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CRITICALITY EVALUATION FOR K-AREA DISASSEMBLY BASIN CLEANUP (U)

by

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FOR K AREA DISASSEMBLY BASIN CLEANUP (U)

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CRITICALITY SAFETY EVALUATION FOR K AREA DISASSEMBLY BASIN CLEANUP (U)

INTRODUCTION

Preparations are currently being made to remove sludge from the Disassembly Basin in all reactor areas. Because this sludge contains fissile isotopes (References 1 and 2), it is necessary to perform a criticality safety evaluation for the planned activities. A previous evaluation examined the criticality safety aspects of the sludge removal process for L Area (Reference 3). This document addresses the criticality safety aspects of the K Area Disassembly Basin cleanup work.

The K Area Disassembly Basin cleanup will involve, as a first step, pumping the basin sludge into the Monitor Basin portion of the Disassembly Basin. From the Monitor Basin, the sludge will be pumped into tanks or containers for permanent disposition. The criticality safety evaluation discussed in this document covers the transfer of the sludge to the Monitor Basin.

SUMMARY

The total mass of fissile material that could be present in the Monitor Basin as a result of the transfer of sludge from the K Area Disassembly Basin may exceed the minimum critical mass, as defined in national criticality safety standards. However, characteristics of the sludge are such that no method has been identified by which a critical configuration can be attained. Thus, there are no criticality safety operating limits required for the K Area Disassembly Basin sludge removal process that transfers sludge to the Monitor Basin. Prior to further transfers of the sludge, additional material sample analyses are required and additional criticality safety evaluations must examine the remaining sludge handling and disposal activities.

DISCUSSION

Description - Basin Sludge Cleanup

As part of the Disassembly Basin cleanup program, sludge will be vacuumed from the floor of the basin and disposed in accordance with appropriate waste management requirements. As an intermediate step, the sludge will first be pumped from the various sections of the basin to the Monitor Basin section of the basin. The Monitor Basin will serve as a temporary storage location for the sludge prior to permanent disposition.

Requirements Documentation

In addition to the general requirements documentation that is applicable to all criticality safety evaluations (Reference 21), ANS-8.15, "American National Standard for Nuclear Criticality Control of Special Actinide Elements", is applicable to this evaluation. Sludge analyses indicate the presence of several special actinide elements (References 1 and 2).

Methodology

Samples were taken from the K Area basin to determine the composition of the sludge. The sampling program itself was designed to provide statistically reasonable sludge composition data (References 1 and 22). The concentrations of isotopes that are of concern for criticality safety evaluations pertaining to the basin environment were determined from ICP/MS spectrometry (Reference 5). The isotopes of interest for this evaluation are those fissile isotopes (i.e.- can support a slow neutron chain reaction) that are present in the sludge, since the sludge is in an aqueous environment. Non-fissile, fissionable isotopes have an insignificant effect on this evaluation because of the aqueous environment and because the fissionable isotope masses present are less than 1% of the applicable subcritical mass limits. References 1 and 2 provide concentrations of various isotopes in the sludge as a function of basin region, as determined from sludge sample analyses. The concentrations used in this evaluation are given in Table 1 in units of grams/gram of sample. For VTS and the Machine Basin, the Table 1 concentrations represent the maximum fissile concentration from multiple sample results. For the Transfer Bay, the concentrations given in Table 1 are the results of the one analyzed sample. SRTC analysts reported the sludge density in Reference 1 as 1.01 grams/cubic centimeter.

The mass of each fissile isotope in the disassembly basin was determined from the concentrations in Table 1, the sludge density (1.01 g/cc) and the sludge volume in the basin. The sludge volumes, shown in Table 2, were determined from dimensions derived from Disassembly Basin drawings (References 11-18) and an estimated sludge depth of 3 inches (Reference 6). Table 3 lists the corresponding sludge masses by Disassembly Basin region. Table 4 lists the fissile isotope masses summed over the basin. The best estimate values were derived from the data in Tables 1, 2, and 3. The values designated as 'including uncertainty' were derived assuming a 6-inch sludge depth (to account for uncertainty in the sludge depth) and fissile concentrations at 130% of the concentrations in Table 1 (to account for estimated measurement uncertainties).

Total fissile isotope masses are then compared to subcritical mass limits for aqueous solutions (Table 5) published in accepted

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criticality safety standards and references (References 7, 8 and 9). Since a mixture of fissile isotopes is involved in this evaluation, a "Rule of Fraction (ROF)" comparison as outlined in Reference 7 was used to assess how much the fissile masses in the basin exceed the minimum mass for criticality, if at all. ROF calculations with and without the effects of U-238 in the mixture were performed. For this evaluation, an upper limit of 0.9 for the ROF calculation was used to declare that a mixture is subcritical. This was done to provide margin to account for uncertainties in the ROF methodology (Reference 10). Subcritical limits other than subcritical mass (such as subcritical fissile concentrations), were considered, as appropriate.

Two important clarifications of the ROF methodology are in order. First, Reference 7 indicates the ROF methodology is only applicable to aqueous (or well moderated) mixtures. This requirement is satisfied for this evaluation. Considering the sludge sample density and composition analyses, the sludge is at least 95 weight percent H₂O and the hydrogen-to-fissile atom ratio is greater than 10⁶. This more than qualifies as a well-moderated mixture, and, since the hydrogen appears primarily in the form of water, the description of this sludge as an aqueous mixture is also appropriate.

The second clarification involves the isotopes (and associated subcritical limits) for which the ROF methodology is applicable. Reference 7 implies that uranium isotopes may not be used with the ROF methodology. It is generally accepted that this implied exclusion of uranium isotopes is not consistent with the actual intent of the authors of Reference 7. Reference 10, in fact, is an example of a ROF evaluation that includes U-235. As a result, this evaluation assumes that it is acceptable to include uranium isotopes in ROF calculations.

In addition to the above analytical calculations, supplemental scoping calculations were performed using the KENO5A-PC computer code (Reference 19). This code is not certified and validated per SRTC requirements (Reference 20) but is adequate for supplemental calculations to support the above analytical work. The calculations were performed to determine, for the best estimate and uncertainty cases, the extent to which the fissile isotopes must preferentially accumulate in a spherical geometry in order to obtain a critical configuration. The geometry setup for the calculations consisted of a sphere of variable radius, containing the aqueous fissile solution, at the center of a water filled cube that is 500 cm on a side. The fissile solution concentrations were changed for each radius to maintain the same fissile mass for each radius. Because of the thickness of the water surrounding the sphere, no additional material was modeled outside the cube. As an additional note, the cross sections for Am-242m and Cm-243 were not available in the library used with KENO5A-PC, so their contributions were modeled by increasing the U-235 mass by equivalent amounts.

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Evaluation and Results

The calculated volume of sludge in each area of the basin, and the associated total mass values, are given in Tables 2 and 3. These values of volume and mass are conservative since only overall basin dimensions were used and no consideration was given to the amount of basin floor space covered by structural materials. The fissile isotope masses for the entire basin, obtained from total sludge mass and isotope concentration, are given in Table 4. In this table, isotope masses are given for the best estimate case and for the case that includes uncertainties.

Application of the ROF methodology to the calculated best estimate masses from Table 4 resulted in a "sum of the ratios" value of 2.02. This result indicates that the total mass of fissile isotopes in the sludge exceeds the minimum critical mass.

The above result, however, does not include the effects of the presence of U-238 in the sludge. U-238 is a neutron poison that effectively increases the subcritical mass limits of the isotopes in the mixture. The mass of U-238 in the sludge was determined from ICP/MS spectrometry results (References 1 and 2). The minimum concentration for weight 238 is given as 8.03×10^{-4} g/g for VTS, 5.16×10^{-5} g/g for the Machine Basin and 4.74×10^{-5} for the Transfer Bay. For criticality safety evaluations, the minimum concentration for a neutron poison should be used to ensure conservatism. To account for the possible contributions of other isotopes of weight 238, the U-238 concentrations were assumed for this evaluation to be equal to 50% of the above concentrations. This gives assumed best estimate U-238 concentrations of 4.02×10^{-4} g/g for VTS, 2.58×10^{-5} g/g for the Machine Basin and 2.37×10^{-5} g/g for the Transfer Bay. This choice of the 50% value is conservative in light of the fact that the only other reasonably possible isotope is Pu-238, the concentration of which is indicated in References 1 and 2 to be several orders of magnitude below the values given above. References 1 and 2, indeed, indicate that the mass number 238 concentration is primarily due to U-238. The associated U-238 best estimate mass and mass including uncertainty are also given in Table 4.

The effects of the presence of U-238 in the sludge were applied to the subcritical mass limit of U-235. When the assumed U-238 best estimate concentrations are added to the sludge mixture, the U-235 weight percent (of total uranium), or enrichment, drops from 100 wt% to 4.4 wt% (neglecting U-233 effects on enrichment). Figure 3.4 of Reference 8 provides factors by which the subcritical mass limit for U-235 can be increased as a result of reduced uranium enrichment. The factor corresponding to 4.4 wt% is approximately 40. This factor leads to an adjusted U-235 subcritical mass limit of 28000g.

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Having determined an adjusted subcritical mass limit for U-235, the ROF calculation was then repeated. The inclusion of U-238 effects resulted in a new ROF value of 0.75, which is below 0.9 and indicates a significantly subcritical system. It is also important to note that this result does not account for the effects of the U-238 on the other subcritical mass limits.

When the uncertainties are applied to the fissile isotopes considered in this evaluation, the minimum subcritical mass limit was exceeded for U-235 and Pu-239 (compare Tables 4 and 5) and the associated ROF calculation produced a value of 5.24, not including U-238 effects. Because there is no available criticality safety experimental data for mixtures like the sludge in the K Area basin, it is difficult to determine exact reasonable and defensible subcritical limits. In these types of situations, it is helpful to convert the mixture of various isotopes into an equivalent mixture of one isotope for which experimental data is available. The fissile mixture was converted to an equivalent U-235 mixture by multiplying the above ROF result (5.24) by the U-235 subcritical mass limit. The resulting mixture contains 3668g of U-235. The U-238 mass, including uncertainties (6-inch sludge depth and 70%, instead of 130%, of best estimate concentration), is approximately 27717 g. This results in an equivalent U-235 enrichment of 11.7 wt%. The associated adjustment factor from Figure 3.4 of Reference 8 is approximately 12, which gives an adjusted U-235 subcritical mass limit of 8400 g. The equivalent U-235 mass is much less than this limit ($3668/8400 = 0.44$). This indicates that the fissile mass in the basin, even with uncertainties added, is less than that amount needed for criticality. Of course, this analysis is only valid for comparative purposes, since the standards give no factors for the effects of U-238 for the other isotopes.

Because of the large uncertainty associated with attempting to show that the mixture is within adjusted subcritical mass limits, fissile nuclide concentration effects were also examined. According to Reference 8, the fissile nuclide concentration subcritical limit for aqueous U-235 solutions is 11.5 g/liter. For the equivalent mass of 3668g, this corresponds to a volume of 319 liters, or a sphere with a 16.7 inch radius. Therefore, to achieve the fissile concentration necessary for criticality, all of the equivalent U-235 mass would have to preferentially accumulate (no U-238) within the Monitor Basin in a sphere with a radius less than 16.7 inches. If one assumes that all of the basin sludge settles in the Monitor Basin to a depth of 3 inches, the above spherical volume represents approximately 7.1% of the "settled volume" of the sludge. If the depth of sludge is greater than 3 inches, the percentage of "settled volume" would decrease proportionally. There is no identified mechanism by which the fissile isotopes could preferentially migrate into a spherical volume that is more than 14 times smaller than the above assumed "settled volume". The presence of U-238 in the spherical region would reduce the

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reactivity of the mixture, as is indicated by the equivalent adjusted U-235 subcritical mass limit that was calculated above when U-238 effects were included.

The KENO5A-PC supplemental calculations considered aqueous solutions using the best estimate and uncertainty-included fissile isotope masses. Cases were executed with and without U-238 effects. These aqueous solutions were modeled in spheres with radii ranging from 5 inches (12.7 cm) to 20 inches (50.8 cm). As discussed above, fissile mass in the spheres was constant and the spheres were assumed to be at the center of a water cube that is 500 cm (196.8 inches) on a side. The average k_{eff} , and associated uncertainty, was then calculated for each case. The results are given in Table 6 and Figures 1 and 2. If one assumes that a $k_{eff} + 3$ sigma value of 0.95 corresponds to a critical configuration, then the approximate critical sphere sizes for the various cases are as follows:

• Best Estimate Mass / No U-238:	27 cm
• Best Estimate Mass / U-238:	Criticality not possible
• Best Est. + Uncertainty / No U-238:	40 cm
• Best Est. + Uncertainty / U-238:	39 cm

These results are consistent with the analytical results in that they indicate the following:

- The best estimate fissile mass can conceivably be made critical if no U-238 is allowed in the mixture and if there exists a means by which the fissile isotopes can accumulate in an optimum spherical geometry. As given above, the sphere in the best estimate case would be one with a radius of approximately 27 cm (approximately 10.6 inches).
- If the best estimate U-238 mass is included with the best estimate fissile mass, it appears that the resulting system is safely subcritical for all configurations. This agrees with the ROF calculation that includes the best estimate U-238 effects.
- For those cases that include the fissile mass uncertainty, the fissile isotopes must accumulate in an aqueous solution within a spherical radius of less than 16.7 inches (42.4 cm), in order for criticality to be possible.

In addition to the above calculational results, there are several favorable aspects that were not included in this evaluation which will further increase the subcritical margin:

- There is a high confidence, based on sample results, that the actual U-238 mass is greater than that assumed for this work.

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- The sludge contains iron (22-38 wt% of solids). The primary stable iron isotopes have thermal neutron capture cross sections that range from 2.5 b to 2.8 b. This is similar to the 2.7 b cross section of U-238. The effects of the presence of U-238 were demonstrated above. Therefore, with the iron present in the sludge, we have an additional neutron poison that was not considered in this evaluation.
- The ICP/MS concentrations, where applicable, were assumed to correspond exclusively to fissile isotopes. The possibility of other, non-fissile isotopes was ignored. The Am-242m concentration is a prime example of the conservatism introduced by this action. The possible presence of Pu-242 (a non-fissile isotope) was excluded. Based on past operating history, Pu-242, not Am-242m, should be the primary weight 242 isotope in the sludge. In the best estimate ROF calculation (with U-238 effects), Am-242m accounted for approximately 0.25 of the 0.75 final result.
- As discussed earlier, the sludge depth is not 6 inches everywhere, as was assumed in the uncertainty calculations, and, in addition, the calculation of sludge mass ignored the fact that some floor space in the disassembly basin is taken up by concrete supports. This would lead to a smaller calculated value of total sludge mass resulting in smaller calculated values for fissile isotope masses.
- The most conservative disassembly basin fissile isotope concentrations were used. This action resulted in a conservative increase in the calculated fissile isotope masses. In some cases, the region concentrations of certain isotopes vary by a factor of 5 or more.

Discussion of Contingencies

Compliance with the double contingency principle is not required for the basin cleanup work, since the results of this evaluation indicate that criticality is not possible. Therefore, no discussion of contingencies is required.

Design Features and Administratively Controlled Limits and Requirements

Since the results of this evaluation indicate that criticality is not possible in the sludge cleanup process, no criticality safety operating limits or special design features are required. It should be mentioned, however, that this evaluation makes use of what could be considered a "physical feature" of the sludge: the fissile material is spread throughout the sludge and doesn't concentrate in small volumes, even when moved from one region of the basin to another.

CONCLUSION

Fissile isotopes are present in the K Area Disassembly Basin sludge in sufficient quantities to support criticality. However, the general characteristics of the sludge and required critical geometries are such that no method of fissile material migration and agglomeration has been identified that can lead to a critical configuration. As a result, there are no criticality safety operating limits required for this process. After the sludge has settled in the Monitor Basin, and prior to the transfer of the sludge from the Monitor Basin to permanent disposition, additional sludge samples must be obtained and composition analyses performed to verify that no changes have occurred that would require criticality safety operating limits for the process associated with removing sludge from the basin.

As a final comment, since the sludge removal process involves the movement of fissile isotopes, NIM operability must be verified and the movement of other components containing fissile material should be suspended during the sludge movement process.

REFERENCES

1. Tovo, L. L., "Results of K-Area Vertical Tube Storage Basin Sludge Analyses (U)", SRTC-ADS-93-0335, June 16, 1993.
2. Tovo, L. L., "Results of K-Area Machine Basin and Transfer Bay Sludge Analyses (U)", SRTC-ADS-93-0359, July 29, 1993.
3. Rosser, M. A., "Criticality Safety Evaluation for L Area Disassembly Basin Cleanup (U)", RRD-RED-930373, October 6, 1993.
4. Reed, R. L., "Criticality Considerations in Disassembly Basin Sludge (U)", RRD-RTS-930020, January 25, 1993.
5. Gibbs, A., "Disassembly Basin Sludge Characterization Analyses (U)", RRD-RTS-930097, May 3, 1993.
6. Stokes, M. W., "Re: Criticality Memo", SRT-EES-930105, June 2, 1993.
7. "American National Standard for Nuclear Criticality Control of Special Actinide Elements," ANS-8.15-1981, November 9, 1981.
8. Nuclear Safety Guide, TID-7016, Revision 2, NUREG/CR-0095, June 1978.
9. "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," ANS-8.1-1983, October 7, 1983.

10. Finch, D. R. and Williamson, T. G., "Validity of the Rule-of-Fractions for Assuring Criticality Safety Margins (U)", WSRC-TR-91-569, October, 1991.
11. Drawing #W133698, Revision 68.
12. Drawing #W133699, Revision 16.
13. Drawing #W133787, Revision 17.
14. Drawing #W133955, Revision 14.
15. Drawing #W134050, Revision 44.
16. Drawing #W134053, Revision 17.
17. Drawing #W134048, Revision 75.
18. Drawing #W168510, Revision 47.
19. "KENO5A-PC: Monte Carlo Criticality Program with Supergrouping", RSIC Computer Code Collection, CCC-548 A/B, May 1991.
20. Procedure Manual 1Q34, Nuclear Reactor Technology and Scientific Computations Department Quality Assurance Manual.
21. Westinghouse Savannah River Company Nuclear Criticality Safety Manual (U), WSRC-IM-93-13, July 1, 1993.
22. Nichols, D. M., "K-Reactor Disassembly Basin Sample Plan (U)", RRD-RES-930047, March 3, 1993.

TABLE 1

BASIN ISOTOPE CONCENTRATIONS (g/g of sample)*

- VTs + D&E Canal

<u>ISOTOPE</u>	<u>CONCENTRATION (g/g)</u>	<u>DETERMINED BY</u>
U-233	3.81×10^{-9}	ICP/MS
U-235	1.36×10^{-5}	ICP/MS
Pu-239	2.67×10^{-6}	ICP/MS
Pu-241	5.91×10^{-8}	ICP/MS
Am-242m	4.10×10^{-8}	ICP/MS
Cm-243	3.44×10^{-8}	ICP/MS

- Machine Basin (Includes Dry Cave, Emergency Disassembly, Monitor Basin, Machine Area and HTS/Bucket Storage)

<u>ISOTOPE</u>	<u>CONCENTRATION (g/g)</u>	<u>DETERMINED BY</u>
U-233	3.81×10^{-9}	ICP/MS
U-235	2.64×10^{-6}	ICP/MS
Pu-239	6.15×10^{-7}	ICP/MS
Pu-241	1.07×10^{-8}	ICP/MS
Am-242m	1.17×10^{-8}	ICP/MS
Cm-243	3.85×10^{-9}	ICP/MS

TABLE 1 (cont.)

BASIN ISOTOPE CONCENTRATIONS (g/g of sample) *

- Transfer Bay

<u>ISOTOPE</u>	<u>CONCENTRATION (g/g)</u>	<u>DETERMINED BY</u>
U-233	None Detected	ICP/MS
U-235	3.39×10^{-7}	ICP/MS
Pu-239	1.41×10^{-7}	ICP/MS
Pu-241	1.78×10^{-9}	ICP/MS
Am-242m	4.37×10^{-10}	ICP/MS
Cm-243	5.09×10^{-10}	ICP/MS

* Where multiple samples were available (VTS, Machine Basin), the concentration recorded here is the maximum observed value.

TABLE 2

SLUDGE VOLUME BY DISASSEMBLY BASIN REGION

<u>DISASSEMBLY BASIN REGION</u>	<u>SLUDGE VOLUME (cm³)</u>
VTs [includes D&E canal] (Drawings W133698, W133699, W133787 and W133955)	4.0×10^7
Dry Cave Area (Drawing W134050)	2.9×10^7
Emergency Disassembly Area (Drawing W133698)	1.2×10^7
Monitor Basin (Drawing W134053)	4.5×10^6
Machine Area (Drawing W134048)	2.8×10^7
HTS & Bucket Storage (Drawings W133698, W133699)	6.0×10^7
Transfer Bay Pit #1 and Pit #2 (Drawing W168510)	3.1×10^6

TABLE 3

SLUDGE MASS BY DISASSEMBLY BASIN REGION

<u>DISASSEMBLY BASIN REGION</u>	<u>SLUDGE MASS (g)</u>
VTs	4.04×10^7
Dry Cave Area	2.93×10^7
Emergency Disassembly Area	1.21×10^7
Monitor Basin	4.55×10^6
Machine Area	2.83×10^7
HTS & Bucket Storage	6.06×10^7
Transfer Bay Pits	3.13×10^6

TABLE 4

ESTIMATED BASIN SLUDGE ISOTOPE MASSES (GRAMS)

<u>ISOTOPE</u>	<u>ESTIMATED ISOTOPE MASSES (g)</u>	
	<u>BEST ESTIMATE</u>	<u>INCLUDING UNCERTAINTY</u>
U-233	0.7	1.8
U-235	906.9	2357.9
Pu-239	191.3	497.4
Pu-241	3.8	9.9
Am-242m	3.3	8.6
Cm-243	1.9	4.9
U-238	19798.0	27717.2

TABLE 5

MINIMUM SUBCRITICAL MASS LIMITS FOR VARIOUS ISOTOPES

<u>ISOTOPE</u>	<u>SUBCRIT. MASS LIMIT</u>	<u>REFERENCE NOTES</u>
U-233	500 g	A
U-235	700 g	A
Pu-239	450 g	A
Pu-241	200 g	B
Am-242m	13 g	B
Cm-243	90 g	B

Reference Notes:

- A. See Section 5.2 of Reference 9.
- B. See Table 2 of Reference 7.

TABLE 6

KENO5A-PC RESULTS

A) Best Estimate Fissile Masses

- No U-238 Effects

<u>Sphere radius (cm)</u>	<u>Keff</u>	<u>Sigma</u>	<u>Keff + 3-Sigma</u>
12.7	1.04551	0.01068	1.07757
25.4	0.99041	0.00571	1.00753
38.1	0.58921	0.00354	0.59982

- U-238 Effects Included

<u>Sphere radius (cm)</u>	<u>Keff</u>	<u>Sigma</u>	<u>Keff + 3-Sigma</u>
12.7	0.50896	0.00641	0.52820
25.4	0.84522	0.00602	0.86329
38.1	0.55556	0.00340	0.56575

TABLE 6 (cont.)

KENO5A-PC RESULTS

B) Fissile Masses Including Uncertainty

- No U-238 Effects

<u>Sphere radius (cm)</u>	<u>Keff</u>	<u>Sigma</u>	<u>Keff + 3-Sigma</u>
12.7	1.07249	0.01178	1.10784
25.4	1.26372	0.00841	1.28894
38.1	1.00095	0.00532	1.01692
43.2	0.84945	0.00439	0.86262
50.8	0.65442	0.00314	0.66384

- U-238 Effects Included

<u>Sphere radius (cm)</u>	<u>Keff</u>	<u>Sigma</u>	<u>Keff + 3-Sigma</u>
12.7	0.66858	0.00775	0.69183
25.4	1.14863	0.00983	1.17813
38.1	0.96252	0.00611	0.98084
43.2	0.83694	0.00427	0.84976

FIGURE 1

KENO5A-PC RESULTS (Keff VS. SPHERE RADIUS)
(Best Estimate Fissile Mass)

FIGURE 2

KENO5A-PC RESULTS (Keff VS. SPHERE RADIUS)
(Fissile Mass Including Uncertainty)

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