# ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 636867

Proj. ECN

2. ECN Category (mark one)

- Supplemental []
- Direct Revision [X]
- Change ECN []
- Temporary []
- Standby []
- Supersedure AH ~~[X]~~
- Cancel/Void []

3. Originator's Name, Organization, MSIN, and Telephone No.
Allen Hess, 8M730, 372-3771

4. USQ Required?
[] Yes [X] No

5. Date
8/21/96

6. Project Title/No./Work Order No.
PFP cementation/K1634

7. Bldg./Sys./Fac. No.
234-5Z

8. Approval Designator
S

9. Document Numbers Changed by this ECN (includes sheet no. and rev.)
WHC-SD-SQA-CSA-513, Rev. 0

10. Related ECN No(s).

11. Related PO No.

12a. Modification Work
[] Yes (fill out Blk. 12b)
[X] No (NA Blks. 12b, 12c, 12d)

12b. Work Package No.

12c. Modification Work Complete

Design Authority/Cog. Engineer Signature & Date

12d. Restored to Original Condition (Temp. or Standby ECN only)

Design Authority/Cog. Engineer Signature & Date

13a. Description of Change

13b. Design Baseline Document? [] Yes [X] No

Revision of criticality safety evaluation to include discussions of new equipment and changes to process for cementation of slag and crucible residues

14a. Justification (mark one)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Criteria Change | [X] | Design Improvement | [] | Environmental | [] | Facility Deactivation | [] |
| As-Found | [] | Facilitate Const | [] | Const. Error/Omission | [] | Design Error/Omission | [] |

14b. Justification Details

Revisions account for a) use in process of filter funnel for liquid return~~ed to~~ water source tank, b) allowing extra storage area for cement cans with 500 g Pu limit, c) discussion of acid addition and controls, discussion of residual Pu contamination.

15. Distribution (include name, MSIN, and no. of copies)
see attached Distribution Sheet

RELEASE STAMP

SEP 06 1996
DATE:
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STA: 34
ID: 22

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A-7900-013-1

# ENGINEERING CHANGE NOTICE

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1. ECN (use no. from pg. 1)
636867

15. Design Verification Required
☐ Yes
☒ No

16. Cost Impact

| ENGINEERING | | | CONSTRUCTION | | |
|---|---|---|---|---|---|
| Additional | ☐ | $ | Additional | ☐ | $ |
| Savings | ☐ | $ | Savings | ☐ | $ |

17. Schedule Impact (days)

Improvement ☐
Delay ☐

18. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 12. Enter the affected document number in Block 19.

| | | | | | |
|---|---|---|---|---|---|
| SDD/DD | ☐ | Seismic/Stress Analysis | ☐ | Tank Calibration Manual | ☐ |
| Functional Design Criteria | ☐ | Stress/Design Report | ☐ | Health Physics Procedure | ☐ |
| Operating Specification | ☐ | Interface Control Drawing | ☐ | Spares Multiple Unit Listing | ☐ |
| Criticality Specification | ☒ | Calibration Procedure | ☐ | Test Procedures/Specification | ☐ |
| Conceptual Design Report | ☐ | Installation Procedure | ☐ | Component Index | ☐ |
| Equipment Spec. | ☐ | Maintenance Procedure | ☐ | ASME Coded Item | ☐ |
| Const. Spec. | ☐ | Engineering Procedure | ☐ | Human Factor Consideration | ☐ |
| Procurement Spec. | ☐ | Operating Instruction | ☐ | Computer Software | ☐ |
| Vendor Information | ☐ | Operating Procedure | ☐ | Electric Circuit Schedule | ☐ |
| OM Manual | ☐ | Operational Safety Requirement | ☐ | ICRS Procedure | ☐ |
| FSAR/SAR | ☐ | IEFD Drawing | ☐ | Process Control Manual/Plan | ☐ |
| Safety Equipment List | ☐ | Cell Arrangement Drawing | ☐ | Process Flow Chart | ☐ |
| Radiation Work Permit | ☐ | Essential Material Specification | ☐ | Purchase Requisition | ☐ |
| Environmental Impact Statement | ☐ | Fac. Proc. Samp. Schedule | ☐ | Tickler File | ☐ |
| Environmental Report | ☐ | Inspection Plan | ☐ | | ☐ |
| Environmental Permit | ☐ | Inventory Adjustment Request | ☐ | | ☐ |

19. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

| Document Number/Revision | Document Number/Revision | Document Number Revision |
|---|---|---|

20. Approvals

| | Signature | Date |
|---|---|---|
| **OPERATIONS AND ENGINEERING** | | |
| Cog. Eng. | AL Hess AL Hess H0-35 | 9/3/96 |
| Cog. Mgr. | JS Greenborg J. Greenborg H0-35 | 9/3/96 |
| QA | | |
| Safety | [redacted] PA CONNERS II DAG S4 | 9/4/96 |
| Environ. | | |
| Other | | |
| CS Peer Reviewer: | EM Miller EM Miller H0-35 | 9/3/96 |
| PFP Crit. Safety Rep: | LT Nirider L.T. Nirider T5-53 | 9/4/96 |

| | Signature | Date |
|---|---|---|
| **ARCHITECT-ENGINEER** | | |
| PE | | |
| QA | | |
| Safety | | |
| Design | | |
| Environ. | | |
| Other | | |

**DEPARTMENT OF ENERGY**

Signature or a Control Number that tracks the Approval Signature

**ADDITIONAL**

# "CSER 96-013: Cementation Process, Glovebox HA-20MB at PFP"

**Allen L. Hess**
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

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Key Words: PU STABILIZATION, SLAG & CRUCIBLE, GLOVEBOX HA-20MB, CEMENTATION, TRU SCRAP

Abstract: This evaluation provides criticality safety controls for the cementation processing in Glovebox HA-20MB at the Plutonium Finishing Plant. Slag and crucible residues from Pu button making will be blended with Portland cement in 5½-in. diam. x 7-in. tall cans, for eventual disposition in special DOT 17C drums. A maximum of 180 g Pu is allowed per liquid-bearing container (mixing bowl, filter funnel, or cement can). In this SD revision, three separate areas with 500 g Pu limits each are established; the airlock cell for input S&C cans, the reaction- and mixing-process area, and a cemented-can storage area. Number and spacing of containers within an area is not restricted, for areas spaced 6 inches apart. Acid addition in the reaction stage is allowed to the extent that plutonium dissolution will not occur.

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Chris Willingham 9-6-96
Release Approval Date

**Approved for Public Release**

## RECORD OF REVISION

(1) Document Number
WHC-SD-SQA-CSA-513

Page 1

(2) Title
CSER 96-013: CEMENTATION PROCESS, GLOVEBOX HA-20MB AT PFP

CHANGE CONTROL RECORD

| (3) Revision | (4) Description of Change - Replace, Add, and Delete Pages | Authorized for Release | |
|---|---|---|---|
| | | (5) Cog. Engr. | (6) Cog. Mgr. Date |
| Rev. 0 | (7) Issued as EDT 610633, July 17, 1996 | | |
| Rev. 1<br>RS | Complete revision of all text pages, Table 2, Figure 4, Appendix C (now D), added new appendix (B): Supersedure of original report by ECN # 636867 | AZ Hess | Jess [illegible]<br>9/6/96 |

A-7320-005 (08/91) WEF168

# CSER 96-013: CEMENTATION PROCESS, GLOVEBOX HA-20MB AT PFP

WESTINGHOUSE HANFORD COMPANY

August 1996

For the U. S. Department of Energy

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Prepared by: Allen I Hess Date: Sept 3, 1996
Engineer, Criticality and Shielding

Reviewed by: Edward M. Miller Date: Sept. 3, 1996
Engineer, Criticality and Shielding

Approved by: Date: Sept 3, 1996
Manager, Criticality and Shielding

# CRITICALITY SAFETY EVALUATION REPORT 96-013: CEMENTATION PROCESS, GLOVEBOX HA-20MB AT PFP

## 1.0 INTRODUCTION AND SUMMARY

The plutonium stabilization program at the Plutonium Finishing Plant (PFP) involves treatment of the residual inventory of plutonium at the plant by various means, depending on form and makeup, to convert it into forms amenable to long term storage at PFP or for disposition elsewhere. There is a significant quantity of scrap Pu-bearing materials stored in cans in various vaults and gloveboxes. One such form is the slag and crucible scrap, from past Pu metal button making, which had not been processed in the Plutonium Reclamation Facility (PRF). The PRF will not be restarted due to the liquid waste volume it would generate.

It has been decided that the most expeditious means for stabilizing the Slag and Crucible (S&C) scrap will be cementation, mixing the granulized S&C with portland cement to form contaminated concrete billets. The glovebox HA-20MB in Room 235B has been selected for this operation, and the equipment therein has been converted to the special requirements for the cementation process. As opposed to the other stabilization process gloveboxes (for furnace firing), the HA-20MB activities involve Pu mixed with water, and at a dilution that full moderation of the fissile material is the norm. The Pu-bearing slurry containers will include 4.73 liter (5 quart) mixing bowls, 2.5-liter filter funnels, and 2.7 liter cementing cans.

Basic criticality safety control is achieved with plutonium inventory limitations of 500 grams each in three separate areas: 1), S&C feed can storage in the input airlock cell; the process working area of the glovebox (for the wet operations of S&C reacting, filtering and cement mixing); and 3), a storage area for loaded cement cans during curing. A further restriction is a limit to no more than 180 g Pu in any one liquid-bearing container. Additions of nitric acid during the calcium reaction stage may prove necessary to enhance slurry settling, in which case the pH of the liquid would have to be controlled to preclude significant plutonium dissolution.

When cured, the 5.5-inch diameter by 7 inch tall cans of hardened cement will be loaded out of the glovebox for eventual disposition in special 55 gallon drums, which will accommodate up to three of these cemented cans. A loading limit of 180 grams is imposed per drum, so that a cement can loaded to the container limit would still be acceptable by itself.

The evaluation shows that under the controls recommended, assurance of subcriticality under normal and plausible upset conditions is provided which well satisfies the double contingency criterion set forth in the Nuclear Criticality Safety Manual (WHC 1989). At least two and usually more error conditions or upsets are needed before criticality would be possible.

There is a pre-existing holdup of Pu as surface contamination of the walls and floor in glovebox HA-20MB. Although the total NDA value for this holdup is on the order of a third of a Minimum Critical Mass (MCM), the material is so thinly distributed to be of minor consequence to the criticality safety controls.

# 2.0 DESCRIPTION OF FACILITY AND EQUIPMENT

## 2.1 PFP AREA DESCRIPTION

Figure 1 shows the layout for the area of first floor of PFP where the Pu stabilization activities take place. The muffle furnace operations and the boat charge preparations/packaging utilize the gloveboxes HC-21C, HC-21A and HA-21I (proposed). The cementation processing will be done in Glovebox HA-20MB, which has access to the conveyor box system through its connection at the south end to Glovebox HA-28. In the future, materials could be entered through the new feed prep glovebox 235-B-5 and transferred via conveyor HA-28 to glovebox HA-20MB.

## 2.2 PROCESS SOURCE MATERIAL

The scrap materials input for cementation are the leftovers from the button making process whereby plutonium fluoride was mixed with calcium in a magnesium oxide crucible and fired at high temperature in an electromagnetic furnace. Iodine also was included in the charge to promote the conversion. In a fully efficient operation, all of the Pu would be converted to metal, leaving a Pu-metal button (up to 2.5 kg mass allowed), plus calcium fluoride slag, calcium iodate, unreacted calcium, and the MgO crucible fragments from breaking out the button. However, usually not all of the $PuF_4$ was converted to metal, and sometimes metal chips may have been carried away with the slag and crucible (S&C) residues.

The process for making a Pu button of up to 2500 g Pu mass, which is 10.5 moles, would thus provide up to 42 moles (798 grams) of fluorine. Full conversion (to Pu + $CaF_2$) would require then at least 21 moles (842 grams of calcium) for each batch - - and likely much more. Typical analyses of S&C material indicate about equal parts by weight of $CaF_2$ and MgO, so that each batch will also include up to about 1600 grams of MgO sand. However, for most of the relevant past button production runs, the typical crucible charge had less than 2000 g Pu, and the inventory of S&C compounds in a storage can could be as low as 50% of the masses cited above.

The S&C residues are in multiple-can storage containers, the primary containers of which are untinned cans of up to 1.5 liters volume (meant to be fed to a S&C dissolver in the PRF). Assay records for the inventory of these S&C scrap containers indicate Pu contents of up to 200 grams per can. But for this cementing program, only cans with no more than 60 grams Pu will be processed, which accounts for the majority of the material in storage.

## 2.3 GLOVEBOX HA-20MB DESCRIPTION

HA-20MB is a conventional glovebox with a 52 inch wide by 15½ foot long floor supported 36 inches above the room floor by a table frame. It has an inside height of 3 ft, and as shown by the end view in Figure 2 the long walls slope inward somewhat starting about midway from floor to ceiling. Running beneath the floor of the box is a 12 inch wide by 14 inch deep by 11.5 ft long conveyor trough, down the middle and about centered lengthwise; this channel has been covered and sealed. The conveyor glovebox HA-28 connects to HA-20MB at the

# Figure 1:

# ROOM CONFIGURATIONS FOR STABILIZATION PROGRAM AT PFP

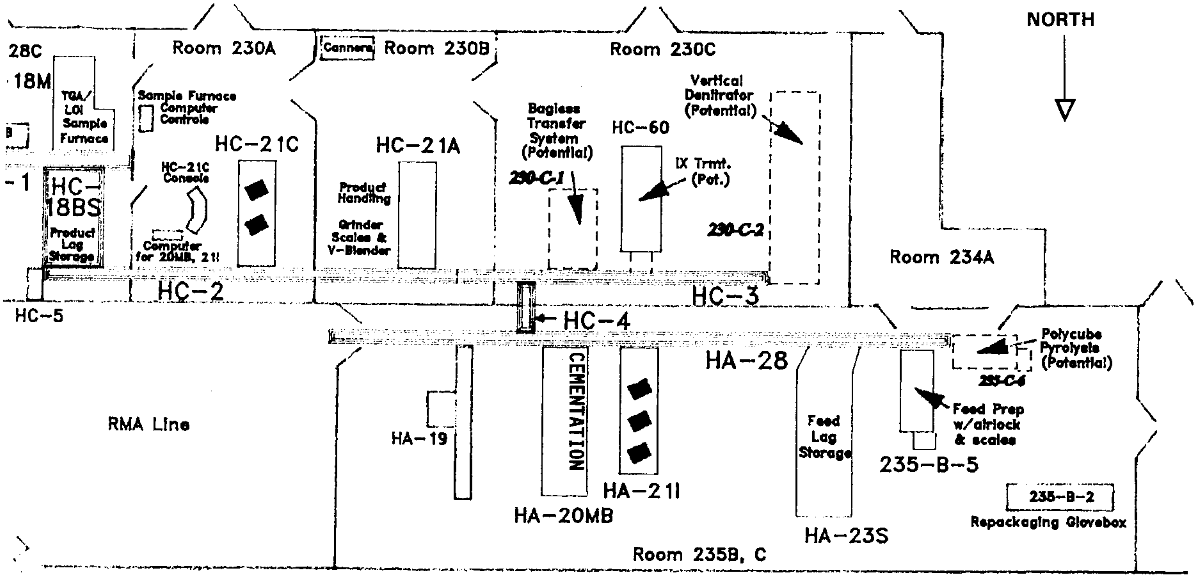
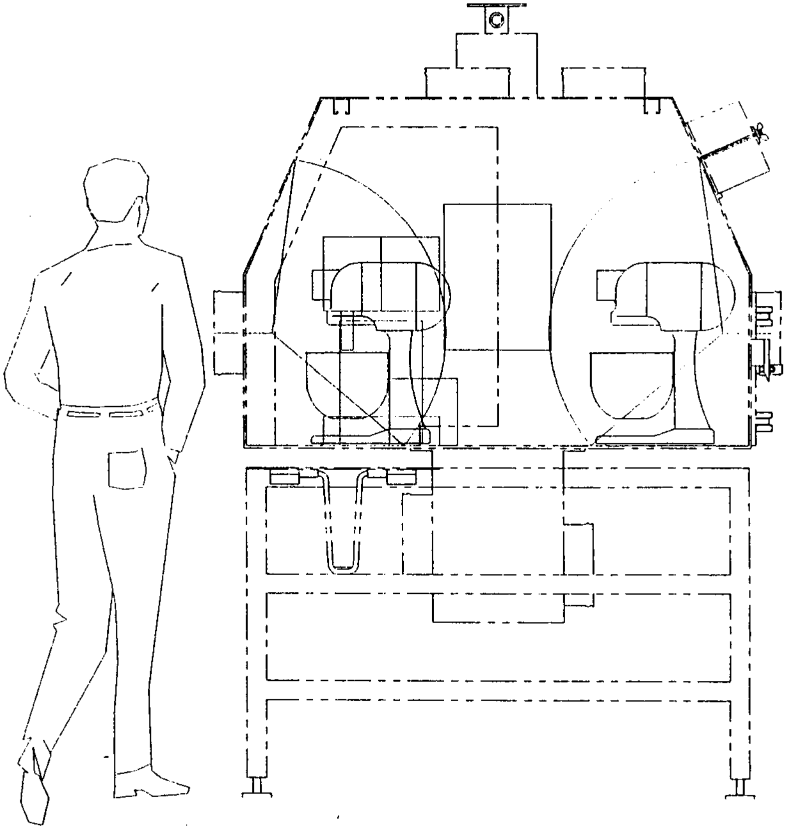


Figure 2:

## CUTAWAY END VIEW FROM NORTH OF GLOVEBOX HA-20MB



south end, opposite the end with the airlock.

Figure 3 shows a possible layout of equipment in Glovebox HA-20MB for the cementing operations. As indicated in this diagram, the northwest (lower left in diagram) portion of the glovebox has an air isolation chamber for staging the input S&C cans from storage. The equipment positions shown suggest that the east side of the glovebox (upper half) will be the "processing area", so that the cemented can storage area (with a separate 500 g Pu inventory limit) could be established in the west side (lower half in figure). However, this arrangement is not necessarily dictated by criticality safety considerations; the floor area segregation could just as well be into north and south segments, or whatever pattern will provide easier logistics for moving around the S&C cans, the mixer bowls, and the filled cement cans.

In addition to the airlock-cell access into the glovebox, transfers of materials could be done through the conveyor box on the south end of HA-20MB, and through one or more bag ports to be installed on the glovebox, probably near the conveyor end of the glovebox. The only likely transfers into the box through the airlock cell will be S&C cans and perhaps cementing cans and cement powder. No containers will be transferred back out through the airlock.

## 2.4 PROCESS DESCRIPTION

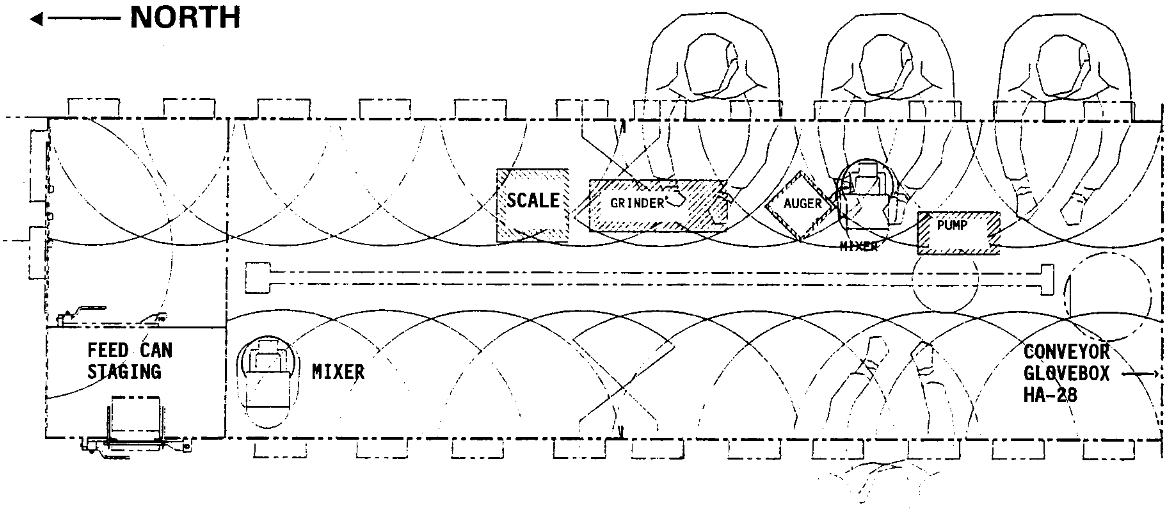
Processing of the dry S&C material begins with load-in of the bagged, sealed untinned cans into the glovebox through the airlock cell, bagport or the conveyor box HA-28. Yet unopened S&C cans, bagged or not, may be stored in the airlock cell without spacing or stacking restrictions, but with the total airlock Pu inventory limited to 500 grams. Logistics and space availability there will likely limit the can count. Only dry, canned S&C material is to be present in this airlock.

The general flow of the cementation process is shown in Figure 4. The upper part of the diagram indicates segmentation of the glovebox into a "wet end" and a "dry end", but this area and equipment layout may not be the final arrangement, nor does this evaluation require such. What will be needed is an area designated for storage of curing cemented cans only (most likely near a bag-out port), marked off for separation from the wet processing activities. The rest of the floor area (exclusive of the airlock) can be considered the "processing area", which may include a zone away from sources of water for charge-splitting operations.

Removal of the outer plastic wrap or bags from the S&C cans will be done in the processing area, and these wrap materials and any seal-in bags then are rendered into "non-containers" and processed for disposal in the usual manner for glovebox waste. Material from opened untinned S&C cans is transferred to catch pans or slip-lid cans for the early process stages, and the emptied untinned cans also are prepared for disposal. Of course, throughout the process stages, appropriate before-and-after weighings are performed on all cans, pans and bowls loaded with S&C material to track the fissile and total material mass flows. A limit of 1700 g is placed on unreacted S&C scrap material (total of slag, Pu, $PuF_4$, crucible sand, etc.) in the vicinity of the wet processing activities (a restriction concerning the potential rate of hydrogen generation - -not for criticality safety). This limit may be raised or eliminated in the future.

Figure 3:

LAYOUT OF GLOVEBOX HA-20MB FOR CEMENTATION PROCESSING



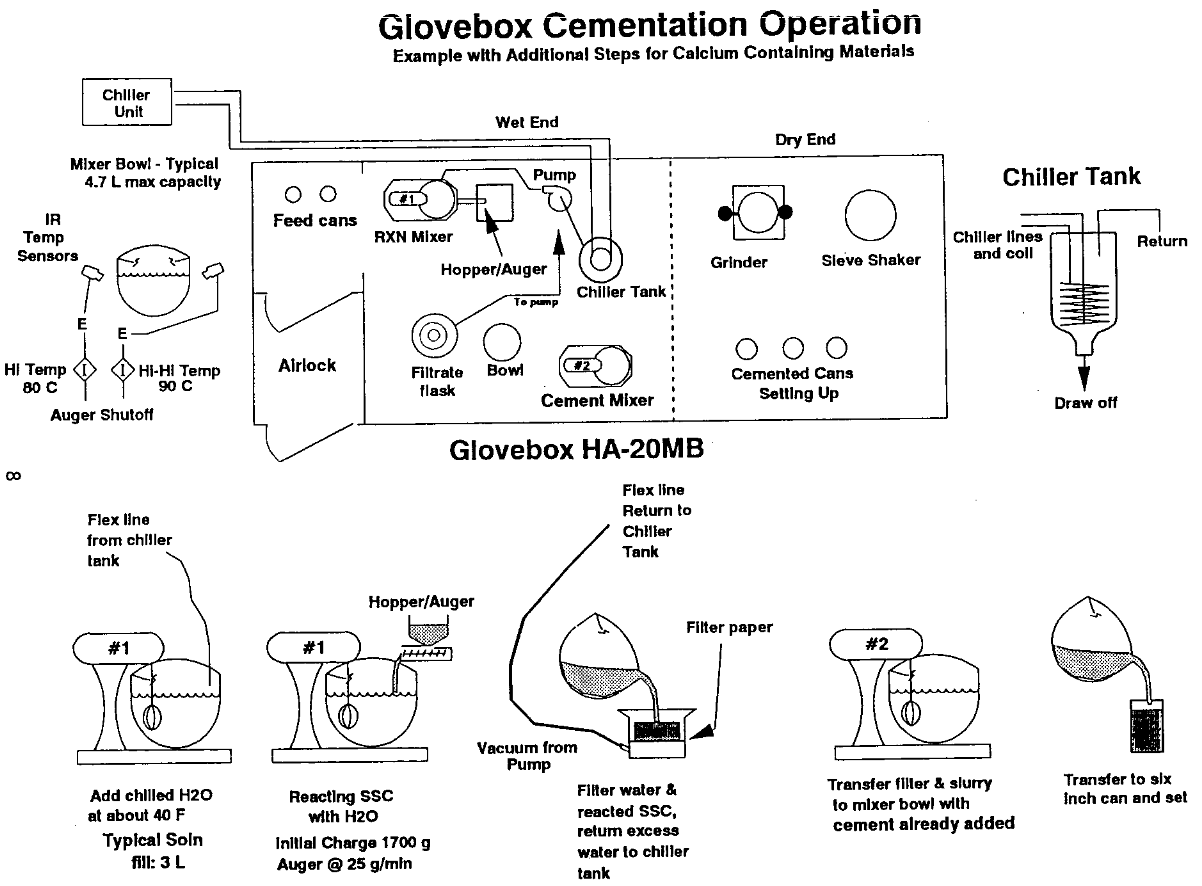


Figure 4: **CEMENTATION PROCESS FLOW DIAGRAM**

File CMT20MB.DRW

Before the reaction stage, the S&C material is run through a grinder to render a consistency which will expedite the reaction of residual calcium. Sieve screens are used over the catch pan under the grinder output port to sort out pieces needing further grinding (the sieve shaker machine indicated in Figure 4 is not actually present). After this stage the material should be a relatively homogeneous blend of calcium fluoride ($CaF_2$), calcium iodate, free iodine, unreacted calcium, MgO sand, $PuF_4$ powder/grains and/or chips and grains of metallic Pu (and possibly other compounds of Pu in minute amounts). If necessary, the batch of properly granulized and blended S&C material could be split, using slip-lid cans of up to 1.2 liters volume for the spit-off portions. Then, batches of no more than 1700 g total S&C will be transferred into the hopper of the auger for subsequent slow metering into a mixer bowl.

It would be preferable to process each input S&C can content as a single batch (carried through the reaction stage and into cementing) so the output can would retain the same Pu mass and assay accuracy as the original input can. This would simplify tracking of the area Pu inventories. However, as discussed in Section 2.2, there may be as much as 3300 g of scrap loaded in an untinned can. Splitting of the dry input material charges to comply with the 1700 g gross material limit would be carried out in the processing area, but in a region area away from the water handling activities (reaction stage, filtering, mixing). Pu accounting for split batches would be determined using the gross weight ratios for the granulized and blended S&C charge portions.

A 5 quart mixing bowl already loaded 2/3 full with water (from the chilled water tank), will be available for reacting the new charge. Thermocouples are affixed to the bowl for monitoring the fluid temperature. With the mixer beaters activated, the S&C material is slowly fed from the auger into the bowl of water, at a rate to limit the slurry temperature heatup caused by the residual free calcium reacting with water. There may also be provisions for simultaneous metered addition of small volumes of dilute nitric acid to inhibit frothing and to promote faster settling of the calcium hydroxide precipitate formed.

Once the bowl contains a designated charge of S&C material (1700 g maximum) the auger is stopped and the mixing is continued for up to 20 minutes, or until the temperature stabilization indicates no further reaction is occurring. Excess material in the auger, if any, would be transferred to a dry slip lid can for use in another charge. After removing the bowl from the mixer stand, the entire slurry contained is run through a filter pot (called a Buchner funnel), with the filtrate liquid drawn off via a pump and routed back up to the chilled water feeder tank inside the glovebox.

When the bowlful of reacted S&C slurry has been filtered, the sludge in the filter funnel, and the filter paper, are transferred into a mixer bowl in preparation for cementing. At this stage, with no more free calcium to react, the 1700 g gross material limit for a batch no longer applies, so that it would be allowed to load a mixer bowl with more than one filter-pot load of S&C sludge, within the constraints of the fissile mass limit (180 g Pu maximum) or other imposed cement can restriction. Based on weighings for the final total charge for cementing, appropriate quantities of water and then dry cement powder are added to the bowl and the bowl is set under the mixer beaters for stirring. Cement and/or water additions are made as required to achieve a proper consistency for the cement mud.

Loading of the cementing cans is done directly by hand from the mixing bowl. It may turn out that the bowl wet cement volume exceeds the desired can fill volume, in which case the excess is poured into another can as a partial fill. Tracking of any Pu contents is then achieved on the basis of total-weight ratios. Loaded cement cans will remain in the glovebox for at least 24 hours to cure.

## 2.5 MIXERS AND OTHER EQUIPMENT

The items inside Glovebox HA-20MB for the cementation process considered as fixed equipment (as opposed to containers) include two mixers, a grinder, balance scales, an auger (for controlled material feed rates), a pump, and a chilled feedwater tank. Above the glovebox is a larger tank for water supply and a chiller unit to supply the cooling coil in the inside feedwater tank. An additional vessel may be installed as a source tank for dilute nitric acid, plus provisions on such for load-in of the acid and for controlled, gravity feeding to the mixer bowl stations.

Conventional beater style mixers (industrial strength) are used for two stages of the operation, 1) reaction of residual calcium in the granulized S&C scrap, and 2) mixing of the granulated scrap slurry with cement. The proportions in the Figure 2 diagram indicate an overall height of 19 inches for the mixer units.

The grinder placed in HA-20MB is the conventional unit described in CSER 96-003 (Hess 1996), initially procured to pulverize hard residues from furnace firing operations. The hopper for this grinder has a capacity of 1.1 liters.

The auger unit is all enclosed in a 8.5 x 8.5 x 7 inch tall, lidded metal box, procured from AccuRate™. According to manufactures specifications, the feed hopper in the unit has a volume of 0.1 $ft^3$ (2.83 liters), or about a third of the overall auger box volume. Material is metered out of the auger through a 3.6 inch long pipe extending out horizontally from a bottom corner of the box. Feed rates as high as 0.5 $ft^3$ per hour (0.24 liters/minute) can be accommodated, according to specifications.

A pump is used to suction off the filtrate from the Buchner filter operation, with the pump outlet connected using Tygon™ tubing as a return line to the chilled water supply tank. For this, a roller-squeezed-tube type pump has been adopted, a Liqui-Sense™ (L/S) precision pump made by Masterflex™. The pump "cavity" as such is thus only a small segment of the TYGON™ tubing. In the tube line between the Buchner funnel and the pump is a small, cylindrical 25-micron in-line filter serving as a backup in case the funnel filter fails.

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One or two conventional scales are available to check weights of S&C material accumulations in cans, pans and bowls as needed at various processing stages.

The interior feedwater/recycled-water tank for the HA-20MB process is an open-top vessel of 5 gallons (18.9 liters) capacity, formed from an inverted polypropylene carbouy jug with its bottom cut off. Its diameter is 11 inches, and the full height from the outlet to the base is 15 inches. This interior tank is feed by gravity through piping from a 25 gallon makeup water tank outside and overhead the glovebox. As Figure 4 shows, water is drawn by gravity out of the conical lower end of the tank to charge the mixer bowls. The cooling coils inside of the tank are supplied in a closed loop circuit from a 1.2 gallon chiller unit outside of the glovebox.

The 25 gallon outside makeup water tank for the glovebox is also open on top, and it is filled by hand using a bucket from a tap on the plant sanitary water line. Thus, replenishing the chiller tank can be accomplished by gravity flow without any threat of unrestricted accidental flow due to line pressure from the PPW system. The geometry of this outside source tank is not important since it is not credible that plutonium would get into it. The tank volume is a concern for glovebox flooding considerations.

Instrumentation for the processing will include the thermocouples on the mixer bowls and probes for monitoring the Ph of the mixing bowl slurry if acid addition is adopted.

## 2.6 CONTAINERS FOR S&C MATERIAL AND SLURRIES

Containers intended to hold the S&C residues include the untinned storage cans, the mixer bowls, the Buchner filter funnel, the cementing cans, sieve catch pans, slip-lid cans, and possibly other small cans for transfer or cleanup purposes. Two sizes of untinned cans had been used for the residues from the button making runs, a 1.1-liter unit of 4 inches diameter and 5.5 inch height, and a 1.5 liter unit which is 4.5 inches in diameter by 6 inches high. As brought into the glovebox, the cans are crimped sealed and enclosed in a sealed, tight fitting plastic bag.

The sieve pans and catch pans are the same as for the sieve-shaker equipment described also in CSER 96-003, where each 8 inch diameter by 2 inch tall sieve or catch pan can hold as much as 1.65 liters. Dry S&C residues will be transferred during the preparations, grinding, splitting and weighing operations in these pans, or in 1.2-liter slip-lid cans. These "2 lb" slip lid cans, 4.25 inches in diameter by 5.5 inches tall, may also be used for cleanup of spills.

The mixer bowls (or beater vessels) are conventional, rounded bottom, 5-quart (4.73-liter) stainless steel bowls, 8 inches in diameter by 7 inches deep (forming effectively a hemispherical pool). A bowl design with handles affixed has been adopted to facilitate the pouring involved in the transfers of slurries to the filter funnel and the cement mud into the output cans.

The Buchner-style filter/funnel is not a conventional funnel with a conical reservoir, but a cylindrical barrel type with a perforated bottom plate upon which a filter-paper disc is placed. The funnel adopted for this process has a ceramic body of 18.6 cm (7.3 inches) inside diameter and overall height of 12.2 cm (4.8 inches), forming a handle-less pot which is stable because of its wide base. The perforated bottom plate is tilted somewhat to form an outlet cavity with the solid pot bottom, and this cavity has a tubulated side outlet. The funnel capacity was measured as 2.42 liters with the outlet plugged.

The cementing cans are 5.5-inch diameter by 7 inches tall, for a volume of 2.725 liters, and these are equipped with a slip-lid style covers. Load-in of these cans into the glovebox may be with the charges of dry cement powder needed for the operations. After curing and load-out, the cemented S&C cans will be loaded into the special drums pictured in Appendix A.

It is intended that the mixer bowls, filter funnel and cement cans will be the only allowed container types to hold S&C residues-plus-water slurries or sludge (perhaps also a slip lid can of up to 1.2 liters capacity for cleanup). The filtrate returned to the 5 gallon chiller tank may include minute concentrations of plutonium, either as a dissolved compound or microscopic particulate. Small amounts of Pu slurry might also be transferred into the tank in the event of multiple filter failures, an off normal situation which will be minimized by incorporation of appropriate controls in the operational procedures.

The allowed container list also includes a 200 ml graduated cylinder for accurate measurement of the water charge required for the cement mixtures.

### 2.7 RESIDUAL PU CONTAMINATION OF THE HA-20MB GLOVEBOX

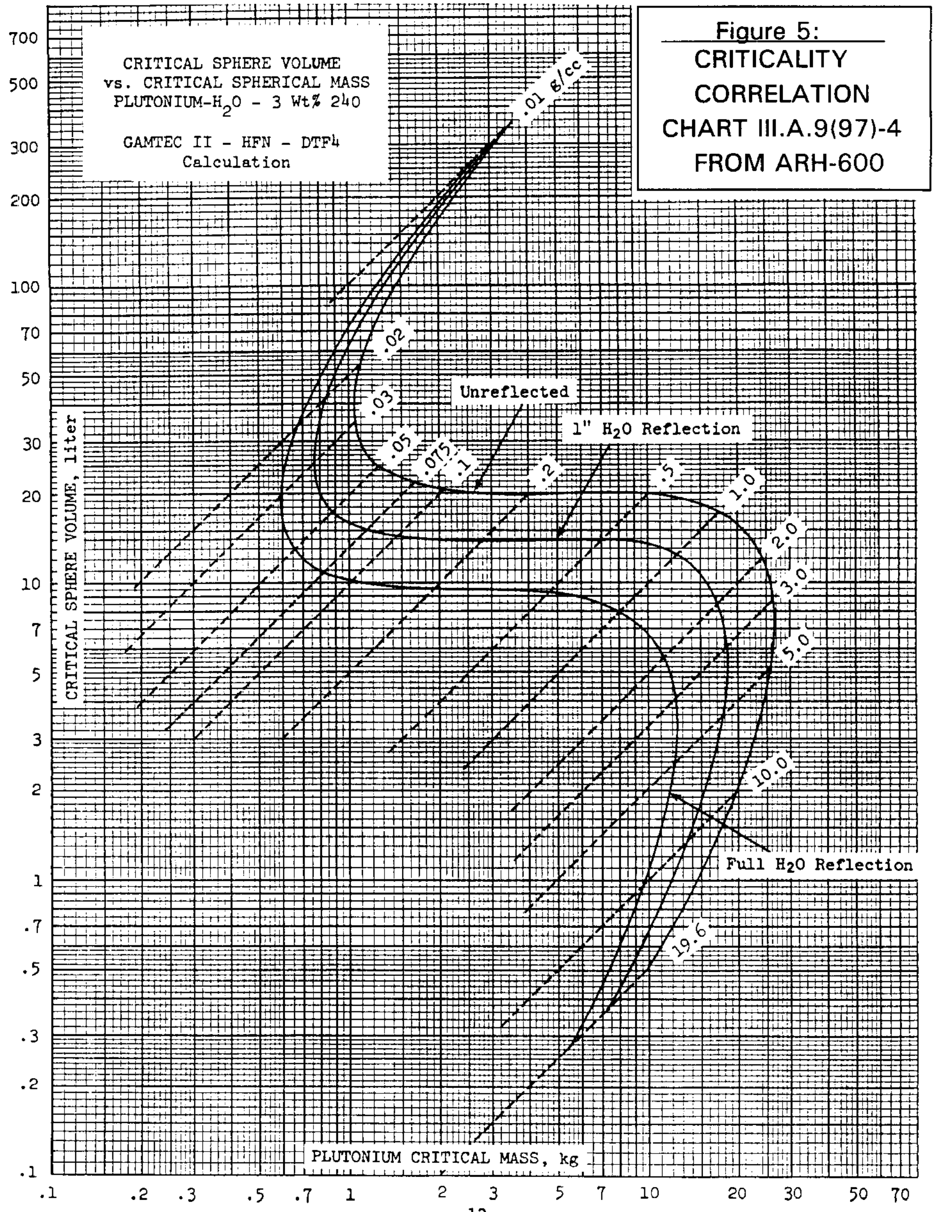
Glovebox HA-20MB was used in the past for other plutonium handling operations which have resulted in some residual Pu contamination on the wall and floor surfaces in the glovebox. Appendix B reports on the NDA determinations of this holdup made after the most recent cleanup efforts and prior to installation of the cementation equipment. An NDA high-side estimate of 179 g Pu was obtained for the total distribution throughout the glovebox proper, which NDA also showed no particular hot-spots for the material. It is not visually evident where the old deposits are, so that it can be assumed the contamination is as a very thin film spread out on the majority of interior surfaces, so the average areal density is on the order of 1 g Pu per square foot, and not likely to exceed 5 g/ft$^2$ in more than a few locations.

## 3.0 CRITICALITY SAFETY CONTROL EVALUATIONS

### 3.1 BASIC CONSIDERATIONS, REFERENCE CRITICAL DATA AND APPLICABILITY

The standard cited minimum critical mass (MCM) for plutonium is 530 grams, for an ideal, not physically real configuration of a pure $^{239}$Pu-water mixture as an 18-liter volume sphere fully reflected by water. Figure 5 shows for a 3%-$^{240}$Pu-plus-water mixture how the critical volume and mass are correlated. (The use of a chart for 3% $^{240}$ Pu content is still conservative because Pu of less than 5 weight-% $^{240}$Pu is not likely to be encountered, and because the negative

## Figure 5:
CRITICALITY CORRELATION CHART III.A.9(97)-4 FROM ARH-600



reactivity impact from the calcium to be carried with the S&C residual Pu will be more than that due to a 3% $^{240}$Pu content. To be noted on the curve is the relatively constant critical volume requirement (around 9 to 10 liters as a sphere with full reflection) for an available Pu mass between 1000 and roughly 5000 grams, which range would entail overbatching of the HA-20MB process area limit by factors of 2 to 10. The ~9.5 liter minimum critical volume is the equivalent of two brimful mixing bowls or about 3½ cementing cans.

However, the MCM and the Figure 5 data are calculated values, by methods effectively calibrated by comparisons with calculations on real, benchmark critical systems. The benchmark experiments encompassed mostly vessels of Pu-nitrate solutions and/or moderated systems involving plutonium oxide mixed with solid hydrocarbons. For the material in the cementation process, the Pu is diluted by significant amounts of fluorine and calcium, for which there are no benchmark systems to gauge the accuracy of neutron cross-sections to use in system calculations. This adds a undefined uncertainty for using the standard charts to evaluate safe mass and volume accumulations. Some additional analysis using Monte-Carlo calculations are thus warranted, and for these the margin of subcriticality desired should be increased to 0.10 $\Delta k$, so that the allowed calculated, bias-corrected k-effective ($k_{eff}$), at a 95% confidence level, should not exceed 0.90.

## 3.2 SAFETY ASSURANCE BY MASS LIMITATION

The essence of the criticality safety approach for this glovebox are the limitations to 500 g Pu maximum for the total Pu inventory in the processing area and in the can storage area, and to 180 g Pu for any liquid-bearing container. The 500 g limit is just slightly less than the conventionally recognized minimum critical mass (MCM) for $^{239}$Pu in a reflected water mixture, and the 180 gram Pu limit about a third of the MCM. These limits will safely accommodate a variety of contingency upsets and conditions resulting in Pu-water combinations of larger mass or volume accumulations. The 180 gram Pu limit for liquid-bearing containers applies to mixer bowls, the Buchner funnel, and to S&C-charged cement cans. As dry material, the S&C scrap loadings of the other equipment vessels and hoppers (the auger, pans, grinder) may be up to the 500 g Pu process area limit.

The separate 500 g Pu limits for the input airlock and cement-can storage areas of the glovebox are even more conservative. In the airlock section, where only dry S&C cans will be stationed during the input stage, no calculations are needed to demonstrate safety with only 500 g PU, since realistically for the constituency and dryness of the S&C material the MCM is about two orders of magnitude higher (50 kg or more). For the cemented S&C cans, results from analyses described in Section 4 suggest that the dilution of the fissile material by the cement constituents raises the wet MCM to on the order of 2500 g Pu.

Although the charges to the various containers are limited to at most 180 g Pu, the normal situation will involve S&C batches averaging 20 to 50 grams of Pu, and input cans are restricted to not more than 60 g Pu. Some degree of Pu contamination of the 5 gallon chilled water source tank is anticipated, and the implications of this are discussed in Section 6.0, below.

### 3.3 CONTAINER SPACING CONSIDERATIONS

With the adoption of the strict fissile mass limits, the question of container spacing rules depends on whether or not a critical geometry could be achieved with mass overbatching in some cluster of allowed containers. Monte-Carlo cases modelling clustering of liquid+Pu bearing containers were carried out in this regard. Section 4 provides details and results of these MONK6B calculations involving various clusters of loaded mixing bowls and cementing cans. For all-dry material containers, spacing is certainly not needed, even for several times overbatching of the area Pu mass limits. For the slurried mixes of S&C with water, the most concern is with the largest volume containers, the mixer bowls, as the material in the funnel and cement can will not be moderated as well.

## 4.0 MONK6B CALCULATIONS FOR CONTAINER CLUSTERS

### 4.1 METHODS VALIDATION

Appendix B provides a standardized summary for the documentation (Maklin 1992, Miller 1994) of the methods validation carried out for the MONK6B Monte-Carlo code, and its predecessor versions, as applicable to plutonium materials encountered at PFP. With the cross-section library supplied, the MONK6A/6B validation calculations on critical experiments indicate that to assure subcriticality with an acceptable margin, including uncertainties in the methods and benchmark experiments, the maximum allowed k-effective ($k_{EFF}$) calculated for systems involving S&C scrap is 0.885.

### 4.2 MONK6B PROBLEM MODELLING

#### 4.2.1 Glovebox Model

A Glovebox HA-20MB model for the MONK6B problems was established based on dimensions in the drawings from which the Figures 2 and 3 were derived. In this model, a rectangular transverse cross-section was adopted instead of the slanted-side outline shown in Figure 2. Also, the model did not depict the box at its elevations off of the room floor. Instead the floor of HA-20MB was modelled as a 5 cm thick slab of steel, to conservatively simulate the actual thin steel floor plus whatever reflection is inherent to the framing, etc., from the bottom of the box down to the room floor. The side walls, end walls and ceiling were all conservatively modelled as 5-cm (~2-inch) thick lucite panels, and along one face of the glovebox a 6-inch thick slab of water was positioned to represent the reflection provided by operating personnel standing there.

For most of the cases, only the mixer bowls and cementing cans, as liquid bearing containers, were modelled inside the HA-20MB glovebox, excluding any volumes of the various equipment items cited in subsection 2.5 that would hold dry materials and also neglecting the water tank. The Buchner funnel was not modelled in any of the calculations (an item adopted more recently than when the calculations were carried out); it is argued that this omission is not important in view of the limited number of funnels (1 or 2) to be present and that its volume (~2.5 liters) is smaller than either a mixer bowl (4.7 liters) or a cement can (2.7 liters). Also, the mode of operation entails passage of most of the liquid through the funnel before the heavy sludge of reacted S&C material is poured in - - thus providing a significantly less moderated fissile medium than for the agitated slurry during the mixing operation.

Clusters of fully filled mixer bowls were modelled set up against the front glovebox wall, with essentially full reflection there from the combined modelling of lucite and water slabs. Cementing cans were modelled as a close cluster in a corner of the glovebox. Combinations of bowls and can clusters were also investigated.

### 4.2.2 Material Representations

For all cases the plutonium involved was assumed to be entirely $^{239}$Pu. Also, none of the calculations accounted for the iodine constituent of the real S&C residues, a conservative omission because of the high neutron absorption properties for the element (7 barns at thermal energies, a factor of 20 times the absorption for hydrogen). For the cement mix, iron oxide, as sometimes present in concrete, was excluded. These conservative material assumptions and exclusions give $k_{eff}$ results which are too high by at least 1%, and possibly up to 4%.

### 4.2.3 Mixer Bowl Model

A precise model of the curved bottom mixer bowl was obtained using the overlap provisions of the MONK6B code. For the S&C material charged to the bowl, concentrations of 347 g/liter $CaF_2$ and 347 g/liter MgO were assumed, representing the residue from at least one button breakout operation, in a full 4.731 liters (5 quarts) of water. The plutonium atom density was varied while the other constituents remained constant.

### 4.2.4 Cement Can Model

Modelling of the cementing can was a straightforward nest of two cylinders (mix and can steel regions) giving a cement volume of 2.725 liters as the interior cylinder of 5.5 inches diameter by 7 inch height. For the cement region, a 2.2 g/cm$^3$ mixture of 63 wt.% CaO, 23 wt.% $SiO_2$, 8 wt.% $Al_2O_3$, and 6 wt.% MgO was assumed for the dry powder charged to the cans. To this mix was added the Pu loading plus fluorine and water. For the just-mixed cement can loading, a 50 v/o water fraction was assumed, or 500 grams per liter; a mix total density of 2.8 g/cm$^3$ was achieved with the water fraction at ~18% by weight, which means a hydrogen content of 2% by weight. This assumption is conservative considering that the hydrogen content of concretes is usually on the order of 1% by weight.

For the cemented-can array calculations also, only the content of $^{239}$Pu was varied for different cases, leaving the fluorine density constant (representing the 42 moles carried over from at least one full button making batch per cement can). Details of the container array modelling are included in the discussions of results below. Input data for selected cases, and output pictures of the modelled configuration, are included in Appendix D.

## 4.3 CALCULATIONS FOR CLUSTERS OF 5-QUART MIXER BOWLS OF S&C SLURRY

Table 1 lists details and results of MONK6B calculations for clusters of loaded mixer bowls set on the floor midway in the glovebox lengthwise, but up against the front wall (where there is 6 inches of water reflector outside to represent operators standing there). For most cases, the Pu loadings of the bowls were in multiples of the 180 gram Pu limit for liquid-bearing containers. The bowls of the array are nearly touching to form a tight triangular or square pitch array. In some cases listed, not all of the bowls of the array contain S&C slurry, but just plain water. The notations for the array pattern column indicate which is which for the clusters.

For these mixer bowl studies, cement cans are also modelled inside the glovebox, but in an array off in the corner and without any Pu content so they would have no impact on the reactivity of the bowl clusters.

The first case in Table 1 has three bowls in a triangular pattern loaded to the 180 g Pu limit in each bowl, which gives a 40 gram overbatch of the whole process area limit. The $k_{eff}$ value of 0.71 obtained for this case (A20MB21) probably represents the maximum which would ever be attained under normal, no-error conditions in the cementing operations.

The next set of four cases in Table 1 has clusters of bowls for which the total Pu inventory is 1080 grams - - somewhat over double batching the process area mass limit. With all of this inventory in one bowl, surrounded by bowls of water giving extra reflection, a $k_{eff}$ of 0.73 is calculated. Spreading this 1080 g Pu over three bowls, down to twice the allowed mass per bowl, increases $k_{eff}$ to 0.80 (case A20MB22). Thereafter, spreading the inventory over more bowls (in 6 bowls for A20MB23 and in 9 bowls for A20MB27) at lower concentrations of Pu reduces the reactivity. Thus for the contingency of overloading the HA-20MB process area by a factor of 2, with no restrictions on bowl count or spacing in a planar array, the maximum $k_{eff}$ is 0.80. Stacking of bowls is assumed not plausible.

Another set of three MONK6B cases were calculated for essentially triple batching the process area, for 1620 grams total Pu inventory. Here, loading the inventory into 3 bowls at 540 g each (case A20MB29) is less reactive than spreading it out into 6 bowls at 270 g each (case A20MB28 with a $k_{eff}$ of 0.85). Spreading it further into 9 clustered bowls at 180 g/bowl reduces the reactivity by about 2%. (case A20MB26). Thus, distribution into even more bowls, a hardly plausible operational situation, would lower $k_{eff}$ even further.

In the last set of three cases in Table 1, plutonium has been added to water-filled bowls as fluoride ($PuF_4$) only, without any calcium or crucible debris. Case # A20MB25 represents an improbable, but conceivable, faulted condition that one of the input untinned S&C cans in reality contained a full charge of 2500 g Pu as $PuF_4$ from a failed or unfired button making operation (also with no calcium added), and this winds up in a mixer bowl of water in a cluster of other water filled bowls. The resulting $k_{eff}$ of 0.83 shows adequate subcriticality for such a scenario involving substantial past and current errors. With only 500 g plutonium as fluoride in one bowl surrounded by water-filled bowls, case A20MB35 gives a $k_{eff}$ of 0.77, which is comparable to cases with 1080 g Pu in several bowls with the MgO and $CaF_2$ included. With two such 500 g bowls adjacent, the $k_{eff}$ of 0.83 is like the cases with 1620 g total Pu with Ca and Mg.

Table 1: MONK6B RESULTS FOR CLUSTERS OF LOADED MIXER BOWLS

| CASE ID # | NO. OF LOADED BOWLS | GRAMS PU PER LOADED BOWL | BOWL ARRAY PATTERN [a]<br>0 = $H_2O$ only<br>● = S&C slurry | TOTAL PROCESS AREA PU, GRAMS | MONK6B DATA<br>k-eff<br>(Std. Dev.) |
|---|---|---|---|---|---|
| A20MB21 | 3 of 3 | 180 | ●<br>● ● | 540 | 0.7142<br>(0.0040) |
| A20MB24 | 1 of 6 | 1080 | 0<br>0 0<br>0 ● 0 | 1080 | 0.7262<br>(0.0044) |
| A20MB22 | 3 of 3 | 360 | ●<br>● ● | 1080 | 0.7952<br>(0.0045) |
| A20MB23 | 6 of 6 | 180 | ●<br>● ●<br>● ● ● | 1080 | 0.7787<br>(0.0040) |
| A20MB27 | 9 of 9 | 120 | ● ● ●<br>● ● ●<br>● ● ● | 1080 | 0.7565<br>(0.0038) |
| A20MB29 | 3 of 9 | 540 | 0 0 0<br>0 ● 0<br>● ● 0 | 1620 | 0.8152<br>(0.0042) |
| A20MB28 | 6 of 9 | 270 | 0 0 0<br>● ● ●<br>● ● ● | 1620 | 0.8539<br>(0.0042) |
| A20MB26 | 9 of 9 | 180 | ● ● ●<br>● ● ●<br>● ● ● | 1620 | 0.8388<br>(0.0041) |
| A20MB25 | 1 OF 6 | 2500 as PuF4, no Calcium | 0<br>0 0<br>0 ● 0 | 2500 | 0.8320<br>(0.0043) |
| A20MB35 | 1 OF 9 | 500 as PuF4, no Calcium | 0 0 0<br>0 0 0<br>0 ● 0 | 500 | 0.7684<br>(0.0042) |
| A20MB36 | 2 OF 9 | 500 as PuF4, no Calcium | 0 0 0<br>0 ● 0<br>0 ● 0 | 1000 | 0.8338<br>(0.0046) |

a) Bottom row of bowls is against front glovebox wall (2" lucite + 6" water reflection). Cuboid box walls of 1" water around other sides of array.

It is thus well demonstrated that with the Pu mass restrictions there need not be limits on the number of mixer bowls in the process area nor any minimum spacing rules.

## 4.4 CALCULATIONS FOR ARRAYS OF 2.7-LITER CANS WITH S&C-CEMENT SLURRY

Table 2 gives result of MONK6B calculations for arrays of S&C-loaded cement cans set in a corner of the glovebox, with lucite reflection on one side and lucite plus 6 inches of water in front. As explained above, the Pu and other S&C sands plus water have been blended with the dry cement in the 5.5-in. diameter by 7 in. tall cans. The dilution of the fissile content by the calcium and silicon oxide components of the cement reduces the reactivity of the S&C slurry transferred from the mixer bowls. For the cases with only the cement cans in the array, there is a cluster of three water-filled mixer bowls modelled at the center of the glovebox.

The total Pu inventory for the cement can arrays modelled in Table 2 range from about double the allowed storage area limit to over five times the limit. For the first three cases in the table, the loaded cans are clustered without stacking, as no such stacking is anticipated for the operations. In a 16-can cluster (case A20MB52) loaded each with 60 g Pu (the probable maximum expected for any can), thus almost doublebatching the storage area limit, a $k_{eff}$ of only 0.63 is obtained. With the same 4 x 4 can arrangement, loading each can to the 180 g Pu maximum (case A20MB53) raises $k_{eff}$ to 0.79, but this is a severe violation of the area limit (factor of ~ 5.5). A similar result is derived for about the same amount of Pu distributed evenly into 9 cans of a 1-tier, 3 x 3 array (case A20MB51), which involves can limit violations also.

The next three cases in Table 2 model 48 cement cans as a 4 x 4 x 3-high stack, in a study to explore if any limit on container count is practical. Even though such stacking is not likely (and not needed operationally), the modelling as a tight cluster (forming an almost perfect cube) provides an indication of just what amount of Pu in S&C cement it takes to approach a critical accumulation. With 48 cement cans loaded to 30 g Pu each, which is more like the average expected load, a $k_{eff}$ of 0.75 is calculated (case A20MB55), and this is with the storage area nearly triple batched. Doubling the loadings to 60 g Pu per can, for almost 6 times the area limit (case A20MB54), increases $k_{eff}$ to 0.97, a value which is unacceptable. But this overbatched, stacked case clearly represents an implausible scenario, and also it includes some conservative material assumptions (no $^{240}$Pu, iron or iodine). Thus, with a restriction imposed against can stacking, the same number of loadings of cans in a single tier would surely be subcritical, so that in effect a limit on can count is not essential.

The third case with a 48-can array in Table 2 shows the effect of halving the cement hydrogen content of the previous case, down to about the 1 weight percent typical of concretes; for the 48-can cubical array with nearly 6 times the allowed area limit the $k_{eff}$ is below 0.80.

The limited number of calculations in Table 2 sufficiently demonstrate that with a 500 g Pu limit for the can storage area and the 180 g/can limit there needs to be no spacing between cans nor limit on number of cans.

Table 2: MONK6B CALCULATIONS FOR CLUSTERS OF CEMENTED-S&C CANS AND MIXER BOWLS IN HA-20MB

| CASE ID # | CEMENT CAN ARRAY DETAILS | | | | ADJACENT MIXER BOWLS | | CLUSTER[c] TOTAL PU | MONK6B RESULTS | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of Cans[a] | Array Form[b] | Grams Pu/can | Water Content | No. of Bowls | Pu per Bowl | | kEFF | Std. Dev. |
| A20MB51 | 9 | 3 x 3 | 300 | 500 g/ℓ | 0 | - | 2700 g | 0.7750 | 0.0044 |
| A20MB52 | 16 | 4 x 4 | 60 | 500 g/ℓ | 0 | - | 960 g | 0.6300 | 0.0035 |
| A20MB53 | 16 | 4 x 4 | 180 | 500 g/ℓ | 0 | - | 2880 g | 0.7933 | 0.0042 |
| A20MB55 | 48 | 4 x 4 x 3[d] | 30 | 500 g/ℓ | 0 | - | 1440 g | 0.7479 | 0.0037 |
| A20MB54 | 48 | 4 x 4 x 3[d] | 60 | 500 g/ℓ | 0 | - | 2880 g | 0.9674 | 0.0037 |
| A20MB56 | 48 dried | 4 x 4 x 3[d] | 60 | 250 g/ℓ | 0 | - | 2880 g | 0.7421 | 0.0027 |
| A20MB58 | 16 | 4 x 4 | 60 | 500 g/ℓ | 1 | 180 g | 1140 g | 0.6315 | 0.0037 |
| A20MB59 | 16 | 4 x 4 | 60 | 500 g/ℓ | 3 | 180 g | 1500 g | 0.7278 | 0.0043 |

a) 5.5-inch diam. x 7-inch tall cans, filled volume of 2.725 liters each.

b) Can array in left front corner of glovebox with 6-inch water reflector in front.

c) 1-inch water slabs enclosing cluster of cans or cans + bowls on right, back and top for nominal reflection.

d) 3-high stack of 16 cans per tier modelled by extending can height to 21 inches.

## 4.5 AREA SPACING REQUIREMENTS

Comparison of the Table 1 results for mixer bowls and the Table 2 data for cement-can arrays shows that for a given total plutonium content the more reactive configuration is the slurry of S&C residues with water in the mixer bowls. Thus, with an allowed 1000 g Pu total for the wet process area and the cement can storage area combined, the reactivity due to close proximity of bowls in the process section to cemented cans in storage would not be more reactive than the last result in Table 1, with a $k_{eff}$ of 0.83 (for which case there is an error condition on fissile material makeup). A double batch of one of the area mass limits also would be safe, as indicated by the results for the set of cases in Table 1 with 1620 g Pu total in bowls.

More precise evaluations of the area spacing question were obtained from the two MONK6B calculations reported as the last two cases in Table 2. A case A20MB58 was run where a mixer bowl containing 180 g Pu in a S&C slurry was set right next to the 4 x 4 cement can array of case A20MB52 of Table 2 (with 960 g Pu); this produced a $k_{eff}$ of 0.63, not really different than for the 4 x 4 array alone. Putting three such 180 g Pu bowls in a column flanking the 4 x 4 array of cement cans, with a Pu content of 1500 g total for the configuration, gave the $k_{eff}$ of 0.73 listed for the last case of the table.

In view of these results, spacing between the area for wet processing activities (mixer operations, etc.) and the area designated for storage of loaded cemented cans is not crucial for criticality safety. More important aspects would be the prospects for loaded cement cans tipping into the process area and perhaps splashing material out of open cement cans in the event water charging and pumping operations go awry. It is thus suggested that the can storage area be marked off on the floor with a separation of 5 inches or so from the wet process area.

Considering also the low reactivity of the dry S&C material, cans of input S&C materials could be stored in either the process area or the cement-can storage areas, providing their Pu contents are accounted for under the 500 g limit for the particular area, and providing they be located where water entry would be precluded if such cans are open.

## 5.0 FEEDWATER TANK PU CONTAMINATION

Some uptake of Pu into the 5 gallon inside tank used to recycle the filtrate from the filtering operation is a possibility. The dimensions of this carbouy jug render it a not geometrically-favorable vessel for criticality safety, and its ideal cylindrical L/D make it almost as good as a sphere, so spherical critical mass data readily apply. Due to its location close to the roof of the glovebox, a fully reflected condition would never exist because flooding to that height is not credible. The nominally-reflected (1" of $H_2O$) curve in Figure 5 shows that for a sphere of 19 liters (~5 gallons) volume, the critical loading would be 800 grams Pu. This is with a 3% $^{240}$Pu fraction, which would have about the same effect as the Ca content of the S&C with pure $^{239}$Pu.

As the plutonium is highly insoluble in the alkaline filtered medium, the filtrate would normally have insignificant concentrations of Pu. However, instances of funnel filter paper failure are to be expected. For this reason the inline filter was incorporated into the pump's Tygon-tube transfer line as a backup to hold up solids from entering the tank.

Thus, although the water tank is not geometrically safe, there are several layers of defense incorporated into the process design and operational procedures to preclude significant quantities of Pu from being transferred to the tank. First, as mentioned earlier, although up to 180 g Pu is allowed, normal batches will probably average 20 to 40 grams of Pu, and the most from any S&C can will be 60 grams. Next, considering breaches of the funnel filter to be not unlikely, there is the backup inline filter (which would probably clog quickly if the funnel filter fails). Finally, the procedures will include filter placement verifications, monitoring of transfers for evidence of sludge passage, and requirements for draining any sludge buildup in the tank before continued filtering activity. To be noted also is the fact that even a double batch (360 g Pu) of the allowed bowl loading if all transferred to the tank would be about half that needed for criticality.

The proposed addition of nitric acid to the slurry during the calcium reaction process, to prevent frothing and help precipitate the calcium hydroxide, introduces another prospect for plutonium transfer into the water feed tank. If the acidity was excessive, one could postulate an ever increasing concentration of dissolved plutonium, which would pass through filters, in the recycled process water. Thus, the acidity needs to be limited so that dissolution of Pu would be insignificant. For the nominal tank volume of 5 gallons (about 18 liters capacity after accounting for the cooling coil displacement), a loading of 180 grams (~1/3 MCM) means a 10 g/liter Pu concentration. Controlling the pH so that the concentration of dissolved plutonium would never exceed 1 gram per liter (giving about ~ 3% of an MCM in the tank) would be certainly be adequate.

# 6.0 OTHER CONTINGENCIES

## 6.1 SPILLS AND OVERFLOWS

Direct spills of mixer bowls already loaded with a S&C charge in water can be expected, considering the various handling operations for such. Scenarios are also conceivable whereby the S&C/water mixture is overflowed from a bowl, as by a), too much initial water volume and over-vigorous stirring or more than expected calcium reaction rates; or b), auguring in too much of the S&C material.

Subcriticality for these spill/overflow contingencies is assured by two aspects of the process; a), the fissile content of the bowl is limited to not more than a third of a minimum critical mass for Pu, and b), the fissile material is not soluble, so dumped solids material will most likely settle out on the glovebox floor in a small pile with the water spread out further, leaving a less moderated fissile medium for which the MCM is higher yet. It is judged not likely that any spills would be of large enough extent to be able to dissolve or dislodge a significant fraction of the glovebox holdup plutonium existing as surface contamination on the floor and sidewalls of the box.

## 6.2 GLOVEBOX FLOODING

The total volume of the chilled water supply tank is 5 gallons, or nearly 20 liters. As Fig. 5 shows, this is just enough for criticality with a fissile inventory of 600 g, but under ideal geometry and full reflection conditions. Such conditions would be impossible to achieve even if the full tankload were to dump into a triple-batched bowl and wash out its contents.

Also possible, but less likely, would be draining all 25 gallons of water from the outside supply tank plus that of the chiller tank onto the glovebox floor, directly or overflowing the mixer bowl. Spread over the 57 $ft^2$ floor area this 30 gallons (114 liters) would give a pool depth of only 0.7 inches, which is not sufficient for criticality with even ten kg of Pu entrained.

The last source of possible, but highly unlikely, flooding would be activation of the room fire sprinkler combined with faults which open the glovebox to input of the spray. Flooding of the glovebox to more than 2 inches is not credible due to drainage out the conveyor glovebox. In addition, container upsets would be needed to dump fissile material into the pool, and these would have to be grossly overbatched to attain a minimum critical areal concentration.

With a faulted coveplate sealing, the pool might then drain into the old conveyor channel below the floor, with an area of 11.5 $ft^2$. Even then there would have to be at least 2760 g Pu entrained (minimum critical areal density of 240 $g/ft^2$ x 11.5 $ft^2$), plus full reflection - altogether a not credible combination of faulted conditions.

## 7.0 CONCLUSIONS

The qualitative analysis and calculated criticality data reported have shown that the cementing operations in HA-20MB will meet the double contingency criterion for criticality prevention if the processing is governed by Criticality Prevention Specifications with the following requirements:

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Material for cementing ------ Slag and Crucible Residues, only

Airlock cell fissile inventory ------------ 500 g, maximum, dry

Process area fissile inventory --------------- 500 g, maximum

Cement can storage area inventory ------------- 500 g, maximum

Volume any container ------------- 5 quarts (4.73 l), maximum

Fissile content in liquid-bearing container ------- 180 g, maximum

Containers allowed with liquid: 5 qt. mixer bowls
5.5" diam. x 7" tall cementing cans
2.5-liter Buchner filter funnel
up to 1.2 liter cleanup cans or jars

Pu-loaded Container Array Restrictions _ _ _ _ _ _ _ _ _ _ No Stacking

Acidity Control for Mixer-bowl slurry, recovered supply water _ _ _ _ _ _ _ minimum pH to assure Pu solubility is less than 1 g/liter

Backup inline filter for filtering process _ _ _ required in place

Filter failure response - - - upon evidence or reason to believe more than 15 g Pu may have been transferred to the 5 gallon chiller tank, pump shutoff required and tank drained to below 5 g Pu holdup before proceeding with next funnel charge and pumping.

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It is required that the operating procedures include steps for verification of the filter placements in the Buchner funnel before pumping filtrate from the funnel to the chiller tank is allowed .

The CPS equipment list is to include as "equipment" the grinder, scale, mixers and auger, which include their hoppers. Under allowed containers, beside the liquid-loading types cited above, will be the sieve pans, catch pans and the untinned cans of the source material. Dry S&C material may be distributed among one or more of the allowed containers, even having the full 500 g maximum allowed in one can (or, for blending dry, in a bowl). With liquid (water or cement slurry) in a container, not more than 180 g Pu is to be included.

## 7. REVIEWER'S COMMENTS

The independent technical review of Revision 1 of this CSER, *CSER 96-013: CEMENTATION PROCESS, GLOVEBOX HA-20MB AT PFP*, was done by E. M. Miller, staff member of the Criticality and Shielding group. His comments are as follows:

The analysis divided the glovebox into the airlock, cement-can storage area, and the process areas. Each of these areas is allowed an inventory of only 500 g of Pu. Since 500 g of Pu can not be made critical with the materials available in the glovebox, the system is inherently safe under normal operating conditions. So although there is 25 gallons of water available, many containers that are allowed to be brought together, and Pu feed material, portland cement, and aggregate of uncertain chemical composition, the system, even under accident conditions, has a significate margin of safety.

The CSER includes many computer runs of accident conditions for more Pu inventory than allowed. These runs show that the operations are substantially subcritical even for two to five times the allowed Pu inventory. A limit of one-third of a critical mass, 180 g, of Pu is imposed on each container. This further enhances criticality safety by dividing the total fissile material allowed in the glovebox. Computer runs of containers showed that a single container alone or in an array of containers with over batching are well subcritical for any reasonable number of containers on a single level. The runs showed that an array of containers reached a maximum reactivity then dropped as Pu concentration was increased. The maximum $k_{eff}$s were significantly less than the conservative allowable limit. Stacking is not allowed. Individual containers are limited to less than five liters. This small volume compared to the large volume needed for criticality with less than kilogram quantities of Pu also adds to the inherent safety of the system.

A sample of the computer runs were reviewed for geometry, materials, convergence, results, and atom densities. The results of the computer runs are accurately reported in the analysis and the inputs are as described in the analysis except for a minor discrepancy in the atom fraction of fluoride, that is less than 10% larger in some cases than would be found from the case description. The discrepancy is too small to change the $k_{eff}$ significantly and the computer results are so far below the allowable limits that the CSER conclusions would not be affected. One case was rerun and the $k_{eff}$ changed by less than 0.01. Since the chemical composition of the slag, scale, and portland cement are not well defined, variations in the input are not necessarily discrepancies.

The material in the cement cans was modelled with a total density of 3 g/cc. This density is not realistic. The water and magnesium add to the cement density of 2.2 g/cc. However, extra dense water and neutron scatters like magnesium normally increase reactivity by lowering leakage.

The reviewer has examined references, component information, and computer output to verify input data to the analysis. The calculations and arguments have been critically examined. Some disagreement exist between the author and reviewer on the value of dimensions used for equipment in the calculations, but in all cases the report's conclusions are unaffected. All items of contention were resolved and many suggestions and corrections were incorporated in the final report. The reviewer concurs that this CSER has incorporated sufficient conservatism into the analysis, that all credible challenges to the system have been adequately analyzed, and that the results are sufficient to demonstrate the safe operation of the process under both normal and accident conditions.

## 8.0 REFERENCES

Carter, R. D., G. R. Kiel and K. R. Ridgeway, 1968, *Criticality Handbook, Volume 2*, ARH-600, June 30 1968 plus updates, Atlantic Richfield Hanford Company, Richland, Washington.

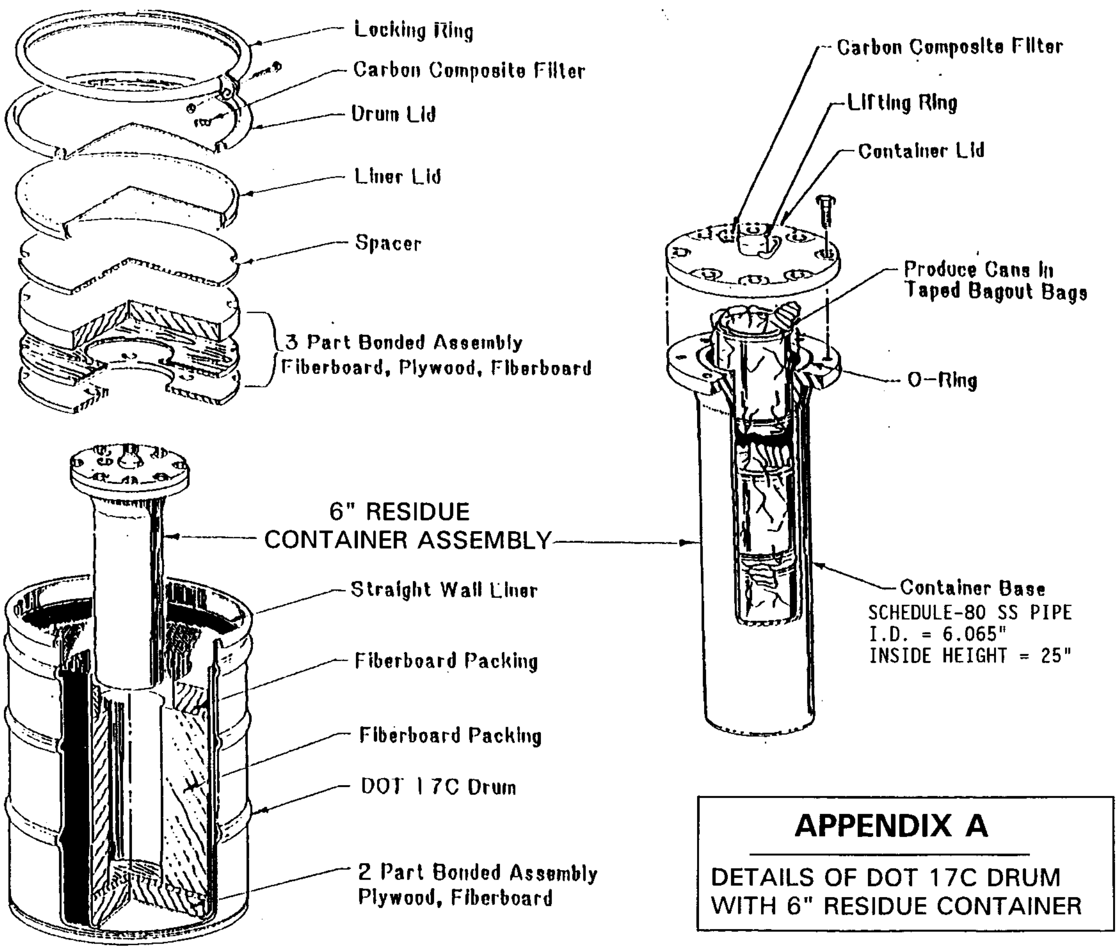
Hess, A.L., 1996, *CSER 96-003, Additions of Sphincter Port and Grinder to Glovebox HC-21A*, WHC-SD-SQA-CSA-501, Rev.0. Westinghouse Hanford Company, Richland, Washington.

Macklin, L. L., and E. M. Miller, 1992, *CCVR 91-001; MONK6A Pu Validation*, WHC-SD-SQA-CSWD-20015, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Miller, E. M., 1994, CCVR 94-001; *MONK6B Pu Validation*, WHC-SD-SQA-CSWD-20019, Rev. 0, Westinghouse Hanford Company, Richland, Washington

# APPENDIX A

## DETAILS OF DOT 17C DRUM WITH 6" RESIDUE CONTAINER



# APPENDIX B: NDA FOR RESIDUAL PU CONTAMINATION IN HA-20MB

**Westinghouse**
**Hanford Company**

**Internal**
**Memo**

From: PFP Analytical Laboratory
Phone: 373-9881 T5-05
Date: August 13, 1996
Subject: HA-20MB Glovebox

15400-96-043

To: B. C. Meese T5-08

cc: G. B. Chronister T5-03
M. B. Nelson T4-20
G. A. Westsik T5-04
NDA File
EWC:LB File

On August 8, 1996, HA-20MB glovebox and sump was assayed for plutonium content using the NaI detector #1000. This assay was completed by K. T. Brasel and D. L. Sorenson. The plutonium content in grams for the glovebox is 161 Best, 144 Least and 179 Most, sump 18 Best, 7 Least, and 70 Most.

Should you have any questions regarding this assay, please contact George Westsik on 373-1947 or myself.

Jeff Hieb
J. M. Hieb
Team Leader

dls

Hanford Operations and Engineering Contractor for the US Department of Energy

# APPENDIX C: COMPUTER CODE VALIDATION

## C.1 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.

For the systems cofigurations involving fissile mixtures with slag and crucible debris and cement, the safety criteria for future calculations on undetermined systems requires that the bias-adjusted $k_{eff}$ does not exceed 0.90 at the 95% confidence level. This is expressed by the following formula;

$$k_{eff} = k_{calc} - \text{bias} + (U_b^2 + U_c^2)^{1/2} \leq 0.90$$

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.

## C.2 GENERIC VALIDATION FOR PLUTONIUM SYSTEMS

A report by L. L. Macklin and E. M. Miller, *MONK6A Pu Validation* (Macklin and Miller 1992), 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 plutonium 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 ($\sigma$) 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 [ $-\text{bias} + (U_b^2 + U_c^2)^{1/2}$ ]. On this basis, it is determined that the true $k_{eff}$ of an analyzed configuration with plutonium will not exceed 0.90 with a 95% confidence level if the calculated value ($k_{calc}$, $\sigma \leq 0.01$) is limited to a maximum value of **0.885**.

The 95% confidence level on 99.9% of the data is 0.9699. So a subcritical margin of 10% is ~ 7 times larger than the uncertainties between the 95.0% and 99.9% coverage of the benchmark data.

## C.3 VALIDATION OF MONK6B

The validation of the MONK6B code on the SUN microcomputers was documented in Miller, 1994. 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 United Kingdom 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.

# APPENDIX D:

# INPUT/OUTPUT DATA FROM MONK6B CALCULATIONS

| ITEM # | DESCRIPTION | PAGE NOS. |
|---|---|---|
| D.1 | MONK6B INPUT LISTING FOR CASE A20MB28:<br>3 x 3 Array of mixer Bowls with 270 g Pu each in 6 bowls, water in outer 3 bowls | D-2 through D-5 |
| D.2 | VERTICAL SCAN PICTURE FOR CASE A20MB28:<br>E-W cross-section through row of mixer bowls. | D-6 |
| D.3 | HORIZONTAL SCAN PICTURE FOR CASE A20MB28:<br>Horizontal cross-section through array of mixer bowls. | D-7 |
| D.4 | MONK6B INPUT LISTING FOR CASE A20MB59<br>3 Mixer bowls of 180 g Pu each next to 4 x 4 array of cement cans with 60 g Pu in each. | D-8 through D-11 |
| D.5 | HORIZONTAL SCAN PICTURE FOR CASE A20MB59:<br>Horizontal cross-section through cluster of 16 cement cans with 3 mixer bowls. | D-12 |

## ITEM D.1: MONK6B INPUT LISTING FOR CASE A20MB28

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```
* A20MB28:  GBOX HA-20MB WITH 9 MIXBOWLS, 6 BILLITS, 1620 TOTAL G PU
FISSION
*  6 BILLETS IN FRONT LEFT CORNER, 3 X 3 ARRAY OF BOWLS AT CENTER FRONT
*  1 INCH WATER SLABS AROUND BOWL CLUSTER FOR NOMINAL REFLECTION
*  270 PU IN 6 BOWLS WITH SLAG MIX 50/50 MGO + CAF2, 79 V/O WATER
*  WATER IN 3 BOWLS OF 3RD ROW AWAY FROM WALL
*   NO PU IN BILLETS, JUST WET CONCRETE MIX
*      MATERIALS OR ISOTOPES USED IN COMPOSITIONS
*      HINH2O        C         O          MG
*          AL27      SI        CA         CR        MN
*          FE        NI        MO         PU-239
*  MAT#  * * * * * *    MATERIAL    * * * * * * * * * * *   SYMBOL
*   1    WATER,  1.00 G/CC                                     +
*   2    304 STAINLESS STEEL, 8.03G/CC GBOX WALLS              S
*   3    316 STAINLESS STEEL,   7.969 G/CC                     3
*   4    PLEXIGLASS FOR  GBOX WINDOWS (LEXAN)                  L
*   5    BOWL MIX, 79 V/O H2O, GPLS = 57 PU, 347CAF2, 347 MGO  X
*   6    WET CONCRETE, 50 V/O WATER  2.2GPCC CEMENT            C
*  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
*   No. of Materials     No. of Nuclides
         6                   14                    NUCNAMES
*** Material #1 - -  Water
CONC   HINH2O   0.06688    0  0.03344
*** Material #2 - - 304 Stainless Steel
CONC  C  0.000161   SI  0.000861   CR  0.017671   MN  0.000880
     FE  0.060151   NI  0.008238
*** Material #3 - - 316 Stainless Steel
CONC   C  0.000200   SI  0.000855   CR  0.015690   MN  0.000874
      FE  0.057536   NI  0.009811   MO  0.001271
***  Material #4  LUCITE - - ACRYLATE PER DATA SHEET IN ARH600
CONC  HINH2O  0.05777   C  0.03611   0  0.01444
***  Matl #5: S&C  slurry 38g/l Pu, 347 g/l CaF2, 347 g/l MgO
CONC   HINH2O 0.05284   0  0.03160  F19  0.005731  CA  0.002674
      MG  0.005177   PU239  0.0001438
***  Matl #6:  WET CEMENT, 2.2 G/CC CEMENT, 50 V/O H2O
CONC   HINH2O .03344   0 0.04407   MG 0.001972   SI 0.005074
     AL27  0.0001890   CA 0.014883
*  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
*   DIMENSIONS ARE IN
CM
***    PART-1; 5-QUART MIXING BOWL, 270 G PU, 347 G EACH CAF2 + MGO
    CLUSTER 6
*  Reg#  Type  TranslationData          Matl#    Radius   Height
    1    ZROD  ORIGIN  0.0  0.0  10.26   5         10.16    7.87
*  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
   OVERLAP        3           2  3   4        4
*  Reg#  Type  TranslationData          Matl#    Radius   Height
    2    ZROD  ORIGIN  0.0  0.0  10.26   3        10.26   7.87
*  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
   OVERLAP        3            1  3  4          3
*  Reg#  Type  TranslationData          Matl#    Radius
```

*Item D.1, continued*

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     3    SPHERE  ORIGIN  0.0  0.0  10.16   5        10.16
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       4            1  2  4  5      2
  *  Reg#  Type  TranslationData           Matl#    Radius
     4    SPHERE  ORIGIN  0.0  0.0  10.26   3       10.26
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       4             1  2  3  5      1
  *  Reg#  Type  TranslationData           Matl#    Radius   Height
     5    ZROD  ORIGIN  0.0  0.0  18.13   0       10.26   2.47
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       2                3  4         3
  *  Reg#  Type       Matl#    Radius    Height
     6     ZROD       0        10.26     20.60
  *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  ***   PART-2; 5-QUART MIXING BOWL, 270 G PU, 347 G EACH CAF2 + MGO
      CLUSTER   6
  *  Reg#  Type  TranslationData           Matl#    Radius   Height
     1    ZROD  ORIGIN  0.0  0.0  10.26   5        10.16   7.87
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       3           2  3  4         4
  *  Reg#  Type  TranslationData           Matl#    Radius   Height
     2    ZROD  ORIGIN  0.0  0.0  10.26   3       10.26   7.87
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       3             1  3  4         3
  *  Reg#  Type  TranslationData           Matl#    Radius
     3    SPHERE  ORIGIN  0.0  0.0  10.16   5        10.16
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       4            1  2  4  5      2
  *  Reg#  Type  TranslationData           Matl#    Radius
     4    SPHERE  ORIGIN  0.0  0.0  10.26   3       10.26
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       4             1  2  3  5      1
  *  Reg#  Type  TranslationData           Matl#    Radius   Height
     5    ZROD  ORIGIN  0.0  0.0  18.13   0       10.26   2.47
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       2                3  4         3
  *  Reg#  Type       Matl#    Radius    Height
     6     ZROD       0        10.26     20.60
  *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  **** PART-3:  5-QUART MIXING BOWL FULL OF WATER
     CLUSTER  6
  *  Reg#  Type  TranslationData           Matl#    Radius   Height
     1    ZROD  ORIGIN  0.0  0.0  10.26    1        10.16   7.87
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       3           2  3  4         4
  *  Reg#  Type  TranslationData           Matl#    Radius   Height
     2    ZROD  ORIGIN  0.0  0.0  10.26   3       10.26   7.87
  *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
     OVERLAP       3             1  3  4         3
  *  Reg#  Type  TranslationData           Matl#    Radius
     3    SPHERE  ORIGIN  0.0  0.0  10.16   1        10.16
```

*Item D.1, continued*

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   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        4           1  2  4  5       2
   *  Reg#  Type  TranslationData           Matl#    Radius
       4    SPHERE  ORIGIN  0.0  0.0  10.26   3        10.26
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        4            1  2  3  5       1
   *  Reg#  Type  TranslationData           Matl#    Radius   Height
       5    ZROD  ORIGIN  0.0  0.0  18.13   0        10.26   2.47
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        2                3  4          3
   *  Reg#  Type       Matl#     Radius     Height
      6     ZROD       0          10.26     20.60
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *    PART-4:  BILLET CAN FULL OF CEMENT PLUS WATER - - NO PU
        NEST  2
         1   ZROD    ORIGIN  0.0   0.0 0.10    6   7.461    20.32
         2   ZROD    3    7.561  20.42
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *    PART-5:  BILLET CAN FULL OF CEMENT PLUS WATER - - NO PU
        NEST  2
         1   ZROD    ORIGIN  0.0   0.0 0.10    6   7.461    20.32
         2   ZROD    3    7.561  20.42
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *    PART-6:  BILLET CAN FULL OF CEMENT PLUS WATER - - NO PU
        NEST  2
         1   ZROD    ORIGIN  0.0   0.0 0.10    6   7.461    20.32
         2   ZROD    3    7.561  20.42
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *    PART-7:  BILLET CAN FULL OF CEMENT PLUS WATER - - NO PU
        NEST  2
         1   ZROD    ORIGIN  0.0   0.0 0.10    6   7.461    20.32
         2   ZROD    3    7.561  20.42
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *    PART-8:  BILLET CAN FULL OF CEMENT PLUS WATER - - NO PU
        NEST  2
         1   ZROD    ORIGIN  0.0   0.0 0.10    6   7.461    20.32
         2   ZROD    3    7.561  20.42
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *    PART-9:  BILLET CAN FULL OF CEMENT PLUS WATER - - NO PU
        NEST  2
         1   ZROD    ORIGIN  0.0   0.0 0.10    6   7.461    20.32
         2   ZROD    3    7.561  20.42
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   ****  PART 10:  EQUIPMENT ARRANGEMENT IN GBOX ****************
      CLUSTER  20
      1  ZROD  ORIGIN  10.27   10.27   0.01   P4   7.561   20.42
      2  ZROD  ORIGIN  30.81   10.27   0.01   P5   7.561   20.42
      3  ZROD  ORIGIN  51.35   10.27   0.01   P6   7.561   20.42
      4  ZROD  ORIGIN  10.27   30.81   0.01   P7   7.561   20.42
      5  ZROD  ORIGIN  30.81   30.81   0.01   P8   7.561   20.42
      6  ZROD  ORIGIN  10.27   51.35   0.01   P9   7.561   20.42
      7  ZROD ORIGIN  225.90   10.27   0.01   P1   10.26    20.60
```

*Item D.1, continued*

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    8  ZROD ORIGIN  246.50  10.27  0.01  P1  10.26   20.60
    9  ZROD ORIGIN  267.20  10.27  0.01  P1  10.26   20.60
   10  ZROD ORIGIN  225.90  30.80  0.01  P2  10.26   20.60
   11  ZROD ORIGIN  246.50  30.80  0.01  P2  10.26   20.60
   12  ZROD ORIGIN  267.20  30.80  0.01  P2  10.26   20.60
   13  ZROD ORIGIN  225.90  51.33  0.01  P3  10.26   20.60
   14  ZROD ORIGIN  246.50  51.33  0.01  P3  10.26   20.60
   15  ZROD ORIGIN  267.20  51.33  0.01  P3  10.26   20.60
   16  BOX  ORIGIN  213.0  0.1  0.1   1   2.54  61.6  20.5
   17  BOX  ORIGIN  277.6  0.1  0.1   1   2.54  61.6  20.5
   18  BOX  ORIGIN  215.7  62.0  0.1   1   61.0  2.54   20.5
   19  BOX  ORIGIN  215.7  0.1  20.8    1  61.0  61.0  2.54
   20   BOX  0  472.44   132.08   91.44
 * ----------------------------------------------------------------------
 *  PART-11:  GLOVEBOX
   NEST 4
    1  BOX  ORIGIN  5.0  20.0  5.0  P10  472.44  132.08   91.44
    2  BOX  ORIGIN  5.0  20.0  0.0   2  472.44  132.08   96.44
    3  BOX  ORIGIN  0.0  15.0  0.0    4   482.44  142.08  101.44
    4  BOX    1   482.44   157.08   101.44
 *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 SUPERHIST   6.0   1.6
 -12   100    100   58  -1
   FISSILE   REGION 1 OF PART 11   \
 END
```

## Item D.2: VERTICAL SCAN PICTURE FOR CASE A20MB28:

```
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PICTURE FRAME (CORNER POINTS IN CMS.)

X= 251.48, Y= 157.08, Z= 40.00 (TOP LEFT)
X= 251.48, Y= 0.00, Z= 40.00 (TOP RIGHT)
X= 251.48, Y= 157.08, Z= 0.00 (BOTTOM LEFT)

SCALE

HORIZONTAL: 1 CHARACTER = 1.208 CM
VERTICAL : 1 LINE = 2.000 CM

LEGEND

| MATL # | MATERIAL | SYMBOL |
|---|---|---|
| 1 | WATER | + |
| 2 | 304 STAINLESSS STEEL (BOX FLOOR) | S |
| 3 | 316 STAINLESS STEEL (BOWLS, CANS) | 3 |
| 4 | PLEXIGLASSS - -BOX WALLS | B |
| 5 | BOWL MIX, 79 V/O H2O, 57 G PU/L, 347 G CAF2/L, 347 G MGO/L | X |
| 6 | 2.2 G/CC CEMENT + 50% $H_2O$, NO PU | C |

## Item D.3: HORIZONTAL SCAN PICTURE FOR CASE A20MB28:

```
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BB  CCCCCC                                                                                    ++++++++++ ++++++++ ++++++++++
BB CCCCCCC                                                                                    ++++++++++ ++++++++ ++++++++++
BB  CCCCC                                                                                     ++++++++++ ++++++++ ++++++++++
BB                                                                                            ++ ++++++   ++++++   ++++++ ++
BB                                                                                            ++  XXXX     XXXX     XXXX  ++
BB  CCCCC    CCCCC                                                                            ++XXXXXXXX XXXXXXXX XXXXXXXX++
BB CCCCCCC  CCCCCCC                                                                           ++XXXXXXXX XXXXXXXX XXXXXXXX++
BB  CCCCCC  3CCCCC3                                                                           ++XXXXXXXX XXXXXXXX XXXXXXXX++
BB   CCC      CCC                                                                             ++ XXXXXX   XXXXXX   XXXXXX ++
BB                                                                                            ++   XX       XX       XX   ++
BB   CCC3     CCC     3CCC                                                                    ++3XXXXXXX XXXXXXX3 XXXXXXX3++
BB 3CCCCCC  CCCCCCC  CCCCCC3                                                                  ++XXXXXXXX XXXXXXXX XXXXXXXX++
BB CCCCCCC  CCCCCCC  CCCCCCC                                                                  ++XXXXXXXX XXXXXXXX XXXXXXXX++
BB  CCCCC    CCCCC    CCCCC                                                                   ++XXXXXXXX XXXXXXXX XXXXXXXX++
BB                                                                                            ++  XXXX     XXXX     XXXX  ++
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PICTURE FRAME (CORNER POINTS IN CMS.)

X=   0.00, Y= 157.08, Z=  20.00 (TOP LEFT)
X= 300.00, Y= 157.08, Z=  20.00 (TOP RIGHT)
X=   0.00, Y=   0.00, Z=  20.00 (BOTTOM LEFT

SCALE

HORIZONTAL: 1 CHARACTER = 2.308 CM
VERTICAL : 1 LINE = 3.831 CM

LEGEND

| MATL # | MATERIAL | SYMBOL |
|---|---|---|
| 1 | WATER | + |
| 3 | 316 STAINLESS STEEL (BOWLS, CANS) | 3 |
| 4 | PLEXIGLASSS - -BOX WALLS | B |
| 5 | BOWL MIX, 79 V/O H2O, 57 G PU/L,<br>347 G CAF2/L, 347 G MGO/L | X |
| 6 | 2.2 G/CC CEMENT + 50% $H_2O$, NO PU | C |

## ITEM D.4: MONK6B INPUT LISTING FOR CASE A20MB59

```
*  A20MB59: HA-20MB GBOX W 3 180G PU BOWLS NEXT 2 4X4 CANS 60 G EA
FISSION
*  CEMENT CANS CORRECT SIZE - - 5.5 IN DIAM X 7-IN TALL
*  WET CONCRETE BILLETS WITH 60 G PU EACH PLUS 795 G FLUORINE
*  CORRECT OXYGEN AND ALUMINUM CONTENTS IN CEMENT
*  CEMENT WATER CONTENT AT 500 GPL, FOR 2.5 WT% HYDROGEN
*  4 x 4 ARRAY OF SUCH BILLETS IN FRONT LEFT CORNER OF BOX
*  1-INCH H2O SLABS EAST, SOUTH AND ABOVE ARRAY, FOR NOMINAL REFLECTION
*  TOTAL 1.50 KG PU IN GLOVEBOX, W CAN STORAGE AREA NEAR DOUBLEBATCHED
*      MATERIALS OR ISOTOPES USED IN COMPOSITIONS
*      HINH2O      C          O        F             MG
*          AL27       SI          CA        CR          MN
*          FE         NI          MO        PU-239
*  MAT#  * * * * * *     MATERIAL    * * * * * * * * * * *   SYMBOL
*   1   WATER,  1.00 G/CC                                       +
*   2   304 STAINLESS STEEL, 8.03G/CC GBOX WALLS                S
*   3   316 STAINLESS STEEL,   7.969 G/CC                       3
*   4   PLEXIGLASS FOR  GBOX WINDOWS (LEXAN)                    L
*   5   BOWL MIX, 79 V/O H2O, GPLS= 38 PU, 347 CAF2, 347 MGO    X
*   6  22 GPL PU WET CONCRETE, 50 V/O WATER  2.2GPCC CEMENT     C
*  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
*   No. of Materials     No. of Nuclides
        6                     14                   NUCNAMES
*** Material #1 - -  Water
CONC   HINH2O   0.06688    0  0.03344
*** Material #2 - - 304 Stainless Steel
CONC  C  0.000161   SI  0.000861   CR  0.017671   MN  0.000880
     FE  0.060151   NI  0.008238
*** Material #3 - - 316 Stainless Steel
CONC   C  0.000200   SI  0.000855   CR  0.015690   MN  0.000874
      FE  0.057536   NI  0.009811   MO  0.001271
***  Material #4  LUCITE - - ACRYLATE PER DATA SHEET IN ARH600
CONC  HINH2O  0.05777   C  0.03611   O  0.01444
***  Matl #5: S&C Slurry, 38 g/l Pu, 347 g/l CaF2, 347 g/l MgO
CONC   HINH2O 0.05284   O  0.03160  F19  0.005731  CA  0.002674
     MG  0.005177   PU239  0.0000959
*** Matl #6:  WET CEMENT, 2.2 G/CC CEMENT, 50 V/O H2O 22.05 GPL PU
**   INCLUDES 795 G BATCH FLUORINE IN 2.725 LITER CAN
CONC   HINH2O .03344   O 0.04684   MG 0.001972   SI 0.005074
     AL27  0.002080   CA 0.014883   PU239 0.00005547  F19  0.009247
*  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
*   DIMENSIONS ARE IN
CM
****  PART-1:  5-QUART MIXING BOWL FILLED W SLAG + CRUCIBLE SLURRY
    CLUSTER 6
*  Reg#  Type  TranslationData          Matl#    Radius   Height
    1    ZROD  ORIGIN  0.0  0.0  10.26   5        10.16    7.87
*  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
   OVERLAP        3            2  3   4       4
*  Reg#  Type  TranslationData          Matl#    Radius   Height
    2    ZROD  ORIGIN  0.0  0.0  10.26   3       10.26   7.87
```

*Item D.4, continued*

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   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        3            1  3  4          3
   *  Reg#  Type  TranslationData           Matl#    Radius
       3    SPHERE  ORIGIN  0.0  0.0  10.16   5        10.16
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        4          1  2  4  5       2
   *  Reg#  Type  TranslationData           Matl#    Radius
       4    SPHERE  ORIGIN  0.0  0.0  10.26   3       10.26
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        4            1  2  3  5       1
   *  Reg#  Type  TranslationData           Matl#    Radius   Height
       5    ZROD  ORIGIN  0.0  0.0  18.13   0        10.26   2.47
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        2                3  4         3
   *  Reg#  Type      Matl#    Radius    Height
      6     ZROD        0      10.26    20.60
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   ****  PART-2:  5-QUART MIXING BOWL FILLED W SLAG + CRUCIBLE SLURRY
       CLUSTER   6
   *  Reg#  Type  TranslationData           Matl#    Radius   Height
       1    ZROD  ORIGIN  0.0  0.0  10.26   5        10.16   7.87
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        3          2  3  4          4
   *  Reg#  Type  TranslationData           Matl#    Radius   Height
       2    ZROD  ORIGIN  0.0  0.0  10.26   3        10.26   7.87
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        3            1  3  4          3
   *  Reg#  Type  TranslationData           Matl#    Radius
       3    SPHERE  ORIGIN  0.0  0.0  10.16   5        10.16
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        4          1  2  4  5       2
   *  Reg#  Type  TranslationData           Matl#    Radius
       4    SPHERE  ORIGIN  0.0  0.0  10.26   3       10.26
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        4            1  2  3  5       1
   *  Reg#  Type  TranslationData           Matl#    Radius   Height
       5    ZROD  ORIGIN  0.0  0.0  18.13   0        10.26   2.47
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        2                3  4         3
   *  Reg#  Type      Matl#    Radius    Height
      6     ZROD        0      10.26    20.60
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   ****  PART-3:  5-QUART MIXING BOWL FILLED W SLAG + CRUCIBLE SLURRY
   * * * INCLUDES 1 INCH WATER ON TOP AS NOMINAL REFLECTOR
      CLUSTER  6
   *  Reg#  Type  TranslationData           Matl#    Radius   Height
       1    ZROD  ORIGIN  0.0  0.0  10.26    5        10.16   7.87
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        3          2  3  4          4
   *  Reg#  Type  TranslationData           Matl#    Radius   Height
       2    ZROD  ORIGIN  0.0  0.0  10.26   3        10.26   7.87
```

*Item D.4, continued*

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   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        3            1  3  4         3
   *  Reg#  Type  TranslationData          Matl#    Radius
      3     SPHERE  ORIGIN  0.0  0.0  10.16   5        10.16
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        4           1  2  4  5      2
   *  Reg#  Type  TranslationData          Matl#    Radius
       4    SPHERE  ORIGIN  0.0  0.0  10.26   3        10.26
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        4            1  2  3  5      1
   *  Reg#  Type  TranslationData          Matl#    Radius   Height
       5    ZROD  ORIGIN  0.0  0.0  18.13   0       10.26   2.47
   *  Keyword   NoBodsOvrlpd  Their Reg #s   Dominance
      OVERLAP        2               3  4         3
   *  Reg#  Type       Matl#    Radius    Height
      6     ZROD        0       10.26    20.60
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *   PART 4:   WET CAST BILLET, 60 G PU IN 2.725 LITER CAN
       NEST  2
        1   ZROD   ORIGIN  0.0  0.0 0.10    6   6.985   17.78
        2   ZROD   3   7.085  17.88
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *   PART 5:   WET CAST BILLET, 60 G PU IN 2.725 LITER CAN
       NEST  2
        1   ZROD   ORIGIN  0.0  0.0 0.10    6   6.985   17.78
        2   ZROD   3   7.085  17.88
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *   PART 6:   WET CAST BILLET, 60 G PU IN 2.725 LITER CAN
       NEST  2
        1   ZROD   ORIGIN  0.0  0.0 0.10    6   6.985   17.78
        2   ZROD   3   7.085  17.88
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *   PART 7:   WET CAST BILLET, 60 G PU IN 2.725 LITER CAN
       NEST  2
        1   ZROD   ORIGIN  0.0  0.0 0.10    6   6.985   17.78
        2   ZROD   3   7.085  17.88
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *   PART 8:   WET CAST BILLET, 60 G PU IN 2.725 LITER CAN
       NEST  2
        1   ZROD   ORIGIN  0.0  0.0 0.10    6   6.985   17.78
        2   ZROD   3   7.085  17.88
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   *   PART 9:   WET CAST BILLET, 60 G PU IN 2.725 LITER CAN
       NEST  2
        1   ZROD   ORIGIN  0.0  0.0 0.10    6   6.985   17.78
        2   ZROD   3   7.085  17.88
   *  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   ****  PART 10:  EQUIPMENT ARRANGEMENT IN GBOX ****************
      CLUSTER  23
      1  ZROD  ORIGIN   7.10   7.10  0.01  P4  7.085  17.88
      2  ZROD  ORIGIN  21.30   7.10  0.01  P5  7.085  17.88
```

*Item D.4, continued*

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    3  ZROD   ORIGIN  35.50    7.10   0.01   P6   7.085   17.88
    4  ZROD   ORIGIN  49.70    7.10   0.01   P6   7.085   17.88
    5  ZROD   ORIGIN   7.10   21.30   0.01   P7   7.085   17.88
    6  ZROD   ORIGIN  21.30   21.30   0.01   P8   7.085   17.88
    7  ZROD   ORIGIN  35.50   21.30   0.01   P9   7.085   17.88
    8  ZROD   ORIGIN  49.70   21.30   0.01   P9   7.085   17.88
    9  ZROD   ORIGIN   7.10   35.50   0.01   P7   7.085   17.88
   10  ZROD   ORIGIN  21.30   35.50   0.01   P8   7.085   17.88
   11  ZROD   ORIGIN  35.50   35.50   0.01   P9   7.085   17.88
   12  ZROD   ORIGIN  49.70   35.50   0.01   P9   7.085   17.88
   13  ZROD   ORIGIN   7.10   49.70   0.01   P7   7.085   17.88
   14  ZROD   ORIGIN  21.30   49.70   0.01   P8   7.085   17.88
   15  ZROD   ORIGIN  35.50   49.70   0.01   P9   7.085   17.88
   16  ZROD   ORIGIN  49.70   49.70   0.01   P9   7.085   17.88
   17  ZROD ORIGIN  67.10   10.30   0.01   P1   10.26    20.60
   18  ZROD ORIGIN  67.10   30.90   0.01   P2   10.26    20.60
   19  ZROD ORIGIN  67.10   51.50   0.01   P3   10.26    20.60
   20  BOX  ORIGIN  0.10   62.0   0.10   1   77.30   2.54   21.00
   21  BOX  ORIGIN  77.50   0.1   0.1    1   2.54   61.5    21.00
   22  BOX  ORIGIN   0.1   0.1   21.20  1   77.20   61.50   2.54
   23   BOX  0  472.44    132.08    91.44
*  ------------------------------------------------------------------
*  PART-11:  GLOVEBOX
   NEST 4
    1  BOX  ORIGIN  5.0   20.0   5.0   P10   472.44   132.08    91.44
    2  BOX  ORIGIN  5.0   20.0   0.0    2  472.44   132.08    96.44
    3  BOX  ORIGIN  0.0   15.0   0.0     4    482.44   142.08   101.44
    4  BOX     1    482.44    157.08    101.44
*  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
SUPERHIST   6.0   1.6
-12   100    100   58  -1
  FISSILE   REGION 1 OF PART 11   \
END
CODE 6
+S3BXC
 241.22   157.08   40.00   241.22   0.00   40.00  241.22 157.08 0.0
  0.0   157.08  20.00    275.0   157.08   20.00    0.00  0.00  20.00
  275.0  30.16   40.0    275.0  30.16   0.0    0.0  30.16  40.0
END
```

## Item D.5: HORIZONTAL SCAN PICTURE FOR CASE A20MB59:

```
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BB3CCCCCCCCCCCCCCCCCCC CCCCCC XXXXXXXXX+
BB CCCCC  CCCCC  CCCC   CCCC   XXXXXXX +
BB  CCCC- CCCC   CCCC   CCCC      3    +
BB CCCCCCCCCCCCCCCCCCC CCCCCC XXXXXXXX +
BBCCCCCCCCCCCCCCCCCCCC CCCCCC3XXXXXXXXX+
BB CCCCC  CCCCC  CCCCC CCCCC XXXXXXXXXX+
BB  CCCC   CCC   CCCC   CCCC  XXXXXXXXX+
BB CCCCCCCCCCCCCCCCCCC CCCCCC  XXXXXX3 +
BBCCCCCCCCCCCCCCCCCCCC CCCCCC    XX    +
BB CCCCC  CCCCC  CCCCC CCCCC  XXXXXXXX +
BB  CCC    CCC   3CCC   CCC3 XXXXXXXXXX+
BB CCCCCCCCCCCCCCCCCCC CCCCCCXXXXXXXXXX+
BBCCCCCCCCCCCCCCCCCCCC CCCCCC XXXXXXXX3+
BB CCCCC  CCCCC  CCCCC CCCCC   XXXXXX  +
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PICTURE FRAME (CORNER POINTS IN CMS.)
X=   0.00  Y= 157.08,  Z=  20.00 (TOP LEFT)
X= 275.00, Y= 157.08,  Z=  20.00 (TOP RIGHT)
X=   0.00, Y=   0.00,  Z=  20.00 (BOTTOM LEFT)
                SCALE
HORIZONTAL:  1 CHARACTER =  2.115 CM
VERTICAL  :  1 LINE      =  3.491 CM
```

LEGEND

| MATL # | MATERIAL | SYMBOL |
|---|---|---|
| 1 | WATER | + |
| 3 | 316 STAINLESS STEEL (BOWLS, CANS) | 3 |
| 4 | PLEXIGLASSS - -BOX WALLS | B |
| 5 | S&C SLURRY, 58 G PU/L | X |
| 6 | WET CEMENT + S&C: 51 G PU/L,<br>50 V/O WATER, 2.2 G/CC CEMENT | C |

# DISTRIBUTION SHEET

| | | |
|---|---|---|
| To<br>Distribution | From<br>Nuclear Physics and Shielding, | Page 1 of 1<br>Date 09/04/96 |
| Project Title/Work Order<br>"CSER 96-013: Cementation Process, Glovebox HA-20MB at PFP" | | EDT No. N/A<br>ECN No. **636867** |

| Name | MSIN | Text With All Attach. | Text Only | Attach./ Appendix Only | EDT/ECN Only |
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