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7. Abstract

This CSER establishes an exemption for 232-Z from the requirement for a Criticality Alarm System, because the formation of a critical configuration is not a credible event for any circumstance involving the cleaning out and removal of the Burning Hood and associated equipment.

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232-Z BUILDING**

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1.0 INTRODUCTION

Decontamination and Decommissioning activities are planned for the 232-Z building. The first of the planned activity is the decontamination and removal of equipment from the Scrubber Cell located in the south portion of the 232-Z facility adjacent to the Incinerator Burning Hood. Plutonium removal from the Scrubber Cell is permitted by Addendum 1 to CSER 90-006 (Reference 4). CSER 90-006 (Reference 3) allows ducting removal, if necessary. Both of these CSERs classify the 232-Z facility as a Limited Control Facility. Criticality Alarm Systems (CAS) are not normally required for Limited Control Facilities under the

definitions provided in WHC-CM-4-29 and DOE Order 5480.24 (See Section 2.0). This CSER provides justification for performing all remaining operations on the Burning Hood without a CAS.

After cleaning the Scrubber Cell, the Burning Hood will be emptied, cleaned, and the remaining contamination stabilized. Criticality Safety Evaluation Report 94-013 (Reference 2) addresses the criticality safety concerns for plutonium removal from the Burning Hood with an estimated 6 kg residual plutonium. However, this plutonium exists as dry, localized accumulations in the Burning Hood and it is reasonable to conclude that due to the form and distribution of the material, a criticality is so improbable that a CAS is not required.

Once the plutonium inventory in the Burning Hood is reduced, the remaining plutonium in 232-Z facility will be in the form of widely separate, enclosed, and significantly subcritical surface contamination fixed in the remaining ducting, hoods, and gloveboxes. Criticality with the residual plutonium that will be left in the 232-Z incinerator facility after the Scrubber Cell and the Burning Hood are cleaned out is considered impossible due to the small amount of insoluble plutonium oxide and its separation.

2.0 CRITICALITY ALARM SYSTEM EXEMPTION REQUIREMENTS

The Nuclear Criticality Safety Manual, WHC-CM-4-29 Chapter 11, Section 5.0 which implements elements of DOE Order 5480.24, provides requirements for coverage of criticality alarm systems. Section 5.1(3) states in part; "In those cases where the mass of fissionable material exceeds the limits established in paragraph 4.2.1 of ANSI/ANS-8.3 [450 grams of ^{239}Pu], but a criticality accident is determined to be impossible due to the physical form of the fissionable material, ...neither a CAS nor a criticality detection system is required." Similarly, WHC-SD-CP-SDD-003, "DEFINITION AND MEANS OF MAINTAINING THE CRITICALITY DETECTORS AND ALARMS PORTION OF THE PFP SAFETY ENVELOPE" states that; "A CAS is not required when a documented safety analysis shows that it is not needed due to the physical form and isotopic distribution of fissionable material". Section 5 of this CSER establishes that a criticality event in Building 232-Z is deemed beyond extremely unlikely, because of the multiplicity of faults or error conditions required.

3.0 CONCLUSIONS

This analysis shows that the formation of a critical configuration is not a credible event in 232-Z for any circumstance involving the cleaning out and removal of the Burning Hood and associated equipment. At least three of the following physical barriers will exist at any time during these operations to preclude the ingress of water to the Burning Hood combustion chambers or flues or their general vicinity; 1) the building itself, 2) the glovebox enclosure, 3) a greenhouse constructed as a necessary part of these operations, and 4) the removal of water sources from the building. Additional administrative controls will limit the introduction of liquids of any form to the building. The administrative controls at the 232-Z facility will include those imposed by CSER 94-013 (Reference 2), and will be summarized in appropriate Criticality Prevention Specifications and Criticality Safety Postings.

This document establishes that a criticality event is beyond extremely unlikely in 232-Z without the presence of significant quantities of water or other moderators. With the room sprinkler system drained and the water supply piping blanked off and administrative controls in place, the introduction of water in significant amounts is so unlikely as to be deemed impossible.

The Burning Hood does not contain plutonium solution, or geometrically favorable tanks, or arrays of plutonium masses stored below floor level. These three examples each have a characteristic necessary for criticality. The Burning Hood's piping is geometrically favorable for criticality safety. Most of the plutonium is in an insoluble form and fixed in place. The Burning Hood is large with no geometrically suitable containers or spaces to confine a critically shaped mass. The Burning Hood does not have characteristics favorable to a criticality.

The many mitigating circumstances of this system were conservatively not included when analyzing the system for critical safety, but when included they show that the system is far safer. A criticality involving 5.9 kilograms with water is theoretically possible. However, the configuration, controls, and accident scenario as described in this document show that the possibility of a large amount of water entry and a criticality with the water in the 232-Z building can be considered beyond extremely unlikely. Thus, the condition necessary for exemption from a CAS documented in Section 2 of this CSER would be met. This CSER establishes that continued cleanout, decontamination, and decommissioning operations in building 232-Z may safely be performed without benefit of a criticality alarm system due to the form and environment of the fissile materials remaining in the facility.

4.0 FACILITY DESCRIPTION

4.0 Burning Hood

The 232-Z incinerator is made up of the Feed, Burning, and Ash Hoods. The Burning Hood is walled off from the other two with only penetrations at each end for the two combustion chambers. Figure 1 shows this arrangement and the interior of the hoods.

The Burning Hood is about 244 cm (96") long, 96 cm (38") wide, and 155 cm (61") tall standing 152 cm (60") off the floor (Reference 10). It contains two horizontal combustion chambers and four vertical, connecting flues as shown in Figure 2. The upper combustion chamber has an ID of 12.1 cm (4.75") and the lower is a half tube ("D" shaped hemitube) 20 cm (7.875") ID. The vertical flues are mostly 4.76 cm (1.875") ID. Surrounding the lower combustion chamber are three voids, the largest being 71 cm (28") long, 40.6 cm (16") wide, and 50.8 cm (20") high to allow radiant heating of the combustion chambers. The upper combustion chamber has two voids of the same dimensions except they are 89 cm (35") long. The remaining volume is filled with refractory insulation, most of which has a density of about 1.45 g/cc. The arrangement of piping, void, and insulation is shown in Figures 3 and 4. The radiant heaters backed by 15.4 cm (10") of insulation are located in the five "windows" shown in Figure 3. The void spaces are between heaters on each outside wall with the combustion chamber in the middle of the void space.

The combustion of debris produced a refractory ash with about 10% plutonium and about 10% carbon. Operations reports showed that deposits on the piping were difficult to ream out and when heated to above the 800 °C operating temperature became a molten slag. Cracks in the piping may have allowed ash to escape the piping and be deposited on the insulation and piping inside the Burning Hood. See Reference 2 for more details and references to original documents on incinerator operations.

4.2 RESIDUAL PLUTONIUM CONTENTS

Figure 5 lists the high estimate of plutonium distribution in the 232-Z facility (References 1 and 8). The only area with more than a minimum critical mass of plutonium is the Burning Hood. The plutonium inventory in the Burning Hood and Scrubber Cell are to be reduced to residuals on interior surfaces. Presently, each of these separate areas except the Burning Hood contain

INCINERATOR FOR PLUTONIUM RECOVERY

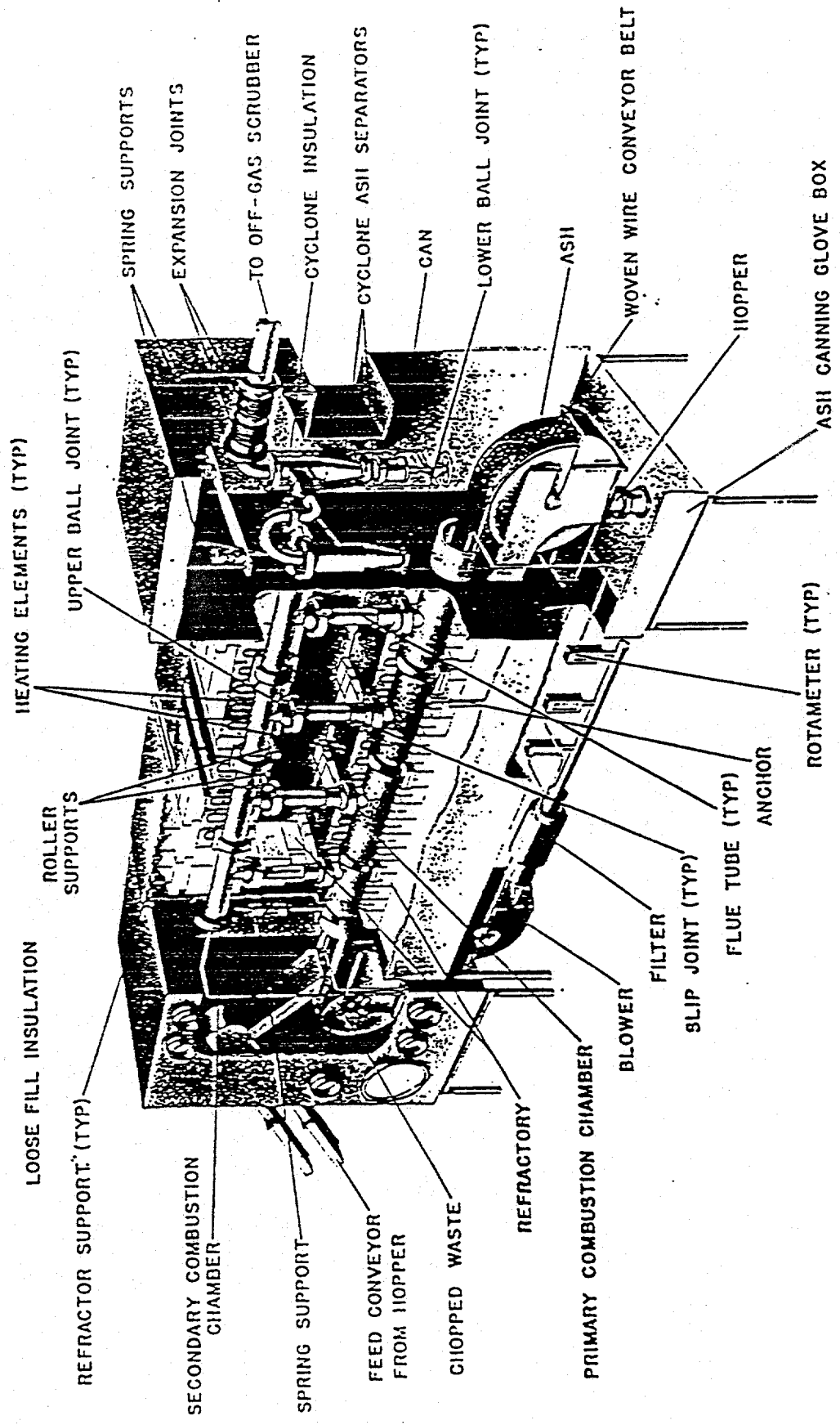
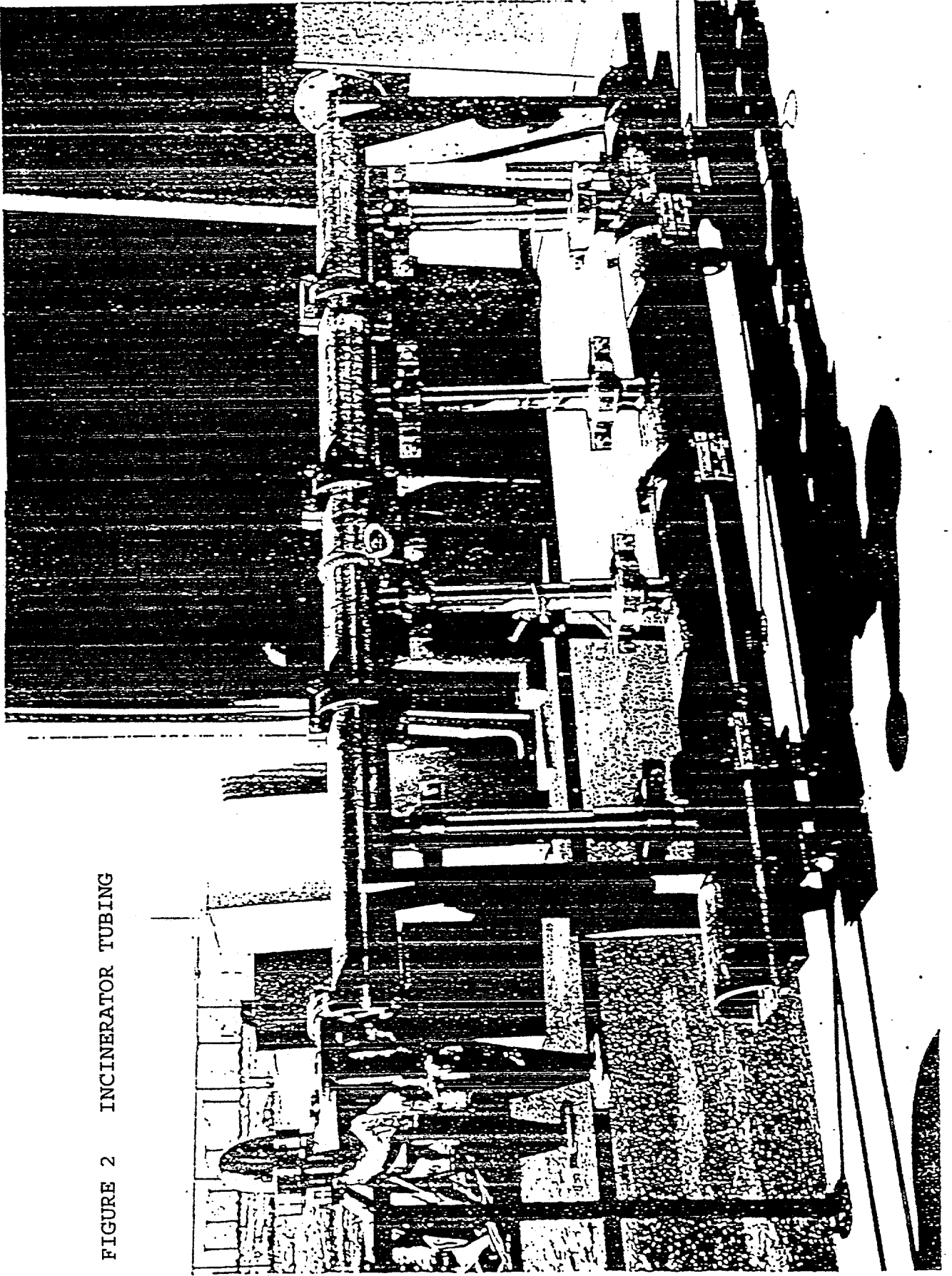


FIGURE 1

FIGURE 2 INCINERATOR TUBING



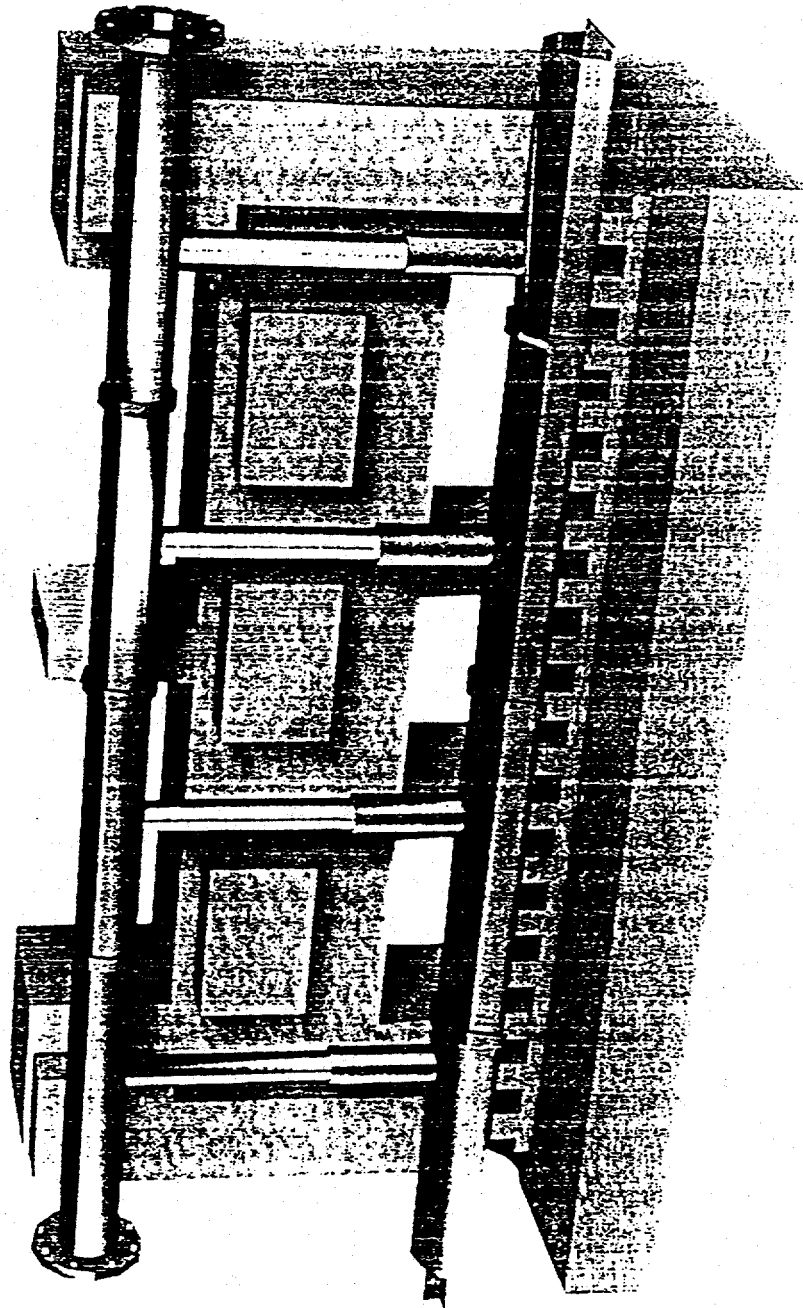


FIGURE 3 CUT AWAY OF INCINERATOR TUBING AND INSULATION

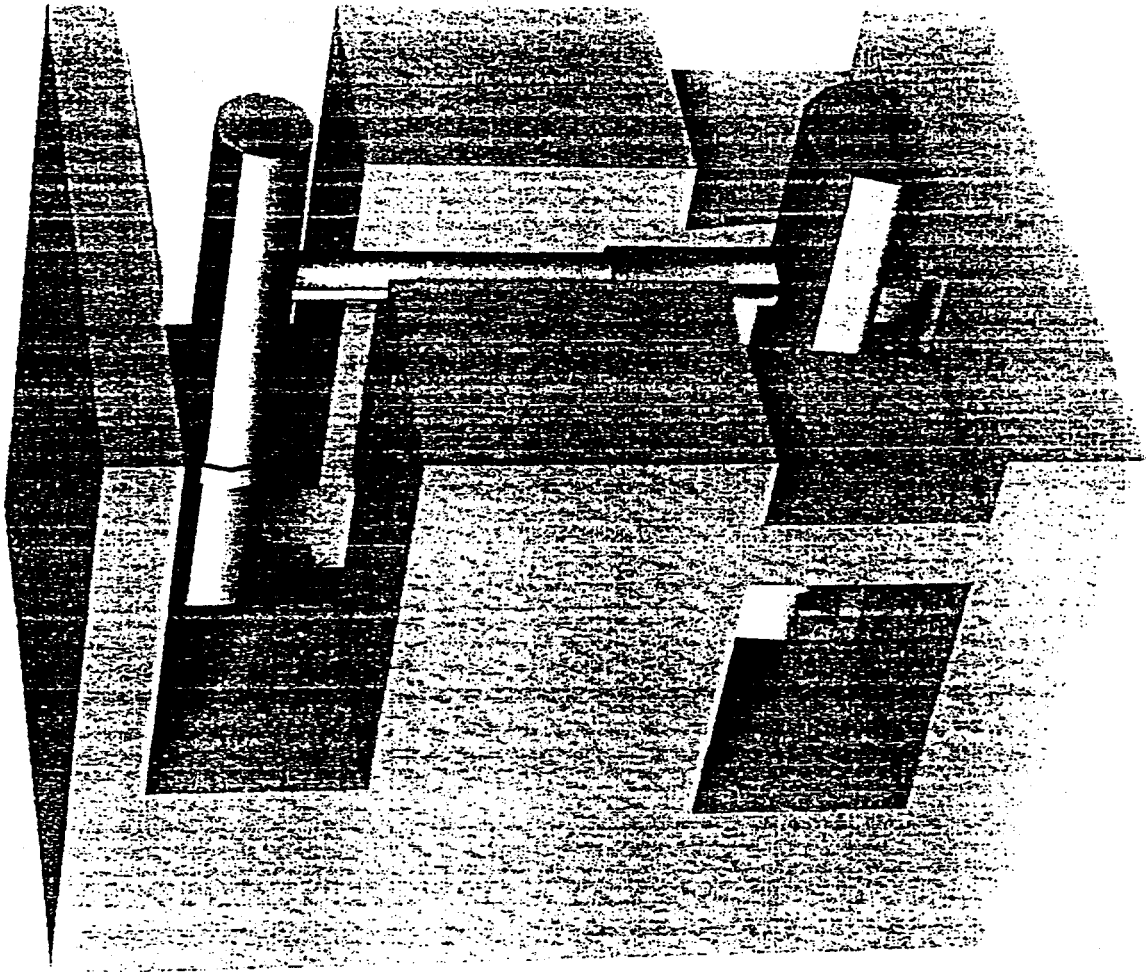


FIGURE 4 PERSPECTIVE OF INCINERATOR CROSS SECTION

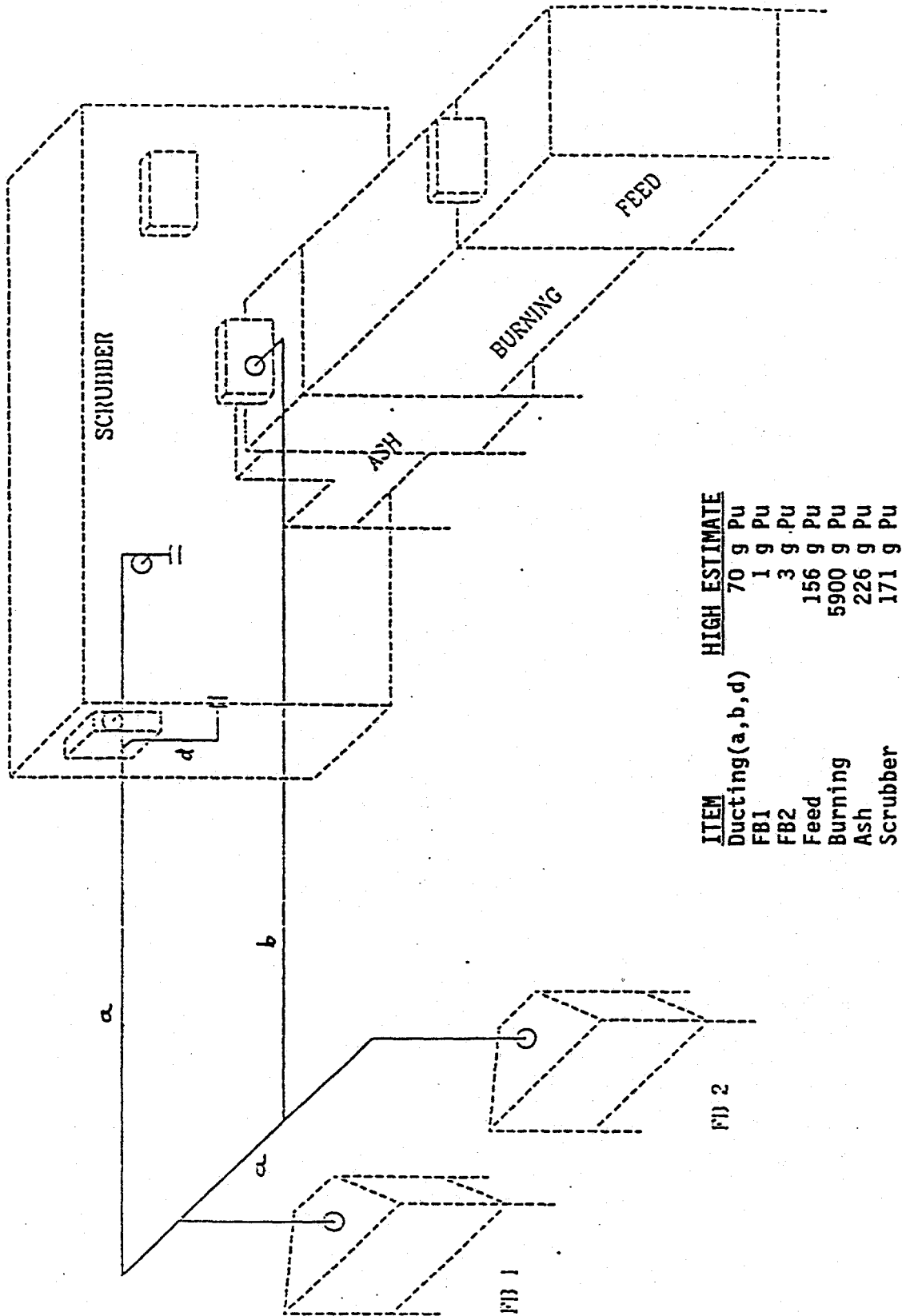


FIGURE 5 10/94 HIGH Pu HOLDUP ESTIMATES FOR THE 232-Z BUILDING INCINERATOR

considerably less than the minimum critical mass in water (530 grams). The areas are physically separated from each other. All plutonium is enclosed in ducting, hoods, or gloveboxes.

5.0 ANALYSIS

The current plutonium holdup in the 232-Z Burning Hood, based upon NDA measurements, is 5.9 kg (Reference 1). For this amount of plutonium, criticality is possible, but only if water were present. The following presentation explains why criticality is not credible due to the form of the plutonium in the Burning Hood in 232-Z incinerator facility and its environment. The following sections address: 1) the Burning Hood as it presently exists, dry, 2) the effect of water inside the Burning Hood piping, and finally, 3) the credibility of water entering the Burning Hood and creating a critical configuration.

5.1 Dry System

Criticality Safety Evaluation Report 94-013, WHC-SD-SQA-CSA-20385, "Classification and Access to PFP 232-Z Incinerator Facility and Limits on Characterization and Disassembly Activities in 232-Z Burning Hood" (Reference 2) addresses criticality safety limits for worst-case conditions in the Burning Hood. The hemitube was analyzed filled with 0.4 g/cc (and denser) PuO₂ in a Al₂O₃/SiO₂ (low neutron absorber) slag with an H/Pu of 20 from hygroscopic absorption. The effect of carbon and additional fissile mixture outside the combustion chambers was also analyzed. K_{eff} 's greater than 0.8 were only found for plutonium inventories of 40 kg or more and with physically impossibly dense fissile/slag and carbon mixtures.

That criticality safety assessment shows that the Burning Hood is "safely subcritical by a wide margin for a plutonium inventory of 10 kg or less mixed with water, carbon, and slag that is confined within the combustion chambers and flues and for an incinerator that has maintained its original internal insulation geometry." Additionally, "for plutonium with an H/Pu ratio < 20, the Burning Hood is safe even with a limited amount of plutonium mixed with carbon and slag **outside** the combustion chambers and flues or with the internal insulation collapsed into the void spaces around the combustion chambers" (Reference 2, page 6). The result was that no credible configuration of fissile material within the geometric limits of the Burning Hood could produce a k_{eff} greater than the subcritical limit of 0.935.

Several MONK6B models were run as part of the analysis effort for Reference 2. One illustrative case is run incin06. This run from that analysis studied the k_{eff} for the lower combustion chamber 'hemitube' filled with PuO₂ and then covered with PuO₂ out to a radius of 6.5 inches above and 1.125 inches below and fully reflected. At an assumed density of 0.4 g/cc of plutonium oxide, four times the expected density of material in Burning Hood ash, this requires 39.3 kg of plutonium. The H/Pu was assumed to be 20, with C/Pu = 0. The resulting k_{eff} was 0.796, well subcritical. This same case with carbon added to determine the affect of residual carbon in the ash at a C/Pu ratio of 48 has a k_{eff} of 0.864, also well subcritical. Another case is incin52 that found a k_{eff} of 0.791 for 64 kg of plutonium mixed with carbon at an C/Pu = 400 and with slag occupying all the void space in the Burning Hood. These allowable values of k_{eff} required far more dry plutonium than is considered credible to be in the Burning Hood.

These cases considered the fissile mixture to be uniformly distributed over the 96 inch length of the Burning Hood, because the NDA results showed that that was how the fissile material was actually distributed. For a 13 inch diameter cylinder to act like an infinitely long cylinder, it would have to be at least 1/4 (24 inches) the Burning Hood's length. This would require at least 10 kg of plutonium. The non-uniformly distributed plutonium case is explicitly analyzed below. Conservatism in these cases are that the 9% Pu-240 is treated as Pu-239, densities are greater than physically possible, and reflection is greater than in the actual Burning Hood.

Additionally, in support of this basis document, several MONK6B runs were made in order to determine k_{eff} for worst-case dry systems filled with plutonium-oxide in ash mixtures. The geometry analyzed was similar to lard cans. Right cylinders of the dimensions listed below were considered. The cylinder was filled with 10% PuO₂ at 4g/cc, 57% Al₂O₃ and 32% SiO₂ both at 1.5 g/cc, 1% BeO, and hydrogen at an H/Pu of 20. The cylinder of plutonium and ash was reflected by 10 inches of slag all around. The results are tabulated below.

	<u>RUN 1</u>	<u>RUN 2</u>	<u>RUN 3</u>
input file	incinb1	incinb2	incinb3
Cylinder: radius	5.2 in.	6.1 in.	7.0 in.
height	10.4 in.	12.2 in.	14.0 in.
volume	14.5 liters	23.4 liters	35.3 liters
PuO ₂ mass	5.8 kgs	9.4 kgs	14.1 kgs
Pu density	0.4 g/cc	0.4 g/cc	0.4 g/cc
H/Pu	20	20	20
k-eff	0.503	0.635	0.751

The k_{eff} standard deviation on these three runs is less than 0.0030. Appendix 1 list the input file for Run 1 to give the details on the modelling used. Appendix 2 gives the QA validation for use of the MONK6B criticality code.

The above models assumed reflection by 10 inches of Kast-O-Lite insulation such as is used inside the Burning Hood. Carbon was not included as part of the moderator, however, separate modeling shows that with carbon included, the k-eff values increase by 0.06 to 0.07 (Reference 2). This results in increases in k-eff for the three models to 0.573, 0.705, and 0.821, respectively. The density of PuO₂ used for these models was four times the expected density of the oxides in the Burning Hood and the 9% Pu-240 was assumed to be Pu-239. This study shows the difficulty in forming a critical configuration with plutonium-oxide powders in ash when the system remains dry (H/Pu \leq 20), even with significant reflection and up to three times the expected plutonium accumulation in 232-Z Burning Hood. In short, even if the entire 6.0 kg of plutonium projected to be in the dry ash in the Burning Hood were put into one container, a lard can, (see RUN 1), it would not represent a safety risk from an accidental criticality event. A criticality with the dry plutonium/slag mixture in the Burning Hood is not considered credible.

5.2 Water Confined to the Burning Hood Piping

Analyses performed by Battelle Pacific Northwest Laboratories (PNL) and appended as part of CSER 94-013 (Reference 2) included numerous KENO computer simulations. Many of these simulations

represented scenarios wherein water is present in the burning Hood as a mixture with plutonium oxide inside the piping and flues. Case 9 from that analysis (Reference 2, Table 2, page 17) represents a scenario where all the pipes and flues in the Burning Hood are filled with a mixture of plutonium oxide and water at a density of 0.16 g Pu/cc. For 10 kilograms of Pu, the calculated k_{eff} is 0.934. This same case with 5 wt% Pu-240 is 0.870. There is actually 9 wt% Pu-240 in the Burning Hood plutonium (Reference 9).

PNL Case 13 assumed the same conditions as for Case 9, with void regions in the hood filled with Kast-O-Lite as a neutron reflector. Case 16 was identical with case 9 but included an external source of water as a neutron reflector. K_{eff} for these Cases is 1.023 and 0.980, respectively. Considering only 5 wt% Pu-240, the k_{eff} 's become 0.959 and 0.946.

Thus, assuming water flooding of the pipes and flues, complete mixing of the available fissile material with water, almost twice the available plutonium mass and reflection by water or Kast-O-Lite outside the piping, the system remains subcritical. The 9% Pu-240 isotopic fraction is the major determinant for rendering the furnace tubing so geometrically favorable to criticality safety.

5.3 Hypothetical General Water Entry

The above criticality safety evaluation of the 232-Z Building and the Burning Hood resulted in the conclusion that criticality was impossible by the form and distribution of plutonium both when dry and with limited amounts of water present inside the piping and flues. The following section and subsections examine the possibility of the general introduction of water into the 232-Z facility and the Burning Hood, and the upsets or abnormalities necessary to achieve criticality.

Reference 5 analyzed the maximum credible criticality accident to determine the 25 rem boundary for the 232-Z facility. The analysis found that significant quantities of water were required to form a critical configuration in the Burning Hood. These computer analyses, performed by K. D. Schwinkendorf of the Nuclear Analysis and Characterization Group, simulated conditions inside the Burning Hood. The calculations assumed 5.9 kg of plutonium present in the glovebox in the form of oxide at 10% by weight of the solid ash material resident there. Under special circumstances, the introduction of water would provide sufficient thermalization of the neutrons present for a critical system to form in the void space, 16 inches (40.6 cm) wide, 76 inches (193 cm) long, and 20 inches (50.8 cm) tall. A neutron diffusion theory code was used to calculate a critical depth for a slab in

this void space as well as k_{eff} for the slab depth. This analysis showed that depths between 11.3 inches and 17 inches of a water/plutonium mixture in the incinerator glovebox are deep enough, but still not too dilute, to support a critical state (Reference 5). Thus, a uniformly mixed slurry of water and plutonium oxide in ash can become critical in a geometrical configuration similar to the Burning Hood at a depth of 11.3 inches. This depth of water corresponds to 7.95 cubic feet of water (225.17 liters/59.48 gallons).

For criticality to occur the following conditions are necessary:

- a credible source of several cubic feet of water is needed;
- a way to free plutonium cemented to the inside of the piping is needed;
- a way to move deposited plutonium on the refractory insulation into proximity with other freed plutonium, if the piping leaked;
- mixing of insoluble plutonium oxide relatively uniformly with the water in a large, continuous volume.

The constraints on these factors in the Burning Hood and at the 232-Z Building are discussed below.

5.3.1 232-Z Building Integrity

The 232-Z Building and the blanked off and drained fire sprinkler system prevent water entry by physical barriers. The fire sprinkler system is blanked off outside 232-Z and no other water line enters the Burning Hood area. The fire sprinkler system must be reactivated or the building damaged in order to allow water entry. Fire, earthquake, vehicle accident, or extremely high winds could breach the building. However, all these accidents are unlikely as is reactivation of the fire sprinklers to 232-Z Building.

5.3.2 Source of Water

Rain water entry is possible after a building breach, but unlikely to direct cubic feet of water into the Burning Hood. Floods on the 200 Area plateau are not credible. Reflooded fire sprinkler lines as a source of water would require physical reconnection, repressurization of the line, and failure of a pipe over the Burning Hood. The Hanford Fire Department no longer

uses streams of water for fire fighting purposes. Fog nozzles are normally used. Such a source is unlikely to provide the cubic feet of water found necessary for criticality in the Burning Hood as such flooding would generally require that a direct stream of water be directed at a breached glovebox for an extended period of time. There is no fire load in the glovebox so there would be no reason to aim firefighting water, if used, at the Burning Hood. Additionally, the 232-Z facility will be placed on Fire Fighting Category 'D'. Category 'D' is defined as an area where only dry chemicals, gases, or high expansion foam may be used to fight a fire. Operations personnel may violate the CPS and bring in some water, but not cubic feet of it. There are no likely sources of water.

5.3.3 Burning Hood Integrity

The Burning Hood is made of a steel frame covered with at least 1/8" thick plate. Invasion of water would require that the hood be opened by operations or physically breached in an accident. The Burning Hood would be open only for the limited time needed to clean out the piping, insulation, and loose plutonium. When the Burning Hood is opened it will be covered by a greenhouse. To admit water, the greenhouse over the Burning Hood must be ruptured over the open portion of the Burning Hood. Water entry to the Burning Hood requires an unlikely or several unlikely events to occur.

The Burning Hood has been braced to prevent it from falling over in an earthquake and releasing dispersible plutonium. This bracing would also keep the Burning Hood upright and flat, maintaining its present orientation.

5.3.4 Plutonium Mobility

Formation of a critical configuration would require the plutonium inside the incinerator tubes to be flushed out. However, experience shows that much of the plutonium is in a slag cemented to the inside of the piping. Although the piping may have cracks, historically they were not large or pervasive. Plutonium oxide is not soluble in water, and there is no source of acid solution. The water would have to wash the plutonium off the insulation, out of the joints between insulation blocks, and out of the piping to the bottom of the Burning Hood. A fog or rain does not provide sufficient motive force for such a rearrangement. The plutonium must be scoured out of the piping and loosened from the refractory insulation if a significant amount resides there.

5.3.5 Water Entry Scenarios

High winds and rain do not have the characteristics to concentrate the plutonium even in an open Burning Hood. A vehicular accident could breach barriers and in combination with a fire, the fire department could supply water. Fire in and of itself does not free plutonium from the slag, it provides heat which melts it to flow to a new place within the piping. Water fog from fire fighting would not mix with the slag. As significant mixing does not occur, water filling the Burning Hood would act primarily as a reflector. An earthquake could rearrange the contents of the Burning Hood, but most likely would not concentrate the plutonium in a small part of the hood bottom. An earthquake could also rupture water lines, but no water lines exist in the 232-Z Burning Hood area unless the sprinkler line is reactivated. Reactivating the water line and an earthquake are two independent, unlikely events.

The 232-Z Building is a single story structure which by its design precludes the accumulation of water on the roof over the Burning Hood. An earthquake may drop building parts on the Burning Hood, but no mechanism exists to put the plutonium that is in the hood in a compact arrangement with all the insulation that is also in the hood. Further, much of the plutonium in slag on the piping walls must be crushed, removed to a large open space in the hood, and suspended in water. Reference 5 concluded that the slab thickness required for a criticality in the Burning Hood floor pool is 11.3 inches.

5.3.6 Floor Pool Configurations

Refractory insulation inside the Burning Hood does not have any spherical or cylindrical shapes in it. If the plutonium could be scoured and slurried out of the piping and insulation it would form a slab shape in the bottom of the hood or on the greenhouse floor, which would be hundreds of square feet. This would prevent the pool from reaching a critical depth. For the given 5.9 kg of plutonium in a slab shape, optimally moderated with 9% plutonium-240, requires 300 grams of plutonium per square foot for criticality. Six kilograms of plutonium spread evenly over the bottom of the Burning Hood gives only 270 grams per square foot. Plutonium would have to be preferentially deposited in the bottom of the hood (or greenhouse) and suspended as a slurry in at least several cubic feet of water. Since plutonium oxide is not soluble in water, criticality requires that the plutonium be continuously agitated to remain suspended (unless it all came down at once already homogenized). The source of water, the

method of moving the insoluble plutonium residue, and suspending it in the water are not known.

5.3.7 Analysis Summary

The addition of cubic feet of water is necessary but insufficient to create a critical system. A criticality requires; 1) an appropriate accumulation geometry of large, continuous volume, 2) sufficient quantity of water for moderation and reflection, 3) an external force for suspension of plutonium in the water, 4) available "loose" plutonium or a washing or scrubbing action which frees plutonium compounds adhering to the walls inside the incinerator combustion chambers and flues, 5) uniform mixing of the plutonium compounds with the water, and 6) the presence of a critical mass of plutonium.

This sequence of necessary events/conditions, especially the introduction of cubic feet of water (in a facility where no source of water exists and for which the most stringent administrative controls available concerning introduction of water are imposed) deems a criticality beyond extremely unlikely.

One can imagine scenarios involving water flooding or flushing which results in the rearrangement and combination of fissile materials from other locations in the 232-Z facility into one area. However, such rearrangement would by necessity occur on the floor of the facility. Insufficient plutonium exists in the facility to reach the areal densities required for formation of a critical mass when spread across the floor. Consolidation of materials would require breaching of the incinerator gloveboxes, washing or other motive force to rearrange the fissile material and a mechanism for placing much of the available plutonium in one geometrically favorable location in combination with water or other moderating material. Such a sequence of events is beyond extremely unlikely.

It is concluded that criticality is beyond extremely unlikely and a CAS system is not required for the 232-Z Building because a mechanism to move and suspend insoluble plutonium oxide in water inside the burning hood does not exist.

6. REVIEWERS COMMENTS

Technical review of this evaluation was provided by A. L. Hess of the Criticality Safety group of the Consequence Analyses section of Safety Analyses and Nuclear Engineering, who provides the following comments.

The unique situation presented by the residual holdup of plutonium compounds within the incinerator glovebox of Building 232-Z requires an in-depth examination to verify the criticality safety of the decontamination process without a criticality alarm system. Such an extensive evaluation has been presented in this report. A number of changes and text clarifications and additions recommended by this reviewer were incorporated into the final draft. Some additional aspects are discussed in the following paragraphs.

This reviewer is of the persuasion that not more than a few percent of the assayed Pu holdup is outside the furnace piping. Unknowns about the configuration include the exact compositions of the residue media containing the plutonium at various locations, and the extent to which the material matrix bearing the Pu might be soluble. But considering the high temperatures at which the deposits were formed, the ash composite is no more likely to be soluble than PuO_2 . Also, how readily the residues could be pulverized for dispersal might depend on possible radiation effects (from alphas and spontaneous fission fragments over the many years presence) which could weaken the matrix adhesion. This latter aspect will be learned as the dismantling of the piping progresses, and may lead to additional containment measures that can only compliment the criticality safety controls. The controls set forth in reference 2 and the CPS for handling the dismantled pipe sections of course still apply.

The seismic fortification structure added to the glovebox should preclude all but minor reorientation and/or tilting of the glovebox, so that any plausible earthquake effects will not alter the conclusions of the evaluation in regards to critical slurry accumulations on the glovebox floor. Before proceeding within the established greenhouse, it should be determined that its floor spreading area is at least as large as the floor inside the glovebox.

This reviewer concurs with the conclusion of the report that a criticality is not credible given the known quantity, distribution and form of the Pu-bearing residues, accounting also for reasonable uncertainty assessments, and given the physical and administrative controls in place to preclude water entry. On this basis there is no need for a criticality detection system.

7. REFERENCES

- 1) Westsik, G. A., Westinghouse Hanford Company (WHC) Internal Memo from PFP Analytical Laboratories to E. C. Vogt, "NONDESTRUCTIVE ASSAY OF THE 232-Z BUILDING INCINERATOR", October 17, 1994.
- 2) WHC-SD-SQA-CSA-20385, CSER 94-013, "CLASSIFICATION AND ACCESS TO PFP 232-Z INCINERATOR FACILITY AND LIMITS ON CHARACTERIZATION ACTIVITIES IN 232-Z BURNING HOOD", Miller, E. M., January 09, 1995.
- 3) WHC-SD-SQA-CSA-20323, CSER 90-006, "CRITICALITY SAFETY CONTROL FOR SOURCE TERM REDUCTION PROJECT IN BUILDING 232-Z", Hess, A. L., July 31, 1990.
- 4) WHC-SD-SQA-CSA-20390, Addendum 1 to CSER 90-006, "CRITICALITY SAFETY CONTROL FOR SOURCE TERM REDUCTION PROJECT IN THE SCRUBBER GLOVEBOX OF BUILDING 232-Z", Friar, D. E., February 01, 1995.
- 5) Internal Memo; K. N. Schwinkendorf to L. T. Nirider, January 30, 1995, "NUCLEAR SOURCE TERM CALCULATION".
- 6) WHC-SD-SQA-CSWD-20015, CCVR 91-001: "MONK6A Pu Validation," Macklin, L. L. and Miller, E. M., January 6, 1992.
- 7) WHC-SD-SQA-CSWD-20019, CCVR 94-001: "MONK6B Pu Validation," Miller, E. M., June 14, 1994.
- 8) Telecon between G. A. Westsik and E. M. Miller on October 20, 1994, listing the amount of plutonium in ducting and gloveboxes other than the Burning Hood in Building 232-Z.
- 9) CC:Mail, Cheryl R Stallbaum, PFP Analytic Laboratory to Edward Miller, Criticality & Radiological Analyses, December 22, 1994, transmitting data on the isotopic distribution of 232-Z plutonium obtained by portable nondestructive assay.
- 10) WHC drawing, "Incinerator Combustion Chamber Arrangement and Details," H-2-25883 Sheet 1 (Rev. 6, 7-10-71), Sheet 2 (Rev. 5, 5-15-69), and Sheet 3 (Rev. 3, 11-17-67).

APPENDIX A MONK6B INPUT LISTING FOR RUN 1

--- Verification Information V2.2 ---

sparc : sun1
SunOS : 4.1.3
monk6b : Jun 7 1994
dicedat1.dat: Jun 7 1994
scan6d : Jun 7 1994
Custodian : EM Miller
User : w93290 (Edward Miller)
Input File : incinb1
Print File : incinb1.prt
Batch File : incinb1.run
Date : 01/18/95
Time : 14:03:53

INPUT READ FROM :
incinb1

```

*+
* File Name      : incinb1
* Description    : PFP 232-Z INCINERATOR
* Author        : Edward Miller
* Date          : January 18, 1995
*
* For Report    :
* Avogadro's No : 6.022045e23
* Fissile       : 10% (Pu-239) PuO2 of density 4.0 g/cc
* %240 Pu      : 0.0
* Moderator     : Slag of Al2O3 and SiO2 with H/Pu of 20
* Model        : Dia = H cylinder of radius 5.2"
* Reflector    : 10" refractory insulation all around
*
* Code         : MONK6B
* Computer     : SECC Sun SPARC 10 workstation with operating
*              : system SunOS 4.1.3
*-

```

FISSION

* MATERIAL DATA AND MAIN CONTROL DATA *

Material #	Material Name	Symbol
1	PuO2 in Slag	F
2	INCOLOY 800	I
3	Fire Brick	B
4	KAST-O-LITE	K
5	CEROFELT	-
6	Water	W
7	Polyethylene	P
8	Hanford concrete	C
9	304 Stainless Steel	4

* # Materials # Elements
6 15

	Pu239	Pu240	Iron	Chromium	H1NH2O
	Oxygen	Nitrogen	Nickel	Manganese	Aluminum
	Calcium	Silicon	Sodium	Carbon	Beryllium
	9161	402C	908A	446C	923A
	933C	259A	907A	88A	935A
	138E	25E	182E	902B	967A

```

* PuO2 in Slag
CONC 0.0008887 0.0 0.0 0.0 0.017774
      0.0352 0.0 0.0 0.0 0.0101
      0.0 0.00452 0.0 0.0 0.000361
* Half Pipe and Plate: INCOLOY 800
CONC 0.0 0.0 0.04018 0.01923 0.0
      0.0 0.0 0.02659 0.0 0.0
      0.0 0.002605 0.0 0.0 0.0
* Fire Brick
ATOM 2.1 0 0 1 0 0
      127 0 0 0 1 32
      1 38 0 0 0 0
* Castable (KAST-O-LITE)
ATOM 1.5 0 0 1 0 0
      127 0 0 0 1 32
      1 38 0 0 0 0
* CERAFELT
ATOM 0.16 0 0 1 0 0
      127 0 0 0 1 32
      1 38 0 0 0 0
* Water
ATOM 0.988 0 0 0 0 2
      1 0 0 0 0 0
      0 0 0 0 0 0
* Slip Lid Container - assume polyethylene ( max. H )
*ATOM 0.92 0 0 0 0 2
* 0 0 0 0 0 0
* 0 0 0 0 1 0
* Hanford Concrete
*CONC 0.0 0.0 0.00035 0.0 0.01375
* 0.04608 0.0 0.0 0.0 0.00175
* 0.00152 0.01663 0.00175 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

```

INCHES

```

*****
*                               GEOMETRY DATA                               *
*****
* PART 1
NEST 2
*
*Body 1 - Pu-Slag Cylinder
*      x y z Mat. Radius Height
1 ZROD ORIGIN 0.0 0.0 10.0 1 5.2 10.4
*
*Body 2 - Refractory Reflector
*      Mat. Radius Height
2 ZROD 4 15.2 30.4
*****
*                               CONTROL DATA                               *
*****
* Override Default # Generations/ Multiplying Factor
SUPERHIST 10 2.00
*
* First Stage Last Stage Number/Stage Time SD Limit Pu Source
-2 40 500 0 STDV 0.0030 -1
*****
*                               SOURCE                               *
*****
FISSILE
REGION 1 PART 1 /
END
*****

```

APPENDIX B VALIDATION OF ANALYTICAL METHODS

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;

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

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 6], 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. Rounded conservatively, a value of +0.015 can be used for $[-bias + (U_b^2 + U_c^2)^{1/2}]$. 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} , $\sigma \leq 0.01$) 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 7]. 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.