 146 -135 151 imp:n=100
259a262,266
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
477c484
< 137 pz -37.577
--
> 137 pz -38.847
479c486
< 138 pz -38.053
--
> 138 pz -39.323
481c488
< 139 pz 7.191
--
> 139 pz 5.921
485c492
< 141 pz -43.133
--
> 141 pz -44.403
495c502,503
< 146 pz -3.0794
--
> 146 pz -4.3494
> 201 pz -1.27
497c505
< 147 pz -6.0794
--
> 147 pz -7.3494

```

```

499c507
< 148 pz -9.0794
--
> 148 pz -10.3494
501c509
< 149 pz -20.0794
--
> 149 pz -21.3494
503c511
< 150 pz -30.0794
--
> 150 pz -31.3494
661c669
< nps 25000000
--
> nps 25000000

surfab8-25_t13.inp (probe bottom suspended 2.5 cm above matrix surface)
161a162
> c 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
163c164
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
--
> 84 2 -1.605 -201 146 -135 -151 imp:n=100
177c178,179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
> 192 13 -.000114 -3 201 -135 imp:n=100
185c187
< 96 2 -1.605 -3 146 -135 151 imp:n=100
--
> 96 2 -1.605 -201 146 -135 151 imp:n=100
259a262,266
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
477c484
< 137 pz -37.577
--
> 137 pz -40.117
479c486
< 138 pz -38.053
--
> 138 pz -40.593
481c488
< 139 pz 7.191
--
> 139 pz 4.651
485c492
< 141 pz -43.133
--
> 141 pz -45.673
495c502,503
< 146 pz -3.0794
--
> 146 pz -5.6194
> 201 pz -2.54
497c505

```

```

< 147 pz -6.0794
—
> 147 pz -8.6194
499c507
< 148 pz -9.0794
—
> 148 pz -11.6194
501c509
< 149 pz -20.0794
—
> 149 pz -22.6194
503c511
< 150 pz -30.0794
—
> 150 pz -32.6194
661c669
< nps 25000000
—
> nps 60000000

surfab9-25_t13.inp (probe bottom suspended 3.8 cm above matrix surface)
161a162
> c 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
163c164
< 84 2 -1.605 -3 146 -135 -151 imp:n=100
—
> 84 2 -1.605 -201 146 -135 -151 imp:n=100
177c178,179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
—
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
> 192 13 -.000114 -3 201 -135 imp:n=100
185c187
< 96 2 -1.605 -3 146 -135 151 imp:n=100
—
> 96 2 -1.605 -201 146 -135 151 imp:n=100
259a262,266
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
477c484
< 137 pz -37.577
—
> 137 pz -41.387
479c486
< 138 pz -38.053
—
> 138 pz -41.863
481c488
< 139 pz 7.191
—
> 139 pz 3.381
485c492
< 141 pz -43.133
—
> 141 pz -46.943
495c502,503
< 146 pz -3.0794
—

```

```

> 146 pz -6.8894
> 201 pz -3.81
497c505
< 147 pz -6.0794
--
> 147 pz -9.8894
499c507
< 148 pz -9.0794
--
> 148 pz -12.8894
501c509
< 149 pz -20.0794
--
> 149 pz -23.8894
503c511
< 150 pz -30.0794
--
> 150 pz -33.8894
661c669
< nps 25000000
--
> nps 25000000

```

surfab17-25_113.inp (probe inclined at a tilt angle of -12.7 deg)

```

14c14
< 6 4 -8.02 -4 3 -1 6 #5 #55 imp:n=100
--
> 6 4 -8.02 -4 195 -1 6 #5 #55 imp:n=100
161a162
> c 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
177c178,179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
> 392 13 -.000114 3 -195 -1 #5 imp:n=100
259a262,267
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
> 195 pz 0.0000000
261c269
< 3 pz 0.0000000
--
> 3 1 pz -0.96505
473c481
< 135 cz 38.1
--
> 135 1 cz 38.1
475c483
< 136 cz 38.58
--
> 136 1 cz 38.58
477c485
< 137 pz -37.577
--
> 137 1 pz -38.5421
479c487
< 138 pz -38.053

```



```

---
> 138 1 pz -39.0181
481c489
< 139 pz 7.191
---
> 139 1 pz 7.191
485c493
< 141 pz -43.133
---
> 141 1 pz -44.0981
487c495
< 142 px -48.26
---
> 142 1 px -48.26
489c497
< 143 px 48.26
---
> 143 1 px 48.26
491c499
< 144 py -48.26
---
> 144 1 py -48.26
493c501
< 145 py 48.26
---
> 145 1 py 48.26
495c503
< 146 pz -3.0794
---
> 146 1 pz -4.04445
497c505
< 147 pz -6.0794
---
> 147 1 pz -7.04445
499c507
< 148 pz -9.0794
---
> 148 1 pz -10.04445
501c509
< 149 pz -20.0794
---
> 149 1 pz -21.04445
503c511
< 150 pz -30.0794
---
> 150 1 pz -31.04445
505c513
< 151 cz 20.0
---
> 151 1 cz 20.0
562a571
> *TR1 0 0 0 12.9 90 102.9 90 0 90 77.1 90 12.9
661c670
< nps 25000000
---
> nps 50000000
---

surfab16-25_t13.inp (probe inclined at a tilt angle of -8.4 deg)
14c14
< 6 4 -8.02 -4 3 -1 6 #5 #55 imp:n=100
---

```

```

> 6 4 -8.02 -4 195 -1 6 #5 #55 imp:n=100
161a162
> c 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
177c178,179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
---
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
> 392 13 -.000114 3 -195 -1 #5 imp:n=100
259a262,267
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
> 195 pz 0.0000000
261c269
< 3 pz 0.0000000
---
> 3 1 pz -0.63725
473c481
< 135 cz 38.1
---
> 135 1 cz 38.1
475c483
< 136 cz 38.58
---
> 136 1 cz 38.58
477c485
< 137 pz -37.577
---
> 137 1 pz -38.2143
479c487
< 138 pz -38.053
---
> 138 1 pz -38.6903
481c489
< 139 pz 7.191
---
> 139 1 pz 7.191
485c493
< 141 pz -43.133
---
> 141 1 pz -43.7703
487c495
< 142 px -48.26
---
> 142 1 px -48.26
489c497
< 143 px 48.26
---
> 143 1 px 48.26
491c499
< 144 py -48.26
---
> 144 1 py -48.26
493c501
< 145 py 48.26
---
> 145 1 py 48.26
495c503
< 146 pz -3.0794
---

```

```

> 146 1 pz -3.71665
497c505
< 147 pz -6.0794
—
> 147 1 pz -6.71665
499c507
< 148 pz -9.0794
—
> 148 1 pz -9.71665
501c509
< 149 pz -20.0794
—
> 149 1 pz -20.71665
503c511
< 150 pz -30.0794
—
> 150 1 pz -30.71665
505c513
< 151 cz 20.0
—
> 151 1 cz 20.0
562a571
> *TR1 0 0 0 8.6 90 98.6 90 0 90 81.4 90 8.6
661c670
< nps 25000000
—
> nps 25000000

surfab15-25_t13.inp (probe inclined at a tilt angle of -4 deg)
14c14
< 6 4 -8.02 -4 3 -1 6 #5 imp:n=100
—
> 6 4 -8.02 -4 195 -1 6 #5 imp:n=100
161a162
> c 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
177c178,179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
—
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
> 392 13 -.000114 3 -195 -1 #5 imp:n=100
259a262,267
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
> 195 pz 0.0000000
261c269
< 3 pz 0.0000000
—
> 3 1 pz -0.30945
473c481
< 135 cz 38.1
—
> 135 1 cz 38.1
475c483
< 136 cz 38.58
—
> 136 1 cz 38.58
477c485
< 137 pz -37.577

```

```

—
> 137 1 pz -37.8865
479c487
< 138 pz -38.053
—
> 138 1 pz -38.3625
481c489
< 139 pz 7.191
—
> 139 1 pz 7.191
485c493
< 141 pz -43.133
—
> 141 1 pz -43.4425
487c495
< 142 px -48.26
—
> 142 1 px -48.26
489c497
< 143 px 48.26
—
> 143 1 px 48.26
491c499
< 144 py -48.26
—
> 144 1 py -48.26
493c501
< 145 py 48.26
—
> 145 1 py 48.26
495c503
< 146 pz -3.0794
—
> 146 1 pz -3.38885
497c505
< 147 pz -6.0794
—
> 147 1 pz -6.38885
499c507
< 148 pz -9.0794
—
> 148 1 pz -9.38885
501c509
< 149 pz -20.0794
—
> 149 1 pz -20.38885
503c511
< 150 pz -30.0794
—
> 150 1 pz -30.38885
505c513
< 151 cz 20.0
—
> 151 1 cz 20.0
562a571
> *TR1 0 0 0 4.2 90 94.2 90 0 90 85.8 90 4.2
661c670
< nps 25000000
—
> nps 25000000

```

surfab18-25_t13.inp (probe inclined at a tilt angle of 4.5 deg)

```

14c14
< 6 4 -8.02 -4 3 -1 6 #5 #55 imp:n=100
--
> 6 4 -8.02 -4 195 -1 6 #5 #55 imp:n=100
161a162
> c 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
177c178,179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
--
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
> 392 13 -.000114 3 -195 -1 #5 imp:n=100
259a262,267
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
> 195 pz 0.0000000
261c269
< 3 pz 0.0000000
--
> 3 1 pz -0.302003
473c481
< 135 cz 38.1
--
> 135 1 cz 38.1
475c483
< 136 cz 38.58
--
> 136 1 cz 38.58
477c485
< 137 pz -37.577
--
> 137 1 pz -37.8791
479c487
< 138 pz -38.053
--
> 138 1 pz -38.3551
481c489
< 139 pz 7.191
--
> 139 1 pz 7.191
485c493
< 141 pz -43.133
--
> 141 1 pz -43.4351
487c495
< 142 px -48.26
--
> 142 1 px -48.26
489c497
< 143 px 48.26
--
> 143 1 px 48.26
491c499
< 144 py -48.26
--
> 144 1 py -48.26
493c501
< 145 py 48.26
--

```

```

> 145 1 py 48.26
495c503
< 146 pz -3.0794
—
> 146 1 pz -3.3814
497c505
< 147 pz -6.0794
—
> 147 1 pz -6.3814
499c507
< 148 pz -9.0794
—
> 148 1 pz -9.3814
501c509
< 149 pz -20.0794
—
> 149 1 pz -20.3814
503c511
< 150 pz -30.0794
—
> 150 1 pz -30.3814
505c513
< 151 cz 20.0
—
> 151 1 cz 20.0
562a571
> *TR1 0 0 0 4.1 90 85.9 90 0 90 94.1 90 4.1
661c670
< nps 25000000
—
> nps 25000000

surfab19-25_t13.inp (probe inclined at a tilt angle of 8.5 deg)
14c14
< 6 4 -8.02 -4 3 -1 6 #5 #55 imp:n=100
—
> 6 4 -8.02 -4 195 -1 6 #5 #55 imp:n=100
161a162
> c 221 2 -1.58 3 -194 192 -193 190 -191 imp:n=100
177c178,179
< 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
—
> 92 13 -.000114 3 -139 -135 1 #49 imp:n=100
> 392 13 -.000114 3 -195 -1 #5 imp:n=100
259a262,267
> 190 px 4.2139000
> 191 px 16.4059000
> 192 py -11.5570000
> 193 py 11.5570000
> 194 pz 6.6040000
> 195 pz 0.0000000
261c269
< 3 pz 0.0000000
—
> 3 1 pz -0.599703
473c481
< 135 cz 38.1
—
> 135 1 cz 38.1
475c483
< 136 cz 38.58

```

```

--
> 136 1 cz 38.58
477c485
< 137 pz -37.577
--
> 137 1 pz -38.1768
479c487
< 138 pz -38.053
--
> 138 1 pz -38.6528
481c489
< 139 pz 7.191
--
> 139 1 pz 7.191
485c493
< 141 pz -43.133
--
> 141 1 pz -43.7328
487c495
< 142 px -48.26
--
> 142 1 px -48.26
489c497
< 143 px 48.26
--
> 143 1 px 48.26
491c499
< 144 py -48.26
--
> 144 1 py -48.26
493c501
< 145 py 48.26
--
> 145 1 py 48.26
495c503
< 146 pz -3.0794
--
> 146 1 pz -3.6791
497c505
< 147 pz -6.0794
--
> 147 1 pz -6.6791
499c507
< 148 pz -9.0794
--
> 148 1 pz -9.6791
501c509
< 149 pz -20.0794
--
> 149 1 pz -20.6791
503c511
< 150 pz -30.0794
--
> 150 1 pz -30.6791
505c513
< 151 cz 20.0
--
> 151 1 cz 20.0
562a571
> *TR1 0 0 0 8.1 90 81.9 90 0 90 98.1 90 8.1
661c670
< nps 25000000

```

—
> nps 50000000

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