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7. Abstract <p>This Addendum 3 to the Criticality Safety Analysis Report 80-027 examines criticality safety during the use of the modified calorimeter (Calorimeter 109B) with enlarged cell tube diameters to assure that an adequate margin of subcriticality is maintained for all normal and contingency conditions. With a K_{eff} of less than 0.95 for both of the most reactive normal and contingency cases, the criteria for safe operation of the calorimeter (Calorimeter 109B) has been met as required by WHC-CM-4-29.</p>		
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ADDENDUM 3 TO CSAR 80-027

Title: USE OF CALORIMETER 109B FOR FISSILE MATERIAL MEASUREMENT

Prepared by: Tony Chiao Date: 11/30/84
Engineer, Criticality and Radiological Analyses

Reviewed by: Edward M. Miller Date: Nov 30, '84
Engineer, Criticality and Radiological Analyses

Approved by: J. M. Daugherty Date: 11-30-84
Manager, Criticality and Radiological Analyses

1.0 PURPOSE

This modification to the PFP calorimeter system involves removing current calorimeter #3 from the water bath and replacing it with a calorimeter that can accommodate larger diameter items (an oversize can). The inside diameters of both the sample and the reference cells will be increased to 5.835 inches at the top opening and to 5.22 inches at the bottom, the 8 inch high measurement zone.

This Addendum 3 to Criticality Safety Analysis Report 80-027 examines criticality safety during the use of the modified calorimeter (Calorimeter 109B) with enlarged cell tube diameters to assure that an adequate margin of subcriticality is maintained for all normal and contingency conditions.

2.0 SUMMARY

A number of normal cases, mainly based on the H/Pu ratios of criticality prevention specifications (CPSs) storage categories of fissile material to be measured, and their abnormal condition cases (contingency cases) were considered and their k_{eff} 's were calculated. The details of the case description are given in Sec. 5.0. The change in the calorimeter diameter does not significantly affect normal operations. However, if an abnormal operation such as placing an additional can of Pu inside the reference cell, double batching the sample cell, etc., occurs, the interaction between the various fissile materials will be different because of the difference in the geometrical arrangement.

The most reactive normal case is for 2.5 kg Pu metal and its k_{eff} was calculated to be 0.700 ± 0.003 . The most reactive contingency case for Pu metal, which is also the most reactive case for all contingency cases, is the placing of a Pu button in the reference cell and also stacking two buttons in the sample cell. For this case the calculated k_{eff} is 0.895 ± 0.003 . In this contingency case the Pu buttons in both the reference and sample cells were

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offset from the centers of the cells and were shifted toward each other to create the most reactive situation.

With a k_{eff} of less than 0.935 for both the most reactive normal and contingency cases, the criteria for safe operation of the calorimeter (Calorimeter 109B) has been met as required by WHC-CM-4-29.

3.0 FACILITY DESCRIPTION

3.1 Apparatus

The current modification to the PFP calorimeter system will remove current calorimeter #3 from the water bath it shares with calorimeter #4 and replace it with a calorimeter that can accommodate larger diameter items such as an oversize can which has a dimension of 12.07 cm diameter and 17.15 cm height (4 3/4" D and 6 3/4" H). The oversize calorimeter is to have two tubes 5.22-inches I.D. at the measurement zone and 5.835-inches at the upper insulation section. The calorimeter tubes have a 6.33-inches O.D.

The 8-inch, center to center spacing of these tubes is fixed by welded steel plates at the bottom and near the top of the tubes. Centerline spacing between the oversize calorimeter and existing calorimeter #4 will remain the same as in the current configuration (32-inches), controlled by the wood panel and metal framework top of the calorimeter bath cabinet. Schematic diagrams for the calorimeters arrangement in their bath and the enlarged calorimeter dimensions are shown in Figures 3.1 and 3.2.

The calorimeter systems are located in Room 637 of the 2736-ZB building. The current calorimeter system is composed of three water filled environmental baths each containing two twin cell calorimeters and a water filled pre-equilibration bath with 4 tubes that may contain up to 16 plutonium containing inventory items. There will be no requirement to change the current configuration of baths relative to each other or building structures.

The calorimeter consists of two fixed geometry, vertical tubes that will be located in an environmental water bath. One, the measurement cell, holds the fissile material sample can in a measurement adapter that fits snugly into the measurement cell. The other tube is a reference cell that contains a measurement adapter and insulator, identical to those in the measurement cell, but with no plutonium. The bath containing the calorimeters is nominally 52.5 x 31-inches inside dimension made of a stainless steel liner and nominally 54 x 32.5-inches of plywood covered with plastic laminate. The top and bottom of the bath are 41 and 9 inches above the floor, respectively.

The center of the calorimeter tube is 7.25-inches from the front and 11.25-inches from the close side of the calorimeter outside boundary. The center of the reference tube is 14.0-inches from the back and 11.25-inches from the

Figure 3.1 Calorimeter

Figure 3.2 Schematic Diagram for the Enlarged Calorimeter Tubes

close side of the environmental bath. The tube runs from 2 inches above the bath down 39 inches to within 4 inches of the bottom.

The sample tube is a complex structure made of stainless steel and aluminum tubing and heating elements. Samples are placed in the measurement tube on the bottom insulating spacer which is 6.25-inches high and is located on the bottom of the calorimeter tube. The cabinet has an overflow line to prevent overfilling the bath with water, but it does not have a drain to allow draining of water from the cabinet. The top of the calorimeter is positioned above the top of the environmental bath so that under normal conditions, an overflowing environmental bath will not fill the calorimeter with water.

3.2 Operations

The sequence of operations may be stated as follows: A sealed can of radioactive material is inserted into a measurement adapter which is 5.02 inches inside diameter and 8.0 inches inside height (including the lid). The space between the sample can and the overpack container is then filled with copper shot to enhance heat transfer. A thermal insulator with a handle is attached to the top end of the overpack container and then they are lowered into the measurement cell of the calorimeter until the positioning flange on the insulator reaches its stop inside the calorimeter. There is one baffle for each calorimeter tube; therefore, a baffle may be dedicated to each position. The tube is capped with a lid before the measurement is made.

The other tube in a pair is used as a reference cell and sample material is never to be placed in that tube. The reference tube is sealed by tapping its lid to the tube and is never to be opened by the operator per procedure LA-948--381/D-1. Only one container is to be hand carried to or from a calorimeter tube at a time per CPS-Z-165-80110, Rev./Mod. C-1. Samples are never to be stored on a calorimeter bath cabinet per CPS-Z-165-80120, Rev./Mod. B-3.

3.3 Fissile Material

The Plutonium Finishing Plant (PFP) CPS for storage (CPS-Z-165-80100, Rev./Mod. J-1) and transportation (CPS-Z-165-80110, Rev./Mod. C-1) limit the mass of plutonium in a single container by the degree of moderation. There are three hydrogen to plutonium (H/Pu) ratios used. Up to 2500 grams are allowed for dry materials ($H/Pu \leq 2$), up to 1500 grams of plutonium for slightly moderated ($H/Pu \leq 20$), and up to 400 grams of plutonium for unrestricted moderation.

Page 11 of the PFP General Limits CPS (CPS-Z-165-80010 Rev./Mod. C-2) lists routinely handled materials for each H/Pu category. Plutonium metal and dry plutonium oxide are expected to comprise most of the dry material ($H/Pu \leq 2$); plutonium oxalate and waste from rooms and hoods comprise much of the fully moderated material. Only floor sweepings from dry gloveboxes and sludge dried on a hot plate are listed for slightly moderated materials ($H/Pu \leq 20$). In addition, incinerator ash at an H/Pu ratio of 10 is also measured in the

calorimeter (Reference 1). The calorimeter needs to be evaluated for safe measurement of each of these three categories of stored materials.

Only Pu-239 is considered in this analysis. Other fissionable material is allowed at equivalences defined in Sections A.4 and A.5 of the PFP General Limits CPS-Z-165-80010, Rev./Mod. C-2.

3.4 Fissile Material Packaging

The plutonium stored in the 2736-ZB building that is to be measured by the calorimeter is required to be triple sealed. For plutonium oxide, there are to be two mechanical seals (metal cans) and a sealed plastic bag. For plutonium metal, there are to be three mechanical seals. Plutonium metal is first sealed in a Tuna Can (3-3/8" D x 2" H, 0.25 l). Plutonium oxide is first put in a 1 lb. Slip Lid Can (3-1/2" D x 3-1/2" H, 0.50 l) or in a Purex Slip Lid Can (3-7/16" D x 5-5/8" H, 0.80 l) that is sealed with tape. The second step is sealing the can from the first stage in a plastic bag. At the third stage, the three primary cans sealed in plastic are mechanically sealed in a Purex Secondary Can (4-1/16" D x 6-1/4" H, 1.30 l), except the 1 lb. Slip Lid Can which may also be put in a Small Tomato Can (4" D x 4-5/8" H, 0.90 l).

At the final stage, the double sealed container of plutonium is mechanically sealed in a 7 inch Can (4-1/4" D x 7", 1.50 l) that fits in the available calorimeters. Sometimes the double sealed container is wrapped in plastic or for other reasons it is mechanically sealed in an Oversize Can (4-3/4" D x 6-3/4" H, 1.90 l). To access the plutonium content in the 1/2" larger diameter can, the 109B calorimeter is to be placed in service. The dimensions of the cans are attached in Appendix 1.

4.0 NORMAL OPERATION AND CONTINGENCY ANALYSIS

Since the PFP CPS for storage (CPS-Z-165-80100, Rev./Mod. J-1) and transportation (CPS-Z-165-80110, Rev./Mod. C-1) limit the mass of plutonium in a single container by the degree of moderation, a number of normal and contingency operation cases were evaluated based on the moderation of the plutonium.

4.1 Normal Operations

The normal operation cases evaluated are listed in Table 4.1 (note: the case number in Table 4.1 is preceded with a letter "n" as "normal" case). Cases 1, 2, and 2-1 define the normal operation cases for dry plutonium material. The maximum amount of Pu is 2500 gm. Cases 3 to 7 define slightly moderated plutonium material. The amount of Pu is limited to 1500 gm Pu in PuO₂. Case 8 defines the normal operation case for unrestricted moderation where the amount of Pu is limited to 400 gm in PuO₂.

In case 1, the Pu material for the calorimeter is a 2500 gm Pu metal button in a storage container. Case 2 and case 2-1 are 2500 gm of Pu in PuO₂. The

Table 4.1 Base (Normal) Case for Pu Metal, PuO₂ with H/Pu ≤ 2, PuO₂ with H/Pu ≤ 20, PuO₂ with unrestricted H₂O (PuO₂ in Polythlene)

Case	Case Description
Dry Pu	Pu Metal
n1	2.5 kg Pu Button
	PuO₂ with H/Pu≤2
n2	2500g PuO ₂ , 11.3 gm/cm ³ Pu density, H/Pu = 2
n2-1	2500g PuO ₂ , 11.3 gm/cm ³ Pu density, H/Pu = 0
Moderated Pu	PuO₂ with H/Pu≤20
n3	1500g PuO ₂ , 1.11 gm/cm ³ , H/Pu = 3.346, 10%H ₂ O
n4	1500g PuO ₂ , 1.409 gm/cm ³ H/Pu = 20, 40%H ₂ O
n5	1500g PuO ₂ , 1.51 gm/cm ³ H/Pu = 20, 40%H ₂ O
n6	1500g PuO ₂ , 3 gm/cm ³ , rest is water, H/Pu = 8.676 Can Size (dia=ht)
n7	1500g PuO ₂ , 5.8 gm/cm ³ rest is water, H/Pu = 3.834 Can Size (dia=ht)
Unsestricted Moderated Pu	PuO₂ in unrestricted H₂O (PuO₂ in Polythlene Solution)
n8	400g PuO ₂ , 0.231 g/cm ³ , in polythlene, Can diameter ≤ 4.75", Ht ≤ 6.75"
n9	800g PuO ₂ , 0.461 g/cm ³ , in polythlene, Can diameter ≤ 4.75", Ht ≤ 6.75"

density of PuO_2 is conservatively taken as 12.81 gm/cm³. The H/Pu ratio for Case 2 is 2, but for Case 2-1 it is 0.

In case 3, it was assumed that 10% of the volume of PuO_2 was water which leads to a H/Pu ratio equivalent to 3.35. Case 4 fixed the H/Pu ratio of the PuO_2 to 20 and the density of PuO_2 is calculated to be 1.409 gm/cm³. Case 5 assumes the density of PuO_2 to be 1.51 gm/cm³ providing a H/Pu ratio close to 20, and the number density of hydrogen close to that in water. Cases 6 and 7 assumed the densities of PuO_2 to be 3.0 and 5.8 gm/cm³, respectively. A density of 3.0 gm/cm³ is the value for PuO_2 commonly achieved at Hanford (private discussion with Joe Teal). A higher density of PuO_2 (5.8 gm/cm³) was chosen for additional information. The H/Pu ratio for 3.0 gm/cm³ and 5.8 gm/cm³ PuO_2 are 8.67 and 3.83, respectively.

It is expected that the k_{eff} values for Cases 6 and 7 will be lower than for Case 5 because the Hydrogen concentration is less. The calculational models of Pu source material were defined as a right cylinder with its diameter equivalent to its height so that conservative results could be obtained. However, if in case of the modeled source diameter, based on the amount of material and its density, is to be larger than the diameter of the oversize can, the diameter of the source will be limited to 4-3/4" and the height of can will be adjusted to conserve the source volume.

Case 8 analyzed 400 gm Pu in the form of PuO_2 in polyethylene for the unrestricted moderation category. It is known that polyethylene will provide a more conservative result than water. Figure 4.1 shows that for a fixed amount of PuO_2 , the k_{eff} value decreases with an increase of the PuO_2 density and decrease in volume. It is desirable to select a lower density of PuO_2 than the actual density to obtain a conservative k_{eff} value for the case. In Case 8, the density of PuO_2 was assumed to be 0.231 gm/cm³, which is lower than the normal PuO_2 density and is within the curve in Figure 4.1, therefore, a conservative result is expected. The density of PuO_2 is chosen so that the material will just fill an oversize can (4.75" D and 6.75 H). The oversize can is the largest diameter container normally used to store plutonium.

4.2 Contingency Analysis

The contingency conditions considered in this analysis included multiple batching, flooding the calorimeter sample tube, placing a sample into the reference tube, losing the calorimeter water, and contact with other fissile equipment such as a fixed array cart. In one case, flooding inside the triple-sealed sample packages was also examined. In many cases, combinations of more than one contingency condition were considered.

Figure 4.1 Parametrical Study for 400 & .800 gm Pu as PuO₂
in Polythlene as unrestricted H₂O

The contingencies listed below result from failures of either equipment or administrative controls. A "c" precedes the number for a contingency case in the list below and in Table 4.2 that also lists the contingency cases. The resulting configurations are shown to be subcritical to demonstrate that the double contingency criteria for the oversized calorimeter is met.

- c1. One fissile unit in the Sample Cell and one unit in the Reference Cell (one error),
- c2. Flooding of calorimeter tube; water gets into the Sample Cell (one error),
- c3. Flooding of calorimeter tube and fissile container; water gets into the Sample Cell and the fissile container (two errors),
- c4. Double batching material in one container (one error),
- c5. Two fissile containers in a calorimeter tube and the calorimeter tube flooded (two errors),
- c6. Double batching in a calorimeter tube and one unit in the Reference Cell (two errors),
- c7. One unit in a calorimeter tube, one unit in the Reference Cell and a fixed array wagon next to environmental bath (two errors),
- c8. One unit in a calorimeter tube, one unit in the Reference Cell and a fixed array wagon next to environmental bath and the water in the environmental bath lost (Three errors),
- c9. No copper shot filling the space between container and the sample tube (one error).

Earthquake induced changes in calorimeter dimensions are not considered credible because of its sturdy construction and low profile with supports at the corners of the calorimeter bath that supports the two tube calorimeter. Having two fissile containers in a tube is the worst case of the contingency of an extra container on the top of the calorimeter so that the case of containers on top of the calorimeter is not treated explicitly. Analyzing containers in the reference tube and an array wagon adjacent to the calorimeter bath as close as possible to the sample tube are more reactive cases than that of a container in the #3 calorimeter.

5.0 EVALUATION MODEL

Material in the calorimeter will be constrained by the dimensions and volumes of the calorimeter and fissile containers. The amount of over batching and the concentration of fissile material is limited to that of the storage

Table 4.2 Normal Operation and Contingency Case Definition

	Case Description	Case Notation
1	Normal Case, one unit in the calorimeter sample tube.	n1
2	One fissile unit in the calorimeter sample tube and one unit in the Reference Cell (One error)	c1
3	Flooding of calorimeter sample tube containing one fissile unit (one error)	c2
4	Flooding of calorimeter sample tube and fissile container (two errors)	c3
5	Double batching material in one container (one error)	c4
6	Two fissile containers in calorimeter sample tube and the calorimeter sample tube flooded (two errors)	c5
7	Double batching in a calorimeter sample tube and one unit in the Reference Cell (two errors)	c6
8	One unit in a calorimeter tube, one unit in the Reference Cell and a fixed array wagon next to the environmental bath (two errors)	c7
9	One unit in a calorimeter tube, one unit in the Reference Cell and a fixed array wagon next to environmental bath and the water in the environmental bath lost (three errors)	c8
10	No copper shot placed between container and the sample tube (one error)	c9

container volume. The largest is an oversize can 4-3/4" in diameter. Using the oversize can for calorimeter measurement is the main reason for the modification of the existing calorimeter and is the only reason for the current criticality evaluation. Using the diameter of an oversize can as the limiting factor for a source is a conservative approach since in reality there are smaller cans which contain the fissile material inside the oversize can as described in Section 3.3.

For fissile material which occupies a volume less than the volume of an oversize can, the fissile material was modeled as a equilateral cylinder (diameter = height) to make the most reactive cylindrical geometry. The calorimeter model uses the calorimeter nominal dimensions plus or minus tolerances to give the most conservative dimensions for the analysis. The interaction between two sets of calorimeters were not considered and not modeled because they are separated by about 27" of water. Figures 5.1 and 5.2 are the schematic diagrams for the calculational models of the calorimeter sample tube and of the geometrical arrangement of the calorimeter and fixed array cart.

All plutonium will be conservatively assumed to be ^{239}Pu . The material of the container and plastic wrapping were not included in the calculation model. However, in many cases, the atomic number densities for plutonium and hydrogen were slightly higher and more conservative to balance the calculational and modeling uncertainties.

Criticality computer code MONK6B (Reference 2) was used for this analysis. Appendix 5 gives the basis of the k_{eff} limit of 0.935 for plutonium systems analyzed using MONK6B and a summary of the code validation.

6.0 RESULTS AND CONCLUSIONS

The calculated k_{eff} values for all normal cases are shown in Table 6.1. It is shown that the most reactive case is the dry plutonium button ($k_{\text{eff}} = 0.700 \pm 0.003$). The unrestricted PuO_2 also provides the same level of reactivity ($k_{\text{eff}} = 0.684$). In order to assess the effect of an enlarged calorimeter tube on reactivity, it is important to evaluate the contingency cases. The contingency cases were defined in Sec. 4.2 and listed in Table 4.2. The calculated results for the normal and contingency cases for the Pu metal button are listed in Table 6.2.

The results indicate that the most reactive contingency cases involve the double batching of material in the calorimeter's sample tube (c4, c5, and c6). The k_{eff} of Case calrim0h (c4, $k_{\text{eff}} = 0.887$) is higher than that of Case calrim0ml (c5, $k_{\text{eff}} = 0.860$). Regarding the increase in reactivity, flooding in the sample tube is a lesser factor than double batching metal buttons, because in Case calrim0h (c4), two 2.5 kg plutonium buttons were stacked in a container whereas in Case calrim0ml (c5), two tuna cans (2" high), which contained one Pu button each, were stacked on top of each other. In Case calrim0ml (c5), there is approximately a 0.7" air gap between the two Pu buttons whereas in calrim0h (c4), there is no air gap between the buttons.

Figure 5.1 Model Diagram for Calorimeter and Fixed Array Cart

Figure 5.2 Schematic of Sample Tube Model

Once two Pu buttons are stacked on top of each other, they form a 5 kg Pu cylinder of 2.8" X 2.55" (D X H) which is close to an equilateral cylinder ($D = H$), the most reactive cylindrical geometry. In addition to two 2.5 kg Pu buttons stacked one on top of each other in a container, Case calrim00 has one more Pu button in the reference tube. Case calrim00 is the most reactive case ($k_{eff} = 0.895 \pm 0.003$) not only among all contingency cases for Pu metal buttons, but also among all contingency cases from other types of PuO_2 material, which include PuO_2 slightly moderated as well as unrestricted.

Double batching calculations were performed for most types of plutonium material in addition to the Pu metal button. The calculated double batching results for other types of plutonium material are presented in Table 6.3 to compare with the double batching of the Pu buttons and the normal operation results. Table 6.1 defines the "n" cases and Table 4.2 defines the c4 case as double batching material in one container (one error).

Since in all cases of PuO_2 with slight moderation as well as unrestricted moderation, the diameter of their containers is less than 6", it is not surprising to find (Table 6.3) that the k_{eff} values from double batching of these plutonium mixtures in cans are less than the k_{eff} value of the Pu button.

Table 6.1 Normal Case for Pu Metal, PuO₂ with H/Pu≤2, PuO₂ with H/Pu≤20 PuO₂ with unrestricted H₂O (PuO₂ in Polythlene Solution)

Case	Case Description	$k_{eff}(\pm 0.003)$	Case Name
	Pu Metal or Dry PuO ₂		
n1	2.5 kg Pu Button	0.700	Calrim0e
	PuO ₂ with H/Pu≤2		
n2	2500g PuO ₂ , 11.3 gm/cm ³ Pu density, H/Pu = 2	0.698	PuO ₂ -d-1
n2-1	2500g PuO ₂ , 11.3 gm/cm ³ Pu density, H/Pu = 0	0.525	puo ₂ -d-1
	PuO ₂ with H/Pu≤20		
n3	1500g PuO ₂ , 1.11 gm/cm ³ H/Pu = 3.346, 10%H ₂ O	0.309	PuO ₂ -m-1
n4	1500g PuO ₂ , 1.409 gm/cm ³ H/Pu = 20, 40%H ₂ O	0.592	PuO ₂ -w-5
n5	1500g PuO ₂ , 1.51 gm/cm ³ H/Pu ≈ 20, 40%H ₂ O	0.640	PuO ₂ -w-2
n6	1500g PuO ₂ , 3 gm/cm ³ , rest is water, H/Pu = 8.676	0.504	PuO ₂ -w-3
n7	1500g PuO ₂ , 5.8 gm/cm ³ , rest is water, H/Pu = 3.834	0.470	PuO ₂ -w-4
	PuO ₂ in unrestricted H ₂ O (PuO ₂ in Polythlene)		
n8	400g PuO ₂ , 0.231 g/cm ³ , filled with polythlene, Can diameter =< 4.75" Ht≤6.75"	0.684	P4-150-1

Table 6.2 Base Case and Contingency Cases for Pu Metal

Case Name	k_{eff} $\pm .003$	Case Description
Calrim0e	0.700	n1. Normal Case, one unit in the calorimeter sample tube. One unit is 2.5 kg Pu button
Calrim0f	0.712	c1. One fissile unit in the Sample Cell and one unit in the Reference Cell (one error)
Calrim0il	0.730	c2. Flooding of calorimeter Sample tube containing one fissile unit (one error)
Calrim0jl	0.777	c3. Flooding of calorimeter tube and fissile container containing one fissile unit (two errors)
Calrim0h	0.887	c4. Double batching fissile material in one container (One error)
Calrim0ml	0.860	c5. Two fissile containers in a calorimeter tube and the calorimeter tube flooded (Two errors)
Calrim0o	0.895	c6. Double batching fissile material in a calorimeter sample tube and one unit in the Reference Cell (Two errors)
Calrim0l	0.709	c7. One unit in a calorimeter tube, one unit in the Reference Cell and a fixed array wagon next to environmental bath (Two errors)
Calrim0n	0.679	c8. One unit in a calorimeter tube, one unit in the Reference Cell and a fixed array wagon next to environmental bath and the water in the environmental bath lost (Three errors)
Calrim0g	0.695	c9. No copper shot placed between container and the sample tube (one error)

Table 6.3 Double Batching Material in One Container (c4)
for selected normal operation cases

Normal Case --> Double Batching	k_{eff} ($\pm$ 0.003) for Normal Case	k_{eff} ($\pm$ 0.003) for Double Batching	Double Batching Case Name
n1 --> c4	0.770	0.887	calrim0h
n2 --> c4	0.698	0.872	Pu02-d-1h
n4 --> c4	0.592	0.739	Pu02-w-5h
n5 --> c4	0.640	0.775	Pu02-w-2h
n6 --> c4	0.504	0.670	Pu02-w-3h
n7 --> c4	0.470	0.618	Pu02-w-4h
n8 --> c4	0.684	0.788	P4-150-1h

Table 6.4 Comparison of one contingency between Pu Button
and 400 gm Pu of PuO₂ in unsegregated solution

Case Description	k_{eff} ($\pm$ 0.003)
c6. Double batching in a calorimeter tube and one unit in the Reference Cell (two errors) for Pu Button	0.895
c6. Double batching in a calorimeter tube and one unit in the Reference Cell (two errors) for 400 gm Pu of PuO ₂ in polyethylene	0.799

Because of the enlargement of the calorimeter tubes to allow measurement of oversize cans, the interaction among oversize cans in some contingency cases may be increased by an increase in solid angle between the containers. Therefore, an additional contingency calculation for 400 gm Pu in PuO_2 mixed with polyethylene was made. In this case, the sample tube was double batched and one more unit was placed in the reference tube. The result is listed in Table 6.4 to compare with a similar contingency for Pu buttons.

From the results listed in Tables 6.3 and 6.4, it is evident that the results of the contingency cases using Pu buttons provide the most reactive k_{eff} values, compared with other Pu forms. The most reactive k_{eff} value (0.895, see Table 6.2) for all the contingency cases is from double batching Pu buttons in a calorimeter tube and placing one button in the Reference Cell (two errors).

Note that there are two errors involved in this case. The most reactive error is double batching in the same tube. However, double batching the sample tube does not explore the reactivity affect of enlarging the calorimeter tube. Another result is that of placing one Pu button in the sample tube and one in the reference tube (one error, Case calrim0f on Table 6.2). The calculated k_{eff} is 0.712.

Based on the calculational results from Tables 6.2, 6.3, and 6.4, one can conclude that the enlargement of the calorimeter tube is acceptable regarding criticality safety.

7.0 LIMITS

7.1 Material Limits:

In our calculations, the Pu material were divided into four groups which should be used with respect to material limits. The material limits are listed in Table 7.1.

7.2 Dimension Limits:

The as-built calorimeter must be confirmed to meet the key dimensions used in this analysis:

(1) Calorimeter tube ID	≤	5.22 inches
(2) Cal-Ref tube pitch	≥	7.99 inches
(3) Cal-Cal tube pitch	≥	24. inches
(4) The max. container diameter	≥	4.75 inches

7.3 Administrative Controls

This addendum does not require any changes in administrative controls. No CPS revision is required.

Table 7.1 Material Limits for the Modified Calorimeter (Calorimeter 109B)

Type of Pu Material	H/Pu	Max. Amount of Pu (gram)
Pu Metal	0	2500
PuO ₂	< or = 2	2500
PuO ₂	< or = 20	1500
PuO ₂	unrestricted	400

8.0 FIREFIGHTING

This addendum does not require any changes of firefighting category; C.

9.0 REVIEWER'S COMMENTS

The independent technical review of this report, "ADDENDUM 3 TO CSAR 80-027, "USE OF CALORIMETER 109B FOR FISSILE MATERIAL MEASUREMENT", was made by E. M. Miller, staff member of the Criticality and Radiological Analysis group. His comments are as follows:

The report analyzes the reactivity of canned fissile material at the 109B calorimeter that is designed to accept the normal 7 Inch Can and the Oversize Can. The Oversize Can required a larger bore to the calorimeter tube which decreases the distance between inside edges of the sample and reference tubes. The analysis adequately addressed this change.

The cases of double batching conservatively addressed the normal operation of bringing a second container to a calorimeter bath to put in the other calorimeter that is in the bath. The container is put on top of the bath before putting it into a calorimeter sample tube. Modeling a container in both the sample and reference tubes in a calorimeter covers the normal situation of having containers in the two sample tubes of the two calorimeters in a calorimeter bath. Showing that the arrangement of containers in both tubes of a calorimeter with a full array wagon adjacent with and without water in the calorimeter is safely subcritical certainly covers most conceivable accidental arrangements of containers. Even the unlikely event of water entering the calorimeter tube and then the triple sealed cans is run. The analysis did not consider the fissile material dissolved in the water filling calorimeter tubes, but because of the triple sealing of fissile samples that is not considered a credible occurrence. The reviewer agrees that the arrangements modeled are adequate.

The reviewer has reviewed the calorimeter drawings and operating procedure and agrees with the model used in the analysis. The atom densities were checked. All values were found to be adequate or conservative. Many suggestions and corrections were incorporated in the final report. The reviewer concurs that these results are sufficient to demonstrate the safe operation of the calorimeter under both normal and accident conditions.

10.0 REFERENCES

1. Personal communication from R. A. Hamilton on August 24, 1994.
2. ANSWERS(MONK6)1 - MONK6 User Guide. Issue 5. The ANSWERS Service. Winfrith Technology Centre. Dorchester, Dorset, DT2 8DH, United Kingdom, May 1993.

APPENDIX 1 Dimension of Cans

[26] From: Richard A Hamilton at -WHC167 11/14/94 2:22PM (1069 bytes: 19 ln)

To: Tang Chiao at -WHC316

cc: Wayne L Louk at -WHC120, George A Westsik at -WHC120

Subject: OVERSIZE CALORIMETER ANALYSIS DIMENSIONS

----- Message Contents -----

At your request the following dimensions are provided:

Pu oxide inner containers

1 lb. slip lid can - 3 1/2 inches dia x 3 1/2 inches
tall

PUREX slip lid can - 3 7/16 inches dia x 5 5/8 inches
tall

Pu metal inner container

Tuna can - 3 3/8 inches dia x 2 inches tall

Outer containers all materials

7 Inch can - 4 1/4 inches dia x 7 inches tall

Oversize can - 4 3/4 inches dia x 6 3/4 inches tall

Distance between calorimeter centerlines (bath for
calorimeters #3 & #4, new calorimeter will replace current
caloirmeter #3) - 32 +/-1/4 inches

APPENDIX 2

Sample Inputs for Calculational Models

WHC-SD-SQA-CSA-20384, REV. 0

Page 24

```

*+
* File Name       : calrim0e
* Description     : PFP Large Diameter Calorimeter
* Author         : Tang Chiao
* Date           : Nov. 8, 1994
*
* For Report      : Addendum 3 to CSER 80-027
* Avogadro's No  : 6.022045e23
* Fissile         : Plutonium Metal at 19.7 g/cc
* %240 Pu        : 0.0
* Solution        : None
* Model           : 2.5 kg of plutonium metal in cans (4-3/4" dia.
                  : x 6.75") in a 5.835" I.D.dia. tube surrounded on
                  : five sides by
                  : thick water. The other edge is xxxxx" from the
                  : tuna can
                  : center. Water is directly below the tuna can and
                  : 6"
                  : above the bottom (shorter than a PUREX secondary
                  : can).
* Reflector       : Water
*
* Code            : MONK6B
* Computer        : Sun SPARC-10 on WHC SECC with SunOS 4.1.3 operating
*                 : system
*_

```

FISSION

```

*****
* MATERIAL DATA AND MAIN CONTROL DATA *
*****
* Material #   Material Name   Symbol
* 1           Pu Metal        F
* 2           Polyethylene     P
* 3           Water            W
* 4           Hanford concrete  C
* 5           304 Stainless Steel 4
* 6           Copper Shots     *
* 7           Al               &
* 8           Styrofoam        %
*****

```

```

* # Materials  # Elements
* 8            15

```

```

* Pu239      Pu240      Iron      Chromium      HINH2O
* Oxygen      Nitrogen   Nickel    Manganese    Aluminum
* Calcium     Silicon    Sodium    Carbon      Copper
*
* 9161        402C       908A      446C         923A
* 933C        259A       907A      88A          935A
* 138E        25E        182E      902B         835B

```

```

* Pu metal
CONC  0.04964  0.0      0.0      0.0      0.0
      0.0      0.0      0.0      0.0      0.0
      0.0      0.0      0.0      0.0      0.0

```

```

* Polyethylene ( max. H )
ATOM  0.92  0  0      0      0      2
      0      0      0      0      0
      0      0      0      1      0.0

```

```

* Water
ATOM  0.988  0  0      0      0      2
      1      0      0      0      0
      0      0      0      0      0.0

```

```

* Hanford Concrete
CONC  0.0      0.0      0.00035  0.0      0.01375

```

	0.00152	0.01663	0.00175	0.0	
* 304 Stainless Steel					
CONC	0.0	0.0	0.05986	0.01745	0.0
	0.0	0.0	0.008135	0.000869	0.0
	0.0	0.0	0.0	0.0	0.0
* Copper Shots					
CONC	0.00000	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.05942
*					
* Al metal					
CONC	0.00000	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.06027
	0.0	0.0	0.0	0.0	0.0
* Stroform					
ATOM	0.13	0	0	0	1
	0	0	0	0	0
	0	0	0	1	0.0

* Input units are inches.

INCHES

* GEOMETRY DATA *

*

* SAMPLE TUBE

*

NEST 10

*

* Body 1 - PU BUTTON

1 ZROD 1 1.40 1.277

*

* Body 2 - CANS

2 ZROD 0 2.375 6.75

*

* Body 3 - COPPER SHOTS ON TOP OF CANS

3 ZROD 6 2.375 8.00

*

* Body 4 - COPPER SHOTS AROUND CANS

4 ZROD 6 2.510 8.00

*

* Body 5 - AL AROUND COPPER SHOTS

5 ZROD 7 2.7975 8.00

*

* Body 6 - AIR AROUND AL REFLECTOR

6 ZROD 0 2.9175 8.00

*

* Body 7 - AL PLATES AT TOP AND BOTTOM

7 ZROD ORIGIN 0.0 0.0 -0.25

7 2.9175 8.50

* Body 8 - STYROFOAM ON TOP OF THE TOP AL PLATE

8 ZROD ORIGIN 0.0 0.0 -0.25

8 2.9175 19.25

* Body 9 - STYROFOAM OR POLYSTYRENE BELOW BOTTOM AL PLATE

9 ZROD ORIGIN 0.0 0.0 -6.50

2 2.9175 25.5

* Body 10 - 304 SS TUBE

10 ZROD ORIGIN 0.0 0.0 -6.50

5 3.1675 25.5

*

* REFERENCE TUBE

*

NEST 10

*

```

1 ZROD 0 1.40 1.277
*
* Body 2 - CANS
2 ZROD 0 2.375 6.75
*
* Body 3 - COPPER SHOTS ON TOP OF CANS (NOW IS AIR)
3 ZROD 0 2.375 8.00
*
* Body 4 - COPPER SHOTS AROUND CANS (NOW IS AIR)
4 ZROD 0 2.510 8.00
*
* Body 5 - AL AROUND COPPER SHOTS (NOW IS AIR)
5 ZROD 0 2.7975 8.00
*
* Body 6 - AIR AROUND AL REFLECTOR
6 ZROD 0 2.9175 8.00
*
* Body 7 - AL PLATES AT TOP AND BOTTOM (NOW IS AIR)
7 ZROD ORIGIN 0.0 0.0 -0.25
0 2.9175 8.50
* Body 8 - STYROFOAM ON TOP OF THE TOP AL PLATE
8 ZROD ORIGIN 0.0 0.0 -0.25
8 2.9175 19.25
* Body 9 - STYROFOAM OR POLYSTYRENE BELOW BOTTOM AL PLATE
9 ZROD ORIGIN 0.0 0.0 -6.50
2 2.9175 25.5
* Body 10 - 304 SS TUBE
10 ZROD ORIGIN 0.0 0.0 -6.50
5 3.1675 25.5

```

*WATER BATH WITH REFERENCE TUBE AND SAMPLE TUBE

CLUSTER 4

```

* Body 1 - SAMPLE TUBE
1 ZROD ORIGIN -3.995 0.0 -25.5
P1 3.1675 25.5
*
# Body #'s Dominance #
OVERLAP 1 3 6
* Body 2 - REFERENCE TUBE
2 ZROD ORIGIN 3.995 0.0 -25.5
P2 3.1675 25.5
*
# Body #'s Dominance #
OVERLAP 1 3 5
* Body 3 - WATER BATH
3 CUBOID 3 17.245 13.25 0.00 -11.245 -11.25 -31.0
*
# Body #'s Dominance #
OVERLAP 2 1 2 4
* Body 4 - Envelope
4 CUBOID 0 17.245 13.25 0.00 -28.245 -17.25 -40.0
ALBEDO -0.6 -0.6 0.0 0.0 0.0 0.0

```

CONTROL DATA

```

* Override Default # Generations/ Multiplying Factor
SUPERHIST 10 1.00

```

```

* Setting Stages, Last Stage, Neutrons/Stage, No Time Limit,
* SD Limit, Fissile Source Specified
-2 40 1000 0 STDV 0.0030 -1

```

SOURCE

FISSILE

REGION 1 PART 1 /

```

**
* File Name       : calrim0o
* Description     : PFP Large Diameter Calorimeter, normal
*                 : normal without Cu, but Pu is twice to
*                 : represent double batch cans, very conservative
* Author         : Tang Chiao
* Date           : Nov. 8, 1994
*
* For Report      : Addendum 3 to CSER 80-027
* Avogadro's No  : 6.022045e23
* Fissile         : Plutonium Metal at 19.7 g/cc
* %240 Pu        : 0.0
* Solution        : None
* Model          : 5.0 kg of plutonium metal in cans (4-3/4" dia.
*                 : x 6.75") in a 5.835" I.D.dia. tube surrounded on
*                 : five sides by
*                 : thick water. The other edge is xxxxx" from the
*                 : tuna can
*                 : center. Water is directly below the tuna can and
*                 : 6"
*                 : above the bottom (shorter than a PUREX secondary
*                 : can).
* Reflector      : Water
*
* Code           : MONK6B
* Computer       : Sun SPARC-10 on WHC SECC with SunOS 4.1.3 operating
*                 : system
*_

```

FISSION

```

*****
* MATERIAL DATA AND MAIN CONTROL DATA *
*****

```

Material #	Material Name	Symbol
1	Pu Metal	F
2	Polyethylene	P
3	Water	W
4	Hanford concrete	C
5	304 Stainless Steel	4
6	Copper Shots	*
7	Al	&
8	Styrofoam	%

```

*****
* # Materials    # Elements
* 8              15

```

	Pu239	Pu240	Iron	Chromium	HINH2O
Oxygen		Nitrogen	Nickel	Manganese	Aluminum
Calcium		Silicon	Sodium	Carbon	Copper
	9161	402C	908A	446C	923A
	933C	259A	907A	88A	935A
	138E	25E	182E	902B	835B
* Pu metal					
CONC	0.04964	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0
* Polyethylene (max. H)					
ATOM	0.92 0	0	0	0	2
	0	0	0	0	0
	0	0	0	1	0.0
* Water					
ATOM	0.988 0	0	0	0	2
	1	0	0	0	0
	0	0	0	0	0.0

CONC	0.0	0.0	0.00035	0.0	0.0
	0.04608	0.0	0.0	0.0	0.00175
	0.00152	0.01663	0.00175	0.0	0.0
* 304 Stainless Steel					
CONC	0.0	0.0	0.05986	0.01745	0.0
	0.0	0.0	0.008135	0.000869	0.0
	0.0	0.0	0.0	0.0	0.0
* Copper Shots					
CONC	0.00000	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.05942
*					
* Al metal					
CONC	0.00000	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.06027
	0.0	0.0	0.0	0.0	0.0
* Stroform					
ATOM	0.13	0	0	0	1
	0	0	0	0	0
	0	0	0	1	0.0

* Input units are inches.

INCHES

 * GEOMETRY DATA *

* SAMPLE TUBE

NEST 10

* Body 1 - PU BUTTON

1 ZROD ORIGIN 0.965 0.0 0.0
 1 1.40 2.554

* Body 2 - CANS

2 ZROD 0 2.375 6.75

* Body 3 - COPPER SHOTS ON TOP OF CANS

3 ZROD 0 2.375 8.00

* Body 4 - COPPER SHOTS AROUND CANS

4 ZROD 0 2.510 8.00

* Body 5 - AL AROUND COPPER SHOTS

5 ZROD 7 2.7975 8.00

* Body 6 - AIR AROUND AL REFLECTOR

6 ZROD 0 2.9175 8.00

* Body 7 - AL PLATES AT TOP AND BOTTOM

7 ZROD ORIGIN 0.0 0.0 -0.25
 7 2.9175 8.50

* Body 8 - STYROFOAM ON TOP OF THE TOP AL PLATE

8 ZROD ORIGIN 0.0 0.0 -0.25
 8 2.9175 19.25

* Body 9 - STYROFOAM OR POLYSTYRENE BELOW BOTTOM AL PLATE

9 ZROD ORIGIN 0.0 0.0 -6.50
 2 2.9175 25.5

* Body 10 - 304 SS TUBE

10 ZROD ORIGIN 0.0 0.0 -6.50
 5 3.1675 25.5

* REFERENCE TUBE

NEST 10

```

*
* Body 1 - PU BUTTON
  1 ZROD ORIGIN -0.965 0.0 0.0
    1 1.40 1.277
*
* Body 2 - CANS
  2 ZROD 0 2.375 6.75
*
* Body 3 - COPPER SHOTS ON TOP OF CANS (NOW IS AIR)
  3 ZROD 0 2.375 8.00
*
* Body 4 - COPPER SHOTS AROUND CANS (NOW IS AIR)
  4 ZROD 0 2.510 8.00
*
* Body 5 - AL AROUND COPPER SHOTS (NOW IS AIR)
  5 ZROD 0 2.7975 8.00
*
* Body 6 - AIR AROUND AL REFLECTOR
  6 ZROD 0 2.9175 8.00
*
* Body 7 - AL PLATES AT TOP AND BOTTOM (NOW IS AIR)
  7 ZROD ORIGIN 0.0 0.0 -0.25
    0 2.9175 8.50
* Body 8 - STYROFOAM ON TOP OF THE TOP AL PLATE
  8 ZROD ORIGIN 0.0 0.0 -0.25
    8 2.9175 19.25
* Body 9 - STYROFOAM OR POLYSTYRENE BELOW BOTTOM AL PLATE
  9 ZROD ORIGIN 0.0 0.0 -6.50
    2 2.9175 25.5
* Body 10 - 304 SS TUBE
  10 ZROD ORIGIN 0.0 0.0 -6.50
    5 3.1675 25.5

```

*WATER BATH WITH REFERENCE TUBE AND SAMPLE TUBE

CLUSTER 4

```

* Body 1 - SAMPLE TUBE
  1 ZROD ORIGIN -3.995 0.0 -25.5
    P1 3.1675 25.5
*
  # Body #'s Dominance #
  OVERLAP 1 3 6
* Body 2 - REFERENCE TUBE
  2 ZROD ORIGIN 3.995 0.0 -25.5
    P2 3.1675 25.5
*
  # Body #'s Dominance #
  OVERLAP 1 3 5
* Body 3 - WATER BATH
  3 CUBOID 3 17.245 13.25 0.00 -11.245 -11.25 -31.0
*
  # Body #'s Dominance #
  OVERLAP 2 1 2 4
* Body 4 - Envelope
  4 CUBOID 0 17.245 13.25 0.00 -28.245 -17.25 -40.0
    ALBEDO -0.6 -0.6 0.0 0.0 0.0 0.0

```

* CONTROL DATA *

* Override Default # Generations/ Multiplying Factor
SUPERHIST 10 1.00

* Setting Stages, Last Stage, Neutrons/Stage, No Time Limit,
* SD Limit, Fissile Source Specified
-4 60 500 0 STDV 0.0020 -1

MULTIFISS

STD

REGION 1 PART 1 /

REGION 1 PART 2 /

END

* SCAN PICTURE INPUT *

CODE 8

FPWC4*&%
*

	Top Left	Top Right	Bottom Left
X-Y VEIW (whole system - Z at center though Pu)	-28.24 13.2 -18.5	17.2 13.2 -18.5	-28.24 -17.25 -18.5
X-Z VEIW (water bath at sample tube side)	-28.24 13.2 -18.5	0.00 13.2 -18.5	-28.24 -17.25 -18.5
X-Z VEIW (sample tube)	-7.50 5.00 -18.5	0.00 5.00 -18.5	-7.50 -5.00 -18.5
X-Z VEIW (reference tube)	0.00 5.00 -18.5	17.20 5.00 -18.5	0.00 -5.00 -18.5
X-Z VEIW (whole system - X though Center at x = -3.995)	-7.995 0.00 -39.0	-7.995 0.00 -0.10	-0.000 0.00 -39.0
X-Z VEIW (whole system - X though Center at x = -3.995)	-7.995 0.00 -32.0	-7.995 0.00 -10.0	-0.000 0.00 -32.0
X-Z VEIW (whole system - X though Center at x = -3.995)	-7.995 0.00 -20.0	-7.995 0.00 -10.5	-0.000 0.00 -20.0
X-Y VEIW (whole system - Z though cans)	-28.24 13.2 -12.3	17.2 13.2 -12.3	-28.24 -17.25 -12.3
X-Z VEIW (water bath at sample tube side)	-28.24 13.2 -12.3	0.00 13.2 -12.3	-28.24 -17.25 -12.3
X-Z VEIW (sample tube)	-7.50 5.00 -12.3	0.00 5.00 -12.3	-7.50 -5.00 -12.3
X-Z VEIW (reference tube)	0.00 5.00 -12.3	17.20 5.00 -12.3	0.00 -5.00 -12.30
X-Y VEIW (whole system - Z though Cu shots)	-28.24 13.2 -12.0	17.2 13.2 -12.0	-28.24 -17.25 -12.0
X-Z VEIW (water bath at sample tube side)	-28.24 13.2 -12.0	0.00 13.2 -12.0	-28.24 -17.25 -12.0
X-Z VEIW (sample tube)	-7.50 5.00 -12.0	0.00 5.00 -12.0	-7.50 -5.00 -12.0
X-Z VEIW (reference tube)	0.00 5.00 -12.0	17.20 5.00 -12.0	0.00 -5.00 -12.00
X-Y VEIW (whole system - Z though top Al plate)	-28.24 13.2 -10.9	17.2 13.2 -10.9	-28.24 -17.25 -10.9
X-Z VEIW (water bath at sample tube side)	-28.24 13.2 -10.9	0.00 13.2 -10.9	-28.24 -17.25 -10.9
X-Z VEIW (sample tube)	-7.50 5.00 -10.9	0.00 5.00 -10.9	-7.50 -5.00 -10.9
X-Z VEIW (reference tube)	0.00 5.00 -10.9	17.20 5.00 -10.9	0.00 -5.00 -10.90
X-Y VEIW (whole system - Z though bottom Al plate)	-28.24 13.2 -19.1	17.2 13.2 -19.1	-28.24 -17.25 -19.1
Z VEIW (water bath at sample tube side)	8.24 13.2 -19.1	0.00 13.2 -19.1	-28.24 -17.25 -19.1
VEIW (sample tube)	0.00 5.00 -19.1	0.00 5.00 -19.1	-7.50 -5.00 -19.1

APPENDIX 3 SCAN outputs from the Sample Inputs

SCAN - PICTORIAL CROSS-SECTION OF A MONK SYSTEM

THE FOLLOWING SYMBOLS WILL BE USED IN THE PICTURES

MATERIAL NUMBER	SYMBOL
0	
1	F
2	P
3	W
4	C
5	4
6	*
7	&
8	%

*
* Top Left Top Right Bottom Left
*

* X-Y VEIW (whole system - Z at center though Pu)

STARTING POSITION NUMBER

PICTURE FRAME IS
 X- 1.5000, Y- 5.0000, Z- 18.5000 (TOP LEFT)
 X- 0.0000, Y- 5.0000, Z- 18.5000 (TOP RIGHT)
 X- -1.5000, Y- -5.0000, Z- -18.5000 (BOTTOM LEFT)

HORIZONTAL SCALE ----- 1 CHARACTER = 0.57692E-01
 VERTICAL SCALE ----- 1 LINE = 0.96154E-01

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TIME TAKEN 0.00000000
 X 2.00000000

Sample Cell only
 2.5 Pa Button in the Sample Cell
 Normal Operation (calrimpo)

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```

PICTURE FRAME IS      X=  -7.9950, Y=  0.0000, Z= -20.0000 (TOP LEFT)
-----              X=  -7.9950, Y=  0.0000, Z= -10.5000 (TOP RIGHT)
                      X=   0.0000, Y=  0.0000, Z= -20.0000 (BOTTOM LEFT)

```

HORIZONTAL SCALE ----- 1 CHARACTER = 0.73077E-01
VERTICAL SCALE ----- 1 LINE = 0.12114E+00

[illegible]

TIME TAKEN 0.0125 MINUTES

X-Z View of 2.5 by Pu Button in the Sample Cell
(calcrimpc, Normal operation)

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THE FOLLOWING SYMBOLS WILL BE USED IN THE PICTURES

MATERIAL NUMBER	SYMBOL
0	
1	F
2	P
3	W
4	C
5	4
6	*
7	6
8	1

Top Left Top Right Bottom Left

X-Y VEIN (whole system - Z at center though Pu)

STARTING REGION NUMBER = 24

ICTURE FRAME IS X= -28.2400, Y= 13.2000, Z= -18.5000 (TOP LEFT)
X= 17.2000, Y= 13.2000, Z= -18.5000 (TOP RIGHT)
X= -28.2400, Y= -17.2500, Z= -18.5000 (BOTTOM LEFT)

HORIZONTAL SCALE ----- 1 CHARACTER = 0.34954E+00
VERTICAL SCALE ----- 1 LINE = 0.58558E+00

*Plan View of
2 Pu Button in the
Sample Cell and 1
Button in the Reference
Cell (calrimpho)*

STARTING REGION NUMBER = 24

```

PICTURE FRAME IS      X=  -7.5000, Y=   5.0000, Z= -18.5000 (TOP LEFT)
-----              X=   0.0000, Y=   5.0000, Z= -18.5000 (TOP RIGHT)
                      X=  -7.5000, Y=  -5.0000, Z= -18.5000 (BOTTOM LEFT)

```

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ORIZONTAL SCALE ----- 1 CHARACTER = 0.57692E-01
 VERTICAL SCALE ----- 1 LINE = 0.96154E-01

Plan View of Pu Buttons in the Sample Cell
(calcrim photo)

X-Z VIEW (whole system - X through Center at $x = -3.995$)

STARTING REGION NUMBER = 24

```

PICTURE FRAME IS      X=  -7.9950, Y=   0.0000, Z= -20.0000 (TOP LEFT)
-----              X=  -7.9950, Y=   0.0000, Z= -10.5000 (TOP RIGHT)
                       X=   0.0000, Y=   0.0000, Z= -20.0000 (BOTTOM LEFT)

```

X-Z View of 2 Pu Buttons in
the Sample Cell (calrimdo)

```

ORIZONTAL SCALE ----- 1 CHARACTER = 0.73077E-01
VERTICAL SCALE ----- 1 LINE = 0.12114E+00

```

[illegible]

APPENDIX 4 Drawings for Calorimeter Tubes

WHC-SD-SQA-CSA-20384, REV. 0

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, 29B, AND 29C WITH EPOXY

(2) HEATER WINDINGS (DET. 28E).
APPROXIMATELY 100 CAMS PER WINDING.

(3) HEATER LEAD-OUT WIRES
CONSISTS OF (2) LEAD CUT WIRES PER
R WIRE, AND ONE GROUND WIRE (DET. 23D)
TUBE (DET. 23A). EACH WIRE TO
TURNS ON DET. 23C.

DET	QWA NO.	DESCRIPTION	QSD	WATE	SPRCK 2155
1		HEATED ASSEMB	1		
1A	INT 2	MOUNTING 2155	1	1042 SST	75 + 3.12 + 14.13
1B	INT 2	WHE	1	1042 SST	600 22.15 21.25 1.24 20
1C	INT 2	BOTTOM 2155	1	1042 SST	75 + 3.12 + 14.13
2		HEATED ASSEMB	1		
2A	INT 3	WHE	1	1042 SST	75 + 3.12 + 14.13
2B	INT 3	BOTTOM	1	1042 SST	75 + 3.12 + 14.13
3		ASSEMB COILS	2		
3A	INT 3	WHE	1	1042 ALUM	66.55 + 1.875
3B	INT 3	WHE	1	1042	SEE NOTE #10
3C	INT 3	COILS, WHE NO.	1	1042	250.22 + 1.35 + 2
4		SPACER	2	2042 ALUM	135.75 + 7.30 + 7.15
5		CLAMP - PLATE	1	2042 ALUM	25.75 + 4.53 + 2.15
6		CLAMP	1	2042 ALUM	25.75 + 4.53 + 2.15
7		WHE	3	1042 SST	1.45 + 1.15 + 1.15
8		CLAMP	1	1042	25.75 + 4.53 + 2.15
9A	INT 2	COILS	1	1042	155 + 1.75 + 1.17
9B	INT 2	BOTTOM WHE	1	1042	155 + 1.75 + 1.17
9C	INT 2	COILS, INT WHE	2	1042	155 + 1.75
10		COILS	3	1042	155 + 1.75 + 1.17
11		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
12		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
13		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
14		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
15		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
16		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
17		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
18		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
19		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
20		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
21A		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
22A		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
23A	FGC13533	SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
24A	FGC13533	SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
25A	FGC13533	SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
26A	FGC13533	SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
27A	FGC13533	SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
28A	FGC13533	SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
29A	FGC13533	SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
30A	FGC13533	SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
31		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
32		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
33		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
34		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
35		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
36		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
37		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
38		SCREEN, WHE NO. ALUM	3	1042	1.15 + 1.15 + 1.15
39A	INT 4	HEATED ASSEMB	1	1042	25.35 + 2.15 + 1.15
39B	INT 4	TOP THERMAL, WHE	1	1042	6400 22.15 + 1.25
39C	INT 4	BOTTOM THERMAL, WHE	1	1042	6400 22.15 + 1.25
39D		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39E		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39F		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39G		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39H		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39I		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39J		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39K		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39L		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39M		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39N		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39O		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39P		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39Q		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39R		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39S		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39T		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39U		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39V		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39W		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39X		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39Y		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
39Z		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40A		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40B		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40C		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40D		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40E		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40F		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40G		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40H		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40I		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40J		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40K		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40L		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40M		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40N		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40O		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40P		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40Q		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40R		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40S		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40T		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40U		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40V		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40W		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40X		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40Y		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
40Z		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41A		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41B		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41C		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41D		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41E		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41F		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41G		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41H		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41I		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41J		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41K		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41L		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41M		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41N		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41O		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41P		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41Q		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41R		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41S		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41T		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41U		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41V		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41W		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41X		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41Y		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
41Z		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42A		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42B		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42C		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42D		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42E		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42F		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42G		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42H		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42I		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42J		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42K		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42L		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42M		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42N		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42O		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42P		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42Q		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42R		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42S		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42T		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42U		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42V		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42W		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42X		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42Y		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
42Z		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43A		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43B		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43C		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43D		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43E		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43F		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43G		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43H		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43I		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43J		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43K		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43L		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43M		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43N		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43O		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43P		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43Q		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43R		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43S		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43T		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43U		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43V		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43W		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43X		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43Y		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
43Z		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44A		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44B		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44C		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44D		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44E		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44F		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44G		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44H		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44I		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44J		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44K		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44L		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44M		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44N		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44O		CLAMP 2 WHE	1	1042	25.75 + 1.75 + 1.15
44P		CL			

MATLS ONLY AS

NOTES

1. ALL WELDS TO BE INERT
ALL WELDED. ALL JOINTS
MUST BE WATER TIGHT.
2. REMOVE ALL BURRS & SHARP EDGES.
3. WELDING MUST BE IMPLEMENTED IN
A WAY TO MAINTAIN ROUNDNESS
OF TUBES (SEE 1B).

2/10
Det's 1A &
CLEAR BOLT HOLES
ROUND PERIMETER OF
PLATES
(SAME POS BOTH PLATES)

1 CA - 24 HOLES,
6 THRU'S

Full Twin - Qty 2 Thermals Road
AIR 6HP - .120" thick

() DEPARTURES AT
GROOVES/INCH
HEATER WIRE DIMS/FT
HEATER LEADOUT-25 GA.
SOLID COPPER-TINNED
(3 FULL TURNS)

PROGRAM(S):	Nett Hammer - HAWKING		
TITLE:	THERMEL DIMENSIONS (NOT TO SCALE)		
DATE:	5/17/92	REFERENCE NO.:	A74/90
DIMENSIONS: D BY:	18" KASPERSKI

PART CLASSIFICATION	DATE CLASSIFIED	DATE CLASSIFIED
LEVEL 1 CAT. 1000	LEVEL 1 CAT. 1000	LEVEL 1 CAT. 1000
DERIVATIVE CLASSIFIED	DERIVATIVE CLASSIFIED	DERIVATIVE CLASSIFIED
DATE	DATE	DATE
DATE	DATE	DATE

MONSANTO RESEARCH CORPORATION	
DATE	DATE
SCALE	SCALE
DWG NO.	DWG NO.
SHEET	SHEET

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APPENDIX 5. VALIDATION OF MONK6B AND SETTING k_{eff} LIMIT

I. Validation Procedure

The validation of the methods used in the analysis consists of testing the ability of the code and neutron cross-sections in calculations of known critical configurations, which are various benchmark experiments with the fissile material in question. Such analyses determine a calculational bias (the deviations of calculated k_{eff} values from unity for the benchmark cases) and the uncertainties culminating from the experimental and calculational errors.

The safety criteria for future calculations on undetermined systems requires that the bias-adjusted k_{eff} does not exceed 0.95 at the 95% confidence level. This is expressed by the following formula:

$$k_{eff} = k_{calc} - \text{bias} + (U_b^2 + U_c^2)^{1/2} \leq 0.95$$

where k_{calc} = k value given by calculation for system in question.
 bias = mean difference ($k_{calc} - 1.0$) for benchmark criticals
 U_b = 95% confidence level uncertainty in the bias determination,
 and U_c = 95% confidence level uncertainty in new calculation.

Thus, the bias-adjusted k_{eff} includes the statistical uncertainties.

II. Generic Validation for Plutonium Systems

A report by L.L. Macklin and E. M. Miller, "MONK6A Pu Validation" [reference 14], presents the results of calculations to determine a generic bias for plutonium configurations, as encountered in the Plutonium Finishing Plant. Seventy benchmark experiments were calculated, ranging from simple metal spheres to highly dilute (9 g Pu per liter) plutonium nitrate solution spheres, and also compacts of PuO_2 blended with polystyrene. A mean k_{eff} value of 1.0047 was determined over the full experimental range, with an overall standard deviation of 0.0097.

The direct calculational bias is thus +0.0047 (average k_{eff} greater than unity). Accounting for the uncertainties using a tolerance limit analysis, the report then concludes that

At least 95% of all critical experiments of this type computed by the MONK6A code will produce calculated k_{eff} values greater than 0.9857 with 95 % confidence.

For a standard deviation (σ) of 0.01 or less for the convergence of a future calculation (U_c), the 0.9857 value is lowered to 0.9855. ²ounded conservatively, a value of +0.015 can be used for $[-\text{bias} + (U_b^2 + U_c^2)^{1/2}]$. On this basis, it is determined that the true k_{eff} of an analyzed configuration with plutonium will not exceed 0.95 with a 95% confidence level if the calculated value (k_{calc} , ± 0.01) is limited to a maximum value of 0.935.

The 95% confidence level on 99.9% of the data is 0.9699. So a subcritical margin of 5% is 2.5% larger than the uncertainties between the 95.0% and 99.9% coverage of the benchmark data.

III Validation of MONK6B

The validation of the MONK6B code on the SUN microcomputers was documented in the Computer Code Validation Report CCVR-94-001 [reference 15]. The essence of the validation was cross-correlation of calculational results obtained with this code version and computer with results for identical input models done on the CRAY machine with MONK6A, as reported in the previous subsection. Also, the equivalence of MONK6B to MONK6A was well documented by the code vendors, the UK Atomic Energy Authority, in the verification package supplied with the software.

The abstract from CCVR 94-001 summarizes the validation study as follows;

The MONK6B validation for bare plutonium and plutonium water systems on the SUN computer and operating system is established in this report. Because the calculational method and nuclear cross-sections have not changed from the MONK6A code to the MONK6B code, the bias determination done for MONK6A is valid for MONK6B.