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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
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Executive Summary

Glovebox HA-20MB is located in Room 235B of the 234-5Z Building at the Plutonium Finishing Plant. This enclosure contains mixers, mixer bowls, a crusher unit, an isolated inoperable conveyor unit, plutonium residue feed cans, cemented cans, and a feedwater container. Plutonium residue, not conducive to other forms of stabilization, is prepared for storage and ultimate disposal by cementation. The feed residue material cans can have plutonium contents of only a few grams or up to 200 grams. This evaluation accommodates this wide range of container fissile concentrations.

Two glovebox limit sets are supported by this document. One limit set is for residue in any form except solutions and allows up to 1200 g plutonium or fissile equivalent in the glovebox. Up to 500 g plutonium can be in feed or cement cans, 200 g plutonium in each of two mixing bowls, and 300 g plutonium as glovebox holdup. The second limit set is specifically for sand, slag, and crucible (SS&C), ash, or oxide feed material and allows up to 2100 g plutonium or fissile equivalent. Up to 500 g plutonium can be in cemented billets, 900 g plutonium in cans as feed, 200 g plutonium in each of two mixing bowls, and 300 g plutonium as glovebox holdup.

Evaluation of this glovebox operation included normal, base cases, and contingencies. The base cases took the normal operations for each type of feed material and added the likely off-normal events. Each contingency is evaluated assuming the unlikely event happens to the conservative base case. A hazards assessment was conducted to assure that each credible unlikely event or set of correlated unlikely events was included in this analysis. The results of this evaluation show that the intended operation in Glovebox HA-20MB meets the double contingency requirement. That is, at least two unlikely, independent, and concurrent changes in process conditions are required before a criticality is possible. Therefore, this CSER meets the requirements for a criticality evaluation contained in the Hanford Site Nuclear Criticality Safety Manuals, HNF-PRO-334 (FDH 2000), HNF-PRO-537 (FDH 1997a), and HNF-PRO-539 (FDH 1997b), ANSI standards (ANSI 1998), and DOE Order 5480.24 (DOE 1992). This CSER also follows Fluor Federal Services, Inc. Practice 134.290.1121 (FFS 1999).

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List of Terms

AIChE	American Institute of Chemical Engineers
ANSI	American National Standards Institute
ANS	American Nuclear Society
CSER	Criticality Safety Evaluation Report
DOE	United States Department of Energy
GB	glovebox
ID	Identification Number
MCM	Minimum Critical Mass
NC	No Controls
NDA	Nondestructive Analysis
PFP	Plutonium Finishing Plant
PHA	Preliminary Hazards Analysis
SS&C	Sand, Slag, and Crucible

List of Definitions

Container - Any vessel that is in a position to hold solids or liquids (e.g., a pan turned upside down is not a container).

Contingency - A possible but unlikely change in a condition/control important to the nuclear criticality safety of a fissionable material operation that would, if it occurred, reduce the number of barriers (either administrative or physical) that are intended to prevent an accidental nuclear criticality.

1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

The plutonium stabilization program at the Plutonium Finishing Plant (PFP) involves treatment of the residual inventory of plutonium at the plant by various means, dependent on the material 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 plutonium-bearing materials stored in cans in various vaults and gloveboxes. Some of the scrap is in the form of sand, slag and crucible (SS&C), ash, or oxide. These materials, along with other fissile residues that could be stabilized by the cementation process, are addressed by this criticality safety evaluation report (CSER).

It has been decided that the most expeditious means for storage and disposal of stabilized SS&C scrap will be cementation by mixing granulized SS&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 is to be 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 L (5 qt) mixing bowls and 2.73 L cementing cans. Ash, oxide, and other less characterized fissile scrap may also undergo this process.

Criticality safety control is achieved with plutonium inventory limitations of 2100 g plutonium or fissile equivalent total in the glovebox for the limit set when the feed material is characterized as SS&C, ash, or oxide. When the feed is not one of these materials, only 1200 g plutonium or fissile equivalent is allowed. No more than 200 g of this fissile material is allowed in any one container and no more than 300 g of this fissile material can be holdup and it must be evenly distributed throughout the glovebox.

Holdup is analyzed separately from the process material in this CSER, contrary to the standard practice of combining it with the other fissile material in the most reactive arrangement. Normally, the holdup is a small percentage of the fissile mass allowed in the glovebox and can be conservatively combined with the process mass, not significantly impacting glovebox operation. However, for cementation operations, the holdup is a significant portion of the allowable fissile mass so it must be analyzed separately as a distributed mass. A spill is considered part of the process mass and must be cleaned up prior to continuing operation, so that the holdup does not become concentrated.

When cured, the 14-cm (5.5-in.) diameter by 17.78 cm (7 in.) 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 200 g 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 specified, assurance of subcriticality under normal and plausible upset conditions is provided which satisfies the double contingency criterion set forth in the Hanford Site Nuclear Criticality Safety Manuals. That is, at least two unlikely, independent, and concurrent changes in process conditions are required before a criticality is 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 of 179 g of plutonium for the present quatity of 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.

1.2 DOUBLE CONTINGENCY DOCUMENTATION

This section presents a summary description of expected operations, expected normal conditions, base case of normal condition plus anticipated off-normal conditions for cementation operations and results of the contingency analyses.

Expected Operation:

Sand, slag, and crucible (SS&C) scrap is processed through a crusher to prepare a particle size to expedite reaction of residual calcium. A sieve may be used to sort out pieces that require further grinding. The resultant material is reacted in 4.73 L mixing bowls containing approximately 1.5 L of chilled water. After reacting the calcium, cement powder and water are added to create a cement mud that is poured into 14 cm (5.5 in.) diameter, 17.8 cm (7 in.) tall cans. After curing, the cans are transferred out of the glovebox to 55 gallon drums for storage. Incinerator ash, oxides, and other residues could also be stabilized by this cementation process and may not use the crusher. There will be no liquid feed material.

The criticality safety of this operation depends upon the characterization of the neutron moderation possible for these materials. It is assumed that the mixing bowls can contain fully moderated plutonium and the cement mud could be up to 90% water. Two limit sets are developed to accommodate either fully moderated feed material or SS&C, ash, or oxide (feed material that fits the description of Appendices F and G). One limit set allows unrestricted moderation feed. The second limit set allows more fissile mass in the glovebox but requires the operator to examine each container as it is brought into the glovebox if the material is ash or oxide to verify contents and assure no free liquid in the container. SS&C does not require operator verification because it is not credible to have H/X>20, free liquid, or to confuse container with other material types.

1.2.1 LIMIT SET A: 1200 G LIMIT WHEN FEED MATERIAL TYPE OR MODERATION DOES NOT SATISFY REQUIREMENTS OF LIMIT SET B

Expected Normal Conditions:

For limit set A, Glovebox HA-20MB may contain general scrap materials with plutonium and/or uranium in metal, alloy, or oxide form with unrestricted moderation. The glovebox total fissile mass, including holdup, is limited to 1200 g plutonium or fissile equivalent with the uranium ^{235}U enrichment less than or equal to 50%. This mass is limited to 200 g Pu in each mixing bowl, 500 g Pu, total, in the other containers, and 300 g Pu evenly distributed around the glovebox as holdup. If the holdup is predominately in one location, such as a spill, then the holdup must be considered part of the mass limit for the containers it spilled from. Therefore, spills should be promptly cleaned up. Each container can contain up to 200 g Pu or fissile equivalent and is limited to a height of 17.8 cm (7 in.) when resting on the glovebox floor. Normally, material enters the glovebox in containers with about 60 g Pu and leaves the glovebox in cement billets with up to 180 g Pu. Container volumes are limited to 4.73 L for mixing bowls and 2.76 L for other containers, except for the sieve assembly that can be 4.9 L and the auger/conveyor unit that can be 2.83 L. Minimum spacing of 25.4 cm (10 in.) is required between mixing bowls and between mixing bowls and other containers except when transferring material into or out of a mixing bowl. Minimum spacing of 25.4 cm is also maintained to fissile items in Conveyor Glovebox HA-28. No spacing is required among the other containers inside Glovebox HA-20MB. Transition and storage spacing of 45.7 cm (18 in.) and 91.4 cm (36 in.), respectively, for fissile material outside of Glovebox HA-20MB apply with one exception. Waste drums containing up to 200 g of plutonium or fissile equivalent are allowed to pass by the north end of Glovebox HA-20MB with 15.2 cm (6 in.) spacing to fissile containers inside the glovebox. A five-gallon feedwater container is allowed, but it is prohibited to add fissile material to this container. Any opening to the feedwater container must be configured such that there is no credible accidental means of introducing fissile-bearing material.

Base Case Model for Limit Set A:

The base case encompasses the normal and worst-case likely off-normal events. Two mixing bowls each contain 200 g Pu homogeneously mixed with water. The other 500 g of Pu is modeled conservatively as 18 cm (7.1 in.) tall, 2.76 L containers. The most reactive arrangement of these containers is to place the 500 g in seven containers completely surrounded by containers of cement or water and the two mixing bowls placed adjacent to each other in the corner of the glovebox and spaced 25.4 cm (10 in.) from the other containers. For the mixing bowls, the corner of the glovebox surrounded by 30.5 cm of water provides the maximum neutron reflection for containers that must be spaced 25.4 cm (10 in.) from other fissile-bearing containers. On the other hand, cement cans or cans of water, close packed, provide the greatest reflection for other fissile material that can be grouped without spacing. The mixing bowls are placed together to allow containers to be brought together for material transfer, for mixing, crushing, and conveying into the mixing bowl, or to simulate the likely loss of spacing between two containers. This arrangement is more reactive than if the containers were at the other end of the glovebox with a 4.7 L container with 400 g of fully moderated Pu on Conveyor HA-28 spaced 25.4 cm (10 in.)

from these containers. A 2.76 L volume containing 200 g of Pu representing a waste drum passing just 15.2 cm (6 in.) past the north end of the glovebox in the normal case is less reactive than the 30.5 cm (12 in.) water reflection that surrounds the entire glovebox. Water reflection of 2.54 cm (1 in.) is placed around non-adjacent containers to represent hands, rags, and plastic waste packages and structural components that may be present in the glovebox. A 2.54 cm (1 in.) of water reflection is placed on top of all containers. The 300 g Pu as holdup is distributed uniformly on the floor of the glovebox including under the fissile containers with 30.5 cm water reflection under that. The k_{eff} for this base case is 0.8647±0.0009 (case c0001f1b7b).

Table 1-1. Glovebox HA-20MB – Limit Set A Base Case Limits Summary

Controlled Parameter	Limit	Abnormal but anticipated conditions (conservatism for analysis)
Mass	Maximum 1200 g Pu & fissile equiv. Glovebox total including holdup; 200 g Pu per mixing bowl; 500 g total in other containers with no more than 200 g in any one container; 300 g Pu holdup	All fissile modeled as ^{239}Pu
Volume	Two mixing bowls with maximum 4.73 L per bowl; 4.9 L sieve pan assembly; 50 ml of lubricants; crusher/hopper 1.1 L; auger/hopper 2.83 L; other containers with maximum height of 17.8 cm and maximum volume of 2.76 L except one five-gallon feedwater container into which it is not permitted to introduce fissile material and no credible accidental means of adding fissile material exists	Mixing bowls were modeled as 4.8 L; other containers as 2.76 L
Moderation	NA	
Interaction	No stacking of containers; 25.4 cm (10 in.) minimum spacing between mixing bowls and between mixing bowls and other containers except during material transfer; 25.4 cm minimum spacing to fissile material in Conveyor Glovebox HA-28; 15.2 cm minimum spacing between waste drums on	Two full mixing bowls are placed next to each other and next to full neutron reflection glovebox walls to conservatively simulate transfer of fissile material from container to container.

Controlled Parameter	Limit	Abnormal but anticipated conditions (conservatism for analysis)
	the north side of the glovebox and fissile material containers inside glovebox	
Reflection	Dry fire suppression system within glovebox	Full water reflection around glovebox , 2.54 cm (1 in.) water reflection around fissile containers if not closely packed
Geometry	Pu in designated containers with a maximum 17.8 cm (7 in.) height except holdup uniformly distributed on floor	Containers modeled 18 cm tall
Isotopics	NA	100% ^{239}Pu
Enrichment	Maximum 50% ^{235}U in U	^{235}U treated as ^{239}Pu fissile equivalent
Density	NA	
Concentration	NA	Plutonium in the most reactive arrangement among the containers
Poisons	NA	

The mass of fissile material in each feed container is determined before it is brought into Glovebox HA-20MB. Therefore, it is unlikely that the mass limits in the table above will be exceeded and subsequently no anticipated abnormal mass conditions are included in the base case.

Contingency Summary for Limit Set A:

Table 1-2 summarizes the analyses of the unlikely, independent, off-normal events (contingencies). Each event is assumed to occur with the glovebox configured as the described base case with the contingency added. The resultant computed reactivity is compared to the subcriticality target k_{eff} of 0.932 for MCNP calculations of metal plutonium systems, as explained in Section 4.0. This table summarizes the results of the contingency evaluation found in Section 5.0. Specific k_{eff} calculations were not made for contingencies in Table 1.2 that were bounded by other analyzed contingencies.

Table 1-2. Glovebox HA-20MB – Limit Set A Contingency Summary

Contingency Description	Affected Parameter (s)	Barriers that make contingency unlikely	k_{eff} bounding contingency (case ID)
Seismic event with container spill and flooding that washes fissile material from containers and holdup to accumulate in conveyor housing	Volume Geometry	Seismic event unlikely; requires severe damage to glovebox, breaking windows and seal to cover of conveyor housing under glovebox, breaking of fire suppression system piping, all containers spilling and washing into conveyor housing.	0.4344 ± 0.0007 (c0001f1q5)
Seismic event with containers grouping together with no spacing surrounded by cans of cement or water	Interaction	Seismic event unlikely; requires severe damage to glovebox, breaking windows with all containers collecting together in the most reactive arrangement, and breaking of fire suppression system piping; it is unlikely that interspersed water from fire suppression system would have as high of a density as 0.1 g/cc	0.9226 ± 0.0009 (c0001f1q1a)
Fire with interspersed water and fissile material washing out of containers	Geometry Reflection	Major building fire that melts glovebox panels is unlikely; it is unlikely that the fire sprinkler water would add as high of an interspersed water density as 0.1 g/cc and cause all the fissile material to be washed from containers	0.8329 ± 0.0008 (c0001f1f2)
Fire with interspersed water and material stays in containers	Reflection	Major fire that melts glovebox glass is unlikely; it is unlikely that the fire sprinkler water would add as high of an interspersed water density as 0.1 g/cc	0.8567 ±0.0009 (c0001f1f1)
Mixing bowl stacked on 2.76 L containers	Interaction	Operator training, procedure, no stacking anywhere at PFP	0.9296 ±0.0008 (c0001f1s3)
Extra container with 200 g Pu in glovebox, stacked on 2.76 L containers	Mass Interaction	Operator training, procedure, fissile inventory control, posted limits	0.9078 ± 0.0009 (c0001f1s5)
Wagon with max. Pu loading under glovebox	Interaction	Operator training, procedure	0.8451 ±0.0010 (c0001f1w1)

Contingency Description	Affected Parameter (s)	Barriers that make contingency unlikely	k_{eff} bounding contingency (case ID)
Mixing bowls stacked	Interaction	Operator training, procedure	0.8674 ±0.0008 (c0001f1s6)
Loss of 15.24-cm (6-in.) spacing between drum passing on north end and contents of glovebox	Interaction	Operator training, procedure	0.8687 ± 0.0008 (c0001f1b7g)
Loss of spacing to item on Conveyor Glovebox HA-28 (400 g, 4.7 L, H/X>20)	Interaction	Operator training, procedure, unlikely to have container greater than 2.7 L	0.9097 ±0.0009 (c0001f1b17)
Extra mixing bowl with some fissile mass out of other containers	Volume	Operator training/procedure; more likely to use smaller container to clean up a mess	Less reactive than extra container stacked
Excess holdup exceeding glovebox mass limit	Mass	Operator training/procedure/inventory control	Less reactive than extra container stacked
Container too large	Volume	Operator training/procedure	Less reactive than bowls stacked
Extra oil or plastic	Moderation	Operator training/procedure	Less reactive than fire analysis for reasonable quantities of plastic present

The hazards assessment determined that it is not credible to have uranium with ^{235}U enrichment exceeding 50% in this glovebox. Therefore, no contingency was evaluated for enrichment.

1.2.2 LIMIT SET B: 2100 G LIMIT FOR SS&C, INCINERATOR ASH, AND OXIDE

Expected Normal Conditions:

For limit set B, feed material into Glovebox HA-20MB shall contain SS&C, incinerator ash, or oxide described in Appendices F and G, provided there is no free liquid inside the feed containers. Each container of ash and oxide will be examined upon entry into the glovebox to verify contents and that there is no free liquid. SS&C does not need examination. The material in Appendices F and G can be characterized as having H/X less than or equal to 20. Unlike limit set A, a distinction must be made between the feed containers with limited moderation and the fully moderated cemented fissile containers. The feed material must be spaced at least 25.4 cm away from the cemented fissile material containers as well as the mixing bowls, except when transferring material into the mixing bowls, or crushing, mixing and conveying feed into the mixing bowls. The glovebox total fissile mass, including holdup, is limited to 2100 g plutonium or fissile equivalent with the uranium ^{235}U enrichment less than or equal to 50%. This mass is limited to 200 g Pu in each mixing bowl with unrestricted moderation, 500 g Pu, total, in other containers as cement with unrestricted moderation, 900 g Pu in other containers as feed material with no free liquid, and 300 g Pu evenly distributed around the glovebox as holdup. Only feed material with plutonium content of up to 200 g in any number of containers can be open at a time. Spills must be promptly cleaned up or considered part of the mass of the group of containers from which it was spilled. Each individual container can contain up to 200 g Pu or fissile equivalent and must be limited to 17.8 cm (7 in.) in height when resting on the glovebox floor. Normally, material enters the glovebox in containers with about 60 g Pu and leaves the glovebox in cement billets with up to 180 g Pu. Much of the feed material fissile mass will enter as less than 60 g Pu per container, but no cemented billet will contain more than 200 g Pu. Container volumes are limited to 4.73 L for mixing bowls and 2.76 L for other containers, except for the sieve assembly that can be 4.9 L. Minimum spacing of 25.4 cm (10 in.) is required between mixing bowls and between mixing bowls and other containers except when transferring material into or out of a mixing bowl. Minimum spacing of 25.4 cm is also maintained to fissile items in Conveyor Glovebox HA-28. No spacing is required among the other containers inside Glovebox HA-20MB. Transition and storage spacing of 45.7 cm (18 in.) and 91.4 cm (36 in.), respectively, for fissile material outside of Glovebox HA-20MB apply with one exception. Waste drums containing up to 200 g of plutonium or fissile equivalent are allowed to pass by the north end of Glovebox HA-20MB with 15.2 cm (6 in.) spacing to fissile containers inside the glovebox. A five-gallon feedwater container is allowed, but it is prohibited to add fissile material to this container. Any opening to the feedwater container must be configured such that there is no credible accidental means of introducing fissile-bearing material.

Base Case Model for Limit Set B:

The base case for limit set B includes the normal and worst-case likely off-normal events. Two mixing bowls each contain 200 g Pu homogeneously mixed with water and placed adjacent to each other in the corner of the glovebox. Cement containing 500 g of Pu is modeled as 90% water and 10 % plutonium and silicon oxide in seven adjacent, close packed 2.76 L, 14 cm diameter, 18 cm high containers completely surrounded by containers filled with cement. Feed material is placed in 7 containers with 900 g of Pu with H/X = 20 and the remaining volume filled with 33% carbon and 67% silicon oxide. These seven containers are also completely surrounded by containers of cement because neutron reflection is greater than if surrounded by containers of water or next to the 30.5 cm of water reflection modeled around the glovebox. Glovebox holdup of 300 g Pu is distributed on the floor of the glovebox, including under each of these containers, with 30.5 cm of water under that. The glovebox is completely surrounded by 30.5 cm thick, full neutron reflection water to simulate operators standing close by. The mixing bowls are placed together to allow containers to be brought together for material transfer, for mixing, grinding, and conveying into the mixing bowl, or to simulate the likely loss of spacing between two containers. This arrangement is more reactive than if the material was placed within 25.4 cm (10 in.) of a 2.76 L container with 400 g of fully moderated Pu that is allowed on the conveyor. A 2.76 L volume containing 200 g of Pu representing a waste drum passing just 15.2 cm (6 in.) past the north end of the glovebox in the normal case is replaced with a more reactive full water reflection wall. Water reflection of 2.54 cm (1 in.) is placed around the containers that are not close packed to represent hands, rags, and plastic waste packages that may be present in the glovebox. A 2.54 cm (1 in.) of water is modeled on top of all containers. Table 1-3 summarizes the base case for Limit Set B. The k_{eff} for this base case is 0.8607±0.0009 (case c0001f2b4).

Table 1-3. Glovebox HA-20MB – Limit Set B Base Case Limits Summary

Controlled Parameter	Limit	Abnormal but anticipated conditions (conservatism for analysis)
Mass	Maximum 2100 g Pu & fissile equiv. Glovebox total including holdup; 200 g Pu per mixing bowl; 500 g Pu total in cement containers, 900 g Pu total with 200 g Pu per container in feed material, containers and crusher/ hopper, auger/hopper; 300 g Pu holdup	All fissile modeled as ^{239}Pu
Volume	Two mixing bowls with maximum 4.73 L per bowl; 4.9 L sieve pan assembly; 50 ml of lubricants; crusher/hopper 1.1 L, auger/hopper 2.83 L;other containers with maximum height of 17.8 cm and maximum volume of 2.76 L except one five-gallon feedwater container into which it is not permitted to introduce fissile material and no credible accidental means of adding fissile material exists	Mixing bowls were modeled as 4.8 L; other containers as 2.76 L.
Moderation	No free liquid in feed containers: no more than 200 g Pu in open feed containers, auger, crusher, or hopper at a time	

Controlled Parameter	Limit	Abnormal but anticipated conditions (conservatism for analysis)
Interaction	No stacking of containers; 25.4 cm (10 in.) minimum spacing between mixing bowls and between mixing bowls and other containers and between feed material and cement containers with fissile material except during material transfer; spacing is not required among feed containers or among cement containers with fissile material,	Two mixing bowls placed next to each other to simulate fissile material transfer.
Interaction (continued)	25.4 cm minimum spacing to fissile material in Conveyor Glovebox HA-28; 15.2 cm minimum spacing between waste drums on the north side of the glovebox and fissile material containers inside glovebox	
Reflection	Dry fire suppression system within glovebox	Full reflection around glovebox and 2.54 cm (1 in.) water reflection on top of and around fissile containers not close packed
Geometry	Pu in designated containers with a maximum 17.8 cm (7 in.) height except uniformly distributed holdup	Containers modeled 18 cm tall
Isotopics	NA	100% ^{239}Pu
Enrichment	Maximum 50% ^{235}U in U	^{235}U treated as ^{239}Pu fissile equivalent
Density	NA	
Concentration	NA	Pu concentration to maximize reactivity
Poisons	NA	

The mass of fissile material in each feed container is determined before it is brought into Glovebox HA-20MB. Therefore, it is unlikely that the mass limits in the table above will be exceeded and subsequently no anticipated abnormal mass conditions are included in the base case.

Contingency Summary for Limit Set B:

Table 1-4 summarizes the analyses of the unlikely, independent, off-normal events (contingencies). Each event is assumed to occur with the glovebox configured as the described base case with the contingency added. The resultant computed reactivity is compared to the subcriticality target k_{eff} of 0.942 for MCNP calculations of plutonium non-metal systems, conservative for the combination of materials in the limit set, as explained in Section 4.0. This table summarizes the results of the contingency evaluation found in Section 5.0. Specific k_{eff} calculations were not made for contingencies in Table 1.4 that were bounded by other analyzed contingencies.

Table 1-4. Glovebox HA-20MB – Limit Set B Contingency Summary

Contingency Description	Affected Parameter(s)	Barriers that make contingency unlikely	k_{eff} bounding contingency (case ID)
Seismic event with container spill and flooding that washes fissile material from containers and holdup to accumulate in conveyor housing	Volume Geometry	Seismic event unlikely; requires severe damage to glovebox, breaking windows and seal to cover of conveyor housing under glovebox and breaking of fire suppression system piping	0.7199 ± 0.0008 (c0001f2q4a)
Seismic event with containers grouping together with no spacing surrounded by close packed cans of cement or water	Interaction	Seismic event unlikely; requires severe damage to glovebox, breaking windows with all containers collecting together in the most reactive arrangement, and breaking of fire suppression system piping; it is unlikely that interspersed water from fire suppression system would have as high of a density as 0.1 g/cc	0.9413 ± 0.0009 (c0001f2q1)
Fire with interspersed water and fissile material washed out of containers	Geometry Reflection	Major building fire that melts glovebox panels is unlikely; it is unlikely that the fire sprinkler water would add as high of an interspersed water density as 0.1 g/cc and cause all the fissile material to be washed from containers	0.6569 ± 0.0009 (c0001f2f3)
Fire with interspersed water and no	Reflection	Major fire that melts glovebox glass is unlikely; it is unlikely that the fire sprinkler water would add as high of an	0.8515 ± 0.0009 (c0001f2f5a)

Contingency Description	**Affected Parameter(s)**	**Barriers that make contingency unlikely**	**k_{eff} bounding contingency (case ID)**
fissile material washed out of containers; one feed container open		interspersed water density as 0.1 g/cc	
One feed container with unrestricted moderation brought into glovebox	Moderation	Feed container contents are from processes with H/X ≤ 20 and stored in vaults where this moderation limit is imposed, so unlikely to get a more moderated container; visual inspection and removal of container from glovebox assures a second moderation violation is not credible	Less reactive than fire with one feed container open
Feed container H/X=200, representing more H associated with carbon content	Moderation	From contents of Appendices F & G, not likely to have that much material with carbon and hydrogen	0.8601±0.0008 (c0001f2b7)
Mixing bowl stacked on 2.76 L containers	Interaction	Operator training, procedure, no stacking anywhere at PFP	0.9236 ±0.0009 (c0001f2s1)
Extra container with 200 g Pu in glovebox, stacked on 2.76 L containers	Mass Interaction	Operator training, procedure, fissile inventory control, posted limits	0.9022 ± 0.0009 (c0001f2s3)
Wagon with max. Pu loading under glovebox	Interaction	Operator training, procedure	0.8427 ±0.0009 (c0001f2w1)
Mixing bowls stacked	Interaction	Operator training, procedure	0.8584 ±0.0008 (c0001f2s2)
Loss of 15.24-cm (6-in.) spacing between drum passing on north end and contents of glovebox	Interaction	Operator training, procedure	0.8602 ± 0.0008 (c0001f2bh4)

Contingency Description	Affected Parameter(s)	Barriers that make contingency unlikely	k_{eff} bounding contingency (case ID)
Loss of spacing to item on Conveyor Glovebox HA-28 (400 g, 4.7 L, H/X>20)	Interaction	Operator training, procedure, unlikely to have container greater than 2.7 L	0.9048 ±0.0008 (c0001f2b9)
Extra mixing bowl with some fissile mass out of other containers	Volume	Operator training/procedure; more likely to use smaller container to clean up a mess	Less reactive than extra container stacked
Excess holdup exceeding glovebox mass limit	Mass	Operator training/procedure/inventory control	Less reactive than extra container stacked
Container too large	Volume	Operator training/procedure	Less reactive than bowls stacked
Extra oil or plastic	Moderation	Operator training/procedure	Less reactive than fire analysis for reasonable quantities of plastic present

The hazards assessment determined that it is not credible to have uranium with ^{235}U enrichment exceeding 50% in this glovebox. Therefore, no contingency was evaluated for enrichment.

1.3 SUMMARY

Glovebox HA-20MB is located in Room 235B of the 234-5Z Building at the Plutonium Finishing Plant. This enclosure contains mixers, mixer bowls, a crusher unit, an isolated inoperable conveyor unit, plutonium residue feed cans, cemented cans, and a feedwater container. Plutonium residue, not conducive to other forms of stabilization, is prepared for storage and ultimate disposal by cementation. The feed residue material cans can have plutonium contents of only a few grams or up to 200 grams. This evaluation accommodates this wide range of container fissile concentrations.

Two glovebox limit sets are supported by this document. One limit set is for residue in any form except solutions and allows up to 1200 g plutonium or fissile equivalent in the glovebox. Up to 500 g plutonium can be in feed or cement cans, 200 g plutonium in each of two mixing bowls, and 300 g plutonium as glovebox holdup. The second limit set is specifically for sand, slag, and crucible (SS&C), ash, or oxide feed material and allows up to 2100 g plutonium or fissile equivalent. Up to 500 g plutonium can be in cemented billets, 900 g plutonium in cans as feed, 200 g plutonium in each of two mixing bowls, and 300 g plutonium as glovebox holdup.

This criticality safety evaluation controls mass, volume, spacing, reflection, and geometry for both limit sets. For limit set B, moderation for the feed material is also controlled by feed material type and operator inspection to assure no free liquids. No fissile material can be allowed in the feedwater tank. Noticeable accumulations of fissile material, such as from spills, must be cleaned up before continuing operation. The cement content of the plutonium, water and cement mix must be adequate to assure that the moisture content of the cement does not exceed 90 volume percent. A ratio of at least 1500 g cement in 4.73L is sufficient to displace 10 volume percent water. Cementation procedures require more than this ratio of cementation to water mixed prior to placing the mixture in the cement billet containers. During HEPA filter changeouts, all fissile-bearing containers must be removed from the glovebox. For limit set B, a maximum of 200 g of plutonium can be in open containers, auger, crusher, or hopper at one time. The other feed material must be in closed containers. Also, for limit set B, each ash and oxide feed container must be inspected when loaded into HA-20MB to assure that it contains no free liquids. SS&C containers need not be inspected. No containers can be stacked and PFP transition and storage spacing applies to fissile-bearing containers outside of the glovebox except for waste drums passing by the north side of HA-20MB where a minimum spacing of 15.2 cm (6 in.) to material inside the glovebox is required.

Evaluation of this glovebox operation included normal, base cases, and contingencies. The base cases took the normal operations for each type of feed material and added the likely off-normal events. Each contingency is evaluated assuming the unlikely event happens to the conservative base case. A hazards assessment was conducted to assure that each credible unlikely event or set of correlated unlikely events was included in this analysis. The results of this evaluation show that the intended operation in Glovebox HA-20MB meets the double contingency requirement. That is, at least two unlikely, independent, and concurrent changes in process conditions are required before a criticality is possible. Therefore, this CSER meets the requirements for a criticality evaluation contained in the Hanford Site Nuclear Criticality Safety Manuals, HNF-PRO-334 (FDH 2000), HNF-PRO-537 (FDH 1997a), and HNF-PRO-539 (FDH 1997b), ANSI standards (ANSI 1998), and DOE Order 5480.24 (DOE 1992). This CSER also follows Fluor Federal Services, Inc. Practice 134.290.1121 (FFS 1999).

2.0 SYSTEM DESCRIPTION AND NORMAL OPERATIONS

Glovebox HA-20MB will be used to process plutonium scrap material by cementation. The normal operational sequence relating to criticality safety is given in Section 2.1 below. Figure 1 shows a sketch of the approximate layout of the glovebox in relation to the other gloveboxes and conveyors used for thermal stabilization activities at the PFP. Figures 2 and 3 are sketches showing equipment and containers to be used, but not necessarily in the specific glovebox locations.

The following sections describe the facilities, fissionable materials, and technical practices and process features of the handling processes.

2.1 OPERATIONAL SEQUENCE

Plutonium residue for cementation in Glovebox HA-20MB can be SS&C, ash, oxide, or other less characterized material. A glovebox limit of 2100 g plutonium or fissile equivalent is allowed as described in Section 3.0 if the feed material is SS&C, ash, or oxide as characterized by the material described in Appendices F and G. If not, then the glovebox fissile mass limit is 1200 g. The SS&C feed contains calcium that is reacted before cementation. The other scrap material can be directly cemented.

Material enters Glovebox HA-20MB through Conveyor Glovebox HA-28, the airlock, or through a port. Mixing bowls are used for the calcium reaction process and for combining the plutonium material with cement. The contents of the bowls are stirred by electric mixers or by hand. A feedwater container provides water for these processes. Cans of cemented material are stored while curing and then transferred out of the glovebox through the HA-28 conveyor.

A minimum separation of 25.4 cm (10 in.) is required between mixing bowls, between mixing bowls and other containers, and between feed containers and cemented containers with two exceptions. A mixing bowl can be brought together with another mixing bowl or be brought next to a feed or cement container for the transfer of material. Also, for limit set A, 1200 g of plutonium or fissile equivalent, there is no separation requirement between feed and cement containers.

2.1.1 Load-In of Feed Material

Processing of feed material begins with load-in of cans through a sphinter port, bag port, the Conveyor Glovebox HA-28, or the airlock cell. Allowed fissile mass and required minimum spacing depend upon which limit set is posted. Logistics and space availability may limit the can count. For limit set B (2100 g Pu), ash and oxide containers must be opened upon entry into Glovebox HA-20MB to assure that the type of feed material is consistent with Appendix G material and that there is no free liquid in the container. If these conditions are not met, then the container must be removed before another feed container is brought into the glovebox. For SS&C,

as described in Appendix F, it is not credible to have an H/X>20, to have free liquid, or be confused with another container because of the process used to create the SS&C and can it (Roemer 1986).

When feed containers are opened and the material removed, these containers and any plastic bagging are rendered into "non-containers" and processed for disposal in the usual manner for glovebox waste. For limit set B, only 200 g of plutonium or fissile equivalent in feed material may be in open containers, auger, crusher or hopper at a time. A lid replaced on a slip lid can is no longer considered open, whether or not it is taped. The analysis requires that the feed containers not fill with water under the contingencies involving glovebox glass damage and sprinkler water entry into the glovebox. For limit set A, a 200 g fissile mass is allowed in each mixing bowl and 500 g fissile mass is allowed in the other containers. For limit set B, 200 g fissile mass is allowed in each mixing bowl, 900 g fissile mass is allowed in feed containers, and 500 g fissile mass is allowed in cemented containers. For both limit sets, 300 g fissile mass is allowed as distributed holdup throughout Glovebox HA-20MB and spills must be expeditiously cleaned up.

2.1.2 SS&C Material Preparation

One container, at a time, is opened in the process area and weighed. Pu is tracked through a running inventory. The SS&C is sieved to separate out the large pieces, which are then transferred to a size reduction unit (crusher) and re-sieved through an 8-mesh screen. An optimum particle size of 8 mesh was determined through laboratory testing and assures that the Ca metal oxidation reaction with water will proceed to completion. Following this pre-cementing activity, the SS&C is transferred into a hopper and fed via a variable speed auger to the mixing bowl containing water. This step is necessary to assure a controlled reaction of the calcium with water. After this stage the material should be a relatively homogeneous blend of calcium fluoride (CaF_2), calcium iodide (CaI_2), unreacted calcium, magnesium oxide (MgO) sand, plutonium fluoride (PuF_4), plutonium oxide (PuO_2) and silicon oxide (SiO_2) as powder grains and/or chips and grains as well as metallic Pu (and possibly other compounds of Pu in minute amounts). Then, batches of up to 2000 g total SS&C will be transferred into the hopper of the auger for subsequent slow metering into a mixer bowl.

Due to WIPP requirements each SS&C can will be processed on a one to one basis 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. On occasion the bulk cemented mixture may not fit in one cement can. In this case, Pu mixture will be assumed to be homogeneous and the Pu accounting for split batches would be determined using the gross weight ratios for the granulized and blended SS&C charge portions. Charges will not be combined.

Figure 1. Approximate Layout for Gloveboxes and Conveyors Utilized for Thermal Stabilization Activities

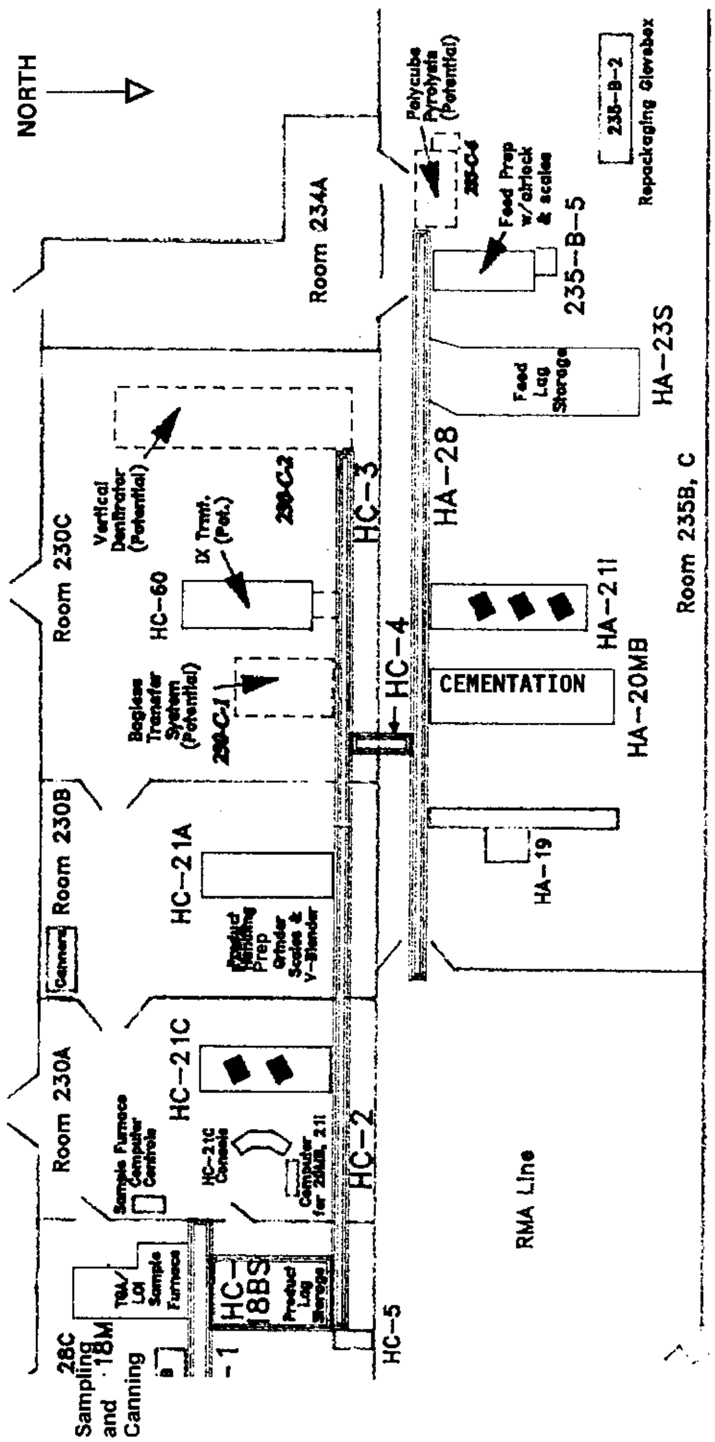


Figure 2. Cutaway End View from North of Glovebox HA-20MB

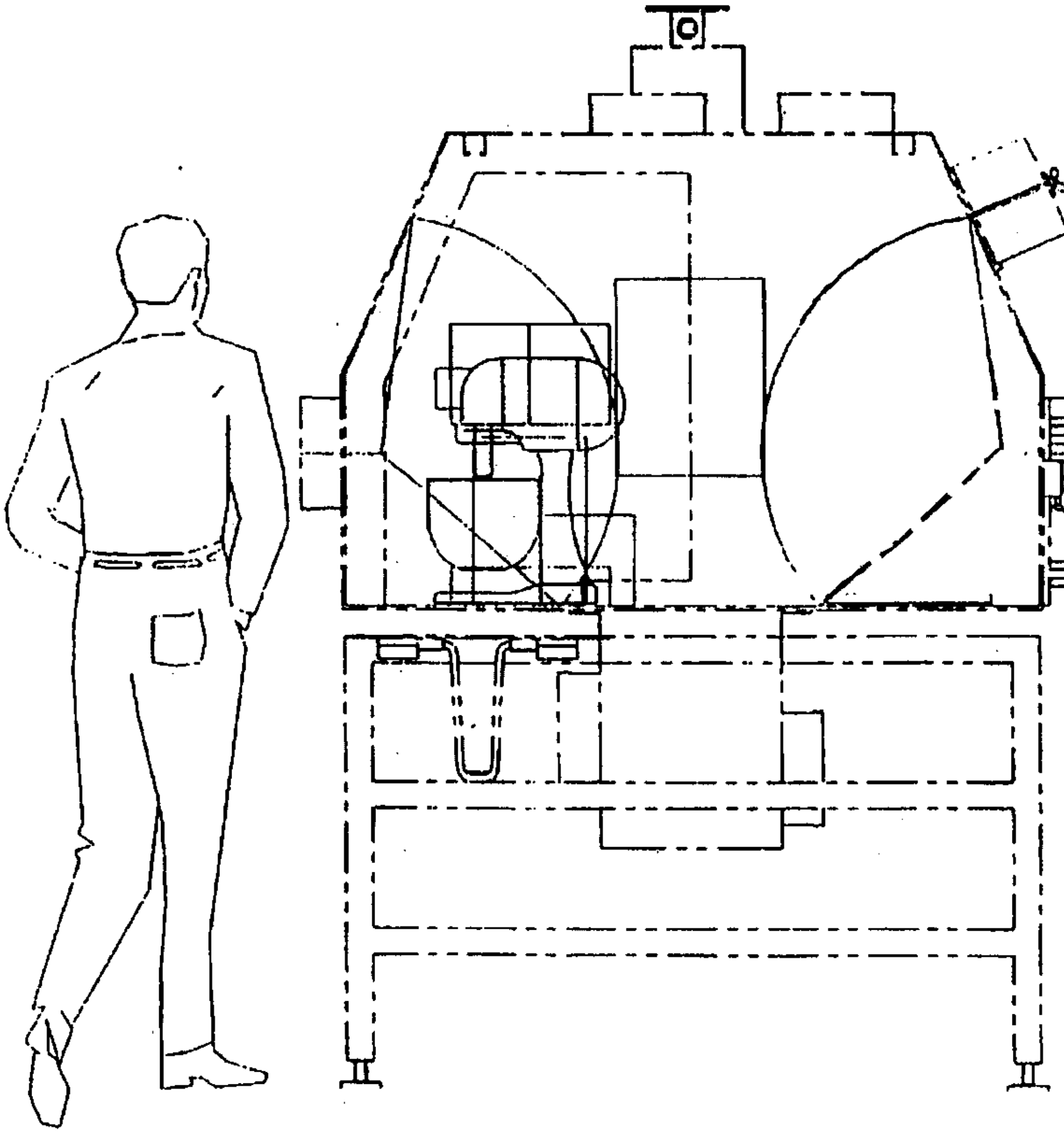
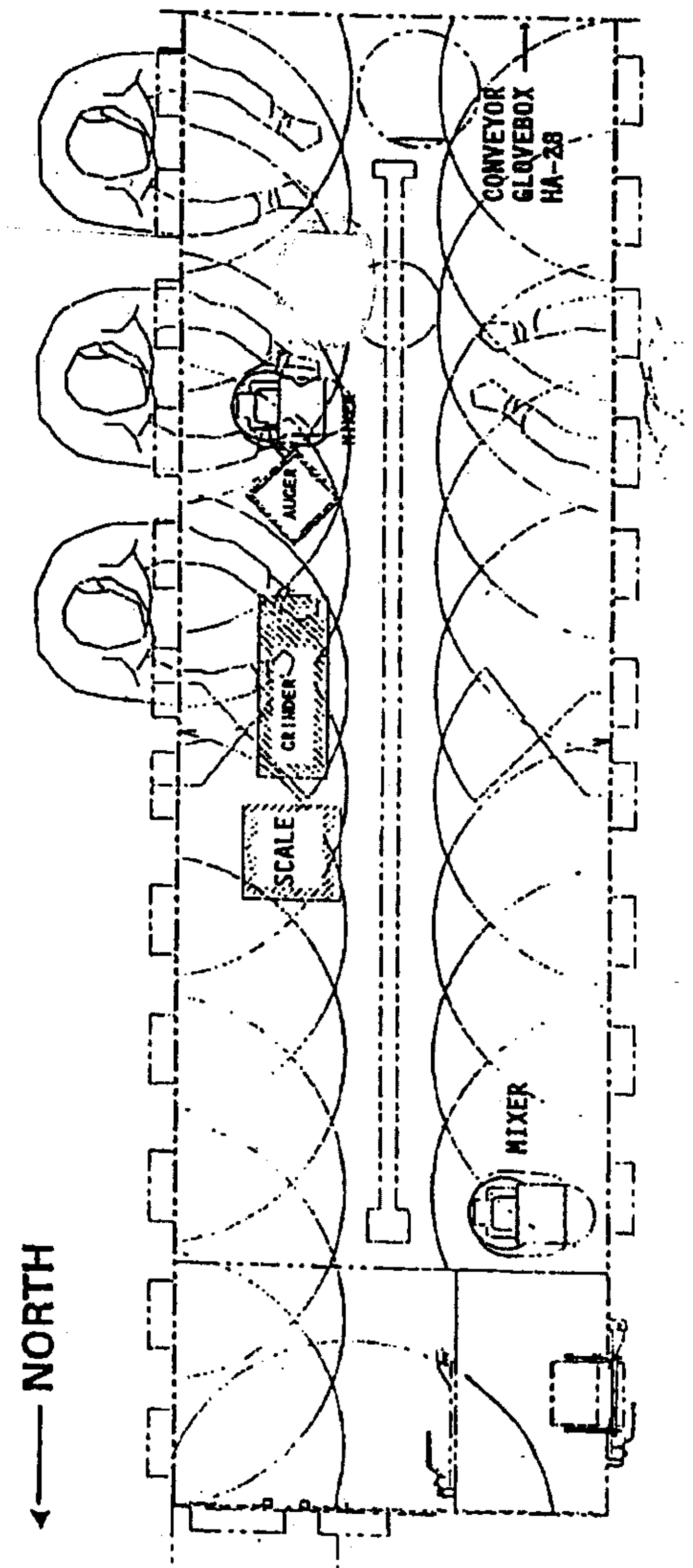


Figure 3. Layout of Glovebox HA-20MB for Cementation Processing



2.1.3 Reacting Charge Material

The SS&C feed will require its calcium to be reacted with water. A 4.73 L, 5 quart mixing bowl loaded with 1.4L to 1.5L of water (from the chilled water tank), will be prepared for reacting the new charge. Infrared thermocouples are affixed to the mixer arms for monitoring the fluid temperature. With the mixer beaters activated, the SS&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.

Once the bowl contains a designated charge of SS&C material (up to 2000 g), the auger is stopped and the mixing is continued for about 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.

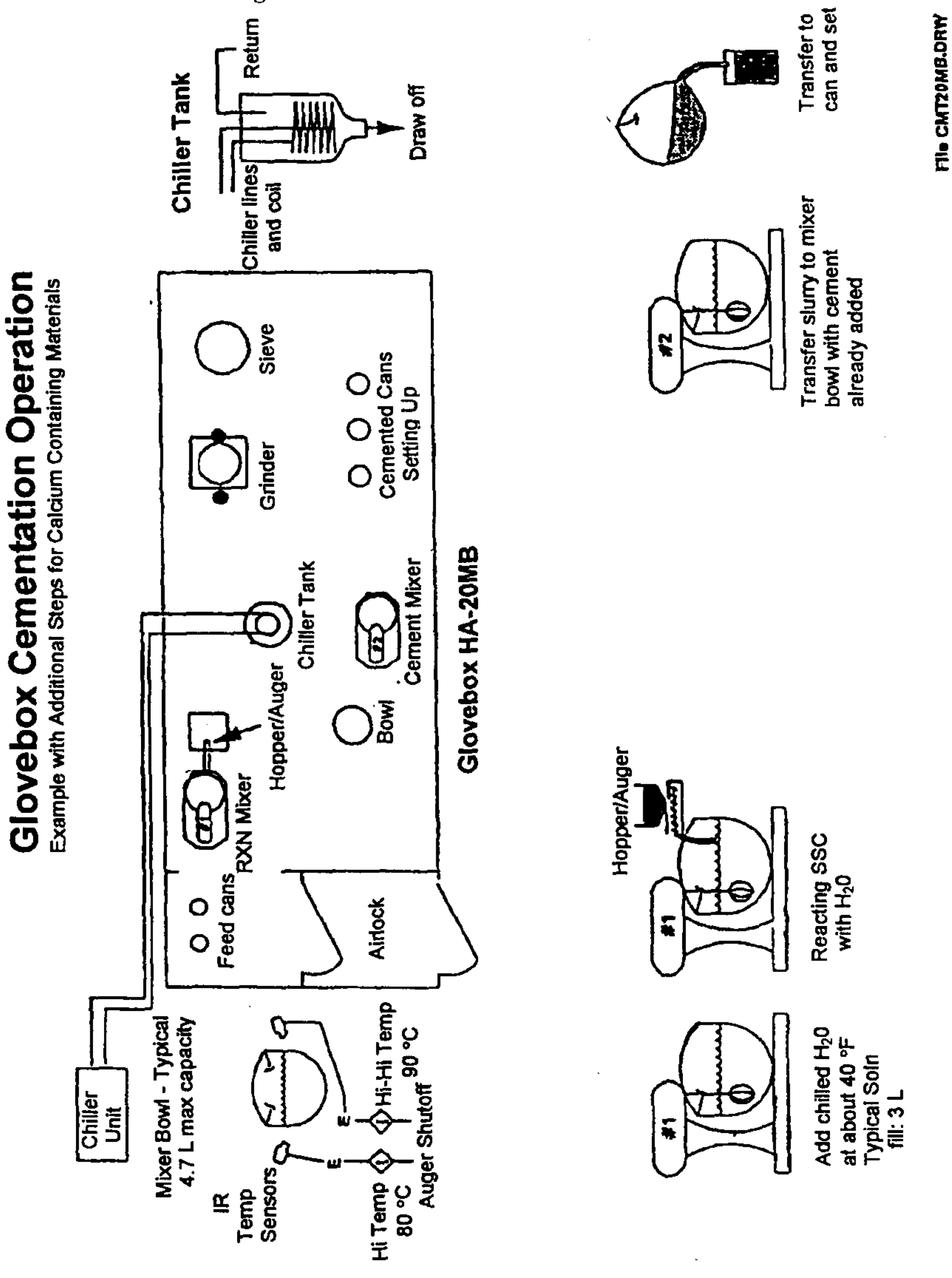
2.1.4 Cementing

For cementing, approximately1500 g of cement is added to the water and SS&C or other feed material slurry mixing bowl. The maximum water content of the cement to have the cement setup with no liquid standing on top, as required by PFP cementation procedures, is 44 volume percent as explained in Appendix J (Greenhalgh 1996). The bowl is set under mixer beaters for stirring. Appropriate quantities of water and additional dry cement powder are added to the bowl 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 of wet cement volume exceeds the desired can fill volume, in which case the excess is poured into either another can as a partial fill or as a smaller can. PFP operations tracks Pu contents on the basis of total-weight ratios. Loaded cement cans will remain in the glovebox for at least 24 hours to cure. After curing, any free liquid is poured back into a mixer bowl for use in the next batch. The cement cans are sealed out of the glovebox in vented PVC bags.

2.2 FACILITY AND EQUIPMENT DESCRIPTION

The glovebox and the equipment within it are described in this section. Figure 3 shows Glovebox HA-20MB equipment layout and Figure 4 shows the cementation process, but not necessarily in the specific glovebox locations.

Figure 4. Cementation Process Flow Diagram



2.2.1 Glovebox HA-20MB Description

Glovebox HA-20MB, located in the main PFP Building 234-5Z in Room 235B next to Glovebox HA-21I, will be used for cementation processing. Glovebox HA-20MB has access to the conveyor box system through its connection at the south end to Conveyor Glovebox HA-28. Materials are brought into HA-20MB via HA-28, an airlock, a sphincter port or bag port. Items can be taken out via Conveyor Glovebox HA-28 or bag port, but no containers will be transferred out through the airlock

HA-20MB is a conventional glovebox with a 132.1 cm (52 in.) wide by 472.4 cm (15.5 ft) long floor supported 91.4 cm (36 in.) above the room floor by a table frame. It has an inside height of 91.4 cm (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 30.5 cm (12 in.) wide by 35.6 cm (14 in.) deep by 350.5 cm (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 Glovebox HA-20MB at the 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) portion of the glovebox has an air isolation chamber for staging the input SS&C cans from storage. The semicircles evident on the drawing express the extent of gloved hand reaches, which through ports on either side give complete coverage for ease of container movements.

The CPS equipment list is to include as "equipment" the crusher, scale, mixers and auger, which include their hoppers. Under allowed containers, beside the liquid-loading types cited above, will be the sieve pans and cans of the source material. Dry SS&C material may be distributed among one or more of the allowed containers. Not more than 200 g Pu is to be included in any one container.

A summary of the process equipment and containers expected in Glovebox HA-20MB for operations is given below.

The equipment available in Glovebox HA-20MB are:

- one crusher unit
- one hopper/auger unit
- two mixers
- two electronic scales

The containers available in Glovebox HA-20MB are:

- feed cans 1.1 L or 1.5 L, up to 2.73 L

• mixer bowls	4.73 L
• crusher/hopper	0.6 L
• sieve catch pans	1.65 L
• hopper/auger	2.83 L
• cemented cans	2.725 L
• slip-lid cans	1.2 L
• graduated cylinder	0.200 L
• feedwater tank	18.9 L

Other materials available in Glovebox HA-20MB are:

- infrared thermocouples
- auger lidded metal box
- electronic scales

A 94.6 L (25 gal.) makeup water tank for the glovebox is located outside the glovebox.

Glovebox HA-20MB is listed as a "seismically qualified" glovebox.

2.2.2 Process Source Material

The SS&C 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. 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 (SS&C) residues.

The process for making a Pu button of up to 2500 g Pu mass, which is 10.5 mol., would thus provide up to 42 mol. (798 g) of fluorine. Full conversion (to Pu + CaF_2) would require then at least 21 mol. (842 g of calcium) for each batch - - and likely much more. Typical analyses of SS&C material indicate about equal parts by weight of CaF_2 and MgO, so that each batch will also include about 1600 g 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 SS&C compounds in a storage can could be as low as 50% of the masses cited above. Process flow documentation for SS&C is presented in Appendix F.

The SS&C residues are in multiple-can storage containers, the primary containers of which are untinned cans of up to 1.5 L volume (meant to be fed to a SS&C dissolver in the PRF). Assay records for the inventory of these SS&C scrap containers indicate Pu contents of up to 200 g per can.

Ash material is a mixture of combustible residues that was generated in plutonium processing and recovery operations and processed in incinerators. The residues were burned to reduce volume, destroy volatile constituents, and recover plutonium. Oxide is generally the most stable form of metals and is expected to be the main species formed as a result of incineration.

Oxide material is plutonium oxides/mixed oxides of < 30 wt% Pu or Pu+U, and are typically oxide and mixed oxide residues recovered from glovebox processes. All oxides were thermally stabilized prior to placing into vault storage.

Other materials that may be processed for cementation include sludges, reactive scrap, nitrates, oxalates, oxycarbonates, and others. Ash and oxide are described further in Appendix G. Other feed materials may have undetermined diluent matter along with the plutonium.

2.2.3 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 crusher, electronic scales, an auger (for controlled material feed rates), and a chilled feedwater tank. A larger tank for water supply and a chiller unit to supply the cooling coil in the inside feedwater tank are located on the mezzanine to the northeast of the glovebox.

2.2.3.1 Mixers

Conventional beater style mixers (industrial strength) are used for two stages of the operation, 1) reaction of residual calcium in the SS&C scrap, and 2) mixing of the granulated scrap slurry with cement prior to transferring to the 14-cm (5.5-in.) diameter cementing can. The proportions in the Figure 2 diagram indicate an overall height of 48 cm (19 in.) for the mixer units.

2.2.3.2 Crusher

A crusher placed in HA-20MB is for size reduction of the feed material. The hopper for this crusher has a capacity of 0.6 L.

2.2.3.3 Auger

The auger unit is all enclosed in a 21.6 x 21.6 x 17.8 cm (8.5 x 8.5 x 7 in.) tall, lidded metal box, procured from AccuRate™. According to manufacturers specifications, the feed hopper in the unit has a volume of 2.83 L (0.1 ft^3), or about a third of the overall auger box volume. Material is metered out of the auger through a 9.14 cm (3.6 in.) long pipe extending out horizontally from a bottom corner of the box. Normal operating feed rate will be 24 g/min. The maximum operating limit of the auger is 46 g/min.

2.2.3.4 Scales

One or two electronic scales are available to check weights of SS&C material accumulations in cans at various stages of the processing, as needed. The portland cement charges

AccuRate is a trademark of Schmeck Corporation of Whitewater Wisconsin.

to the cementing cans will already be properly weighed out and put in the cans before transfer into the glovebox.

2.2.3.5 Feedwater Tank

The interior feedwater tank for the HA-20MB process is an open top vessel of 18.9 L (5 gal.) capacity, formed from an inverted polypropylene carbuoy jug with its bottom cut off. Its diameter is 27.9 cm (11 in.), and the full height from the outlet to the base is 38.1 cm (15 in.). This interior tank is fed by gravity through piping from a 94.6 L (25 gal.) makeup water tank located on the mezzanine to the northeast of 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 4.5 L (1.2 gal.) chiller unit outside of the glovebox. It is prohibited to introduce fissile material to this tank and its opening must be configured such that it is not credible to have fissile material accidentally enter this tank.

2.2.3.6 Makeup Water Tank Outside Glovebox

The 94.6 L (25 gal.) outside makeup water tank for the glovebox is also open on top, and 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 plant water system. The geometry of this outside source tank is not important because it is not credible that plutonium would get into it. Glovebox flooding from this tank is no more severe than from the fire or seismic events.

2.2.3.7 Instrumentation

Instrumentation for the processing will include the infrared thermocouples attached to the mixer.

2.2.4 Containers for SS&C Material and Slurries

Containers intended to hold the SS&C residues include the storage cans, the mixer bowls, the cementing cans, and possibly other small cans for transfer or cleanup purposes. It is intended that the mixer bowls and cement cans will be the only allowed container types to hold SS&C residues-plus-water slurries or sludge (perhaps also a slip lid can of up to 1.2 L capacity for cleanup).

2.2.4.1 SS&C Containers

Two sizes of cans have been used in the button making runs, a 1.1-L unit of 10.1 cm (4 in.) diameter and 14.0 cm (5.5 in.) height, and a 1.5 L unit which is 11.3 cm (4.5 in.) diameter by 15.2 cm (6 in.) high. As brought into the glovebox though a sphincter port or bag-in port, the cans are crimped sealed and enclosed in a sealed, tight fitting plastic bag. Containers are limited to a height of 17.8 cm (7 in.) when resting on the glovebox floor.

2.2.4.2 Sieve Pans

The sieve pans and catch pans are the same as for the sieve-shaker equipment described also in CSER 96-003 (Hess 1996), where each 20.3 cm (8 in.) diameter by 5.1 cm (2 in.) tall sieve or catch pan can hold as much as 1.65 L.

2.2.4.3 Slip-Lid Cans

Dry SS&C residues will be transferred during the preparations, grinding, splitting, and weighing operations in these pans, or in 1.2 L slip-lid cans. These "2 lb" slip-lid cans, 10.8 cm (4.25 in.) in diameter by 14.0 cm (5.5 in.) tall, may also be used for cleanup of spills.

2.2.4.4 Mixer Bowls

The mixer bowls (or beater vessels) are conventional, rounded bottom, 4.73 L (5-quart) stainless steel bowls, 20.3 cm (8 in.) in diameter by 17.8 cm (7 in.) deep.

2.2.4.5 Cementing Cans

The cementing cans are 14.0 cm (5.5-in.) diameter by 17.8 cm (7 in.) tall, for a volume of 2.725 L, and these are equipped with a slip-lid style cover. 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 SS&C cans will be loaded into 55 gallon waste drums.

2.2.4.6 Graduated Cylinder

The allowed container list also includes a 0.2 L graduated cylinder for accurate measurement of the water charge required for the cement mixtures.

2.3 FISSIONABLE MATERIALS DESCRIPTION

The fissionable material handled in Glovebox HA-20MB is plutonium in the forms of SS&C, metal, oxide, ash, sludge, scrap, and other compounds. The fissionable isotope content and physical forms are discussed below.

2.3.1 Fissionable Isotopes

Each container is labeled with the mass of plutonium or fissile material. The plutonium and other fissile mass is assumed to be ^{239}Pu. This simplification is conservative for the plutonium with more ^{240}Pu than ^{241}Pu, which is the case for the reactor produced plutonium at PFP. The ^{239}Pu assumption also applies to the fissile atoms in depleted or natural uranium or mixed oxides of plutonium and uranium that may be present. For uranium, the ^{235}U enrichment must not exceed 50 weight percent in order for the ^{239}Pu to conservatively model this uranium.

2.3.2 Carbon Content

The carbon content of the feed material may vary. For the materials described in Appendices F and G, the carbon could be as high as 33% of the material. For other material, the carbon content is assumed to be 10%, maximum.

2.3.3 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 H 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 included the installed HEPA filter. The 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. The average areal density is on the order of 10.8 g Pu/m^2 (1 g Pu/ft^2), and not likely to exceed 53.8 g/m^2 (5 g/ft^2) in more than a few locations. If additional material is spilled, it must be expeditiously cleaned up or its mass must be included in the limit set for the type of material from the container it spilled from. Periodic NDA measurements will confirm glovebox holdup changes over time.

2.4 FISSIONABLE MATERIAL HANDLING

Fissionable material will be inventoried as containers enter and leave the type of container controlled by the posted limit set. Controls include multiple levels of protection of a safe batch such as limits on fissionable mass, maximum container volume, elimination of moderation, and separation distance from other fissionable materials. The multiple levels of protection will assure that criticality safety will not be jeopardized by the inadvertent failure of a single control.

In addition, processing will be stopped as necessary to clean up visible accumulations of fissionable materials from spills or processing.

2.4.1 Receipt of Fissionable Material

Material will be received in Glovebox HA-20MB in cans. Two sizes of cans had been used in the button making runs, a 1.1-L unit of 10.1 cm (4 in.) diameter and 14.0 cm (5.5 in.) height, and a 1.5 L unit which is 11.4 cm (4.5 in.) diameter by 15.2 cm (6 in.) high. The maximum container mass will be 200 g Pu or fissile equivalent and maximum container volume will be 2.76 L except for mixing bowls and sieve shaker.

2.4.2 Waste Packages

Glovebox waste is generated from PFP plutonium stabilization operations. It is placed into plastic bags, transferred to Isolated Transport Containers, assayed, then placed into waste drums. This waste consists of gloves, bags, rags, containers used to port-in items, etc. Prior to bagging, all noticeable fissile material is shaken or brushed from these items and no fissile item is intentionally placed in these packages. Inspection of historical assay data shows that normally these packages contain only 1 or 2 g of fissile material. Appendix H documents this inspection and supports the conclusion that it is not credible for the packages to contain more than a few tens of grams of fissile material except for the upset of a fissile item in the waste package, which is bounded by other upset conditions (reflection).

Waste packages are allowed in Glovebox HA-20MB and would result from glovebox cleaning operations. Waste packages created in this glovebox would only contain the fissile material already inventoried and resultant neutron reflection/moderation is already conservatively modeled by water in the base calculations.

It is unlikely that a waste package containing fissile material from another glovebox would be transferred to HA-20MB because it is not a destination glovebox for waste packages. This event is not forbidden and is bounded by the analysis of upset conditions for Glovebox HA-20MB.

3.0 LIMITS AND CONTROLS

Table 3-1 lists each of the parameters of concern for criticality safety, and discusses whether these parameters are necessary.

Table 3-1. Controls on Parameters Related to Criticality in Glovebox HA-20MB

Parameter	Controlled	Discussion (Limit or Process Control if Yes, Reason if No)
Mass	Yes	Maximum mass limit per container, per group of feed containers, per group of cement containers (combined with feed containers in limit set A), and glovebox holdup
Volume	Yes	Volume limit on mixing bowls, sieve pan assembly, lubricants, and other containers
Spacing	Yes	Minimum spacing between mixing bowls and other containers, containers on the HA-28 conveyor, and waste drums on north side of glovebox, otherwise, general transition and storage spacing requirements outside of glovebox; no stacking
Moderator	No/Yes	Optimum moderation in analysis for limit Set A/feed must be SS&C, ash, or oxide with no free liquids for limit Set B.
Reflector	Yes	Dry fire suppression system within glovebox
Poisons	No	Poisons were not used in this analysis.
Concentration	No	Worst credible concentrations were analyzed.
Enrichment	Plutonium, no; Uranium, yes	Plutonium was assumed to be 100 wt% ^{239}Pu. This conservatively encompasses all allowed fissionable materials including uranium enriched to 50% ^{235}U.
Density	No	Most reactive credible densities were used for all materials.
Geometry	Yes	Plutonium in designated containers with a maximum height of 17.8 cm (7 in.) except holdup uniformly distributed on floor

3.1 LIMITS

The operations in Glovebox HA-20MB are defined in Section 2.0. Operations are performed in the main glovebox area. There are two fissionable material mass limit sets for cementation glovebox operation. Tables 3-2 and 3-3 show the parameter limits for the 1200 g fissile unrestricted feed and 2100 g fissile SS&C, ash, and oxide limit sets, respectively.

Table 3-2. Limit Set A: 1200 g Total Glovebox Fissile Mass

Mass	Max. 1200 g plutonium or fissile equivalent in glovebox Max. 200 g plutonium or fissile equivalent per mixing bowl Max. 500 g plutonium or fissile equivalent in feed and cement containers, crusher, auger, hopper with a maximum 200 g plutonium or fissile equivalent in any one container, crusher, auger, or hopper Max. 300 g plutonium or fissile equivalent glovebox holdup
Volume	Two mixing bowls, each 4.73 L, max. Sieve pan assembly, 4.9 L, max. Lubricants, 50 ml, max. Crusher/hopper, 1.1 L Auger/hopper, 2.83 L Other containers, 2.76 L, max. except one 18.9 L (five-gallon) feedwater container in which fissile material not permitted and no credible accidental means of adding fissile material exists
Spacing	Minimum spacing of 25.4 cm (10 in.) between mixing bowls and mixing bowls and other containers except during material transfer; 25.4 cm minimum spacing from fissile material in glovebox to that in Conveyor Glovebox HA-28; 15.2 cm (6 in.) minimum spacing between fissile material containers in glovebox to that in waste drums on the north side of the glovebox; no stacking
Moderator	None
Reflector	Dry fire suppression system within glovebox
Poisons	Poisons were not used in this analysis.
Concentration	Worst credible concentrations were analyzed.
Enrichment	Plutonium was assumed to be 100 wt% ^{239}Pu. This conservatively encompasses all allowed fissionable materials including uranium enriched to 50% ^{235}U.
Density	Most reactive credible densities were used for all materials.
Geometry	Plutonium in designated containers with a maximum height of 17.8 cm (7 in.) except holdup uniformly distributed on floor

Table 3-3. Limit Set B: 2100 g Total Glovebox Fissile Mass

Allowed Material Type: SS&C, Ash, and Oxide

Mass	Max. 2100 g plutonium or fissile equivalent in glovebox Max. 200 g plutonium or fissile equivalent per mixing bowl Max. 900 g plutonium or fissile equivalent in feed containers, crusher, auger, hopper with a maximum 200 g plutonium or fissile equivalent in any one container, crusher, auger, or hopper Max. 500 g plutonium or fissile equivalent in cement containers Max. 300 g plutonium or fissile equivalent glovebox holdup
Volume	Two mixing bowls, each 4.73 L, max. Sieve pan assembly, 4.9 L, max. Lubricants, 50 ml, max. Crusher/hopper, 1.1 L Auger/hopper, 2.83 L Other containers, 2.76 L, max. except one 18.9 L (five-gallon) feedwater container in which fissile material not permitted and no credible accidental means of adding fissile material exists
Spacing	Minimum spacing of 25.4 cm (10 in.) between mixing bowls and mixing bowls and other containers and between feed containers and fissile material bearing cement containers except during material transfer; 25.4 cm minimum spacing from fissile material in glovebox to that in Conveyor Glovebox HA-28; 15.2 cm (6 in.) minimum spacing between fissile material containers in glovebox to that in waste drums on the north side of the glovebox; spacing is not required among feed containers or among fissile bearing cement containers no stacking
Moderator	Feed material must be SS&C, ash, or oxide with no free liquid
Reflector	Dry fire suppression system within glovebox
Poisons	Poisons were not used in this analysis.
Concentration	Worst credible concentrations were analyzed.
Enrichment	Plutonium was assumed to be 100 wt% ^{239}Pu. This conservatively encompasses all allowed fissionable materials including uranium enriched to 50% ^{235}U.
Density	Most reactive credible densities were used for all materials.
Geometry	Plutonium in designated containers with a maximum height of 17.8 cm (7 in.) except holdup uniformly distributed on floor

3.2 PROCESS CONTROLS

To assure continued criticality safety during operations, the following process controls are required.

- A maximum of 200 g of plutonium feed material in open containers, auger, crusher, or hoppers at a time for limit set B.
- Each feed container will be opened and examined for free liquid before another container is brought into the glovebox for limit set B.
- No fissile material will be placed into the feedwater tank.
- Containers shall not be stacked.
- Noticeable accumulations of fissionable materials, such as from spills, are not allowed to remain in Glovebox HA-20MB, and are to be cleaned up before continuing operating.
- During HEPA filter change out, all containers with fissile material shall be removed from the glovebox.
- Fire fighting category C.
- Waste packages minimized to those required for cleanup of HA-20MB.
- No waste packages, generated outside HA-20MB, shall be brought into glovebox HA-20MB.
- At least 15.2 cm (6 in.) spacing must be maintained between fissile material in HA-20MB and waste drums passing by the north end of this glovebox (this spacing can be either inside or outside HA-20MB).
- PFP transition and storage spacing shall be maintained on the east and west sides of HA-20MB and on the north side for fissile containers other than waste drums.
- Cement brought into HA-20MB must be in containers no larger than 2.76 L or 7 in. tall.
- Contents of only one container can be transferred to another at one time.
- No liquids shall be added to feed containers for limit set B.
- Rags (maximum 6 sq. ft. total) allowed for cleaning.

3.3 ENGINEERED CONTROLS

Engineered controls are the primary means of preventing a criticality in the Glovebox HA-20MB. These controls include the following:

- Containers limit height of fissile material to 17.8 cm (7 in.).
- Glovebox seismically qualified to remain upright during an earthquake.
- Cover seal over old conveyor housing under the glovebox so that fissile material does not enter during a fire.
- Old conveyor equipment remains in the housing to prevent fissile material containers from falling into conveyor during earthquake, if cover comes loose.
- Potential liquid depth around containers limited to 5.08 cm (2") because elevation of HA-20MB only 5.08 cm (2") lower than HA-28

3.4 ADMINISTRATIVE CONTROL IMPLEMENTATION

Criticality Prevention Specifications (CPS), postings and procedures provide limits and controls for handling fissionable materials, moderators, and other conditions that will assure criticality safety. These controls will address the limit sets of Tables 3-2 & 3-3 and process controls of Section 3.2.

The criticality analysis in this document demonstrates that a single failure of any administrative control will not result in a k_{eff} that will exceed the criticality prevention criterion.

3.5 SUPPORTING INFORMATION

Operations within Glovebox HA-20MB require:

Fire Fighting Category: C.

This allows mists or fogs during fire fighting, but no directed solid streams of water are allowed (that may move or upset containers of fissionable materials).

3.6 EVALUATION ASSUMPTIONS

The important assumptions of this criticality safety evaluation are:

- The only operation analyzed is cementation.
- Glovebox holdup is evenly distributed throughout glovebox.
- It is not credible for significant quantities of fissile mass to get into the five gallon feedwater tank.
- Glovebox is seismically qualifed and remains upright and horizontal during earthquake.
- Neutron reflection from people and other objects external to glovebox is conservatively modeled as 30.5 cm of water.
- Neutron reflection from hands and other objects internal to glovebox is conservatively modeled as 2.54 cm of water around single containers and around the outside of close-packed groups of containers.
- Fissile material is conservatively modeled as ^{239}Pu.
- It is not credible to have uranium with enrichment greater than 50% ^{235}U.
- It is unlikely that SS&C, ash, or oxide, as described in Appendices F and G has H/X>20.
- Maximum water content in cemented billets is 90 volume percent. A ratio of at least 1500 g cement in 4.73 L is sufficient to displace 10 volume percent water.

Cementation procedures require more than this ratio of cement to water mixed prior to placing the mixture in cement billet containers.

- The auger/conveyor and crusher units are part of the feed material when determining quantity of plutonium in open feed containers.
- Internal glovebox fire suppression is dry so that a major fire or earthquake is required to get water into glovebox.

4.0 METHODOLOGY

4.1 ANALYSIS PHILOSOPHY

It is desired to both maximize the quantity of SS&C, ash, or oxide to be processed and allow any non-solution plutonium residue to be cemented in Glovebox HA-20MB. Therefore, two limit sets are evaluated. One set limits the glovebox to 1200 g fissile based upon plutonium and water conservatively representing any plutonium or uranium (^{235}U enrichment less than or equal to 50%) compounds. The second set allows up to 2100 g fissile in the glovebox if the feed material is characterized as SS&C, ash, or oxide as described in Appendices F and G and there is no free liquid in the feed container.

The computer code, MCNP 4B,* is used to calculate the k_{eff} of the allowed limit sets and credible upset events. Validation of this code was performed by evaluation of benchmark experiments involving the materials that will be used in this glovebox. As described in Section 4.2, Erickson evaluated plutonium and uranium in systems involving water and concrete as reflectors and water as a moderator. Because Glovebox HA-20MB will be mixing cement with the fissile material, another benchmark experiment using concrete as a moderator was evaluated as reported in Appendix B.

4.2 MCNP CODE

The Monte Carlo code MCNP Version 4B, was certified (Schwinkendorf 1998) and validated (Erickson 1998a and Lan 1999) for plutonium systems such as the operation in this glovebox. Because that validation did not include concrete or cement as a moderator, an additional validation was performed and reported in Appendix B, MCNP 4B Computer Code Validation. Room temperature cross sections were used for the MCNP calculations. In Appendix B, a maximum allowable k_{eff} value of 0.932 was established for calculations for limit Set A that could contain metal chunks large enough to warrant the metal limit. For limit set B, the material charaterized by the descriptions of Appendices A and F can be considered non-metal for purposes of setting a k_{eff} bias with a maximum allowable k_{eff} value of 0.942. These values are for calculations with statistical uncertainties ≤ 0.002 and assure subcriticality with an acceptable margin, including the uncertainties in the analytical methods and benchmark experimental data.

4.3 SUBCRITICALITY LIMIT

For the purposes of this report, the principal criticality prevention criterion or parameter is that the effective neutron multiplication (or criticality) factor (k_{eff}) shall not exceed 0.95 (i.e., $k_{eff} \leq 0.95$) for all permitted normal configurations of materials, containers, etc., and for any credible off-normal event. This criterion is based on implementing the applicable DOE Orders, ANSI standards, and HNF-PROs. The subcriticality criterion is used to judge the acceptability of a calculated k_{eff} value for fissionable material configuration. This criterion must account for

*MCNP & Monte Carlo are trademarks of the Regents of the University of California, Los Alamos National Laboratory.

the bias inherent in the code and cross sections used, any uncertainties in the physical problem being analyzed, and the uncertainties in both the bias determination (the experimental basis) and the calculational methods.

4.4 APPLICATION OF DOUBLE CONTINGENCY PRINCIPLE

This analysis must meet the requirements of HNF-PRO-334, *Criticality Safety General Requirements,* (FDH 2000), HNF-PRO-537, *Criticality Safety Control of Fissionable Material,* (FDH 1997a) and HNF-PRO-539, *Criticality Safety Evaluations* (FDH 1997b). HNF-PRO-539 states that for all new operations and changes pertinent to criticality safety issues in existing operations, the CSER is required to demonstrate that there is an acceptable margin of subcriticality for all normal and credible abnormal conditions. To demonstrate the Double Contingency Principle is satisfied, this CSER must show that there are sufficient factors of safety in the operation of Glovebox HA-20MB such that at least two unlikely, independent, and concurrent changes in process conditions are required before a criticality accident is possible.

4.5 HAZARDS ASSESSMENT

Identification of the contingencies for the operation described in Section 2.0 and evaluated in Section 5.0 used a hazards assessment technique called a Preliminary Hazard Assessment (PHA). The goal of this effort is to identify deviations from the planned operation that may pose a challenge to criticality safety. Analysis is performed as necessary to demonstrate that each identified condition satisfies the criticality safety criteria.

In a PHA, an interdisciplinary team uses a disciplined, systematic approach to identify hazards and deviations that could lead to undesirable consequences. Because the criticality safety concerns usually arise from deviations from the process design, an experienced team leader systematically guides the team through the planned operation. Off-normal events are identified and separated into likely and unlikely to happen during the lifetime of the operation. The likely events become part of the base case and the unlikely events are the contingencies of Section 5.0. The detailed results of this assessment are presented in Appendix D.

5.0 EVALUATION AND RESULTS

5.1 NORMAL CASE

Normally, this glovebox receives containers with 60 g or less plutonium and mixes these together in bowls to prepare containers that contain on the order of 180 g of plutonium for disposal. However, the feed containers could contain just a few grams or 200 g of plutonium each. Because of the variability of the plutonium content of this residue, it would be hard to define what the normal case would be. In fact, such a model would add very little value over the base case, except to conclude that the reactivity would be less if the fissile material was not in the worst concentration assumed in the base case. Also, one spacing violation is assumed in the base case that also covers the quasi-normal condition of a container or auger/conveyor with the maximum 200 g of plutonium being used to top off a mixing bowl with nearly 200 g in it.

The models used for this criticality safety evaluation are described in Section 5.2 as base cases. There will be one for limit set A, 1200 g plutonium and one for limit set B, 2100 g plutonium glovebox limit. Contingencies are described in Section 5.3. Input files can be found in Appendix C and model figures can be found in Appendix E.

5.2 BASE CASE

This section presents the standard model of the HA-20MB Glovebox under base conditions of operations. The base case is composed of the normal operation with all parameters at their limiting values and likely abnormal conditions. This model includes two adjacent mixing bowls to represent either one spacing violation or the transfer of material from one container to another. Fissionable, moderating, and reflecting materials are modeled in the most conservative arrangement to represent the highest neutron multiplication for the glovebox.

Base cases for Limit Set A (1200 g plutonium) and Limit Set B (2100 g plutonium) are described in detail in the sections below. The items modeled within the glovebox are the mixer bowls, cement billet cans, and feed cans. A 2.54 cm (1 in.) of water is placed around containers or groups of containers in the model to represent neutron reflection from operator hands and other objects within the glovebox. A full neutron reflecting, 30.5 cm water jacket is placed around, under, and over the glovebox to allow operators and technicians to approach the glovebox from any angle. Details of the base model for Limit Sets A and B are summarized in Table 5-1, and Table 5-3, respectively.

5.2.1 Base Case Model for Limit Set A: 1200 g Plutonium Limit Set

The base case model for the unrestricted moderation feed had a k_{eff} of 0.8647±0.0009 (case c0001f1b7b). This value is well below the allowable k_{eff} of 0.932. Description of this model is as follows.

Table 5-1. Base Case Model for 1200 g Plutonium Limit Set

Glovebox Assumptions	Glovebox is surrounded with a minimum of 30.48 cm (12 in.) of water for neutron reflection. Rectangular transverse cross-section instead of actual slanted-side outlines. 2.54 cm (1 in.) water reflection representing hands around each container group. Array of close packed triangular pitched 2.76 L cans filled with cement or water surround each group of cans. Pu holdup in glovebox included in total glovebox mass limit. Modeled as 300 g Pu in thin 0.001 cm layer over entire floor of glovebox.
Glovebox dimensions	132.1 cm (52 in.) deep, 91.44 cm (36 in.) high, 518.16 cm (204 in.) long. The length is 45.7 cm (18 in.) longer than the actual glovebox to include the adjoining Conveyor Glovebox HA-28.
Mixer bowls	Two 4.80 L bowl shape 20.3 cm (8 in.) diameter and 18.0 cm (7.1 in.) deep. Lower part of bowl is hemispherical with flattened bottom. The height is modeled slightly greater than the actual height of 17.8 cm (7 in.) so the volume is larger than the actual volume of 4.73 L. Each bowl contains 200 g Pu as PuO_2 mixed with water to the full volume. The two bowls are touching to represent a single spacing violation, and are located in a corner of the glovebox spaced 25.4 cm (10 in.) from other containers.
Feed cans and Billet cans	2.76 L cylinder 14.0 cm (5.5 in.) diameter and 18.0 (7.1 in.) high. The height is modeled slightly greater than the actual height of 17.8 cm (7 in.) so the volume is larger than the actual volume of 2.73 L. 500 g Pu in 7 cans filled with 90 vol% water, 10 vol% carbon represents both unrestricted moderation feed cans and cement filled cans.
Sieve Pan Assembly	Not explicitly modeled since covered by feed and billet cans.
Crusher Unit	Not explicitly modeled since covered by feed and billet cans.
Auger/Conveyor Unit	Not explicitly modeled since covered by feed and billet cans.
Feedwater tank	Not explicitly modeled since covered by external water reflection and cement cans reflection.
Maintenance fluids	Not explicitly modeled since covered by water reflection.
Sweeps container	Not included since more reactive to have all Pu in billet cans, feed cans, and bowls.
Room Assumptions	One 2.76 L cylindrical can 15.2 cm (6 in.) from glovebox wall with 200 g Pu with water representing waste barrel moving past north end of glovebox.

5.2.2 Glovebox HA-20MB

A Glovebox HA-20MB model for the MCNP problems was established based on dimensions in the drawings from which the Figures 2 and 3 were derived. A rectangular transverse cross-section was adopted in the model instead of the slanted-side outline shown in Figure 2. The metal glovebox walls, floor, and ceiling were not modeled, but were surrounded by 30.48 cm (12 in.) full water reflection.

Only the mixer bowls, cementing cans, and feed cans were modeled inside the HA-20MB Glovebox. Volumes of the various equipment items that would hold feed materials such as the auger hopper and crusher hopper were not explicitly modeled, but assumed to be part of the group of feed containers with mass within that limit. Cemented fissile-bearing cans were modeled in a close cluster surrounded by close packed cans of cement. Clusters of fully filled mixer bowls were modeled up against the glovebox wall in a corner.

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 SS&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.

5.2.3 Feed and Cement Container

Feed and cement containers were modeled as cylinders with a volume of 2.76 L as the interior cylinder of 14.0 cm (5.5 in.) diameter by 18.0 cm (7.1 in.) height. They contain either feed material with fissile material, cement with fissile material, or cement without fissile material. For mixtures of cement and fissile material, the cement acts as a moderator and the most reactive container is one with the most water. Cementation procedures require more cement than required to displace 10 volume percent water. Therefore, 90 volume percent water content was used for those containers. For limit set B the rest of the cement container is filled with the specified mass of plutonium as plutonium oxide and silicon oxide to fill the 2.76 L per container. The silicon oxide, water, and plutonium oxide mixture bonds the cement for limit set B. Cement containers without fissile material act as reflectors where the greatest neutron reflectivity occurs with 9% water in the cement and close packing around the containers with fissile material.

Feed and cement containers are modeled differently for limit set A than for limit set B. For limit set A, the feed and cement container is 90 volume percent water with the remaining 10 volume percent containing both the specified plutonium as plutonium oxide and carbon which is the most reactive constituent along with the plutonium oxide. The carbon, water, and plutonium oxide mixture bounds both the feed material and cement for limit set A. For limit set B, the material in the feed containers is characterized by Appendices F and G and has an effective maximum moderation H/X <20. That feed material is modeled as the plutonium as plutonium oxide, sufficient water to make H/X = 20 with the rest of the volume of the container filled with 67% silicon oxide and 33% carbon.

5.2.4 Mixer Bowl

A detailed model of the curved bottom mixer bowl was created. For the feed material charged to the bowl, concentrations of Pu and water were assumed, in a full volume of water. Two 4.80 L bowls, each 20.3 cm (8 in.) diameter and 18.0 cm (7.1 in.) deep are included in the model. The lower part of the bowl is hemispherical with a flattened bottom. The height is modeled slightly greater than the actual height of 17.8 cm (7 in.) so the volume is larger than the actual volume of 4.73 L. Each bowl contains 200 g Pu as PuO_2 mixed with water to the full volume. The two bowls are touching to represent a single spacing violation, and are located in a corner of the glovebox spaced 25.4 cm (10 in.) from other containers.

5.2.5 HA-28 Conveyor Fissile Movement Past HA-20MB Glovebox

Glovebox HA-20MB is open to the HA-28 conveyor, providing a path for fissile material movement to, from, and past HA-20MB. The PFP conveyor CPS (CPS-Z-165-80031) requires an edge-to-edge spacing limit of 25.4 cm (10 in.) between a container on a conveyor and a loaded container in a connecting glovebox. It is more reactive to have the containers in Glovebox HA-20MB fully reflected than to be spaced 25.4 cm (10 in.) from allowed fissile containers in Conveyor Glovebox HA-28. Therefore, the base case was reflected. A variation of the base case was created with one 4.7 L can containing 400 g plutonium of unrestricted H/X from conveyor HA-28 inside the glovebox with 25.4 cm (10 in.) spacing from other containers. For the loss of spacing contingency, the conveyor can was brought into contact with the plutonium cans while maintaining reflective cement cans on the other sides of the plutonium cans.

5.2.6 Glovebox Filter Holdup for HEPA Filter Replacement Operation

PFP gloveboxes have in-place High Efficiency Particulate Air (HEPA) filters in the exhaust lines to remove plutonium dust and other particulate. The nominal 20.3 cm x 20.3 cm x 15.2 cm (8 in. x 8 in. x 6 in.) filter is normally located in a recess in the glovebox roof. A glovebox would only have one significantly contaminated filter since experience has shown that even if there are two filters in sequence, only the first is contaminated with sufficient fissile material to be of any concern for criticality safety. The second filter will be contaminated but only with milligram quantities of plutonium (unless the first filter has been physically broken through).

CSAR 80-014 shows that over the credible range of plutonium particle densities, criticality in an optimally moderated filter is not credible at either full or nominal water reflection. In Glovebox HA-20MB with water lines, nominal reflection is considered normal. Per CSAR 80-014, dozens of filters are needed to approach criticality at low plutonium densities; at higher densities, tens of kg of plutonium are needed; and in between, both the number and mass required for criticality is incredible. Clearly the HEPA filter alone is not a threat to criticality safety.

The HEPA filter is made of material that is considered a moderator, so the HEPA filter is classified as having unrestricted moderation. CSER 80-014 shows that for a critical configuration at an optimal moderation of 30 g Pu/L and full water reflection, the 111 g of plutonium contained in the 3.72 L media volume of the 20.3 cm x 20.3 cm x 15.2 cm (8 in. x 8 in. x 6 in.) HEPA filter at 30 g/L is about 21% of the minimum critical mass. Glovebox holdup is limited to 300 g and includes the fissile material in the HEPA filter. Even if all this holdup was in the filter, not a credible scenario, the result is only 60% of a MCM. No containers of fissionable material are allowed in the glovebox while removing a HEPA filter. Floor accumulations are minimized by the requirement to expeditiously clean up spills. Therefore, reactivity would not be increased significantly above that for the filter by itself, which is well within allowables for credible accumulations in the filter.

5.2.7 Base Cases Results for Limit Set A

Base case evaluations were conservatively modeled to represent the operations defined in Section 4.4. The results for all of the base case evaluations are given in Table 5-2. These k_{eff}s are all significantly less than the criticality safety limit of 0.932. The criticality safety criterion has been met for the base situation with unrestricted moderation feed.

The base case (case c0001f1b7b) had a k_{eff} of 0.8647± 0.0009. The other cases in Table 5-2 are sensitivity studies that were used to develop this base case. These cases addressed issues of fissile material location, reflection, moderation, composition, and interaction.

Case c0001f1b7c showed that it is more reactive to have the fissile cans surrounded by close packed cement cans than to have the cans located in a corner of the glovebox with full water reflection on two sides. Case c0001f1b7e, with water in the close packed cans surrounding the fissile containers, had essentially the same k_{eff} as the base case c0001f1b7b, with cement in the surrounding containers.

The set of cases c0001f1b3a, c0001f1b4a, c0001f1b1a, c0001f1b6a, c0001f1b8a, c0001f1b10b, and c0001f1b11a varied the number of fissile cans from three to ten, with the same 500 g Pu fissile content. This showed that concentrations higher or lower than the base case of seven cans would have lower reactivity.

The k_{eff} for Case c0001f1b13a was lower than the base case c0001f1b7b, showing that it is more reactive to have close packed cement cans reflection surrounding the fissile cans (with nominal 5.1 cm water reflection on top of the containers) than to have the fissile containers against the fully reflecting glovebox wall along with nominal 5.1 cm water reflection around the containers.

Comparing case c0001f1b18 with the base case c0001f1b7b showed that it is more reactive to have close packed cement can reflection surrounding the fissile containers than to have the most reactive container that could be on the HA-28 conveyor (400 g Pu in 4.7 L fully moderated with water) spaced at 25.4 cm from the glovebox fissile containers.

Cases c0001f1b23, c0001f1b21, c0001f1b22, together with the base case c0001f1b7b, showed that displacing ten percent of the container volume with carbon is more reactive than substituting silicon oxide or cement for the water. The fissile cans represent both feed and cemented product containers. The 90 % water content covers hydrogeneous materials as well as water in the feed and cement containers.

Case c0001f1b20 illustrates that the two adjacent bowls in the corner of the glovebox alone provide a k_{eff} of 0.8081±0.0008. Adding the container with 200 g Pu representing a drum outside the north wall of the glovebox at 15.2 cm (6 in.) spacing (case c0001f1b19a) provides a negligible decrease in reactivity. The impact of the outside container at 15.2 cm spacing was also evaluated by comparing the base case c0001f1b7b with case c0001f1b7f, which located the drum container near the two bowls and indicated a negligible increase in k_{eff}. The impact of the outside container at 15.2 cm spacing was also evaluated by comparing the case c0001f1b7c (with the fissile cans in the glovebox corner without the outside drum container) with case c0001f1b7d (with the drum container at 15.2 cm from the cans), which had identical k_{eff}'s. The net result of these studies was that the outside drum container spaced 15.2 cm from the fissile containers in the glovebox has a negligible impact on the glovebox reactivity.

Table 5-2. MCNP Calculational Results of Base Cases in Glovebox HA-20MB for Limit Set A: 1200 g Plutonium Glovebox Total

Case	Description	K_{calc}	1σ
c0001f1b7b	500 g Pu in 7 cans 90% by volume water, 10% carbon 400 g Pu in 2 bowls filled with water. 300 g Pu holdup on floor. Close packed cans surrounded by cement cans(9% water).	0.8647	0.0009
c0001f1b7e	Same as c0001f1b7b except water cans reflection	0.8641	0.0010
c0001f1b7c	Same as c0001f1b7b except cans in corner of glovebox	0.8540	0.0008
c0001f1b7d	Same as c0001f1b7c except 200 g in 2.76 L can 15.2 cm (6 in.) outside glovebox close to cans	0.8540	0.0008
c0001f1b7f	Same as c0001f1b7b except 200 g in 2.76 L can 15.2 cm (6 in.) outside glovebox close to bowls	0.8665	0.0008
c0001f1b18	Same as c0001f1b7b except 400 g in 4.7 L can representing container on conveyor 25.4 cm (10 in.) from cans	0.8510	0.0008
c0001f1b3a	Same as c0001f1b7b except 500 g in 3 cans	0.8324	0.0009

Case	Description	K_{calc}	1σ
c0001f1b4a	Same as c0001f1b7b except 500 g in 4 cans	0.8572	0.0009
c0001f1b1a	Same as c0001f1b7b except 500 g in 5 cans	0.8590	0.0009
c0001f1b6a	Same as c0001f1b7b except 500 g in 6 cans	0.8591	0.0009
c0001f1b8a	Same as c0001f1b7b except 500 g in 8 cans	0.8510	0.0009
c0001f1b10b	Same as c0001f1b7b except 500 g in 9 cans	0.8371	0.0008
c0001f1b11a	Same as c0001f1b1a except 500 g in 10 cans	0.8256	0.0008
c0001f1b13a	Same as c0001f1b7b except 2.54 cm (1 in.) water around sides of cans as well as top, no close packed cement cans for reflection. Container groupings 25.4 cm (10 in.) apart. 400 g Pu in 4.7 L spaced 25.4 cm (10 in.) from cans representing container on conveyor	0.8603	0.0008
c0001f1b7i	Same as c0001f1b7b except 18% water content cement cans reflection	0.8721	0.0008
c0001f1b20	Only 2 bowls, full water reflection from glovebox walls	0.8081	0.0008
c0001f1b19a	Only 2 bowls plus 200 g Pu can located 6" from bowls outside glovebox	0.8046	0.0009
c0001f1b22	Same as c0001f1b7b except 7 cans with 10% SiO_2 rather than Carbon	0.8590	0.0008
c0001f1b21	Same as c0001f1b7b except 7 cans with Pu + water	0.8867	0.0008
c0001f1b23	Same as c0001f1b7b except 7 cans with 10% cement rather than Carbon	0.8487	0.0008

5.2.8 Base Case Model for Limit Set B: 2100 g Plutonium Total Glovebox

The base case model for the feed, restricted to the compositions of SS&C, ash, or oxides documented in Appendices F and G and a physical inspection by operators that the feed containers have no free liquid had a k_{eff} of 0.8607 ± 0.0009 (case c0001f2b4). This value is well below the allowable k_{eff} of 0.942.

Table 5-3. Base Case Model 2100 g Plutonium Limit Set

Glovebox Assumptions	Glovebox is surrounded with a minimum of 30.48 cm (12 in.) of water for neutron reflection. Rectangular transverse cross-section instead of actual slanted-side outlines. 2.54 cm (1 in.) water reflection representing hands around each container group. Array of close packed triangular pitched 2.76 L cans filled with cement or water surround each group of cans. Pu holdup in glovebox included in total glovebox mass limit. Modeled as 300 g Pu in thin 0.001 cm layer over entire floor of glovebox.
Glovebox dimensions	132.1 cm (52 in.) deep, 91.44 cm (36 in.) high, 518.16 cm (204 in.) long. The length is 45.7 cm (18 in.) longer than the actual glovebox to include the adjoining Conveyor Glovebox HA-28.
Mixer bowls	Two 4.80 L bowls 20.3 cm (8 in.) diameter and 18.0 cm (7.1 in.) deep. Lower part of bowl is hemispherical with flattened bottom. The height is modeled slightly greater than the actual height of 17.8 cm (7 in.) so the volume is larger than the actual volume of 4.73 L. Each bowl contains 200 g Pu as PuO2 mixed with water to the full volume. The two bowls are touching to represent a single spacing violation, and are located in a corner of the glovebox spaced 25.4 cm (10 in.) from other containers.
Feed cans	2.76 L cylinder 14.0 cm (5.5 in.) diameter and 18.0 (7.1 in.) high. The height is modeled slightly greater than the actual height of 17.8 cm (7 in.) so the volume is larger than the actual volume of 2.73 L. 900 g Pu as PuO2 with H/X =20 in 7 cans filled with 33 wt% carbon, 67 wt% silicon dioxide representing restricted moderation feed cans containing one of the identified feed materials (ash, oxide scrap, or sand, slag and crucible material). These cans are grouped together and surrounded close packed by other cement filled cans, but are spaced 25.4 cm (10 in.) from the Pu containing billet cans.
Billet cans	2.76 L cylinder 14.0 cm (5.5 in.) diameter and 18.0 cm (7.1 in.) high. The height is modeled slightly greater than the actual height of 17.8 cm (7 in.) so the volume is larger than the actual volume of 2.73 L. 500 g Pu in 7 cans filled with 90 vol% water, 10 vol% silicon dioxide represents unrestricted moderation cement filled cans. These cans are grouped together and surrounded close packed by

	other cement filled cans, but are spaced 20.5 cm (10 in.) from other Pu containing containers.
Sieve Pan Assembly	Not explicitly modeled since covered by feed and billet cans.
Crusher Unit	Not explicitly modeled since covered by feed and billet cans.
Auger/Conveyor Unit	Not explicitly modeled since covered by feed and billet cans.
Feedwater tank	Not explicitly modeled since covered by external water reflection and cement cans reflection.
Maintenance fluids	Not explicitly modeled since covered by water reflection.
Sweeps container	Not included since more reactive to have all Pu in billet cans, feed cans, and bowls.
Room Assumptions	One 2.76 L cylindrical can 15.2 cm (6 in.) from glovebox wall with 200 g Pu with water representing waste barrel moving past north end of glovebox.

5.2.9 Base Case Model Differences from Limit Set A

To increase the glovebox mass limit to 2100 g plutonium or fissile equivalent, less than optimum moderation must be assumed for the feed material. The mass limit is increased by separating the feed material from the cemented billets and requiring that the feed be material characterized as SS&C, ash, or oxide. Appendixes F and G describe the composition of that material. Also, the feed containers must be inspected as they are brought into the glovebox to assure that there is no free liquid and only one container at a time can have its cover off.

Feed containers are then restricted in moderation due to the nature of the material and the requirements of where it is stored. SS&C, ash, or oxides must have an $H/X \leq 20$, so using $H/X=20$ in these calculations is conservative. Vigilance must be exercised to maintain this restricted moderation level by inspecting each container brought into the glovebox for free liquid. Also, only one feed container can be uncovered at a time to not allow the cans to fill with water if an event breaks the glovebox windows and actuates the fire suppression water.

A minimum 25.4 cm spacing is maintained between the feed containers and the cemented billet cans. This requirement is in addition to the spacing required between the mixing bowls and the bowls and cement cans of limit set A.

5.2.10 Base Case Results for Limit Set B

Base case evaluations were conservatively modeled to represent the operations for the 2100 g plutonium total glovebox limit. The results for these base case evaluations are given in Table 5-9. These k_{eff}s are all significantly less than the criticality safety limit. The criticality safety criterion has been met for the base situation with SS&C, ash, or oxide feed.

The base case (case c0001f2b4) had a k_{eff} of 0.8607± 0.0009. The other cases in Table 5-4 are sensitivity studies that were used to develop this base case. These cases addressed issues of fissile material location, reflection, moderation, composition, and interaction.

Case c0001f2b5 with water in the close packed cans surrounding the fissile containers, had a k_{eff} of 0.8579±0.0008 which is negligibly smaller than the k_{eff} for the base case c0001f2b4 with cement in the surrounding containers.

The set of cases c0001f2b3, c0001f2bh3, c0001f2bh1, and c0001f2bh4 varied the number of fissile limited moderation feed cans from five to ten, with the same 900 g Pu fissile content. The number of fissile cans was also varied in cases c0001f2b1 and c0001f2b2. These cases showed that concentrations higher or lower than the base case of seven cans would have lower reactivity.

Sensitivity to the number of feed cans was demonstrated in the sensitivity studies for the Limit Set A base case in Section 5.2.7. As a check, the case c0001f2b3 reduced the number of fissile cement feed cans from seven to five, with the same 500 g Pu fissile content. The resulting lower k_{eff} showed that concentrations higher than the base case of seven cans would have lower reactivity and indicated that the most reactive configuration would be the same .

The k_{eff} for case c0001f2b6a was lower than the base case c0001f2b4, showing that it is more reactive to have close packed cement cans reflection surrounding the fissile cans (with nominal 5.1 cm water reflection on top of the containers) than to have the fissile containers against the fully reflecting glovebox wall along with nominal 5.1 cm water reflection around the containers.

Comparing case c0001f2b8 with the base case c0001f2b4 showed that it is more reactive to have close packed cement can reflection surrounding the fissile containers than to have the most reactive container that could be on the HA-28 conveyor (400 g Pu in 4.7 L fully moderated with water) spaced at 25.4 cm from the glovebox fissile containers. Case c0001f2b8 located the conveyor container 25.4 cm from both feed and cement product container groupings.

Table 5-4. MCNP Calculational Results of Base Cases in Glovebox HA-20MB for Limit Set B: 2100 g Plutonium Total Glovebox

Case	Description	k_{calc}	1σ
c0001f2b4	500 g Pu in 7 cans 90% by volume water, 10% silicon oxide 400 g Pu in 2 bowls 100% water touching. 900 g Pu in 7 cans H/X=20 33% carbon 67% silicon oxide 300 g Pu holdup on floor. 200 g Pu in 2.7 L outside glovebox at 15.24 cm (6 in.) spacing from glovebox wall next to bowls representing drum passing by. Close packed cans surrounded by cement cans. 2.54 cm (1 in.) water reflection on top of cans.	0.8607	0.0009

Case	Description	k_{calc}	1σ
c0001f2b3	Same as c0001f2b4 except 900 g in 5 cans, H/X=20.	0.8591	0.0009
c0001f2b1	Same as c0001f2b3 except 500 g in 5 cans, 90% water, 10% silicon oxide, 900 g in 5 cans, H/X=20.	0.8530	0.0009
c0001f2b2	Same as c0001f2b1 except 900 g in 6 cans, H/X=20.	0.8535	0.0008
c0001f2b5	Same as c0001f2b4 except water cans reflection.	0.8579	0.0008
c0001f2b8	Same as c0001f2b4 except 4.7 L can with 400 g Pu, 25.4 cm (10 in.) from other cans representing container on HA-28 conveyor.	0.8456	0.0008
c0001f2b6a	Same as c0001f2b4 except 2.54 cm (1 in.) water around sides of cans as well as top, next to walls, no close packed cement cans for reflection. 400 g in 4.7 L can representing conveyor container. Container groupings 25.4 cm (10 in.) apart.	0.8553	0.0008
c0001f2bh2	Same as c0001f2b4 except no 500 g Pu in 7 cans, 900 g in 5 cans H/X=20.	0.8074	0.0008
c0001f2bh3	Same as c0001f2b4 except no 500 g Pu in 7 cans, 900 g in 6 cans H/X=20.	0.8088	0.0008
c0001f2bh1	Same as c0001f2b4 except no 500 g Pu in 7 cans, 900 g in 7 cans H/X=20.	0.8094	0.0009
c0001f2bh4	Same as c0001f2b4 except no 500 g Pu in 7 cans, 900 g in 10 cans H/X=20.	0.8076	0.0009

5.3 CONTINGENCY ANALYSIS

The contingency analysis section addresses the effect of various unlikely, off-normal events on the critical parameters and their associated controls to confirm the double contingency criterion has been met.

Mass is controlled administratively by measurement. The total fissile mass of the glovebox is limited to1200 g plutonium or fissile equivalent for limit set A and 2100 g plutonium or fissile equivalent for limit set B. These mass limits were determined by the maximum mass that would satisfy the criticality safety limits on k_{eff} for the limiting conditions of the seismic contingency analysis. Sections 5.3.4, 5.3.5, 5.3.10, and 5.3.11 address the contingency of exceeding the glovebox mass limit as well as the container limit of 200 g plutonium or equivalent.

Volume and Geometry are physically controlled by restrictions on container volume and height. It is important in an unrestricted moderation glovebox not to allow large, low neutron leakage arrangement of containers. This is accomplished by limiting the height of the containers in the base case and the size of container that could be mistakenly stacked. Container height is limited to 17.8 cm and the volume of containers other than mixing bowls, sieve pan assembly, and crusher/auger is 2.76 L. Sections 5.3.4 and 5.3.10 address the contingency of exceeding the volume limits.

Density is not controlled. The most reactive credible densities were used for all materials.

Moderation is not controlled for limit set A. For limit set B, the feed material must be SS&C, ash, or oxide as described in Appendices F and G, cannot have free liquid in the feed containers, or more than one feed container open at one time. Sections 5.3.9 and 5.3.11 address the contingency of the H/X ratio being too high in the feed material.

Reflection is controlled by a dry fire suppression system within the HA-20MB Glovebox but not controlled by the volume of water or number of water-bearing containers within the glovebox. Sections 5.3.1, 5.3.2, 5.3.8, and 5.3.9 explain the contingencies where an earthquake or major fire causes the glovebox windows to melt or break and the fire suppression system to rain water down on the glovebox contents.

Interaction is controlled administratively by a minimum 25.4 cm (10 in.) spacing requirement between mixing bowls and between mixing bowls and the other containers of fissile material for both limit sets. For limit set B, the feed material and cemented fissile containers shall be separated by 25.4 cm. One spacing violation is included in the base case. Sections 5.3.4 and 5.3.10 address the contingency of container stacking. Firefighting Category C is specified to restrict solid streams of water that could cause significant loss of interaction control. Stacking bounds a second spacing violation.

Enrichment, Concentration, and Isotopes are not controlled for plutonium which was assumed to be 100 wt% ^{239}Pu. This conservatively encompasses all allowed fissionable materials including uranium enriched to 50% ^{235}U. The hazards assessment, Appendix D, states that it isn't credible to exceed this uranium enrichment in Glovebox HA-20MB.

Neutron Absorption is not controlled.

The off-normal situations of fissionable material handling for the operations in Glovebox HA-20MB are listed in Tables 1-2 and 1-4. The following discussions in this section give a description of the off-normal conditions and the calculational results. Each of the unlikely off-normal events results from a loss of one or more controls, and is therefore considered to be a contingency. For each contingency, the model assumed the most limiting allowed conditions for criticality controls shown in Section 3.0 including likely off-normal events.

5.3.1 Contingencies for Limit Set A

Contingencies for the 1200 g plutonium or equivalent fissile mass limit set are evaluated by imposing the unlikely event upon the base case described in Section 5.2.1. Each of these events are described below.

5.3.2 Seismic Event

The seismic contingency is the limiting event for setting the glovebox fissile mass limits. The Plutonium Finishing Plant Final Safety Analysis Report (FDH 1999) states that Glovebox HA-20MB is seismically qualified. The glovebox will remain upright but the contents can move around during an earthquake. The worst case is for the feed, cement billets, and mixing bowls to group together, thus losing the 25.4 cm spacing control between these groups of containers and then flooding.

The source of possible, but highly unlikely, flooding during a seismic event would be breakage of the room fire sprinkler pipes or heads combined with breakage of the glovebox windows to allow entry of water to the glovebox and contents. Open containers could collect water and free liquid could accumulate to a depth of 5.08 cm (2 in.) on the floor before draining into the HA-28 conveyor. Analysis with water to this depth adequately covers the potential flooding depth caused by this elevation difference. Table 5-5 shows the seismic event for several arrangements of the base case containers where k_{eff} does not exceed 0.923 for sprinkler spray densities up to 0.1 g/cc.

Water spray densities from the sprinkler system was evaluated as described in Appendix I. Fire suppression water densities will be on the order of 0.01 g/cc or less for contingencies that could actuate or break the water lines. Table 5-5 shows a parametric study of interspersed water through the credible range of sprinkler water densities for the seismic contingency for limit set A. The reactivity steadily rises with no intermediate peak. It is assumed in this evaluation that unlikely water densities could range up to 0.1 g/cc and greater water densities are not credible.

Table 5-5. MCNP Calculational Results of Seismic Cases in Glovebox HA-20MB for 1200 g Plutonium Limit Set

Case	Description	k_{calc}	1σ
c0001f1q1a	500 g Pu in 5 cans 90% by volume water, 10% carbon 400 g Pu in 2 bowls filled with water. 300 g Pu holdup on floor. All containers grouped together with close packed cement cans surrounding all Pu cans and bowls. Glovebox flooded to 5.08 cm (2 in.), rest of glovebox filled with 10% dense water spray.	0.9226	0.0009

Case	Description	k_{calc}	1σ
c0001flq1	Same as c0001flq1a but 4 cans	0.9152	0.0009
c0001flq4	Same as c0001flq1a but 7 cans	0.9120	0.0009
c0001flq3	Same as c0001flq1a but 7 cans (same can arrangement as base case c0001flb7b)	0.9015	0.0009
c0001flq5	1200 g Pu in slab on floor of conveyor housing at 150 g/L	0.4344	0.0007
c0001flq1e	Same as c0001flq1a except 0.001 g/cc water spray	0.8789	0.0008
c0001flq1b	Same as c0001flq1a except 0.01 g/cc water spray	0.8840	0.0009
c0001flq1c	Same as c0001flq1a except 0.05 g/cc water spray	0.9004	0.0009
c0001flq1d	Same as c0001flq1a except 0.15 g/cc water spray	0.9398	0.0009

5.3.3 Major Fire

It is unlikely that the PFP will have a major structural fire that will melt the glovebox windows and actuate the fire suppression sprinklers. That contingency is evaluated two ways. One is to assume that open containers fill with water but don't overflow in such a way as to wash out fissile material. The other evaluation assumes that all the fissile material in open containers washes out onto the floor of the glovebox that fills to a 5.08-cm (2-in.) depth before draining into the HA-28 conveyor. This depth adequately covers the potential flooding caused by the elevation difference between the two gloveboxes. Table 5-6 shows the results of these calculations with the k_{eff}'s less than 0.86.

Table 5-6. MCNP Calculational Results of Flooding Cases in Glovebox HA-20MB for 1200 g Plutonium Limit Set

Case	Description	k_{calc}	1σ
c0001flf1	Same as base case c0001flb7b except glovebox flooded to 5.08 cm (2 in.), rest of glovebox filled with 10% dense water spray.	0.8567	0.0009
c0001flf2	Same as base case c0001flb13a (no close packed cement cans for reflection) except flooded to 5.08 cm (2 in.), rest of glovebox filled with 10% dense water spray	0.8329	0.0008
c0001flf3	1200 g Pu mixed with water in 5.08 cm (2 in.) layer on glovebox floor	0.2047	0.0003
c0001flf4	1200 g Pu in water in 0.13 cm thick slab on glovebox floor at 150 g/L	0.6571	0.0011

5.3.4 Stacking Event

Stacking is prohibited at the PFP. Also, operators are trained not to move one container over another. However, it is credible, but unlikely, that either a mixing bowl or another fissile container is moved over the top of another. For this contingency, a mixing bowl is analyzed stacked on top of another mixing bowl or on the top of the most reactive arrangement of other fissile containers. Also, an additional 2.76 L container with 200 g of plutonium is stacked on top of the most reactive arrangement of other fissile containers. These results are presented in Table 5-7 with k_{eff} not exceeding 0.93.

Table 5-7. MCNP Calculational Results of Stacking Cases in Glovebox HA-20MB for 1200 g Plutonium Limit Set

Case	Description	k_{calc}	1σ
c0001f1s3	Same as base case c0001f1b7b except one bowl with 200 g Pu stacked on top of seven 2.76 L cans containing 500 g Pu in center of glovebox with cement can reflection.	0.9296	0.0008
c0001f1s4	Same as base case c0001f1b7c except one bowl with 200 g Pu stacked on top of seven 2.76 L cans containing 500 g Pu in corner of glovebox with cement can reflection.	0.9223	0.0009
c0001f1s1	Same as base case c0001f1b7b except one bowl with 200 g Pu stacked on top of five 2.76 L cans containing 500 g Pu in center of glovebox with cement can reflection.	0.9276	0.0009
c0001f1s2	Same as base case c0001f1b7b except one bowl with 200 g Pu stacked on top of five 2.76 L cans containing 500 g Pu in corner of glovebox with cement can reflection.	0.9214	0.0009
c0001f1s6	Same as base case c0001f1b7b except one bowl stacked on top of other bowl.	0.8674	0.0008
c0001f1s5	Same as base case c0001f1b7b except one extra 2.76 L can with 200 g Pu stacked on top of seven cans containing 500 g Pu.	0.9078	0.0009

5.3.5 Interaction Events

Minimum spacing is required for certain fissile containers within the glovebox and between these containers and fissile containers in Conveyor Glovebox HA-28, and to waste drums and wagons in Room 235B. One spacing violation inside the glovebox is likely and is included in the base case. The other spacing violations are unlikely and are analyzed as contingencies. The seismic event conservatively bounds the loss of spacing within the glovebox. Loss of the 25.4 cm minimum spacing to containers in Conveyor Glovebox HA-28, the 15.2 cm minimum spacing to the waste drums passing the north side of the glovebox, and the wagons allowed in the room are reported in Table 5-8. No k_{eff} exceeds 0.91.

The sensitivity cases described in Section 5.2.1 showed that the drum container would have a negligible impact on the glovebox reactivity as long as the 15.2 cm spacing is maintained to the containers in the glovebox. Interaction contingencies were evaluated to assess the impact of losing this spacing. The k_{eff} for case c0001fl b7g of 0.8687±0.0008, with the outside can against the glovebox wall next to the two bowls, can be compared directly to the base case c0001fl b7b k_{eff} of 0.8647±0.0009. The k_{eff} for case c0001fl b7h of 0.8669±0.0008, with the outside can against the glovebox wall next to the fissile cans in the corner of the glovebox, can be compared directly to the case c0001fl b7c k_{eff} of 0.8540±0.0008, with the fissile cans in the corner of the glovebox. This comparison indicated an increase in k_{eff} of 0.013 associated with losing the 15.2 cm spacing. While the k_{eff}'s calculated for this contingency are well below the k_{eff} limit of 0.932 for this system, the increase in k_{eff} associated with the loss of spacing could impact other contingencies, such as stacking and seismic, if the loss of spacing was included as part of the base case. To illustrate this impact, case c0001fl s8 was constructed as a duplicate of the stacking contingency case c0001fl s4 with the fissile cans and a stacked bowl in the glovebox corner, with the addition of the outside drum container adjacent to the glovebox wall next to the cans. The k_{eff} of case c0001fl s8 was 0.9351±0.0009, which is 0.013 higher than the case c0001fl s4 k_{eff} of 0.9223±0.0009, and exceeds the k_{eff} limit of 0.932. A similar increase would be expected on seismic contingencies, which would also exceed the k_{eff} limit. Therefore, the 15.2 cm spacing limit is required for the current analysis assumptions.

Table 5-8. MCNP Calculational Results of Interaction Cases in Glovebox HA-20MB for 1200 g Plutonium Limit Set

Case	Description	k_{calc}	1σ
c0001flwl	Same as base case c0001fl b7c except one wagon with max Pu loading under glovebox directly under cans.	0.8451	0.0010
c0001flb7h	Same as base case c0001fl b7b except 2.76 L container with 200 g Pu representing drum outside glovebox located against glovebox wall adjacent to seven 2.76 L cans containing 500 g Pu in corner.	0.8669	0.0008
c0001flb7g	Same as base case c0001fl b7b except 2.76 L container with 200 g Pu representing drum outside glovebox located against glovebox wall adjacent to two 4.8 L bowls containing 400 g Pu in corner.	0.8687	0.0008
c0001flb17	Same as base case c0001fl b7b except 400 g in 4.7 L can adjacent to other cans	0.9097	0.0009

Case	Description	k_{calc}	1σ
c0001f1bs8	Same as stacking case c0001f1s4 except 2.76 L container with 200 g Pu representing drum outside glovebox located against glovebox wall adjacent to seven 2.76 L cans containing 500 g Pu in corner.	0.9351[(a)]	0.0009

(a) This case includes two contingencies, a stacking violation and a spacing violation, and was only included to illustrate why the spacing violation was not part of the base case configuration.

5.3.6 Other Contingencies for Limit Set A

Extra Mixing Bowl with Some Fissile Mass Out of Other Containers

The additional 200 g Pu container stacked on the other containers (case c0001f1s3) covers the contingency of an extra mixing bowl with some of the fissile mass outside the other containers with a k_{eff} of 0.9296± 0.0008.

Excess Glovebox Holdup Exceeding the Glovebox Mass Limit

The additional 200 g Pu container stacked on the other containers (case c0001f1s3) covers the contingency of excess holdup exceeding the glovebox mass limit by up to 200 g since it is more reactive to have the excess Pu concentrated in one container on top of the other containers than to have the Pu distributed around the glovebox as holdup.

Container too Large

The stacking of two 4.8 L mixing bowls, each containing 200 g of Pu with unrestricted moderation (case c0001f1s6) provides a bounding reactivity for up to 400 g Pu in a total of 9.6 L, which is much larger than any container that could be introduced into the glovebox. Therefore the contingency of having a container larger than the 4.8 L mixing bowl is covered.

Extra Oil or Plastic

The fire case c0001f1f1 is an analysis of the base case configuration with 5 cm of water flooding on the floor and 10% dense water spray filling the glovebox. The k_{eff} for this case was 0.8567± 0.0009, which was lower than the 0.8647±0.0009 k_{eff} for the base case with nominal reflection (case c0001f1b7b). Extra oils or plastics in the glovebox would have to be very extensive in order to exceed the hydrogen content of the water in either of these cases.

5.3.7 Contingencies for Limit Set B

Contingencies for the 2100 g plutonium or equivalent fissile mass limit set are evaluated by imposing the unlikely event upon the base case described in Section 5.2.2. Each of these events is described below.

5.3.8 Seismic Event

The seismic contingency is the limiting event for setting the glovebox fissile mass limits. The Plutonium Finishing Plant Final Safety Analysis Report (FDH 1999) states that Glovebox HA-20MB is seismically qualified. The glovebox will remain upright but the contents can move around during an earthquake. Worst case is for the feed, cement billets, and mixing bowls to group together, thus losing the 25.4 cm spacing control between these groups of containers and then flooding.

The source of possible, but highly unlikely, flooding during a seismic event would be breakage of the room fire sprinkler pipes or heads combined with breakage of the glovebox windows to allow entry of water to the glovebox and contents. Open containers could collect water and free liquid could accumulate to a depth of 5.08 cm (2 in.) on the floor. Flooding of the glovebox with more than 5.08 cm (2 in.) of water is not credible due to drainage out the conveyor glovebox. Table 5-9 shows the seismic event for several arrangements of the base case containers where k_{eff} does not exceed 0.942 for sprinkler water densities up to 0.1 g/cc.

Water spray densities from the sprinkler system was evaluated as described in Appendix I. Fire suppression water densities will be on the order of 0.01 g/cc or less for contingencies that could actuate or break the water lines. Table 5-9 shows a parametric study of interspersed water through the credible range of sprinkler water densities for the seismic contingency for limit set B. The reactivity steadily rises with no intermediate peak. It is assumed in this evaluation that unlikely water densities could range up to 0.1 g/cc and greater water densities are not credible.

Table 5-9. MCNP Calculational Results of Seismic Cases in Glovebox HA-20MB for 2100 g Plutonium Limit Set

Case	Description	k_{calc}	1σ
c0001f2q1	500 g Pu in 4 cans 90% by volume water, 10% silicon oxide 400 g Pu in 2 bowls 100% water. 900 g Pu in 7 cans, H/X=20 33%, carbon, 67% silicon oxide. 300 g Pu holdup on floor. All containers grouped together with close packed cement cans surrounding all Pu cans and bowls. Glovebox flooded to 5.08 cm (2 in.), rest of glovebox filled with 10% dense water spray.	0.9413	0.0009
c0001f2q2	Same as c0001f2q1 except water cans reflection	0.9410	0.0010
c0001f2q1a	Same as c0001f2q1 except 500 g Pu in 5 cans, 90% by volume water, 10% silicon oxide 900 g Pu in 5 cans, H/X=20 33%, carbon 67%, silicon oxide.	0.9387	0.0008
c0001f2q4	2100 g Pu in water layer in under-floor conveyor region.	0.6553	0.0009

Case	Description	k_{calc}	1σ
c0001f2q4a	2100 g Pu in 6.55 cm water layer in under-floor conveyor region (30 g/L).	0.7199	0.0009
c0001f2q4b	2100 g Pu in 1.3 cm water layer in under-floor conveyor region (150 g/L).	0.6582	0.0009
c0001f2q1b	Same as c0001f2q1 except 0.01 g/cc water spray	0.8991	0.0010
c0001f2q1c	Same as c0001f2q1 except 0.05 g/cc water spray	0.9199	0.0009
c0001f2q1d	Same as c0001f2q1 except 0.15 g/cc water spray	0.9612	0.0010
c0001f2q1e	Same as c0001f2q1 except 0.001 g/cc water spray	0.8938	0.0009
c0001f2q5a	Same as c0001f2q1 except 18% water content cement reflection	0.9420	0.0010

5.3.9 Major Fire

It is unlikely that the PFP will have a major structural fire that will melt the glovebox windows and actuate the fire suppression sprinklers. That contingency is evaluated two ways. One is to assume that open containers fill with water but don't overflow in such a way as to wash out fissile material. The other evaluation assumes that all the fissile material in open containers washes out onto the floor of the glovebox that fills to a 5.08-cm (2-in.) depth before draining into the HA-28 conveyor. Table 5-10 shows the results of these calculations where k_{eff} does not exceed 0.85.

Table 5-10. MCNP Calculational Results of Flooding Cases in Glovebox HA-20MB for 2100 g Plutonium Limit Set

Case	Description	k_{calc}	1σ
c0001f2f1	Same as base case c0001f2b4 except glovebox flooded to 5.08 cm (2 in.), rest of glovebox filled with 10% dense water spray.	0.8494	0.0009
c0001f2f2a	Same as base case c0001f2b5 (no close cement reflection around cans) except glovebox flooded to 5.08 cm (2 in.), rest of glovebox filled with 10% dense water spray.	0.8283	0.0009
c0001f2f3	2100 g Pu mixed with water in 5.08 cm (2 in.) layer on glovebox floor	0.6569	0.0009
c0001f2f4	2100 g Pu mixed with water at 150 g/L in 0.22 cm thick slab covered by water to 5.08 cm (2 in.) on glovebox floor	0.6575	0.0011
c0001f2f5a	Same as c0001f2f1 except one 2.76 L can with 200 g Pu filled with water, 6 other cans with 700 g and H/X = 20	0.8515	0.0009

5.3.10 Stacking Event

Stacking is prohibited at the PFP. Also, operators are trained not to move one container over another. However, it is credible, but unlikely, that either a mixing bowl or another fissile container is moved over the top of another. For this contingency, a mixing bowl is analyzed stacked on top of another mixing bowl or on the top of the most reactive arrangement of other fissile containers. Also, an additional 2.76 L container with 200 g of plutonium is stacked on top of the most reactive arrangement of other fissile containers. These results are presented in Table 5-11. The most reactive arrangement is for the mixing bowl to be stacked on top of the seven 2.7 L cans containing 500 g Pu with reflection from close packed cement cans. The k_{eff} for that case is less than 0.924.

Table 5-11. MCNP Calculational Results of Stacking Cases in Glovebox HA-20MB for 2100 g Plutonium Limit Set

Case	Description	k_{calc}	1σ
c0001f2s1	Same as base case c0001f2b4 except one bowl with 200 g Pu stacked on top of seven 2.76 L cans containing 500 g Pu in center of glovebox with cement can reflection.	0.9236	0.0009
c0001f2s2	Same as base case c0001f2b4 except one bowl with 200 g Pu stacked on top of other bowl.	0.8584	0.0008
c0001f2s3	Same as base case c0001f2b4 except one extra 2.76 L can with 200 g Pu stacked on top of seven cans containing 500 g Pu.	0.9022	0.0009
c0001f2s5	Same as base case c0001f2b4 except one extra 2.76 L can with 200 g Pu stacked on top of seven cans containing 900 g Pu, H/X=20.	0.8591	0.0009
c0001f2s4	Same as base case c0001f2b4 except one bowl stacked on top of seven 2.76 L cans containing 900 g Pu, H/X=20.	0.8610	0.0008

5.3.11 Interaction Events

Minimum spacing is required for certain fissile containers within the glovebox and between these containers and fissile containers in Conveyor Glovebox HA-28, and to waste drums and wagons in Room 235B. One spacing violation inside the glovebox is likely and is included in the base case. The other spacing violations are unlikely and are analyzed as contingencies. The seismic event conservatively bounds the loss of spacing within the glovebox. Loss of the 25.4 cm minimum spacing to containers in Conveyor Glovebox HA-28, the 15.2 cm minimum spacing to the waste drums passing the north side of the glovebox, and the wagons allowed in the room are reported in Table 5-12. The k_{eff}s do not exceed 0.91.

Table 5-12. MCNP Calculational Results of Interaction Cases in Glovebox HA-20MB for 2100 g Plutonium Limit Set

Case	Description	k_{calc}	1σ
c0001f2w1	Same as base case c0001f2b3 except one wagon with max Pu loading under glovebox directly under 7 cans with 500 g Pu.	0.8427	0.0009
c0001f2b4h	Same as base case c0001f2b4 except 2.76 L container with 200 g Pu representing drum outside glovebox located against glovebox wall adjacent to two 4.8 L bowls containing 400 g Pu in corner.	0.8602	0.0008
c0001f2b9	Same as base case c0001f2b4 except 400 g in 4.7 L can adjacent to other cans	0.9048	0.0008
c0001f2b7	Same as base case c0001f2b4 except one 200 g can with H/X=200 in middle of 6 cans with 700 g Pu, H/X=20	0.8601	0.0008
c0001f2b11a	Same as base case c0001f2b4 except 200 g in 2.2 L furnace boat mixed with water adjacent to other cans	0.8689	0.0009
c0001f2b13	Same as base case c0001f2b4 except 200 g in metal cubed 2.2 L furnace boat filled with water adjacent to other cans	0.8583	0.0009

5.3.12 Other Contingencies for Limit Set B

Extra Mixing Bowl with Some Fissile Mass Out of Other Containers

The additional 200 g Pu container stacked on the other containers (case c0001f2s3) covers the contingency of an extra mixing bowl with some of the fissile mass outside the other containers with a k^{eff} of 0.9022±0.0009.

Excess Glovebox Holdup Exceeding the Glovebox Mass Limit

The additional 200 g Pu container stacked on the other containers (case c0001f2s3) covers the contingency of excess holdup exceeding the glovebox mass limit by up to 200 g since it is more reactive to have the excess Pu concentrated in one container on top of the other containers than to have the Pu distributed around the glovebox as holdup.

Container too Large

The stacking of two 4.8 L mixing bowls, each containing 200 g of Pu with unrestricted moderation (case c0001f2s2) provides a bounding reactivity of 0.8584±0.0008 for up to 400 g Pu in a total of 9.4 L, which is much larger than any container that could be introduced into the glovebox. Therefore the contingency of having a container larger than the 4.8 L mixing bowl is covered.

Extra Oil or Plastic

The fire case c0001f2f1 is an analysis of the base case configuration with 5 cm of water flooding on the floor and 10% dense water spray filling the glovebox. The k_{eff} for this case was 0.8494± 0.0009, which was lower than the 0.8607±0.0009 k_{eff} for the base case with nominal reflection (case c0001f2b4). Extra oils or plastics in the glovebox would have to be very extensive in order to exceed the hydrogen content of the water in either of these cases.

One Feed Container with Unrestricted Moderation Brought into Glovebox

The fire case c0001f2f5a provided a k_{eff} of 0.8515±0.0009 for the configuration of one 2.76 L container with 200 g and unrestricted moderation surrounded by other 2.76 L containers with a total of 700 g Pu as feed material with H/X=20. The interaction case c0001f2b7 provided a k_{eff} of 0.8601±0.0008 for the configuration of one 2.76 L container with 200 g and H/X=200 surrounded by other containers with a total of 700 g Pu as feed material with H/X =20.

6.0 REFERENCES

Altschuler, S. J., 1981, WHC-SD-SQA-CSA-20231, Rev. 0, *CSAR 80-014: In-place Filters*, Westinghouse Hanford Company, Richland, Washington.

ANSI/ANS-8.1-1983: R1998, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*, American Nuclear Society, La Grange Park, Illinois.

Carter, R. D., G. R. Kiel, and K. R. Ridgway, 1968, *Criticality Handbook,* ARH-600, 1980 Revision, Atlantic Richfield Hanford Company, Richland, Washington.

CPS-Z-165-80010, 1998, Rev/Mod C-4, *General Limits*, Plutonium Finishing Plant, Criticality Prevention Specification.

CPS-Z-165-80031, 1997, Rev/Mod B-0, *Conveyor and Pass-Through Gloveboxes in Room 235-B,* Plutonium Finishing Plant, Criticality Prevention Specification.

DOE, 1992, *Nuclear Criticality Safety*, DOE Order 5480.24, August 12, 1992, U. S. Department of Energy, Washington, D. C.

Erickson, D. G., 1998a, *MCNP 4B Plutonium Validation*, HNF-1905, Rev. 1, CCVR 97-001, Fluor Daniel Northwest, Inc., Richland, Washington.

Erickson, D. G., 1998b, *CSER 98-003: Criticality Safety Evaluation Report for PFP Glovebox HC-21A with Button Can Opening*, HNF-2705, Rev. 1, Fluor Daniel Northwest, Inc., Richland, Washington.

FDH, 2000, *Criticality Safety General, Requirements*, HNF-PRO-334, Rev. 1, Fluor Daniel Hanford, Inc., Richland, Washington.

FDH, 1997a, *Criticality Safety Control of Fissionable Material*, HNF-PRO-537, Rev. 0, Fluor Daniel Hanford, Inc., Richland, Washington.

FDH, 1997b, *Criticality Safety Evaluations*, HNF-PRO-539, Rev. 0, Fluor Daniel Hanford, Inc., Richland, Washington.

FDH, 1999, *Plutonium Finishing Plant Final Safety Analysis Report*, HNF-SD-CP-SAR-021, Rev. 1, Fluor Daniel Hanford Inc., Richland, Washington.

FFS, 1999, *Criticality Safety Evaluation Reports,* Practice 134 290 1121.

Greenborg, J. 1999, *CSER 98-008: Analysis of Plutonium Compounds as Applied to PFP Criticality Limits for Oxide and Metal Systems*, HNF-3572, Rev. 0, Fluor Daniel Hanford, Richland, Washington.

Greenhalgh, W. O., 1996, *Results of The PFP Cementation Process*, Internal Memo 8A400-96-032, Westinghouse Hanford Company, Richland, Washington.

Hess, A. L., 1996, *CSER 96-013: Cementation Process, Glovebox HA-20MB at PFP*, WHC-SD-SQA-CSA-513, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Lan, J. S., 1999, *MCNP Version 4B Approval for Use Documentation & Authorized User List*, FDNW-DSL-99-004, January 12, 1999, Fluor Daniel Northwest, Inc., Richland, Washington.

Marusich, R. M., 1999, *CSER 99-003: Criticality Mass of Uranium as Compared to Plutonium – Implications for PFP Processing Uranium*, HNF-4436, Rev. 0, Fluor Daniel Hanford, Richland, Washington.

Pruvost, N. L. and Paxton, H. C., 1996, *Nuclear Criticality Safety Guide*, LA-12808, Los Alamos National Laboratory, Los Alamos, New Mexico.

Roemer, J. J., 1986, *Remote Mechanical C Button Line*, SD-CP-SAR-020, Rev. 0, March 1986, Rockwell Hanford Company, Richland, Washington.

Schwinkendorf, K. N., 1998, *Software Certification Report for MCNP 4B*, HNF-3316, Rev. 0, October 14, 1998, Fluor Daniel Northwest, Inc., Richland, Washington.

APPENDIX A

INDEPENDENT REVIEW COMMENTS AND CHECKLIST

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Independent Peer Reviewer Comments: K. N. Schwinkendorf - 03/03/2000

This CSER was independently peer reviewed by K. N. Schwinkendorf, a qualified Criticality Safety Specialist in the Criticality and Shielding group of Fluor Federal Services. This technical review covered all aspects of this CSER with the exception of checking computer code input and output files. This phase of the review was carried out by S. R. Gedeon, also of the Criticality and Shielding group of Fluor Federal Services. As shown in the two Independent Review Checklists, taken together, this CSER has been reviewed with no gaps.

The construction of base case models using bounding, abnormal but credible conditions was well documented and is conservative. There were some analyzed cases that exceeded the criticality safety criterion, but these were determined not to be credible (for example, interspersed moderation in excess of 0.10 g/cm^3). One validation issue was raised. The sand, slag, and crucible (SS&C) material, as defined in this CSER, may include Pu metal-phase material, so the metal system k_{eff} limit of 0.932 was used for the "Limit Set A" materials (1200 g Pu limit set), instead of the 0.942 limit for non-metal systems, as per the Pu validation document. Use of the 0.942 limit was retained for the "Limit Set B" materials (2100 g Pu limit set) because these material are more well characterized, and will not contain large Pu metal pieces. Although some fine metal phase particles may still be present, they will be well-mixed with other materials such that the system may be considered "non-metal" from a neutronics perspective. Reducing the criticality safety criterion for Limit Set A did not impact any evaluated contingencies, as they were all below 0.932.

No single contingency violated the criticality safety criterion, and so this reviewer concurs with the conclusion of this CSER, that this cementation process satisfies double contingency.

Finally, minor editorial comments were suggested, and were incorporated into the final version of the CSER.

Independent Peer Reviewer Comments: S. R. Gedeon - 03/03/2000

Computer inputs, outputs and spreadsheets were checked for consistency and reasonableness. Densities were checked with data in ARH-600 and found equal or conservative.

Input files were checked for model adequacy, material densities, geometry, and container volume. K_{eff} values given in the report were verified against output files. Output files were reviewed for adequate convergence. Minor typographical errors were corrected.

Practice 134 290 1112
Publication Date 22Nov99
Attachment 02 - Sheet 1 of 1

FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: HNF-5988 Rev. 0
Title: CSER 00-001: Criticality Safety Evaluation Report for Cementation Operations At the PFP
Author: K. D. Dobbin and D. W. Wootan
Date: 3/3/00
Scope of Review:

Yes	No*	NA	
[✓]	[ ]	[ ]**	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[✓]	[ ]	[ ]	Problem completely defined.
[✓]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[✓]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[✓]	[ ]	[ ]	Computer codes and data files documented.
[ ]	[ ]	[✓]	Data used in calculations explicitly stated in document.
[ ]	[ ]	[✓]	Data checked for consistency with original source information as applicable.
[ ]	[ ]	[✓]	Mathematical derivations checked including dimensional consistency of results.
[✓]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[ ]	[ ]	[✓]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[✓]	Software input correct and consistent with document reviewed.
[ ]	[ ]	[✓]	Software output consistent with input and with results reported in document reviewed.
[✓]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[✓]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[✓]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[✓]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[✓]	[ ]	[ ]	Format consistent with applicable guides or other standards.
[✓]		[ ]**	Review calculations, comments, and/or notes are attached.
[✓]	[ ]	[ ]	Document approved (i.e., the reviewer affirms the technical accuracy of the document).

K. N. Schwinkendorf *Kevin N. Schwinkendorf* 3/3/00
Reviewer: (Printed and Signed) Date

* All "NO" responses must be explained below or on an additional page.

** Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

NUCLEAR ENGINEERING

Practice 134 290 1112
Publication Date 22Nov99
Attachment 02 - Sheet 1 of 1

FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

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Author: K. D. Dobbin and D. W. Wootan
Date: 3/3/00
Scope of Review:

Yes	No*	NA	
[ ]	[ ]	[✓]**	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[ ]	[ ]	[✓]	Problem completely defined.
[ ]	[ ]	[✓]	Accident scenarios developed in a clear and logical manner.
[ ]	[ ]	[✓]	Necessary assumptions explicitly stated and supported.
[✓]	[ ]	[ ]	Computer codes and data files documented.
[✓]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[✓]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[✓]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[✓]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[✓]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[✓]	[ ]	[ ]	Software input correct and consistent with document reviewed.
[✓]	[ ]	[ ]	Software output consistent with input and with results reported in document reviewed.
[ ]	[ ]	[✓]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[ ]	[ ]	[✓]	Safety margins consistent with good engineering practices.
[ ]	[ ]	[✓]	Conclusions consistent with analytical results and applicable limits.
[ ]	[ ]	[✓]	Results and conclusions address all points required in the problem statement.
[ ]	[ ]	[✓]	Format consistent with applicable guides or other standards.
[ ]		[✓]**	Review calculations, comments, and/or notes are attached.
[✓]	[ ]	[ ]	Document approved (i.e., the reviewer affirms the technical accuracy of the document).

S. R. Gedeon [signature]
Reviewer: (Printed and Signed)

3 Mar 2000
Date

* All "NO" responses must be explained below or on an additional page.

** Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

NUCLEAR ENGINEERING

MOHR AND ASSOCIATES

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March 3, 2000

To: Kenneth D. Dobbin, Fluor Federal Services, Inc.

From: Warner A. Blyckert

Subject: Review of CSER 00-001: Criticality Safety Evaluation Report for Cementation Operations at the PFP (HNF-5988 Rev 0)

Document HNF-5988, Rev. 0, *CSER 00-001: Criticality Safety Evaluation Report for Cementation Operations at the PFP*, was given an independent technical review. The approach to analyzing the proposed operations and the technique used were checked for suitability, accuracy and completeness. The input files were used to generate pictures of the calculation models used in the evaluation.

The material which was reviewed consisted of the draft of the final report. The output files of the computer calculations were not reviewed during the review and the results were accepted as recorded in the report. The correctness and results of the validation effort was not reviewed so that the limits used in the CSER were not checked for accuracy nor applicability other than the narrative account of the approach which is reported in an appendix. The referenced CSERs and CSARs were not reviewed and the statements concerning their results were accepted without verification.

Responses to the reviewer's comments have been incorporated into the final report and adequately address the comments.

The reviewer agrees with the conclusion of the report that the proposed cementation operations may be safely conducted with the postulated material under the limiting conditions of operation.

Very truly yours,

Warner A. Blyckert

Warner A. Blyckert

Practice 134 290 1112
Publication Date 22Nov99
Attachment 02 - Sheet 1 of 1

FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: HNF-5988 Rev. 0
Title: CSER 00-001: Criticality Safety Evaluation Report for Cementation Operations At the PFP
Author: K. D. Dobbin and D. W. Wootan
Date: 3/3/00
Scope of Review:

Yes	No*	NA	
[ ]	[ ]	[X]**	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[X]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[ ]	[ ]	[X]	Data checked for consistency with original source information as applicable.
[ ]	[ ]	[X]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[ ]	[ ]	[X]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[X]	[ ]	[ ]	Software input correct and consistent with document reviewed.
[X]	[ ]	[ ]	Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[X]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[X]	[ ]	[ ]	Format consistent with applicable guides or other standards.
[X]		[ ]**	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]	Document approved (i.e., the reviewer affirms the technical accuracy of the document).

W. Blyckert W.Blyckert
Reviewer: (Printed and Signed)

March 3, 2000
Date

* All "NO" responses must be explained below or on an additional page.

** Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

NUCLEAR ENGINEERING

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APPENDIX B

MCNP COMPUTER CODE VALIDATION

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B.1 VALIDATION PROCEDURE

Validation of the computer code methods in this analysis consisted of testing the code and neutron cross sections on calculations of known critical configurations. These benchmark experiments have fissile isotopes in systems similar to that evaluated by this CSER. The computed and measured k_{eff}s for the benchmark configurations were compared to establish a bias that includes the uncertainty in the calculational methods. A bias-adjusted k_{eff} for the benchmark systems was defined to include both the deviations of the calculated from the measured k_{eff}'s, and experimental and calculational uncertainties along with the spread in the ability of the computer code to calculate similar systems. In addition, criticality safety criteria require that the bias-adjusted k_{eff} for CSER analysis calculations not exceed the established k_{eff} safety limit at the 95% confidence level.

This method is illustrated in Figure B.1. Critical is defined as a k_{eff} of unity, adjusted by the bias established from the comparison of calculations with benchmarks. The bias is combined with the safety margin of 0.05 (a safety limit that k_{eff} must be less than or equal to 0.95) to compare with the calculated value and statistical uncertainty of the computer calculated k_{eff}'s of this CSER analysis. The calculated target k_{eff} is established by adding the bias, 0.05, and 1.645 times the one-sigma uncertainty of the calculated k_{eff} for the particular CSER analysis and subtracting that value from 1.0. For the analyses in this CSER, all the computer statistical uncertainties were less than 0.002, so this value was used to set the target k_{eff}'s as described in Section B.2.

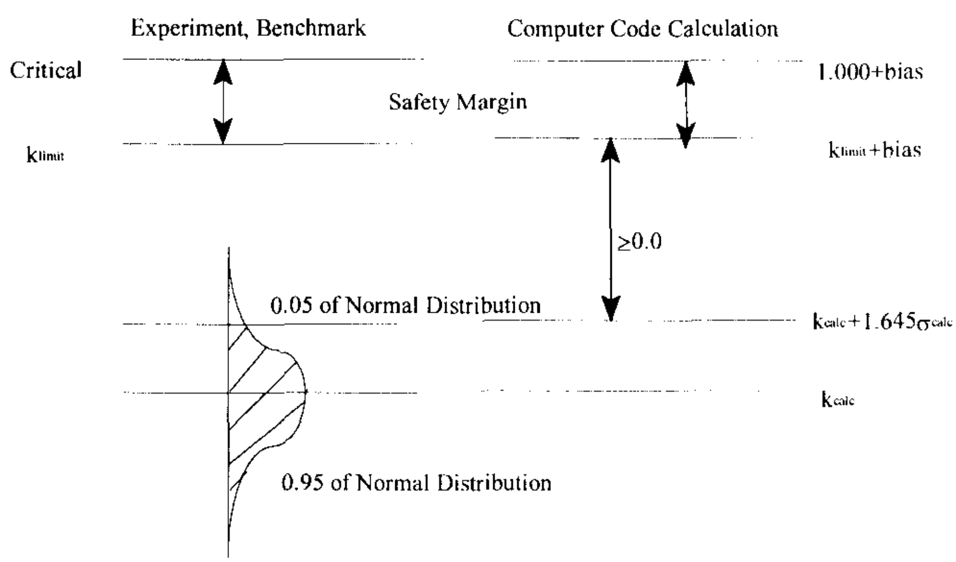

Figure B.1. Logic of Validation Procedure

B.2 GENERIC VALIDATION FOR PLUTONIUM SYSTEMS

A report by J. S. Lan, *MCNP Version 4B Approval For Use Documentation & Authorized User List* (Lan 1999), presents the results of calculations to determine a generic bias for plutonium configurations, as encountered in the Plutonium Finishing Plant. One hundred and forty three benchmark experiments were calculated. There were different material types that were considered in the plutonium validation calculations:

- Plutonium metal,
- Plutonium oxide,
- Plutonium solutions,
- Plutonium solutions with cadmium (a neutron poison),
- Water and polystyrene moderators, and
- Water, plexiglass, paraffin, polyethylene, and steel and concrete reflectors

The lower tolerance limit b_L was calculated for the benchmark experiments such that there is 95% confidence that 95% of the benchmark calculated k_{eff}'s is above that limit. This is expressed by the following formula:

$$b_L = k_{avg} - K_b * \sigma_{avg}$$

where: b_L = lower tolerance limit for 95% confidence that 95% of the benchmark calculated k_{eff}'s is above this limit,
k_{avg} = the average of the k_{eff}'s calculated by MCNP 4B,
K_b = a multiplier found from statistical tables for non-central t-distribution, and depends on number of degrees of freedom, and
σ_{avg} = standard deviation of the MCNP k_{eff}'s.

Bias is calculated by the following formula:

$$bias = b_L - k_{crit}$$

where:

k_{crit} = the average of the k_{eff}'s for the critical experiments; for the plutonium experiments $k_{crit} = 1.000$.

The bias for the plutonium metal group was significantly different than for all other groups. For this reason, it was concluded that separate bias values for metal and non-metal groupings would be appropriate. The lower tolerance limit for the metal group (17 benchmark critical experiments) calculated to be 0.9884. The lower tolerance limit for the non-metal group (126 benchmark critical experiments) calculated to be 0.9991. These lower tolerance limits yielded the bias appropriate for each material category:

- Plutonium metal bias is -0.0116,
- Plutonium non-metal bias is -0.0009.

For conservatism, these calculated biases were recommended to be increased to:

- Plutonium metal — recommended bias is -0.0150,
- Plutonium non-metal — recommended bias is -0.0050.

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

$$k_{eff} = k_{calc} - bias + 1.645 * \sigma_{calc} \leq k_{limit}$$

where:

k_{calc}	=	k value given by MCNP 4B calculation for system in question,
bias	=	-0.015 for Pu metal, and -0.005 for Pu non-metal systems,
1.645	=	a constant number of standard deviations for 0.95 of the distribution for a one-sided standard normal distribution
σ_{calc}	=	standard deviation given by MCNP 4B calculation for system in question, and
k_{limit}	=	0.95 for plutonium systems, generally.

k_{limit} is generally taken to be 0.95 for plutonium systems.

For a standard deviation (σ_{calc}) of 0.002 or less, the k_{eff} value for plutonium metal systems is:

$$k_{calc} - (-0.015) + 1.645 * 0.002 \leq 0.95, \text{ or}$$

$$k_{calc} \leq 0.95 + (-0.015) - 1.645 * 0.002 = 0.932.$$

On this basis, it is determined that the true k_{eff} of an analyzed configuration with plutonium will not exceed 0.95 with a 95% confidence level for plutonium metal systems if the calculated value (k_{calc}, and $\sigma \leq 0.002$) is limited to a maximum value of **0.932**.

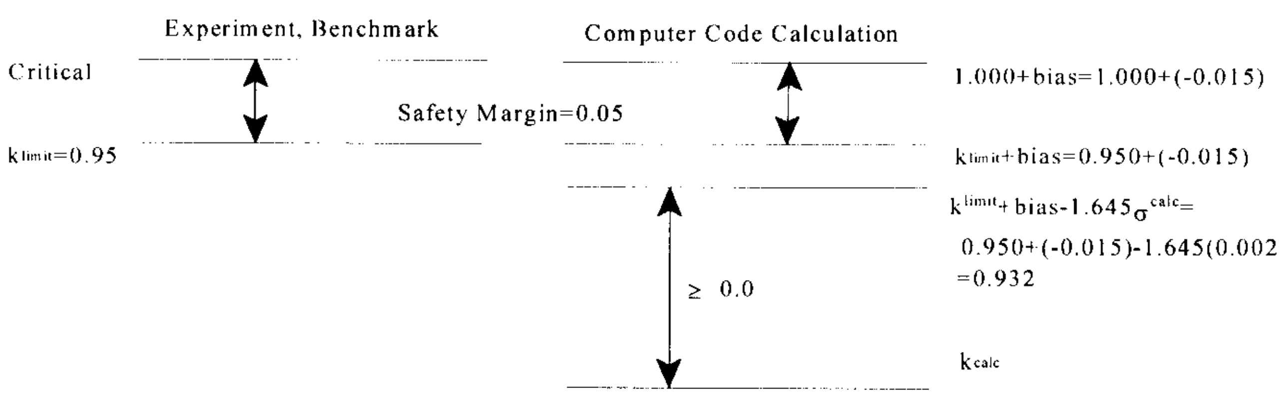

Figure B.2. Implementation of Validation Procedure

For a standard deviation (σ_{calc}) of 0.002 or less, the k_{eff} value for non-metal systems is:

$$k_{calc} - (-0.005) + 1.645 * 0.002 \leq 0.95, \text{ or}$$

$$k_{calc} \leq 0.95 + (-0.005) - 1.645 * 0.002 = 0.942.$$

On this basis, it is determined that the true k_{eff} of an analyzed configuration with plutonium will not exceed 0.95 with a 95% confidence level for plutonium non-metal systems if the calculated value (k_{calc}, and $\sigma \leq 0.002$) is limited to a maximum value of **0.942**.

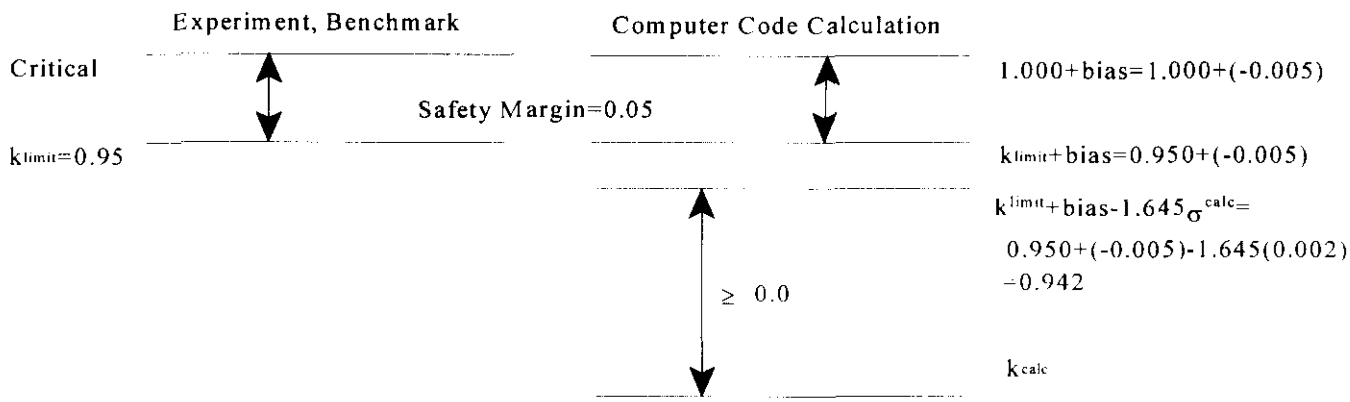

Figure B.3 Implementation of Validation Procedure

B.3 VALIDATION OF MCNP 4B

The validation of the MCNP4B code on the new computing system, Intergraph™, 400/450 MHz Pentium II, personal computers was documented in Lan, 1999. The essence of the validation was cross-correlation of calculational results obtained with this code version and results of critical experiments, as reported in *MCNP Version 4B Approval for Use Documentation & Authorized User List* (Lan 1999).

B.4 CONCRETE AS MODERATOR BENCHMARK

B.4.1 INTRODUCTION

The MCNP Version 4B Monte Carlo code was certified (Schwinkendorf 1998) and validated (Erickson 1998a and Lan 1999) for plutonium systems. The benchmark configurations analyzed for the validation included plutonium solutions with concrete reflection. Some concerns were identified about the application of the documented calculational biases to configurations expected in the cementation process that involve mixing plutonium compounds with water and cement. To address these concerns, additional experimental configurations were identified that included both moderation and reflection by concrete. Calculation of these benchmark experiments with the MCNP code provides additional assurance that MCNP calculational biases can be applied to the cementation process configurations.

B.4.2 EXPERIMENTAL CONFIGURATION

Critical experiments were performed at the Pacific Northwest Laboratory – Critical Mass Laboratory from 1985 to 1987 with mixed Pu+U nitrate solutions in annular geometry (Smolen 1994). Figure B.4 shows a schematic of the experimental configuration. The 25.4 cm diameter central region of the annular vessel contained various inserts, including a bottle containing fissile solution and annular concrete inserts. For the complete set of experiments, the fissile solution concentrations ranged from 47 to 226 g Pu/L with Pu/Pu+U ratios of 1.0, 0.5, and 0.2. While these geometrical configurations and material compositions do not correspond closely to the configurations and materials involved in the HA-20MB cementation process, they do provide a means for identifying systematic calculational issues involving significant internal moderation and scattering from the constituents in concrete. Two of these experimental configurations were modeled in detail to evaluate the biases of the MCNP code for these types of calculations.

Table B.1 summarizes the important parameters for the two critical experiments selected for analysis. Experiment Run 091 consisted of a mixed Pu+U nitrate solution with an annular concrete insert between the outer solution tank and the center solution bottle. This was the only experimental configuration with no B_4C in the concrete insert. Experiment Run 095 consisted of

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Pentium is a trademark of Intel Corporation, Santa Clara, Alabama.

a primarily Pu nitrate solution with an annular 2 wt% B_4C concrete insert. All of the primarily Pu solution configurations included this 2 wt% B_4C concrete insert.

The critical experiments were performed in a Type 304L stainless steel, 53.34 cm o.d. annular cylinder that had a 25.4 cm i.d. central region. The 13.82 cm thick annular region of the cylinder contained fissile solution. The average inside height of the annular solution vessel is 105.57 cm. The side wall thickness is 0.074 cm, and the thickness of the top and bottom plates are 0.953 and 0.653 cm, respectively. The experiments were performed with various items located in the central region of the annular vessel. During the experiments, a 14.56 cm i.d. bottle was placed in the center of the vessel. The bottle was fabricated of Type 304L stainless steel, with a wall thickness of 0.074 cm. The bottle was elevated so that the heights of the fissile solution in the bottle and annulus were equal.

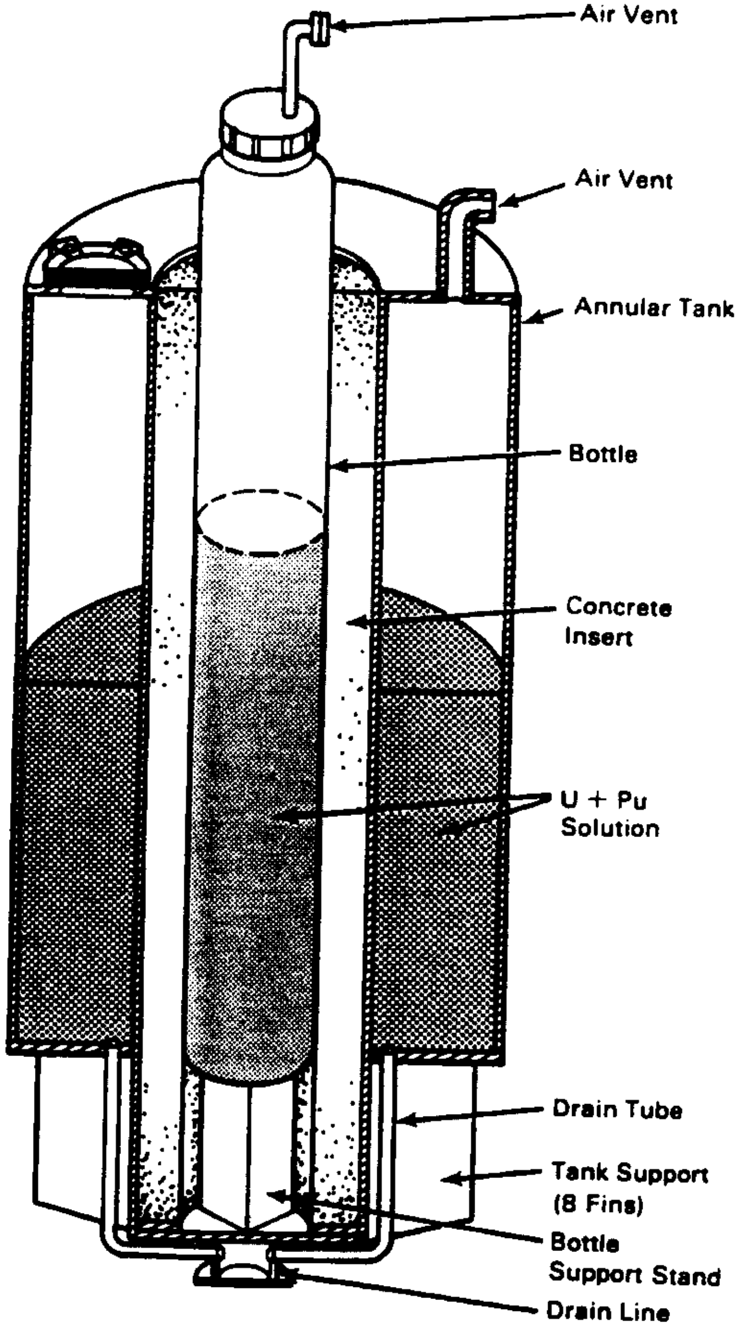

Figure B.4. Schematic of annular cylinder with concrete insert and bottle.

Table B.1. Critical Parameters for Selected Experimental Configurations

Run		Water height (cm)[a]	Pu (g/L)	U (g/L)	Density (g/cm3)	Free Acid (M)	Critical Height (cm)
091 0wt%	Tank	24.1	102.69	364.88	1.6780	0.77	48.99
B_4C concrete insert	Bottle B-2		103.36	363.30	1.6777	0.77	59.4
095 2wt%	Tank	24.1	195.61	6.5	1.4390	3.28	27.51
B_4C concrete insert	Bottle B-3		194.92	5.1	1.4362	3.31	36.8

[a] distance between top of water and top of annular vessel.

Annular concrete inserts were placed in the central region separating the annular tank and the bottle. These concrete inserts were 5.0 cm thick. The inserts were fabricated so that the elevation of their tops would be within 4 mm of the top of the annular vessel. The density of the concrete insert was determined to be 2.19 ± 0.05 g/cm^3. The isotopic composition of the concrete inserts used in the two inserts is described in Table B.2. The analysis of the B_4C used in the fabrication of some of the inserts disclosed that ^{10}B constitutes 20.02 ±0.1 at.%, with the balance being ^{11}B. The elemental composition of each insert was measured. The amount of water in the hardened concrete was measured as the total of free and chemically combined water. The estimated uncertainty in the actual water content for each insert is ± 1 wt%.

Analysis of selected fissile solution samples indicated the average concentration of impurities shown in Table B.3 related to acidic corrosion products from the stainless steel storage tanks. As the plutonium concentration is diluted, the impurities would also be diluted.

Analysis of the fissile solution used in the critical experiments was periodically performed to assess the change in plutonium and uranium isotopic concentrations over time. Table B.4 shows the isotopic concentrations corresponding to the dates that the particular experiments were performed.

A summary of the estimated uncertainties on key experimental parameters is shown in Table B.5. The overall uncertainty in k_{eff} due to the experimental uncertainties was estimated to be on the order of ±0.0020 in Smolen 1994.

Table B.2. Elemental Composition of Concrete Inserts

Element	Insert Composition (wt%)	
	$0B_4C$	$2B_4C$
Aluminum	4.82	4.82
Boron	0.02	1.56
Barium	0.07	0.07
Calcium	15.4	13.9
Copper	0.01	0.01
Iron	4.39	4.35
Potassium	0.54	1.52
Lithium	0.02	0.02
Magnesium	1.12	1.15
Manganese	0.07	0.07
Sodium	1.89	1.48
Silicon	21.8	22.1
Strontium	0.04	0.03
Titanium	0.57	0.58
Zirconium	0.04	0.10
Carbon	0.0	0.43
Hydrogen	0.95	0.87
Oxygen	48.25	46.94

Table B.3. Solution Impurity Concentrations

Element	Specific Concentration (μg/g Pu)
Iron	2935
Aluminum	950
Chromium	746
Calcium	598
Nickel	542
Titanium	225
Manganese	148
Cadmium	57
Boron	49

Table B.4. Isotopic Composition of Mixed Pu+U Solutions

Isotope	Isotopic composition	
	Run 091	Run 095
^{238}Pu (wt% Pu)	0.029	0.027
^{239}Pu (wt% Pu)	91.118	91.572
^{240}Pu (wt% Pu)	8.310	7.940
^{241}Pu (wt% Pu)	0.450	0.393
^{242}Pu (wt% Pu)	0.093	0.068
^{238}U (wt% U)	99.236	97.103
^{236}U (wt% U)	0.053	0.467
^{235}U (wt% U)	0.704	2.292
^{234}U (wt% U)	0.007	0.138
^{241}Am (mg/g Pu)	5.3	4.9

Table B.5. Experimental Parameter Uncertainties

Parameter	Uncertainty
Pu concentration (%)	±0.2
U concentration (%)	±0.2
Density (g/cm^3)	±0.0003
Free acid concentration (M)	±0.04
Critical height (cm)	±0.16

B.4.5 CALCULATIONAL MODEL

Computational models were developed for each of the experimental configurations using MCNP Version 4B. The models included the annular cylinder walls, bottom, and lid. The concrete inserts rested on the bottom of the annular vessel, and the full height of the inserts was modeled. The rebar in the concrete inserts was not modeled since the four 1.27 cm diameter rods were centrally located within the concrete and comprised only 1.6 vol%. Although the bottles actually extended above the annular vessel, the height of the bottle in the model was truncated at the top of the annular vessel. The cruciform stainless steel bottle support stand was not included in the model. Full water reflection was included around the annular vessel, to model the actual water thickness of greater than 35.57 cm for the experiments analyzed. Full water reflection was also included below the annular cylinder. Figure B.5 shows a cross section of the model. Listings of the models have been included in this report.

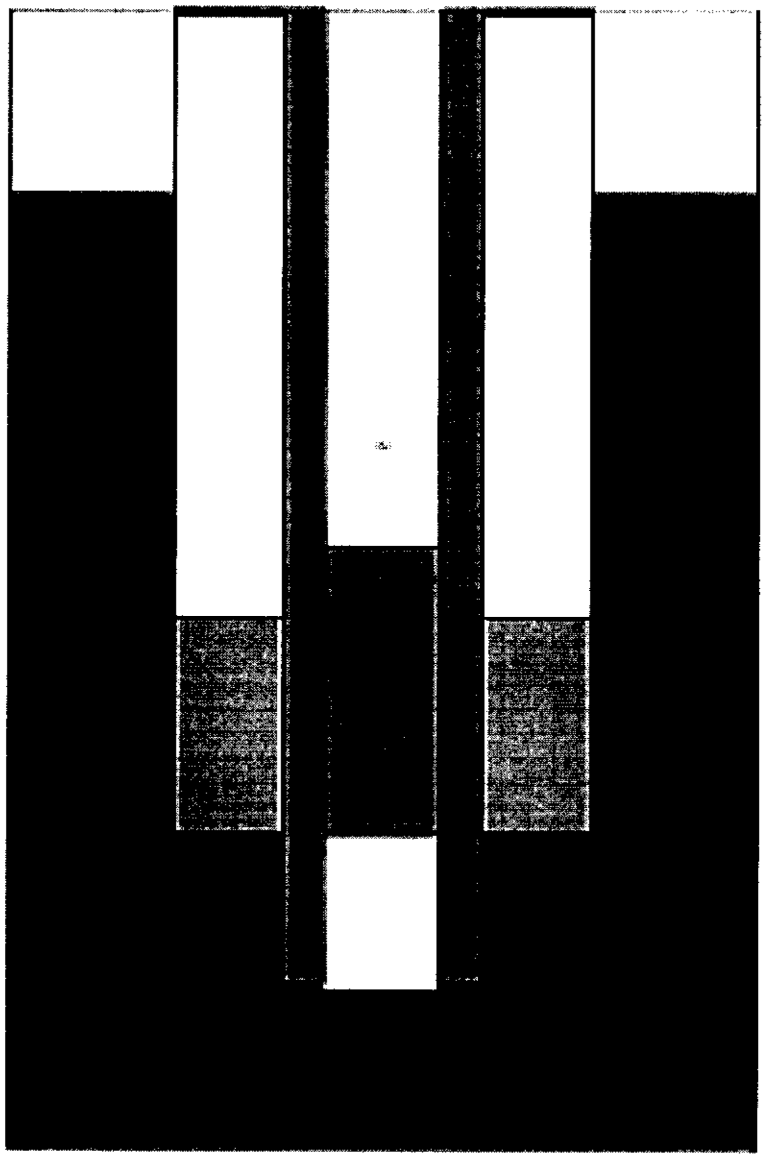

Figure B.5. Calculational Model of Annular Tank with Concrete Insert.

B.4.6 CALCULATIONAL RESULTS

Table B.6 summarizes the results of the MCNP calculations for the two experimental configurations. The calculated k_{eff} for Case 'annulus2' with plutonium solution of 1.0050 ±0.0008 is consistent with the mean of 97 MCNP calculated plutonium benchmark solution cases of 1.0119 ±0.0056 documented in Erickson 1998. Therefore, no change to the calculational bias for plutonium systems is justified. The calculated k_{eff} for Case 'annulus1' of 0.9925 ±0.0007 is lower than the mean k_{eff} for non-metal plutonium benchmarks. However, the 'annulus1' configuration is not a plutonium system, but a mixed uranium+plutonium system. Marusich 1999 showed that the mean value of k_{eff} calculated using MCNP for uranium solutions is approximately 0.02 lower than for plutonium solution benchmarks. The calculated k_{eff}'s for case annulus1 and case annulus2 agree with the differences between uranium and plutonium solutions sytems observed in Marusich 1999. Thus, these results show that the presence of concrete moderation does not change the conclusions of Marusich 1999 that the calculational biases for plutonium and uranium systems allows for the presence of less than 50% enriched uranium in plutonium systems.

Case 'annulus1water' is a calculational variation of case 'annulus1' where the concrete insert was replaced with water. The k_{eff} for this case, 1.0055 ±0.0007, is higher than the k_{eff} for case 'annulus1' by 0.0130 Δk, which is significantly larger than the range of uncertainty in the calculated k_{eff}-s and the estimated uncertainty in k_{eff} due to the measurement uncertainties of 0.002. This case illustrates that for this configuration water is more effective as a moderator than concrete and can be conservatively substituted for concrete.

Table B.6. Calculational Results

Case	Description	k_{calc}	1σ
Annulus1	Experiment 091- Part 24/B-2 Tank: 0.22 Pu/Pu+U 103.37 g Pu/L H/X= 225 Bottle: B-2 Insert: Part 24=annular concrete insert with 0 wt% B_4C	0.9925	0.0007
Annulus2	Experiment 095- Part 26/B-3 Tank: 0.97 Pu/Pu+U 195.61 g Pu/L H/X= 126 Bottle: B-3 Insert: Part 26=annular concrete insert with 2 wt% B4C	1.0050	0.0008
annulus1water	Same as case annulus1 except concrete insert replaced with water	1.0055	0.0007

B.4.7 REFERENCES

Erickson, D. G., 1998, *MCNP 4B Plutonium Validation*, HNF-1905, Rev. 1, CCVR 97-001, Fluor Daniel Northwest, Inc., Richland, Washington.

Lan, J. S., 1999, *MCNP Version 4B Approval for Use Documentation & Authorized User List*, FDNW-DSL-99-004, January 12, 1999, Fluor Daniel Northwest, Inc., Richland, Washington.

Marusich, R. M., E. M. Miller, S. R. Gedeon, 1999, *CSER 99-003: Critical Mass of Uranium As Compared to Plutonium-Implications For PFP Processing Uranium*, HNF-4436, Rev. 0, Fluor Daniel Northwest, Inc., Richland, Washington.

Schwinkendorf, K. N., 1998, *Software Certification Report for MCNP 4B*, HNF-3316, Rev. 0, October 14, 1998, Fluor Daniel Northwest, Inc., Richland, Washington.

Smolen, G. R., R. C. Lloyd, and T. Koyama, 1994, "Criticality Data and Validation Studies of Plutonium-Uranium Nitrate Solutions in Annular Geometry", Nuclear Technology, Vol. 107, September 1994.

MCNP Models

annulus1

```
annular tank criticality benchmark  annulus1 091 24/b2
    1     0               (9:-10:20) -100                   imp:n=0 $ outside world
    2     1 -1.00         ((8:-11):(-14 6)) -9 -18 10       imp:n=1 $water tank
    3     0               18 -20 8 -9                       imp:n=1 $air above water
    4     5 -1.6776       -7 6 15 -16                       imp:n=1 $solution tank
    5     0               16 -19 -7 6                       imp:n=1 $air above solution
    6     2 -8.03         -8 7 15 -19                       imp:n=1 $soln tank outer wall
    7     2 -8.03         -6 5 12 -19                       imp:n=1 $soln tank inner wall
    8     2 -8.03         19 -20 -8 5                       imp:n=1 $soln tank top
    9     2 -8.03         14 -15 -8 6                       imp:n=1 $soln tank bottom
   10     0               12 -20 4 -5                       imp:n=1 $air gap
   11     3 -2.1          -4 3 13 -20                       imp:n=1 $concrete insert
   12     2 -8.03         12 -13 3 -4                       imp:n=1 $concrete insert bottom plate
   13     2 -8.03         11 -12 -6                         imp:n=1 $center hole bottom plate
   14     0               12 -20 2 -3                       imp:n=1 $concrete insert air gap
   15     2 -8.03         12 -20 1 -2                       imp:n=1 $solution bottle wall
   16     0               17 -20 -1                         imp:n=1 $solution tank plenum
   17     6 -1.6777       -1 15 -17                         imp:n=1 $solution bottle soln
   18     2 -8.03         14 -15 -1                         imp:n=1 $solution tank plenum
   19     0               12 -14 -1                         imp:n=1 $solution tank plenum

c    ---------------------------------------------------------------------------
   1        cz    7.354
   2        cz    7.428
   3        cz    7.5465
   4        cz    12.541
   5        cz    12.700
   6        cz    12.774
   7        cz    26.594
   8        cz    26.668
   9        cz    47.630
  10        pz    -40.905
  11        pz    -22.005
  12        pz    -20.735
  13        pz    -19.465
  14        pz     -0.635
  15        pz      0.0
  16        pz     27.67
  17        pz     59.4
  18        pz     82.425
  19        pz    105.572
  20        pz    106.525
 100        so    300.                                        $ outside world

mode  n
m1     1001.50c  0.66667   8016.50c  0.3333                  $ rho=1.00      , h20
mt1    lwtr.01t
m2     6012.50   0.000161  14000.50  0.000861  24000.50  0.017671
      25055.50   0.000880  26000.55  0.060151  28000.50  0.008238    $304 steel
m3     1001.50   -0.95     8016.50   -48.2     40000.50  -0.04
      22000.50   -0.57   14000.50   -21.8     11023.50   -1.89 25055.50  -0.07
      12000.50   -1.12     3006.50  -0.0013   3007.55   -0.0187 19000.50  -0.54
      26000.55   -4.39   29000.50   -0.01     20000.50   -15.4 56138.50  -0.07
       5010.50   -0.0037 5011.55   -0.01629  13027.50   -4.82         $concrete 0%b4c
mt3    lwtr.01t
m4     1001.50   -0.87     8016.50  -46.94    6012.50   -0.43  40000.50  -0.10
      22000.50   -0.58   14000.50   -22.1     11023.50   -1.48 25055.50  -0.07
      12000.50   -1.15     3006.50  -0.0013   3007.55   -0.0187 19000.50  -1.52
      26000.55   -4.35   29000.50   -0.01     20000.50   -13.9 56138.50  -0.07
       5010.50   -0.28922 5011.55  -1.2708    13027.50   -4.82         $concrete 2%b4c
mt4    lwtr.01t
m5     94238.50  -2.998E-05
       94239.55  -9.419E-02
       94240.50  -8.590E-03
       94241.50  -4.652E-05
       94242.50  -9.613E-05
       92238.50  -3.609E-01
       92236.50  -1.927E-04
       92235.50  -2.560E-03
```

```
          92234.50  -2.546E-05
          95241.50  -5.479E-04
           1001.50  -9.206E-02
           7014.50  -7.792E-02
           8016.50  -1.041E+00
          26000.55  -3.034E-04
          13027.50  -9.820E-05
          24000.50  -7.711E-05
          20000.50  -6.182E-05
          28000.50  -5.603E-05
          22000.50  -2.326E-05
          25055.50  -1.530E-05
          48000.50  -5.892E-06
           5010.50  -5.065E-06                              $b-2 tank solution
mt5       lwtr.01t
m6        94238.50  -2.997E-05
          94239.55  -9.418E-02
          94240.50  -8.589E-03
          94241.50  -4.651E-05
          94242.50  -9.612E-05
          92238.50  -3.605E-01
          92236.50  -1.925E-04
          92235.50  -2.558E-03
          92234.50  -2.543E-05
          95241.50  -5.478E-04
           1001.50  -9.220E-02
           7014.50  -7.774E-02
           8016.50  -1.041E+00
          26000.55  -3.034E-04
          13027.50  -9.819E-05
          24000.50  -7.711E-05
          20000.50  -6.181E-05
          28000.50  -5.602E-05
          22000.50  -2.326E-05
          25055.50  -1.530E-05
          48000.50  -5.892E-06
           5010.50  -5.065E-06                              $b-2 bottle solution
mt6       lwtr.01t
m7        94238.50  -5.281E-05
          94239.55  -1.791E-01
          94240.50  -1.553E-02
          94241.50  -7.687E-04
          94242.50  -1.330E-04
          92238.50  -6.312E-03
          92236.50  -3.036E-05
          92235.50  -1.490E-04
          92234.50  -8.970E-06
          95241.50  -9.585E-04
           1001.50  -9.537E-02
           7014.50  -9.252E-02
           8016.50  -1.049E+00
          26000.55  -5.741E-04
          13027.50  -1.858E-04
          24000.50  -1.459E-04
          20000.50  -1.170E-04
          28000.50  -1.060E-04
          22000.50  -4.401E-05
          25055.50  -2.895E-05
          48000.50  -1.115E-05
           5010.50  -9.585E-06                              $b-3 tank solution
mt7       lwtr.01t
m8        94238.50  -5.263E-05
          94239.55  -1.785E-01
          94240.50  -1.548E-02
          94241.50  -7.660E-04
          94242.50  -1.325E-04
          92238.50  -4.952E-03
          92236.50  -2.382E-05
          92235.50  -1.169E-04
          92234.50  -7.038E-06
          95241.50  -9.551E-04
           1001.50  -9.529E-02
           7014.50  -9.261E-02
           8016.50  -1.048E+00
          26000.55  -5.721E-04
          13027.50  -1.852E-04
```

```
       24000.50  -1.454E-04
       20000.50  -1.166E-04
       28000.50  -1.056E-04
       22000.50  -4.386E-05
       25055.50  -2.885E-05
       48000.50  -1.111E-05
        5010.50  -9.551E-06                                       $b-3 bottle solution
mt8    lwtr.01t
kcode  5000 1.0  10  300
ksrc   0 0 15  0 15 15
prdmp   j  -300  1  3
totnu
print
ctme   600
```

****

annulus2

```
annular tank criticality benchmark  annulus2 095 26/b3
    1     0               (9:-10:20) -100                imp:n=0 $ outside world
    2     1 -1.00         ((8:-11):(-14 6)) -9 -18 10    imp:n=1 $water tank
    3     0               18 -20 8 -9                    imp:n=1 $air above water
    4     7 -1.4390       -7 6 15 -16                    imp:n=1 $solution tank
    5     0               16 -19 -7 6                    imp:n=1 $air above solution
    6     2 -8.03         -8 7 15 -19                    imp:n=1 $soln tank outer wall
    7     2 -8.03         -6 5 12 -19                    imp:n=1 $soln tank inner wall
    8     2 -8.03         19 -20 -8 5                    imp:n=1 $soln tank top
    9     2 -8.03         14 -15 -8 6                    imp:n=1 $soln tank bottom
   10     0               12 -20 4 -5                    imp:n=1 $air gap
   11     4 -2.1          -4 3 13 -20                    imp:n=1 $concrete insert
   12     2 -8.03         12 -13 3 -4                    imp:n=1 $concrete insert bottom plate
   13     2 -8.03         11 -12 -6                      imp:n=1 $center hole bottom plate
   14     0               12 -20 2 -3                    imp:n=1 $concrete insert air gap
   15     2 -8.03         12 -20 1 -2                    imp:n=1 $solution bottle wall
   16     0               17 -20 -1                      imp:n=1 $solution tank plenum
   17     8 -1.4362       -1 15 -17                      imp:n=1 $solution bottle soln
   18     2 -8.03         14 -15 -1                      imp:n=1 $solution tank plenum
   19     0               12 -14 -1                      imp:n=1 $solution tank plenum

c    -----------------------------------------------------------------------
   1        cz    7.354
   2        cz    7.428
   3        cz    7.5465
   4        cz    12.541
   5        cz    12.700
   6        cz    12.774
   7        cz    26.594
   8        cz    26.668
   9        cz    47.630
  10        pz    -40.905
  11        pz    -22.005
  12        pz    -20.735
  13        pz    -19.465
  14        pz     -0.635
  15        pz      0.0
  16        pz     27.51
  17        pz     36.80
  18        pz     82.425
  19        pz    105.572
  20        pz    106.525
 100        so    300.                              $ outside world

mode  n
m1      1001.50c  0.66667   8016.50c  0.3333                  $ rho=1.00      , h20
mt1     lwtr.01t
m2      6012.50  0.000161  14000.50  0.000861  24000.50  0.017671
       25055.50  0.000880  26000.55  0.060151  28000.50  0.008238    $304 steel
m3      1001.50  -0.95    8016.50  -48.2    40000.50  -0.04
       22000.50  -0.57  14000.50  -21.8    11023.50  -1.89 25055.50  -0.07
       12000.50  -1.12    3006.50  -0.0013  3007.55  -0.0187 19000.50  -0.54
       26000.55  -4.39  29000.50  -0.01   20000.50  -15.4 56138.50  -0.07
        5010.50  -0.0037 5011.55  -0.01629  13027.50  -4.82        $concrete 0%b4c
mt3     lwtr.01t
m4      1001.50  -0.87    8016.50  -46.94   6012.50  -0.43  40000.50  -0.10
```

```
        22000.50  -0.58  14000.50  -22.1    11023.50  -1.48 25055.50  -0.07
        12000.50  -1.15    3006.50  -0.0013  3007.55  -0.0187 19000.50  -1.52
        26000.55  -4.35  29000.50  -0.01    20000.50  -13.9 56138.50  -0.07
         5010.50  -0.28922 5011.55 -1.2708    13027.50  -4.82         $concrete 2%b4c
mt4     lwtr.01t
m5       94238.50   -2.998E-05
         94239.55   -9.419E-02
         94240.50   -8.590E-03
         94241.50   -4.652E-05
         94242.50   -9.613E-05
         92238.50   -3.609E-01
         92236.50   -1.927E-04
         92235.50   -2.560E-03
         92234.50   -2.546E-05
         95241.50   -5.479E-04
          1001.50   -9.206E-02
          7014.50   -7.792E-02
          8016.50   -1.041E+00
         26000.55   -3.034E-04
         13027.50   -9.820E-05
         24000.50   -7.711E-05
         20000.50   -6.182E-05
         28000.50   -5.603E-05
         22000.50   -2.326E-05
         25055.50   -1.530E-05
         48000.50   -5.892E-06
          5010.50   -5.065E-06                                $b-2 tank solution
mt5     lwtr.01t
m6       94238.50   -2.997E-05
         94239.55   -9.418E-02
         94240.50   -8.589E-03
         94241.50   -4.651E-05
         94242.50   -9.612E-05
         92238.50   -3.605E-01
         92236.50   -1.925E-04
         92235.50   -2.558E-03
         92234.50   -2.543E-05
         95241.50   -5.478E-04
          1001.50   -9.220E-02
          7014.50   -7.774E-02
          8016.50   -1.041E+00
         26000.55   -3.034E-04
         13027.50   -9.819E-05
         24000.50   -7.711E-05
         20000.50   -6.181E-05
         28000.50   -5.602E-05
         22000.50   -2.326E-05
         25055.50   -1.530E-05
         48000.50   -5.892E-06
          5010.50   -5.065E-06                                $b-2 bottle solution
mt6     lwtr.01t
m7       94238.50   -5.281E-05
         94239.55   -1.791E-01
         94240.50   -1.553E-02
         94241.50   -7.687E-04
         94242.50   -1.330E-04
         92238.50   -6.312E-03
         92236.50   -3.036E-05
         92235.50   -1.490E-04
         92234.50   -8.970E-06
         95241.50   -9.585E-04
          1001.50   -9.537E-02
          7014.50   -9.252E-02
          8016.50   -1.049E+00
         26000.55   -5.741E-04
         13027.50   -1.858E-04
         24000.50   -1.459E-04
         20000.50   -1.170E-04
         28000.50   -1.060E-04
         22000.50   -4.401E-05
         25055.50   -2.895E-05
         48000.50   -1.115E-05
          5010.50   -9.585E-06                                $b-3 tank solution
mt7     lwtr.01t
m8       94238.50   -5.263E-05
         94239.55   -1.785E-01
```

```
         94240.50  -1.548E-02
         94241.50  -7.660E-04
         94242.50  -1.325E-04
         92238.50  -4.952E-03
         92236.50  -2.382E-05
         92235.50  -1.169E-04
         92234.50  -7.038E-06
         95241.50  -9.551E-04
          1001.50  -9.529E-02
          7014.50  -9.261E-02
          8016.50  -1.048E+00
         26000.55  -5.721E-04
         13027.50  -1.852E-04
         24000.50  -1.454E-04
         20000.50  -1.166E-04
         28000.50  -1.056E-04
         22000.50  -4.386E-05
         25055.50  -2.885E-05
         48000.50  -1.111E-05
          5010.50  -9.551E-06                                        $b-3 bottle solution
mt8      lwtr.01t
kcode    5000 1.0  10  300
ksrc     0 0 15  0 15 15
prdmp     j  -300  1  3
totnu
print
ctme     600
```

```
*****************************************************************************************
```

annulus1water

```
annular tank criticality benchmark  annulus1 091 24/b2 concrete ->water
    1      0               (9:-10:20) -100                   imp:n=0 $ outside world
    2      1 -1.00         ((8:-11):(-14 6)) -9 -18 10       imp:n=1 $water tank
    3      0               18 -20 8 -9                       imp:n=1 $air above water
    4      5 -1.6776       -7 6 15 -16                       imp:n=1 $solution tank
    5      0               16 -19 -7 6                       imp:n=1 $air above solution
    6      2 -8.03         -8 7 15 -19                       imp:n=1 $soln tank outer wall
    7      2 -8.03         -6 5 12 -19                       imp:n=1 $soln tank inner wall
    8      2 -8.03         19 -20 -8 5                       imp:n=1 $soln tank top
    9      2 -8.03         14 -15 -8 6                       imp:n=1 $soln tank bottom
   10      0               12 -20 4 -5                       imp:n=1 $air gap
   11      1 -1.0          -4 3 13 -20                       imp:n=1 $concrete insert
   12      2 -8.03         12 -13 3 -4                       imp:n=1 $concrete insert bottom plate
   13      2 -8.03         11 -12 -6                         imp:n=1 $center hole bottom plate
   14      0               12 -20 2 -3                       imp:n=1 $concrete insert air gap
   15      2 -8.03         12 -20 1 -2                       imp:n=1 $solution bottle wall
   16      0               17 -20 -1                         imp:n=1 $solution tank plenum
   17      6 -1.6777       -1 15 -17                         imp:n=1 $solution bottle soln
   18      2 -8.03         14 -15 -1                         imp:n=1 $solution tank plenum
   19      0               12 -14 -1                         imp:n=1 $solution tank plenum

c     ------------------------------------------------------------------------
   1        cz    7.354
   2        cz    7.428
   3        cz    7.5465
   4        cz    12.541
   5        cz    12.700
   6        cz    12.774
   7        cz    26.594
   8        cz    26.668
   9        cz    47.630
  10        pz    -40.905
  11        pz    -22.005
  12        pz    -20.735
  13        pz    -19.465
  14        pz     -0.635
  15        pz      0.0
  16        pz     27.67
  17        pz     59.4
  18        pz     82.425
  19        pz    105.572
  20        pz    106.525
```

```
 100       so    300.                                        $ outside world

mode  n
m1     1001.50c  0.66667   8016.50c  0.3333                     $ rho=1.00      , h20
mt1    lwtr.01t
m2     6012.50  0.000161  14000.50  0.000861  24000.50  0.017671
      25055.50  0.000880  26000.55  0.060151  28000.50  0.008238    $304 steel
m3     1001.50  -0.95     8016.50  -48.2     40000.50  -0.04
      22000.50  -0.57  14000.50  -21.8     11023.50  -1.89 25055.50  -0.07
      12000.50  -1.12    3006.50  -0.0013   3007.55  -0.0187 19000.50  -0.54
      26000.55  -4.39  29000.50  -0.01     20000.50  -15.4 56138.50  -0.07
       5010.50  -0.0037 5011.55  -0.01629  13027.50  -4.82        $concrete 0%b4c
mt3    lwtr.01t
m4     1001.50  -0.87     8016.50  -46.94    6012.50  -0.43  40000.50  -0.10
      22000.50  -0.58  14000.50  -22.1     11023.50  -1.48 25055.50  -0.07
      12000.50  -1.15    3006.50  -0.0013   3007.55  -0.0187 19000.50  -1.52
      26000.55  -4.35  29000.50  -0.01     20000.50  -13.9 56138.50  -0.07
       5010.50  -0.28922 5011.55 -1.2708   13027.50  -4.82        $concrete 2%b4c
mt4    lwtr.01t
m5     94238.50  -2.998E-05
       94239.55  -9.419E-02
       94240.50  -8.590E-03
       94241.50  -4.652E-05
       94242.50  -9.613E-05
       92238.50  -3.609E-01
       92236.50  -1.927E-04
       92235.50  -2.560E-03
       92234.50  -2.546E-05
       95241.50  -5.479E-04
        1001.50  -9.206E-02
        7014.50  -7.792E-02
        8016.50  -1.041E+00
       26000.55  -3.034E-04
       13027.50  -9.820E-05
       24000.50  -7.711E-05
       20000.50  -6.182E-05
       28000.50  -5.603E-05
       22000.50  -2.326E-05
       25055.50  -1.530E-05
       48000.50  -5.892E-06
        5010.50  -5.065E-06                                    $b-2 tank solution
mt5    lwtr.01t
m6     94238.50  -2.997E-05
       94239.55  -9.418E-02
       94240.50  -8.589E-03
       94241.50  -4.651E-05
       94242.50  -9.612E-05
       92238.50  -3.605E-01
       92236.50  -1.925E-04
       92235.50  -2.558E-03
       92234.50  -2.543E-05
       95241.50  -5.478E-04
        1001.50  -9.220E-02
        7014.50  -7.774E-02
        8016.50  -1.041E+00
       26000.55  -3.034E-04
       13027.50  -9.819E-05
       24000.50  -7.711E-05
       20000.50  -6.181E-05
       28000.50  -5.602E-05
       22000.50  -2.326E-05
       25055.50  -1.530E-05
       48000.50  -5.892E-06
        5010.50  -5.065E-06                                    $b-2 bottle solution
mt6    lwtr.01t
m7     94238.50  -5.281E-05
       94239.55  -1.791E-01
       94240.50  -1.553E-02
       94241.50  -7.687E-04
       94242.50  -1.330E-04
       92238.50  -6.312E-03
       92236.50  -3.036E-05
       92235.50  -1.490E-04
       92234.50  -8.970E-06
       95241.50  -9.585E-04
        1001.50  -9.537E-02
```

```
         7014.50   -9.252E-02
         8016.50   -1.049E+00
        26000.55   -5.741E-04
        13027.50   -1.858E-04
        24000.50   -1.459E-04
        20000.50   -1.170E-04
        28000.50   -1.060E-04
        22000.50   -4.401E-05
        25055.50   -2.895E-05
        48000.50   -1.115E-05
         5010.50   -9.585E-06                                     $b-3 tank solution
mt7     lwtr.01t
m8      94238.50   -5.263E-05
        94239.55   -1.785E-01
        94240.50   -1.548E-02
        94241.50   -7.660E-04
        94242.50   -1.325E-04
        92238.50   -4.952E-03
        92236.50   -2.382E-05
        92235.50   -1.169E-04
        92234.50   -7.038E-06
        95241.50   -9.551E-04
         1001.50   -9.529E-02
         7014.50   -9.261E-02
         8016.50   -1.048E+00
        26000.55   -5.721E-04
        13027.50   -1.852E-04
        24000.50   -1.454E-04
        20000.50   -1.166E-04
        28000.50   -1.056E-04
        22000.50   -4.386E-05
        25055.50   -2.885E-05
        48000.50   -1.111E-05
         5010.50   -9.551E-06                                     $b-3 bottle solution
mt8     lwtr.01t
kcode   5000 1.0   10   300
ksrc    0 0 15   0 15 15
prdmp    j  -300   1   3
totnu
print
ctme    600
```

APPENDIX C

MCNP INPUT FILES

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```
C0001f1b7b.i
glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
c      base case 900g + 0 g conveyor + 300g holdup + 0g outside
c      glovebox - full water reflection on all sides, cement can refl
c
c      bowls -  two bowls in corner 10" from cans
c              0.04167 g pu/cc pu
c              0.200 kg pu/bowl
c              h/x=634
c              sides, bottom of bowls not included
c      containers - 7 2.76 L cans 90% water 10% carbon
c                      0.02585 g pu/cc
c                      h/x=921
c                      500 g pu total
c
c      glovebox
  1    0          1 -2 3 -4 20 -6                               imp:n=1
c      glovebox floor conveyor box
  2    1  -1.0 24 -25 7 -5 8 -9                                 imp:n=1
c      glovebox lead sidewall and window
  4    1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #23            imp:n=1
  5    1  -1.0    (-1:2:-3) (10 -11 12 -4 19 -6)                imp:n=1
c      full water reflection
  6    1  -1.0    (((((-10:11:-12:4:6)(13 -14 15 -16 5 -18 #23)):
                  ((13 -14 15 -16 -5 21) (17:(-23 22 -27 26))
                 (-8:-7:9:-24:25))) (53:-70:28))):(-13 -67 -68 17)
                                                                imp:n=1
c      outside world
  7    0          14:(-13 (67:68)):-15:16:18:-21:
                  ((-22:23:27:-26) -17)                         imp:n=0
c      bowl
  8    3  -1.0431  ((63 -28):(-63 -61 69)) -32                  imp:n=1
c      bowl water reflection
  9    1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
                  (-69 70 -62)) -2 1  103                       imp:n=1
 10    0          -33 -63 70 62 -2 1  103                       imp:n=1
c      bowl
 11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                  imp:n=1
c      bowl water reflection
 12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
                  (-69 70 -60)) -2 1 -103                       imp:n=1
 13    0          -35 -63 70 60 -2 1 -103                       imp:n=1
c      container in drum outside glovebox
 22    1  -1.0    70 -28 -53                                    imp:n=1
 23    1  -1.0    70 -28 53 64 -65 41 66 -1                     imp:n=1
c      holdup on floor
 24    8  -5.562 5 -70 1 -4 -2 3                                imp:n=1
c      filled cans
 25    0  1 3 -433 -444 70 -20 33 35
          fill=1 (7.035 7.035 0)                                imp:n=1
 26    0    -331 334 -330 333 -329 332  u=1 lat=2
       fill= -5:12 -1:10 0:0
       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
       4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
                                                                imp:n=1
201    4  -1.098   -201 -28 u=2                                 imp:n=1
202    1  -1.0      28       u=2                                imp:n=1
203    0            201 -28 u=2                                 imp:n=1
204    10 -2.911   -201 -28 u=3                                 imp:n=1
205    1  -1.0      28       u=3                                imp:n=1
206    0            201 -28 u=3                                 imp:n=1
207    0            777    u=4                                  imp:n=1
 28    0            1 -2 3 -4 (433:444) 70 -20 33 35            imp:n=1

  1    px   0.0
```

```
2    py   132.08
3    py   0.0
4    px   518.16
5    pz   0.0
6    pz   91.44
7    pz   -35.56
8    px   60.96
9    px   411.48
10   px   -1.27
11   py   133.35
12   py   -1.27
13   px   -30.48
14   py   162.56
15   py   -30.48
16   px   548.64
17   pz   -30.48
18   pz   121.92
19   pz   41.91
20   pz   20.57
21   pz   -66.04
22   px   30.48
23   px   441.96
24   py   50.80
25   py   81.28
26   py   20.32
27   py   111.76
28   pz   18.03
29   pz   35.733
30   pz   38.273
32   c/z 10.21 121.87 10.16
33   c/z 10.21 121.87 12.70
34   c/z 10.21 101.45 10.16
35   c/z 10.21 101.45 12.70
36   c/z 281.94 10.16 6.985
37   c/z 281.94 10.16 9.525
38   c/z 113.344 79.375 6.985
39   c/z 127.316 79.375 6.985
40   c/z 34.99 125.09 6.985
41   c/z 113.344 65.405 6.985
42   c/z 127.316 65.405 6.985
43   c/z 34.99 111.11 6.985
44   c/z 6.99 125.09 9.525
45   c/z 6.99 111.11 9.525
46   c/z 20.99 111.11 9.525
47   c/z 34.99 111.11 9.525
48   c/z 34.99 125.09 9.525
49   c/z 20.99 125.09 9.525
51   py   101.585
52   px   30.515
53   c/z -23.495 121.87 6.985
54   px   6.986
55   px   20.958
56   py   125.094
57   py   111.122
58   s    10.21 101.45 9.98 10.16
59   pz   27.68
60   s    10.21 101.45 9.98 12.70
61   s    10.21 121.87 9.98 10.16
62   s    10.21 121.87 9.98 12.70
63   pz   9.98
64   py   114.885
65   py   128.855
66   px   -23.495
67   c/z -23.495 121.87 37.465
68   pz   48.514
69   pz   0.33
70   pz   0.001
71   pz   5.080
101  py   104.136
102  c/z 130.49 121.918 35.56
103  py   111.66
104  px   30.48
105  py   132.08
106  px   106.35
107  py 121.918
```

```
108   px 130.49
109   c/z 17.465 13.0353 12.70
110   c/z 17.465 13.0353 10.16
111   s   17.465 13.0353 27.68 10.16
112   s   17.465 13.0353 27.68 12.70
201   cz  6.985
329   p  -0.5  0.866025 0 7.035
330   p   0.5  0.866025 0 7.035
331   px  7.035
332   p  -0.5  0.866025 0 -7.035
333   p   0.5  0.866025 0 -7.035
334   px  -7.035
433   px  154.770
444   py  124.613
202   c/z 70.350 86.577 6.985
203   c/z 84.0797 89.5674 6.985
204   c/z 95.4726 81.3125 6.985
205   c/z 56.6203 89.5674 6.985
206   c/z 45.2274 81.3125 6.985
777   pz   -777.   $ redundant surface to put on cell cards with none

m1    1001.5  2  8016.5 1                                  $water
mt1   lwtr.01
m3   94239.55 -0.04167 8016.50 -0.89002 1001.50 -0.11144   $pu + water
mt3   lwtr.01
m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
      6012.50 -0.17100                                   $pu + carbon +water
mt4   lwtr.01
m5   94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110   $pu + water
mt5   lwtr.01
m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
mt7   lwtr.01
m8   94239.55 -4.80769 8016.50 -0.67026 1001.50 -0.08445   $pu + water
mt8   lwtr.01
m10  20000.50 -0.40973 14000.50 -0.09782 13027.50 -0.03853
     12000.50 -0.03293  8016.50 -0.41092  1001.50 -0.01007 $cement 9% h2o
mt10  lwtr.01
m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
      6012.50 -0.68842 14000.50 -0.65338                  $pu +c+sio2+ water
mt11  lwtr.01
kcode 5000 1.0 10 200
ksrc  84. 43. 10
      98. 43. 10
      77. 55. 10
      91. 55. 10
      105. 55. 10
      84. 68. 10
      98. 68. 10
      10. 122. 10
      10. 101. 10
ctme 240
print 10 40 50
prdmp j j j 3

*****************************************************************************************
diff c0001f1b7e.i c0001f1b7b.i >diff1b7eb7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7e
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
3c3
< c     glovebox - full water reflection on all sides, water can refl
---
> c     glovebox - full water reflection on all sides, cement can refl
68c68
< 204    1  -1.0    -201 -28 u=3                               imp:n=1
---
> 204    10 -2.911  -201 -28 u=3                               imp:n=1

*****************************************************************************************
diff c0001f1b7c.i c0001f1b7b.i >diff1b7cb7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7c
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
```

```
49c49
<           fill=1 (0 7.035 0)                                        imp:n=1
---
>           fill=1 (7.035 7.035 0)                                    imp:n=1
53,57c53,58
<         4 4 4 4 4 4 2 2 3 3 3 3 3 3 3 3 4 4
<         4 4 4 4 4 2 2 2 3 3 3 3 3 3 3 4 4 4
<         4 4 4 4 4 2 2 3 3 3 3 3 3 3 3 4 4 4
<         4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4
<         4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4
---
>         4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>         4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>         4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>         4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>         4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>         4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
59d59
<         4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
175c175
< m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.1004
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
191,197c191,197
< ksrc  14. 7. 10
<       28. 7. 10
<       7. 19. 10
<       21. 19. 10
<       35. 19. 10
<       14. 31. 10
<       28. 31. 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10

*************************************************************************************
diff c0001f1b7d.i c0001f1b7b.i >diff1b7db7b
1,2c1,2
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7d
< c     base case 900g + 0 g conveyor + 300g holdup + 200g outside
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
14,15d13
< c     room - 1 2.76 L can 6" spacing from glovebox wall
< c            0.200 kg pu + water
45,46c43,44
<  22   5  -1.0749   70 -28 -53                                     imp:n=1
<  23   0            70 -28 53 64 -65 41 66 -1                      imp:n=1
---
>  22   1  -1.0   70 -28 -53                                        imp:n=1
>  23   1  -1.0   70 -28 53 64 -65 41 66 -1                         imp:n=1
51c49
<           fill=1 (0 7.035 0)                                        imp:n=1
---
>           fill=1 (7.035 7.035 0)                                    imp:n=1
55,59c53,58
<         4 4 4 4 4 4 2 2 3 3 3 3 3 3 3 3 4 4
<         4 4 4 4 4 2 2 2 3 3 3 3 3 3 3 4 4 4
<         4 4 4 4 4 2 2 3 3 3 3 3 3 3 3 4 4 4
<         4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4
<         4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4
---
>         4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>         4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>         4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>         4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>         4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>         4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
61d59
```

```
<        4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
126c124
<  53   c/z -23.495 19.220 6.985
---
>  53   c/z -23.495 121.87 6.985
137,138c135,136
<  64   py  12.235
<  65   py  26.205
---
>  64   py  114.885
>  65   py  128.855
140c138
<  67   c/z -23.495 19.220 37.465
---
>  67   c/z -23.495 121.87 37.465
177c175
< m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.1004
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
193,199c191,197
< ksrc  14. 7. 10
<       28. 7. 10
<       7. 19. 10
<       21. 19. 10
<       35. 19. 10
<       14. 31. 10
<       28. 31. 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
202d199
<       -23. 19. 10

*****************************************************************************************
diff c0001f1b7f.i c0001f1b7b.i >diff1b7fb7b
1,2c1,2
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7f
< c     base case 900g + 0 g conveyor + 300g holdup + 200g outside
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
14,15d13
< c     room - 1 2.76 L can 6" spacing from glovebox wall
< c           0.200 kg pu + water
45,46c43,44
<  22   5  -1.0749   70 -28 -53                                       imp:n=1
<  23   0           70 -28 53 64 -65 41 66 -1                         imp:n=1
---
>  22   1  -1.0   70 -28 -53                                          imp:n=1
>  23   1  -1.0   70 -28 53 64 -65 41 66 -1                           imp:n=1
202d199
<       -23. 121. 10

*****************************************************************************************
diff c0001f1b18.i c0001f1b7b.i >diff1b18b7b
1,2c1,2
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b18
< c     base case 900g + 400 g conveyor + 300g holdup + 0g outside
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
14,17d13
< c     conveyor container - 1 4.7 L can pu + water 10" from cans
< c                 0.08511 g pu/cc
< c                 h/x=309
< c                 400 g pu total
46,49d41
< c     container on conveyor
<  19   7  -1.088   70 -28 -138                                       imp:n=1
<  20   1  -1.0     70 -20 138 -139                                   imp:n=1
```

```
< 21    1  -1.0      28 -20 -138                                    imp:n=1
56c48
< 25    0  1 3 -433 -444 70 -20 33 35 #19 #20 #21
---
> 25    0  1 3 -433 -444 70 -20 33 35
61,67c53,59
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 3 2 2 4 4 4 4 4 4 4
<       4 4 4 3 3 3 3 3 2 2 2 4 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 2 2 3 3 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
178,180d169
< 138   c/z 140.00 31.4 9.1091
< 139   c/z 140.00 31.4 11.6491
< 142   c/z 133.665 31.405 30.25
191c180
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
211d199
<       140. 31. 10

***************************************************************************************
diff c0001f1b3a.i c0001f1b7b.i >diff1b3ab7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b3a
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10,12c10,12
< c     containers - 3 2.76 L cans 90% water 10% carbon
< c                  0.06032 g pu/cc
< c                  h/x=393
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
> c                  0.02585 g pu/cc
> c                  h/x=921
56,57c56,58
<       4 4 4 4 3 3 3 3 3 2 3 3 3 3 4 4 4 4
<       4 4 4 3 3 3 3 3 2 2 3 3 3 3 4 4 4 4
---
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
59d59
<       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
65c65
< 201   4  -1.133  -201 -28 u=2                                     imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                     imp:n=1
175c175
< m4   94239.55 -0.06032 8016.50 -0.80207 1001.50 -0.10004
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
191,192c191
< ksrc  70. 43. 10
<       84. 43. 10
---
> ksrc  84. 43. 10
195a195,197
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10

***************************************************************************************
diff c0001f1b4a.i c0001f1b7b.i >diff1b4ab7b
```

```
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b4a
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10,12c10,12
< c      containers - 4 2.76 L cans 90% water 10% carbon
< c                   0.04523 g pu/cc
< c                   h/x=525
---
> c      containers - 7 2.76 L cans 90% water 10% carbon
> c                   0.02585 g pu/cc
> c                   h/x=921
56,57c56,58
<        4 4 4 4 3 3 3 3 2 2 3 3 3 3 4 4 4 4
<        4 4 4 3 3 3 3 3 2 2 3 3 3 3 4 4 4 4
---
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>        4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
59d59
<        4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
65c65
< 201    4  -1.118   -201 -28 u=2                                   imp:n=1
---
> 201    4  -1.098   -201 -28 u=2                                   imp:n=1
175c175
< m4   94239.55 -0.04523 8016.50 -0.80137 1001.50 -0.10021
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
191,192c191
< ksrc  70. 43. 10
<       84. 43. 10
---
> ksrc  84. 43. 10
195a195,197
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10

**************************************************************************************
diff c0001f1b1a.i c0001f1b7b.i >diff1b1ab7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b1a
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10,12c10,12
< c      containers - 5 2.76 L cans 90% water 10% carbon
< c                   0.03619 g pu/cc
< c                   h/x=657
---
> c      containers - 7 2.76 L cans 90% water 10% carbon
> c                   0.02585 g pu/cc
> c                   h/x=921
56,57c56,58
<        4 4 4 4 3 3 3 3 2 2 2 3 3 3 4 4 4 4
<        4 4 4 3 3 3 3 3 2 2 3 3 3 3 4 4 4 4
---
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>        4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
59d59
<        4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
65c65
< 201    4  -1.108   -201 -28 u=2                                   imp:n=1
---
> 201    4  -1.098   -201 -28 u=2                                   imp:n=1
175c175
< m4   94239.55 -0.03619 8016.50 -0.80095 1001.50 -0.10031
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
191,192c191
< ksrc  70. 43. 10
<       84. 43. 10
---
> ksrc  84. 43. 10
```

```
195a195,197
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10

*******************************************************************************************
diff c0001f1b6a.i c0001f1b7b.i >diff1b6ab7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b8a
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10,12c10,12
< c     containers - 8 2.76 L cans 90% water 10% carbon
< c                  0.02262 g pu/cc
< c                  h/x=1053
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
> c                  0.02585 g pu/cc
> c                  h/x=921
58c58
<       4 4 4 4 4 3 3 3 2 2 2 3 3 4 4 4 4 4
---
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
65c65
< 201   4  -1.094  -201 -28 u=2                                     imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                     imp:n=1
175c175
< m4   94239.55 -0.02262 8016.50 -0.80033 1001.50 -0.10046
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
198d197
<       112. 68. 10

*******************************************************************************************
diff c0001f1b8a.i c0001f1b7b.i >diff1b8ab7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b8a
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10,12c10,12
< c     containers - 8 2.76 L cans 90% water 10% carbon
< c                  0.02262 g pu/cc
< c                  h/x=1053
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
> c                  0.02585 g pu/cc
> c                  h/x=921
58c58
<       4 4 4 4 4 3 3 3 2 2 2 3 3 4 4 4 4 4
---
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
65c65
< 201   4  -1.094  -201 -28 u=2                                     imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                     imp:n=1
175c175
< m4   94239.55 -0.02262 8016.50 -0.80033 1001.50 -0.10046
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
198d197
<       112. 68. 10

*******************************************************************************************
diff c0001f1b10b.i c0001f1b7b.i >diff1b10bb7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b10b
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10,12c10,12
< c     containers - 9 2.76 L cans 90% water 10% carbon
< c                  0.02010 g pu/cc
< c                  h/x=1185
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
```

```
> c                 0.02585 g pu/cc
> c                 h/x=921
56c56
<       4 4 4 4 3 3 3 3 3 2 2 2 3 3 4 4 4 4
---
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
58c58
<       4 4 4 4 4 3 3 3 2 2 2 3 3 4 4 4 4 4
---
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
65c65
< 201   4  -1.092  -201 -28 u=2                                     imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                     imp:n=1
175c175
< m4   94239.55 -0.02010 8016.50 -0.80021 1001.50 -0.10049
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
198,199d197
<       112. 68. 10
<       70. 43. 10

*************************************************************************************
diff c0001f1b11a.i c0001f1b7b.i >diff1b11ab7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b11a
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10,12c10,12
< c     containers - 10 2.76 L cans 90% water 10% carbon
< c                 0.01809 g pu/cc
< c                 h/x=1317
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
> c                 0.02585 g pu/cc
> c                 h/x=921
53d52
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 4
55,59c54,58
<       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 4 4
<       4 4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4
<       4 4 4 3 3 3 3 3 2 2 2 2 3 3 3 4 4 4
<       4 4 4 4 4 3 3 3 2 2 2 3 3 3 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 4 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
61,62c60,62
<       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
<       4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
65c65
< 201   4  -1.090  -201 -28 u=2                                     imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                     imp:n=1
162c162
< 433   px  168.840
---
> 433   px  154.770
175c175
< m4   94239.55 -0.01809 8016.50 -0.80012 1001.50 -0.10051
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
193d192
<       112. 43. 10
197d195
<       119. 55. 10
200d197
<       112. 68. 10
```

```
*********************************************************************************
diff c0001f1b13a.i c0001f1b7b.i >diff1b13ab7b
1,3c1,3
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b13a
< c      base case 900g + 400 g conveyor + 300g holdup + 200g outside
< c      glovebox - full water reflection on all sides, 1" water refl
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c      base case 900g + 0 g conveyor + 300g holdup + 0g outside
> c      glovebox - full water reflection on all sides, cement can refl
14,19d13
< c      conveyor container - 1 4.7 L can pu + water 10" from cans
< c                    0.08511 g pu/cc
< c                    h/x=309
< c                    400 g pu total
< c      room - 1 2.76 L can 6" spacing from glovebox wall
< c             0.200 kg pu + water
48,50d41
< c      container on conveyor
<  20    7  -1.088  70 -28 -138                                imp:n=1
<  21    1  -1.0      70 -20 (138:28) -139                       imp:n=1
52,53c43,44
<  22    5  -1.0749 70 -28 -53                                  imp:n=1
<  23    0          70 -28 53 64 -65 41 66 -1                   imp:n=1
---
>  22    1  -1.0    70 -28 -53                                  imp:n=1
>  23    1  -1.0    70 -28 53 64 -65 41 66 -1                   imp:n=1
57,72c48,72
< 201    4  -1.098  -120 70 -28                                 imp:n=1
< 202    4  -1.098  -122 70 -28                                 imp:n=1
< 203    4  -1.098  -124 70 -28                                 imp:n=1
< 204    4  -1.098  -126 70 -28                                 imp:n=1
< 205    4  -1.098  -128 70 -28                                 imp:n=1
< 206    4  -1.098  -130 70 -28                                 imp:n=1
< 207    4  -1.098  -132 70 -28                                 imp:n=1
< 208    1  -1.0     ((-121:-123:-125:-129:-131:-133)
<                    (120 122 124 128 130 132 134)) 134 -28 70 -2
<                    (135:-136:-137)                            imp:n=1
< 209    1   -1.0 ((-121:-123:-125:-127:-129:-131:-133) 28 -20 -2) imp:n=1
< 210    0          120 122 124 126 128 130 132 -134 -28 70      imp:n=1
< 211    0          121 123 125 127 129 131 133 -134 28 -20      imp:n=1
< 212    0          -135 136 137 120 122 -2 -28 70              imp:n=1
<  28    0     1 -2 3 -4 121 123 125 127 129 131 133 134 70 -20 33 35
<              (-136:135:-137:28) 139                           imp:n=1
---
>  25    0   1 3 -433 -444 70 -20 33 35
>            fill=1 (7.035 7.035 0)                             imp:n=1
>  26    0     -331 334 -330 333 -329 332  u=1 lat=2
>       fill= -5:12 -1:10 0:0
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                               imp:n=1
> 201    4  -1.098  -201 -28 u=2                               imp:n=1
> 202    1  -1.0     28      u=2                               imp:n=1
> 203    0           201 -28 u=2                               imp:n=1
> 204    10 -2.911  -201 -28 u=3                               imp:n=1
> 205    1  -1.0     28      u=3                               imp:n=1
> 206    0           201 -28 u=3                               imp:n=1
> 207    0           777     u=4                              imp:n=1
>  28    0           1 -2 3 -4 (433:444) 70 -20 33 35          imp:n=1
170,189d169
< 120    c/z 56.280 125.045 6.985
< 121    c/z 56.280 125.045 9.525
< 122    c/z 70.350 125.045 6.985
```

```
< 123   c/z 70.350 125.045 9.525
< 124   c/z 49.245 112.860 6.985
< 125   c/z 49.245 112.860 9.525
< 126   c/z 63.315 112.860 6.985
< 127   c/z 63.315 112.860 9.525
< 128   c/z 77.385 112.860 6.985
< 129   c/z 77.385 112.860 9.525
< 130   c/z 56.280 100.675 6.985
< 131   c/z 56.280 100.675 9.525
< 132   c/z 70.350 100.675 6.985
< 133   c/z 70.350 100.675 9.525
< 134   c/z 63.315 112.860 12.185
< 135   px  70.350
< 136   px  56.280
< 137   py  125.045
< 138   c/z 63.315 59.131 9.1091
< 139   c/z 63.325 59.131 11.6491
200c180
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
211,217c191,197
< ksrc  56 125 10
<       70 125 10
<       49 112 10
<       63 112 10
<       77 112 10
<       56 100 10
<       70 100 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
220,221d199
<       63. 59. 10
<       -23. 121. 10

*****************************************************************************************
diff c0001f1b7i.i c0001f1b7b.i >diff1b7ib7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7i
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
68c68
< 204   10 -2.722  -201 -28 u=3                              imp:n=1
---
> 204   10 -2.911  -201 -28 u=3                              imp:n=1
184,185c184,185
< m10  20000.50 -0.36921 14000.50 -0.08815 13027.50 -0.03472
<      12000.50 -0.02967  8016.50 -0.45811  1001.50 -0.02014 $cement 18% h2o
---
> m10  20000.50 -0.40973 14000.50 -0.09782 13027.50 -0.03853
>      12000.50 -0.03293  8016.50 -0.41092  1001.50 -0.01007 $cement 9% h2o

*****************************************************************************************
diff c0001f1b20.i c0001f1b7b.i >diff1b20b7b
1,3c1,3
< glovebox ha20mb cementation model - base sens case 1200 g pu - c0001f1b20
< c     base case 400g + 0 g conveyor + 000g holdup + 0g outside
< c     glovebox - full water reflection on all sides, 1" water refl
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
> c     glovebox - full water reflection on all sides, cement can refl
10c10
< c     containers - 0 2.76 L cans 90% water 10% carbon
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
13,19c13
< c                 0 g pu total
< c     conveyor container - 0 4.7 L can pu + water 10" from cans
```

```
< c                 0.08511 g pu/cc
< c                 h/x=309
< c                 0 g pu total
< c      room - 0 2.76 L can 6" spacing from glovebox wall
< c             0.00 kg pu + water
---
> c                 500 g pu total
48,50d41
< c     container on conveyor
<  20   0           70 -28 -138                                    imp:n=1
<  21   0           70 -20 (138:28) -139                           imp:n=1
52c43
<  22   1  -1.0     70 -28 -53                                     imp:n=1
---
>  22   1  -1.0    70 -28 -53                                      imp:n=1
55c46
<  24   0          5 -70 1 -4 -2 3                                 imp:n=1
---
>  24   8  -5.562 5 -70 1 -4 -2 3                                  imp:n=1
57,72c48,72
< 201   0           -120 70 -28                                    imp:n=1
< 202   0           -122 70 -28                                    imp:n=1
< 203   0           -124 70 -28                                    imp:n=1
< 204   0           -126 70 -28                                    imp:n=1
< 205   0           -128 70 -28                                    imp:n=1
< 206   0           -130 70 -28                                    imp:n=1
< 207   0           -132 70 -28                                    imp:n=1
< 208   0        ((-121:-123:-125:-129:-131:-133)
<                   (120 122 124 128 130 132 134)) 134 -28 70 -2
<                   (135:-136:-137)                                imp:n=1
< 209   0       ((-121:-123:-125:-127:-129:-131:-133) 28 -20 -2) imp:n=1
< 210   0           120 122 124 126 128 130 132 -134 -28 70        imp:n=1
< 211   0           121 123 125 127 129 131 133 -134 28 -20        imp:n=1
< 212   0           -135 136 137 120 122 -2 -28 70                 imp:n=1
<  28   0   1 -2 3 -4 121 123 125 127 129 131 133 134 70 -20 33 35
<           (-136:135:-137:28) 139                                 imp:n=1
---
>  25   0  1 3 -433 -444 70 -20 33 35
>          fill=1 (7.035 7.035 0)                                  imp:n=1
>  26   0     -331 334 -330 333 -329 332  u=1 lat=2
>       fill= -5:12 -1:10 0:0
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                 imp:n=1
> 201   4  -1.098  -201 -28 u=2                                   imp:n=1
> 202   1  -1.0  .  28      u=2                                   imp:n=1
> 203   0           201 -28 u=2                                   imp:n=1
> 204   10 -2.911  -201 -28 u=3                                   imp:n=1
> 205   1  -1.0     28      u=3                                   imp:n=1
> 206   0           201 -28 u=3                                   imp:n=1
> 207   0           777    u=4                                   imp:n=1
>  28   0           1 -2 3 -4 (433:444) 70 -20 33 35              imp:n=1
170,189d169
< 120   c/z 56.280 125.045 6.985
< 121   c/z 56.280 125.045 9.525
< 122   c/z 70.350 125.045 6.985
< 123   c/z 70.350 125.045 9.525
< 124   c/z 49.245 112.860 6.985
< 125   c/z 49.245 112.860 9.525
< 126   c/z 63.315 112.860 6.985
< 127   c/z 63.315 112.860 9.525
< 128   c/z 77.385 112.860 6.985
< 129   c/z 77.385 112.860 9.525
< 130   c/z 56.280 100.675 6.985
< 131   c/z 56.280 100.675 9.525
```

```
< 132   c/z 70.350 100.675 6.985
< 133   c/z 70.350 100.675 9.525
< 134   c/z 63.315 112.860 12.185
< 135   px  70.350
< 136   px  56.280
< 137   py  125.045
< 138   c/z 63.315 59.131 9.1091
< 139   c/z 63.325 59.131 11.6491
200c180
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
211,217c191,197
< ksrc  56 125 10
<       70 125 10
<       49 112 10
<       63 112 10
<       77 112 10
<       56 100 10
<       70 100 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
220,221d199
<       63. 59. 10
<       -23. 121. 10

*********************************************************************************************
diff c0001f1b19a.i c0001f1b7b.i >diff1b19ab7b
1,3c1,3
< glovebox ha20mb cementation model - base sens case 1200 g pu - c0001f1b19a
< c     base case 400g + 0 g conveyor + 000g holdup + 200g outside
< c     glovebox - full water reflection on all sides, 1" water refl
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
> c     glovebox - full water reflection on all sides, cement can refl
10c10
< c     containers - 0 2.76 L cans 90% water 10% carbon
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
13,19c13
< c                 0 g pu total
< c     conveyor container - 0 4.7 L can pu + water 10" from cans
< c                 0.08511 g pu/cc
< c                 h/x=309
< c                 0 g pu total
< c     room - 1 2.76 L can 6" spacing from glovebox wall
< c            0.200 kg pu + water
---
> c                 500 g pu total
48,50d41
< c     container on conveyor
<  20   0          70 -28 -138                              imp:n=1
<  21   0          70 -20 (138:28) -139                     imp:n=1
52,53c43,44
<  22   5  -1.0749 70 -28 -53                               imp:n=1
<  23   0         70 -28 53 64 -65 41 66 -1                 imp:n=1
---
>  22   1  -1.0   70 -28 -53                                imp:n=1
>  23   1  -1.0   70 -28 53 64 -65 41 66 -1                 imp:n=1
55c46
<  24   0         5 -70 1 -4 -2 3                           imp:n=1
---
>  24   8  -5.562 5 -70 1 -4 -2 3                           imp:n=1
57,72c48,72
< 201   0          -120 70 -28                              imp:n=1
< 202   0          -122 70 -28                              imp:n=1
< 203   0          -124 70 -28                              imp:n=1
< 204   0          -126 70 -28                              imp:n=1
```

```
< 205   0           -128 70 -28                                     imp:n=1
< 206   0           -130 70 -28                                     imp:n=1
< 207   0           -132 70 -28                                     imp:n=1
< 208   0         ((-121:-123:-125:-129:-131:-133)
<                   (120 122 124 128 130 132 134)) 134 -28 70 -2
<                   (135:-136:-137)                                 imp:n=1
< 209   0        ((-121:-123:-125:-127:-129:-131:-133) 28 -20 -2) imp:n=1
< 210   0           120 122 124 126 128 130 132 -134 -28 70         imp:n=1
< 211   0           121 123 125 127 129 131 133 -134 28 -20         imp:n=1
< 212   0           -135 136 137 120 122 -2 -28 70                  imp:n=1
<  28   0    1 -2 3 -4 121 123 125 127 129 131 133 134 70 -20 33 35
<            (-136:135:-137:28) 139                                 imp:n=1
---
>  25   0  1 3 -433 -444 70 -20 33 35
>          fill=1 (7.035 7.035 0)                                   imp:n=1
>  26   0     -331 334 -330 333 -329 332  u=1 lat=2
>       fill= -5:12 -1:10 0:0
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                   imp:n=1
> 201   4  -1.098   -201 -28 u=2                                    imp:n=1
> 202   1  -1.0      28      u=2                                    imp:n=1
> 203   0            201 -28 u=2                                    imp:n=1
> 204   10 -2.911   -201 -28 u=3                                    imp:n=1
> 205   1  -1.0      28      u=3                                    imp:n=1
> 206   0            201 -28 u=3                                    imp:n=1
> 207   0            777     u=4                                   imp:n=1
>  28   0            1 -2 3 -4 (433:444) 70 -20 33 35               imp:n=1
170,189d169
< 120   c/z 56.280 125.045 6.985
< 121   c/z 56.280 125.045 9.525
< 122   c/z 70.350 125.045 6.985
< 123   c/z 70.350 125.045 9.525
< 124   c/z 49.245 112.860 6.985
< 125   c/z 49.245 112.860 9.525
< 126   c/z 63.315 112.860 6.985
< 127   c/z 63.315 112.860 9.525
< 128   c/z 77.385 112.860 6.985
< 129   c/z 77.385 112.860 9.525
< 130   c/z 56.280 100.675 6.985
< 131   c/z 56.280 100.675 9.525
< 132   c/z 70.350 100.675 6.985
< 133   c/z 70.350 100.675 9.525
< 134   c/z 63.315 112.860 12.185
< 135   px  70.350
< 136   px  56.280
< 137   py  125.045
< 138   c/z 63.315 59.131 9.1091
< 139   c/z 63.325 59.131 11.6491
200c180
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
211,217c191,197
< ksrc  56 125 10
<       70 125 10
<       49 112 10
<       63 112 10
<       77 112 10
<       56 100 10
<       70 100 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
```

```
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
220,221d199
<       63. 59. 10
<       -23. 121. 10
```

```
***********************************************************************************
diff c0001f1b21.i c0001f1b7b.i >diff1b21b7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b21
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10c10
< c     containers - 7 2.76 L cans pu + water
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
12c12
< c                 h/x=1024
---
> c                 h/x=921
65c65
< 201   4  -1.027  -201 -28 u=2                                  imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                  imp:n=1
175c175,176
< m4   94239.55 -0.02585 8016.50 -0.88929 1001.50 -0.11161   $pu + water
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
>       6012.50 -0.17100                              $pu + carbon +water
```

```
***********************************************************************************
diff c0001f1b22.i c0001f1b7b.i >diff1b22b7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b22
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10c10
< c     containers - 7 2.76 L cans pu + sio2 + water
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
65c65
< 201   4  -1.167  -201 -28 u=2                                  imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                  imp:n=1
175,176c175,176
< m4   94239.55 -0.02585 8016.50 -0.92848 1001.50 -0.10042
<       14000.50 -0.11200                                $pu + sio2 + water
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
>       6012.50 -0.17100                              $pu + carbon +water
```

```
***********************************************************************************
diff c0001f1b23.i c0001f1b7b.i >diff123b7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b23
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
10c10
< c     containers - 7 2.76 L cans 90% water 10% dry cement
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
65c65
< 201   4  -1.0268 -201 -28 u=2                                  imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                  imp:n=1
175,177c175,176
< m4   94239.55 -0.02585 8016.50 -0.83685 1001.50 -0.10042
<      20000.50 -0.04503 14000.50 -0.01075 13027.50 -0.00423
<      12000.50 -0.00362                               $pu + cement +water
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
>       6012.50 -0.17100                              $pu + carbon +water
```

```
************************************************************************************
diff c0001f1q1a.i c0001f1b7b.i >diff1q1ab7b
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
4d3
< c      2" water flooded, 10% water spray
6c5
< c      bowls -  two bowls next to cans
---
> c      bowls -  two bowls in corner 10" from cans
11,13c10,12
< c      containers - 5 2.76 L cans 90% water 10% carbon
< c                   0.03619 g pu/cc
< c                   h/x=627
---
> c      containers - 7 2.76 L cans 90% water 10% carbon
> c                   0.02585 g pu/cc
> c                   h/x=921
17c16
<   1   1  -0.1   1 -2 3 -4 20 -6                              imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                              imp:n=1
31d29
< c      containers
33,35c31,35
<   8   3  -1.0431  ((63 -28):(-63 -61 69)) -32                 imp:n=1
<   9   1  -0.1     -32 -63 61 71                              imp:n=1
<  10   1  -1.0     -32 70 -71 (61:-69)                        imp:n=1
---
>   8   3  -1.0431  ((63 -28):(-63 -61 69)) -32                imp:n=1
> c      bowl water reflection
>   9   1  -1.0   ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                 (-69 70 -62)) -2 1  103                        imp:n=1
>  10   0         -33 -63 70 62 -2 1  103                        imp:n=1
37,45c37,41
<  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                 imp:n=1
<  12   1  -0.1     -34 -63 58 71                              imp:n=1
<  13   1  -1.0     -34 70 -71 (58:-69)                        imp:n=1
< c      can
<  14   10 -2.911 -202 70 -28                                   imp:n=1
<  15   10 -2.911 -203 70 -28                                   imp:n=1
<  16   10 -2.911 -204 70 -28                                   imp:n=1
<  17   10 -2.911 -205 70 -28                                   imp:n=1
<  18   10 -2.911 -206 70 -28                                   imp:n=1
---
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                imp:n=1
> c      bowl water reflection
>  12   1  -1.0   ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                 (-69 70 -60)) -2 1 -103                        imp:n=1
>  13   0         -35 -63 70 60 -2 1 -103                        imp:n=1
52c48
<  25   0  1 3 -433 -444 70 -28 32 34 202 203 204 205 206
---
>  25   0  1 3 -433 -444 70 -20 33 35
57,66c53,62
<        4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
<        4 4 3 3 4 3 3 3 3 3 3 3 3 3 3 4 4 4
<        4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
<        4 4 3 4 3 3 3 2 2 3 3 3 3 3 4 4 4 4
<        4 4 3 3 3 3 2 2 2 3 3 3 3 3 4 4 4 4
<        4 4 4 3 3 3 4 4 4 3 3 3 3 4 4 4 4 4
<        4 4 3 3 3 4 4 4 4 3 3 3 3 4 4 4 4 4
<        4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
<        4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4
<        4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4
---
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>        4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
```

```
>        4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
69,79c65,72
< 201    4  -1.108   -201  u=2                                       imp:n=1
< 202    1  -0.1      201 71  u=2                                    imp:n=1
< 203    1  -1.0      201 -71 u=2                                    imp:n=1
< 204    10 -2.911   -201  u=3                                       imp:n=1
< 205    1  -0.1      201 71  u=3                                    imp:n=1
< 206    1  -1.0      201 -71 u=3                                    imp:n=1
< 207    1  -0.1      71  u=4                                        imp:n=1
< 208    1  -1.0     -71  u=4                                        imp:n=1
<  27    1  -0.1      1  3 -433 -444 28 -20                          imp:n=1
<  28    1  -0.1      1 -2 3 -4 (433:444) 71 -20                     imp:n=1
<  29    1  -1.0      1 -2 3 -4 (433:444) 70 -71                     imp:n=1
---
> 201    4  -1.098   -201 -28 u=2                                    imp:n=1
> 202    1  -1.0      28      u=2                                    imp:n=1
> 203    0            201 -28 u=2                                    imp:n=1
> 204    10 -2.911   -201 -28 u=3                                    imp:n=1
> 205    1  -1.0      28      u=3                                    imp:n=1
> 206    0            201 -28 u=3                                    imp:n=1
> 207    0            777     u=4                                   imp:n=1
>  28    0            1 -2 3 -4 (433:444) 70 -20 33 35               imp:n=1
111,114c104,107
<  32    c/z 60.162 72.690 10.16
<  33    c/z 60.162 72.690 12.70
<  34    c/z 80.538 72.690 10.16
<  35    c/z 80.538 72.690 12.70
---
>  32    c/z 10.21 121.87 10.16
>  33    c/z 10.21 121.87 12.70
>  34    c/z 10.21 101.45 10.16
>  35    c/z 10.21 101.45 12.70
136c129
<  58    s    80.538 72.690 9.98 10.16
---
>  58    s    10.21 101.45 9.98 10.16
138,140c131,133
<  60    s    80.538 72.690 9.98 12.70
<  61    s    60.162 72.690 9.98 10.16
<  62    s    60.162 72.690 9.98 12.70
---
>  60    s    10.21 101.45 9.98 12.70
>  61    s    10.21 121.87 9.98 10.16
>  62    s    10.21 121.87 9.98 12.70
152c145
< 103    px   120.33
---
> 103    py   111.66
169c162
< 433    px   155.870
---
> 433    px   154.770
182c175
< m4    94239.55 -0.03619 8016.50 -0.80095 1001.50 -0.10031
---
> m4    94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
185c178
< m5    94239.55 -0.07339 8016.50 -0.89148 1001.50 -0.11109   $pu + water
---
> m5    94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110   $pu + water
198,201c191,192
< ksrc  56. 43. 10
<       70. 43. 10
<       84. 43. 10
<       63. 55. 10
---
> ksrc  84. 43. 10
>       98. 43. 10
204,210c195,199
<       49. 31. 10
<       63. 31. 10
<       77. 31. 10
<       42. 43. 10
```

```
<       49. 55. 10
<       60. 72. 10
<       80. 72. 10
---
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
>       10. 122. 10
>       10. 101. 10

***************************************************************************************
diff c0001f1q1.i c0001f1q1a.i >diff1q1q1a
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f1q1
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
7c7
< c             0.04228 g pu/cc pu
---
> c             0.04167 g pu/cc pu
9c9
< c             h/x
---
> c             h/x=634
11,13c11,13
< c     containers - 4 2.76 L cans 90% water 10% carbon
< c                    0.04587 g pu/cc
< c                    h/x=525
---
> c     containers - 5 2.76 L cans 90% water 10% carbon
> c                    0.03619 g pu/cc
> c                    h/x=627
61c61
<       4 4 3 3 3 3 3 2 2 3 3 3 3 3 4 4 4 4
---
>       4 4 3 3 3 3 2 2 2 3 3 3 3 3 4 4 4 4
69c69
< 201   4  -1.118  -201  u=2                                 imp:n=1
---
> 201   4  -1.108  -201  u=2                                 imp:n=1
131c131
<  53   c/z -23.495 111.11 6.985
---
>  53   c/z -23.495 121.87 6.985
142,143c142,143
<  64   py  104.125
<  65   py  118.095
---
>  64   py  114.885
>  65   py  128.855
145c145
<  67   c/z -23.495 111.11 37.465
---
>  67   c/z -23.495 121.87 37.465
182c182
< m4   94239.55 -0.04523 8016.50 -0.80137 1001.50 -0.10021
---
> m4   94239.55 -0.03619 8016.50 -0.80095 1001.50 -0.10031

***************************************************************************************
diff c0001f1q4.i c0001f1q1a.i >diff1q4q1a
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f1q4
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
11,13c11,13
< c     containers - 7 2.76 L cans 90% water 10% carbon
< c                    0.02585 g pu/cc
< c                    h/x=921
---
> c     containers - 5 2.76 L cans 90% water 10% carbon
> c                    0.03619 g pu/cc
> c                    h/x=627
57,61c57,61
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
```

```
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
<       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
<       4 4 4 4 3 3 3 2 2 2 3 3 3 3 4 4 4 4
<       4 4 4 3 3 3 2 2 2 2 3 3 3 3 4 4 4 4
---
>       4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 3 3 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 3 4 3 3 3 2 2 3 3 3 3 3 4 4 4 4
>       4 4 3 3 3 3 2 2 2 3 3 3 3 3 4 4 4 4
69c69
< 201   4  -1.098  -201  u=2                                 imp:n=1
---
> 201   4  -1.108  -201  u=2                                 imp:n=1
182c182
< m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
---
> m4   94239.55 -0.03619 8016.50 -0.80095 1001.50 -0.10031
201d200
<       49. 55. 10
204a204,208
>       49. 31. 10
>       63. 31. 10
>       77. 31. 10
>       42. 43. 10
>       49. 55. 10

*******************************************************************************************
diff c0001f1q3.i c0001f1q1a.i >diff1q3q1a
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f1q3
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
11,13c11,13
< c     containers - 7 2.76 L cans 90% water 10% carbon
< c                  0.02585 g pu/cc
< c                  h/x=921
---
> c     containers - 5 2.76 L cans 90% water 10% carbon
> c                  0.03619 g pu/cc
> c                  h/x=627
57,61c57,61
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
<       4 4 4 4 3 3 3 3 2 2 3 3 3 3 3 4 4 4
<       4 4 4 4 3 3 3 2 2 2 3 3 3 3 4 4 4 4
<       4 4 4 3 3 3 3 2 2 3 3 3 3 3 4 4 4 4
---
>       4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 3 3 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 3 4 3 3 3 2 2 3 3 3 3 3 4 4 4 4
>       4 4 3 3 3 3 2 2 2 3 3 3 3 3 4 4 4 4
69c69
< 201   4  -1.098  -201  u=2                                 imp:n=1
---
> 201   4  -1.108  -201  u=2                                 imp:n=1
182c182
< m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
---
> m4   94239.55 -0.03619 8016.50 -0.80095 1001.50 -0.10031
202a203,204
>       91. 55. 10
>       49. 31. 10
204a207,208
>       42. 43. 10
>       49. 55. 10

*******************************************************************************************
diff c0001f1q5.i c0001f1q1a.i >diff1q5q1a
1,6c1,4
< glovebox ha20mb cementation model - seismic case 1200 g pu - c0001f1q5
< c     base case 900g + +300g holdup
< c     glovebox - full water reflection on all sides
< c
```

```
< c      1200 g pu at 150 g/L in water in glovebox conveyor housing under floor,
< c      2" water on floor, 10% water spray
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
> c      base case 900g + 0 g conveyor + 300g holdup + 0g outside
> c      glovebox - full water reflection on all sides, cement can refl
> c      2" water flooded, 10% water spray
7a6,14
> c      bowls -  two bowls next to cans
> c              0.04167 g pu/cc pu
> c              0.200 kg pu/bowl
> c              h/x=634
> c              sides, bottom of bowls not included
> c      containers - 5 2.76 L cans 90% water 10% carbon
> c                      0.03619 g pu/cc
> c                      h/x=627
> c                      500 g pu total
10c17
<   1    1  -0.1    1 -2 3 -4 71 -6                                    imp:n=1
---
>   1    1  -0.1    1 -2 3 -4 20 -6                                    imp:n=1
12,13c19
<   2    20 -1.155242  24 -25 7 -72 8 -9                               imp:n=1
<   3    1  -1.0       24 -25 72 -5 8 -9                               imp:n=1
---
>   2    1  -1.0 24 -25 7 -5 8 -9                                      imp:n=1
25,26c31,45
< c      2 inch layer on floor
<   8    1  -1.0       1 -2 3 -4  70 -71                               imp:n=1
---
> c      containers
> c      bowl
>   8    3  -1.0431  ((63 -28):(-63 -61 69)) -32                        imp:n=1
>   9    1  -0.1     -32 -63 61 71                                     imp:n=1
>  10    1  -1.0     -32 70 -71 (61:-69)                               imp:n=1
> c      bowl
>  11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                        imp:n=1
>  12    1  -0.1     -34 -63 58 71                                     imp:n=1
>  13    1  -1.0     -34 70 -71 (58:-69)                               imp:n=1
> c      can
>  14    10 -2.911 -202 70 -28                                         imp:n=1
>  15    10 -2.911 -203 70 -28                                         imp:n=1
>  16    10 -2.911 -204 70 -28                                         imp:n=1
>  17    10 -2.911 -205 70 -28                                         imp:n=1
>  18    10 -2.911 -206 70 -28                                         imp:n=1
28,29c47,48
<  22    1  -1.0     70 -28 -53                                        imp:n=1
<  23    1  -1.0   70 -28 53 64 -65 41 66 -1                           imp:n=1
---
>  22    1  -1.0   70 -28 -53                                          imp:n=1
>  23    1  -1.0   70 -28 53 64 -65 41 66 -1                           imp:n=1
31c50,79
<  24    1  -1.0      5 -70 1 -4 -2 3                                  imp:n=1
---
>  24    8  -5.562 5 -70 1 -4 -2 3                                     imp:n=1
> c      filled cans
>  25    0  1 3 -433 -444 70 -28 32 34 202 203 204 205 206
>            fill=1 (7.035 7.035 0)                                    imp:n=1
>  26    0    -331 334 -330 333 -329 332  u=1 lat=2
>        fill= -5:12 -1:10 0:0
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>        4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 3 3 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 3 4 3 3 3 2 2 3 3 3 3 3 4 4 4 4
>        4 4 3 3 3 3 2 2 2 3 3 3 3 3 4 4 4 4
>        4 4 4 3 3 3 4 4 4 3 3 3 3 4 4 4 4 4
>        4 4 3 3 3 4 4 4 4 3 3 3 3 4 4 4 4 4
>        4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                      imp:n=1
> 201    4  -1.108   -201  u=2                                         imp:n=1
> 202    1  -0.1      201 71  u=2                                      imp:n=1
```

```
> 203    1  -1.0      201 -71 u=2                                         imp:n=1
> 204    10 -2.911   -201  u=3                                            imp:n=1
> 205    1  -0.1      201 71  u=3                                         imp:n=1
> 206    1  -1.0      201 -71 u=3                                         imp:n=1
> 207    1  -0.1      71  u=4                                             imp:n=1
> 208    1  -1.0     -71  u=4                                             imp:n=1
>  27    1  -0.1      1  3 -433 -444 28 -20                               imp:n=1
>  28    1  -0.1      1 -2 3 -4 (433:444) 71 -20                          imp:n=1
>  29    1  -1.0      1 -2 3 -4 (433:444) 70 -71                          imp:n=1
63,66c111,114
<  32   c/z 10.21 121.87 10.16
<  33   c/z 10.21 121.87 12.70
<  34   c/z 10.21 101.45 10.16
<  35   c/z 10.21 101.45 12.70
---
>  32   c/z 60.162 72.690 10.16
>  33   c/z 60.162 72.690 12.70
>  34   c/z 80.538 72.690 10.16
>  35   c/z 80.538 72.690 12.70
88c136
<  58   s    10.21 101.45 9.98 10.16
---
>  58   s    80.538 72.690 9.98 10.16
90,92c138,140
<  60   s    10.21 101.45 9.98 12.70
<  61   s    10.21 121.87 9.98 10.16
<  62   s    10.21 121.87 9.98 12.70
---
>  60   s    80.538 72.690 9.98 12.70
>  61   s    60.162 72.690 9.98 10.16
>  62   s    60.162 72.690 9.98 12.70
102d149
<  72   pz  -34.81
105c152
< 103   py  111.66
---
> 103   px  120.33
121a169,170
> 433   px  155.870
> 444   py  124.613
128,165d176
< 120   c/z 56.280 125.045 6.985
< 121   c/z 56.280 125.045 9.525
< 122   c/z 70.350 125.045 6.985
< 123   c/z 70.350 125.045 9.525
< 124   c/z 49.245 112.860 6.985
< 125   c/z 49.245 112.860 9.525
< 126   c/z 63.315 112.860 6.985
< 127   c/z 63.315 112.860 9.525
< 128   c/z 77.385 112.860 6.985
< 129   c/z 77.385 112.860 9.525
< 130   c/z 56.280 100.675 6.985
< 131   c/z 56.280 100.675 9.525
< 132   c/z 70.350 100.675 6.985
< 133   c/z 70.350 100.675 9.525
< 134   c/z 63.315 112.860 12.185
< 135   px  70.350
< 136   px  56.280
< 137   py  125.045
< 138   c/z 63.315 59.131 9.1091
< 139   c/z 63.315 59.131 11.6491
< 420   c/z 123.890 125.045 6.985
< 421   c/z 123.890 125.045 9.525
< 422   c/z 137.960 125.045 6.985
< 423   c/z 137.960 125.045 9.525
< 424   c/z 116.855 112.860 6.985
< 425   c/z 116.855 112.860 9.525
< 426   c/z 130.925 112.860 6.985
< 427   c/z 130.925 112.860 9.525
< 428   c/z 144.995 112.860 6.985
< 429   c/z 144.995 112.860 9.525
< 430   c/z 123.890 100.675 6.985
< 431   c/z 123.890 100.675 9.525
< 432   c/z 137.960 100.675 6.985
< 433   c/z 137.960 100.675 9.525
```

```
< 434   c/z 130.925 112.860 12.185
< 435   px  137.960
< 436   px  123.890
< 437   py  125.045
171c182
< m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
---
> m4   94239.55 -0.03619 8016.50 -0.80095 1001.50 -0.10031
174c185
< m5   94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110   $pu + water
---
> m5   94239.55 -0.07339 8016.50 -0.89148 1001.50 -0.11109   $pu + water
176c187
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
186,187d196
< m20   94239.55 -0.1500 8016.50 -0.895002 1001.50 -0.11024  $pu + water
< mt20   lwtr.01
189,190c198,210
< ksrc  235. 66. -35.
<
---
> ksrc  56. 43. 10
>       70. 43. 10
>       84. 43. 10
>       63. 55. 10
>       77. 55. 10
>       91. 55. 10
>       49. 31. 10
>       63. 31. 10
>       77. 31. 10
>       42. 43. 10
>       49. 55. 10
>       60. 72. 10
>       80. 72. 10

*****************************************************************************************
diff c0001f1q1e.i c0001f1q1a.i >diff1q1eq1a
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f1q1e
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
4c4
< c      2" water flooded, 0.001 g/cc water spray
---
> c      2" water flooded, 10% water spray
17c17
<   1    1  -0.001 1 -2 3 -4 20 -6                          imp:n=1
---
>   1    1  -0.1    1 -2 3 -4 20 -6                         imp:n=1
34c34
<   9    1  -0.001   -32 -63 61 71                          imp:n=1
---
>   9    1  -0.1     -32 -63 61 71                          imp:n=1
38c38
<  12    1  -0.001   -34 -63 58 71                          imp:n=1
---
>  12    1  -0.1     -34 -63 58 71                          imp:n=1
70c70
< 202    1  -0.001   201 71  u=2                            imp:n=1
---
> 202    1  -0.1     201 71  u=2                            imp:n=1
73c73
< 205    1  -0.001   201 71  u=3                            imp:n=1
---
> 205    1  -0.1     201 71  u=3                            imp:n=1
75c75
< 207    1  -0.001   71  u=4                                imp:n=1
---
> 207    1  -0.1     71  u=4                                imp:n=1
77,78c77,78
<  27    1  -0.001   1  3 -433 -444 28 -20                  imp:n=1
<  28    1  -0.001   1 -2 3 -4 (433:444) 71 -20             imp:n=1
---
```

```
>  27   1  -0.1      1  3 -433 -444 28 -20                           imp:n=1
>  28   1  -0.1      1 -2 3 -4 (433:444) 71 -20                      imp:n=1

***************************************************************************************
diff c0001f1q1b.i c0001f1q1a.i >diff1q1bq1a
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f1q1b
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
4c4
< c      2" water flooded, 1% water spray
---
> c      2" water flooded, 10% water spray
17c17
<    1    1  -0.01  1 -2 3 -4 20 -6                                  imp:n=1
---
>    1    1  -0.1   1 -2 3 -4 20 -6                                  imp:n=1
34c34
<    9    1  -0.01   -32 -63 61 71                                   imp:n=1
---
>    9    1  -0.1    -32 -63 61 71                                   imp:n=1
38c38
<   12    1  -0.01   -34 -63 58 71                                   imp:n=1
---
>   12    1  -0.1    -34 -63 58 71                                   imp:n=1
70c70
< 202     1  -0.01    201 71  u=2                                    imp:n=1
---
> 202     1  -0.1     201 71  u=2                                    imp:n=1
73c73
< 205     1  -0.01    201 71  u=3                                    imp:n=1
---
> 205     1  -0.1     201 71  u=3                                    imp:n=1
75c75
< 207     1  -0.01    71  u=4                                        imp:n=1
---
> 207     1  -0.1     71  u=4                                        imp:n=1
77,78c77,78
<  27     1  -0.01    1  3 -433 -444 28 -20                          imp:n=1
<  28     1  -0.01    1 -2 3 -4 (433:444) 71 -20                     imp:n=1
---
>  27     1  -0.1     1  3 -433 -444 28 -20                          imp:n=1
>  28     1  -0.1     1 -2 3 -4 (433:444) 71 -20                     imp:n=1

***************************************************************************************
diff c0001f1q1c.i c0001f1q1a.i >diff1q1cq1a
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f1q1c
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
4c4
< c      2" water flooded, 5% water spray
---
> c      2" water flooded, 10% water spray
17c17
<    1    1  -0.05  1 -2 3 -4 20 -6                                  imp:n=1
---
>    1    1  -0.1   1 -2 3 -4 20 -6                                  imp:n=1
34c34
<    9    1  -0.05   -32 -63 61 71                                   imp:n=1
---
>    9    1  -0.1    -32 -63 61 71                                   imp:n=1
38c38
<   12    1  -0.05   -34 -63 58 71                                   imp:n=1
---
>   12    1  -0.1    -34 -63 58 71                                   imp:n=1
70c70
< 202     1  -0.05    201 71  u=2                                    imp:n=1
---
> 202     1  -0.1     201 71  u=2                                    imp:n=1
73c73
< 205     1  -0.05    201 71  u=3                                    imp:n=1
---
> 205     1  -0.1     201 71  u=3                                    imp:n=1
75c75
```

```
< 207   1  -0.05    71  u=4                                          imp:n=1
---
> 207   1  -0.1     71  u=4                                          imp:n=1
77,78c77,78
<  27   1  -0.05    1  3 -433 -444 28 -20                            imp:n=1
<  28   1  -0.05    1 -2 3 -4 (433:444) 71 -20                       imp:n=1
---
>  27   1  -0.1     1  3 -433 -444 28 -20                            imp:n=1
>  28   1  -0.1     1 -2 3 -4 (433:444) 71 -20                       imp:n=1

*************************************************************************************
diff c0001f1q1d.i c0001f1q1a.i >diff1q1dq1a
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f1q1d
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f1q1a
4c4
< c     2" water flooded, 15% water spray
---
> c     2" water flooded, 10% water spray
17c17
<   1   1  -0.15  1 -2 3 -4 20 -6                                    imp:n=1
---
>   1   1  -0.1   1 -2 3 -4 20 -6                                    imp:n=1
34c34
<   9   1  -0.15   -32 -63 61 71                                     imp:n=1
---
>   9   1  -0.1    -32 -63 61 71                                     imp:n=1
38c38
<  12   1  -0.15   -34 -63 58 71                                     imp:n=1
---
>  12   1  -0.1    -34 -63 58 71                                     imp:n=1
70c70
< 202   1  -0.15    201 71  u=2                                      imp:n=1
---
> 202   1  -0.1     201 71  u=2                                      imp:n=1
73c73
< 205   1  -0.15    201 71  u=3                                      imp:n=1
---
> 205   1  -0.1     201 71  u=3                                      imp:n=1
75c75
< 207   1  -0.15    71  u=4                                          imp:n=1
---
> 207   1  -0.1     71  u=4                                          imp:n=1
77,78c77,78
<  27   1  -0.15    1  3 -433 -444 28 -20                            imp:n=1
<  28   1  -0.15    1 -2 3 -4 (433:444) 71 -20                       imp:n=1
---
>  27   1  -0.1     1  3 -433 -444 28 -20                            imp:n=1
>  28   1  -0.1     1 -2 3 -4 (433:444) 71 -20                       imp:n=1

*************************************************************************************
diff c0001f1f1.i c0001f1b7b.i >diff1f1b7b
1c1
< glovebox ha20mb cementation model - fire case 1200 g pu - c0001f1f1
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
6c6
< c             0.04228 g pu/cc pu
---
> c             0.04167 g pu/cc pu
8c8
< c             h/x
---
> c             h/x=634
16c16
<   1   1  -0.1   1 -2 3 -4 20 -6                                    imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                                    imp:n=1
30d29
< c     containers
33,35c32,35
<   9   1  -0.1    -32 -63 61 71                                     imp:n=1
<  10   1  -1.0    -32 70 -71 (61:-69)                               imp:n=1
<  11   1  -0.1    -32 28 -20                                        imp:n=1
```

```
---
> c      bowl water reflection
>   9    1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                   (-69 70 -62)) -2 1  103                          imp:n=1
>  10    0          -33 -63 70 62 -2 1  103                          imp:n=1
37,40c37,41
<  12    3  -1.0431  ((63 -28):(-63 -58 69)) -34                   imp:n=1
<  13    1  -0.1     -34 -63 58 71                                 imp:n=1
<  14    1  -1.0     -34 70 -71 (58:-69)                           imp:n=1
<  15    1  -0.1     -34 28 -20                                    imp:n=1
---
>  11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                   imp:n=1
> c      bowl water reflection
>  12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                   (-69 70 -60)) -2 1 -103                          imp:n=1
>  13    0          -35 -63 70 60 -2 1 -103                          imp:n=1
47c48
<  25    0  1 3 -433 -444 70 -20 32 34
---
>  25    0  1 3 -433 -444 70 -20 33 35
65,75c66,72
< 202    1  -0.1     -201 28  u=2                                  imp:n=1
< 203    1  -0.1      201 71  u=2                                  imp:n=1
< 204    1  -1.0      201 -71 u=2                                  imp:n=1
< 205    10 -2.911   -201 -28 u=3                                  imp:n=1
< 206    1  -0.1     -201 28  u=3                                  imp:n=1
< 207    1  -0.1      201 71  u=3                                  imp:n=1
< 208    1  -1.0      201 -71 u=3                                  imp:n=1
< 209    1  -0.1      71  u=4                                      imp:n=1
< 210    1  -1.0     -71  u=4                                      imp:n=1
<  28    1  -0.1      1 -2 3 -4 (433:444) 71 -20 32 34             imp:n=1
<  29    1  -1.0      1 -2 3 -4 (433:444) 70 -71 32 34             imp:n=1
---
> 202    1  -1.0      28       u=2                                 imp:n=1
> 203    0            201 -28 u=2                                  imp:n=1
> 204    10 -2.911   -201 -28 u=3                                  imp:n=1
> 205    1  -1.0      28       u=3                                 imp:n=1
> 206    0            201 -28 u=3                                  imp:n=1
> 207    0            777     u=4                                 imp:n=1
>  28    0            1 -2 3 -4 (433:444) 70 -20 33 35             imp:n=1
127c124
<  53    c/z -23.495 111.11 6.985
---
>  53    c/z -23.495 121.87 6.985
138,139c135,136
<  64    py  104.125
<  65    py  118.095
---
>  64    py  114.885
>  65    py  128.855
141c138
<  67    c/z -23.495 111.11 37.465
---
>  67    c/z -23.495 121.87 37.465
148c145
< 103    py 111.66
---
> 103    py  111.66
165c162
< 433    px  155.870
---
> 433    px  154.770
181c178
< m5    94239.55 -0.07339 8016.50 -0.89148 1001.50 -0.11109    $pu + water
---
> m5    94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110    $pu + water
202c199
<        30. 122. 10
---
>        10. 101. 10

*****************************************************************************************
diff c0001f1f2.i c0001f1b13a.i >diff1f2b13a
1c1
< glovebox ha20mb cementation model - flooding case 1200 g pu - c0001f1f2
```

```
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b13a
3,4c3
< c     glovebox - full water reflection on all sides, no can reflection
< c     glovebox flooded to 2", 10% water spray
---
> c     glovebox - full water reflection on all sides, 1" water refl
23c22
<   1   2  -0.10    1 -2 3 -4 20 -6                          imp:n=1
---
>   1   0           1 -2 3 -4 20 -6                          imp:n=1
40,43c39,41
<   9   2  -0.1   ((63 -33 -20 (32:28)):(-63 61 -62 71)) -2 1 103 imp:n=1
<  10   1  -1.0    70 -71 -62 (61:-69)  -2 1  103              imp:n=1
<  11   2  -0.1    -33 -63 71 62 -2 1  103                     imp:n=1
<  12   1  -1.0    -33 -71 70 62 -2 1  103                     imp:n=1
---
>   9   1  -1.0   ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                 (-69 70 -62)) -2 1  103                     imp:n=1
>  10   0          -33 -63 70 62 -2 1  103                     imp:n=1
45c43
<  13   3  -1.0431  ((63 -28):(-63 -58 69)) -34                imp:n=1
---
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                imp:n=1
47,50c45,47
<  14   2  -0.1   ((63 -35 -20 (34:28)):(-63 58 -60 71)) -2 1 -103 imp:n=1
<  15   1  -1.0    70 -71 -60 (58:-69) -2 1 -103               imp:n=1
<  16   2  -0.1    -35 -63 71 60 -2 1 -103                     imp:n=1
<  17   1  -1.0    -35 -71 70 60 -2 1 -103                     imp:n=1
---
>  12   1  -1.0   ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                 (-69 70 -60)) -2 1 -103                     imp:n=1
>  13   0          -35 -63 70 60 -2 1 -103                     imp:n=1
52d48
<  19   1  -1.0      70 -71 138 -139                           imp:n=1
54c50
<  21   2  -0.1      71 -20 (138:28) -139                      imp:n=1
---
>  21   1  -1.0      70 -20 (138:28) -139                      imp:n=1
57c53
<  23   0          70 -28 53 64 -65 41 66 -1                   imp:n=1
---
>  23   0          70 -28 53 64 -65 41 66 -1                   imp:n=1
68,69c64,65
< 208   2  -0.1      ((-121:-123:-125:-129:-131:-133)
<                    (120 122 124 128 130 132 134)) 134 -28 71 -2
---
> 208   1  -1.0      ((-121:-123:-125:-129:-131:-133)
>                    (120 122 124 128 130 132 134)) 134 -28 70 -2
71,82c67,71
< 209   2   -0.1 ((-121:-123:-125:-127:-129:-131:-133) 28 -20 -2) imp:n=1
< 210   2  -0.1      120 122 124 126 128 130 132 -134 -28 71      imp:n=1
< 211   2  -0.1      121 123 125 127 129 131 133 -134 28 -20      imp:n=1
< 212   2  -0.1      -135 136 137 120 122 -2 -28 71               imp:n=1
< 213   1  -1.0      ((-121:-123:-125:-129:-131:-133)
<                    (120 122 124 128 130 132 134)) 134 -71 70 -2
<                    (135:-136:-137)                              imp:n=1
< 214   1  -1.0      120 122 124 126 128 130 132 -134 -71 70      imp:n=1
< 215   1  -1.0      -135 136 137 120 122 -2 -71 70               imp:n=1
<  28   2   -0.1 1 -2 3 -4 121 123 125 127 129 131 133 134 71 -20 33 35
<             (-136:135:-137:28) 139                              imp:n=1
<  29   1   -1.0 1 -2 3 -4 121 123 125 127 129 131 133 134 70 -71 33 35
---
> 209   1   -1.0 ((-121:-123:-125:-127:-129:-131:-133) 28 -20 -2) imp:n=1
> 210   0            120 122 124 126 128 130 132 -134 -28 70      imp:n=1
> 211   0            121 123 125 127 129 131 133 -134 28 -20      imp:n=1
> 212   0            -135 136 137 120 122 -2 -28 70               imp:n=1
>  28   0     1 -2 3 -4 121 123 125 127 129 131 133 134 70 -20 33 35
204,205d192
< m2    1001.5  2  8016.5 1                              $water
< mt2   lwtr.01

*************************************************************************************
diff c0001f1f3.i c0001f1b7b.i >diff1f2b7b
1,5c1,3
```

```
< glovebox ha20mb cementation model - flooding case 1200 g pu - c0001f1f3
< c      base case 900g + +300g holdup
< c      glovebox - full water reflection on all sides
< c
< c      1200 g pu in 2" slab on floor mixed with water, 10% water spray
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c      base case 900g + 0 g conveyor + 300g holdup + 0g outside
> c      glovebox - full water reflection on all sides, cement can refl
6a5,13
> c      bowls -  two bowls in corner 10" from cans
> c              0.04167 g pu/cc pu
> c              0.200 kg pu/bowl
> c              h/x=634
> c              sides, bottom of bowls not included
> c      containers - 7 2.76 L cans 90% water 10% carbon
> c                 0.02585 g pu/cc
> c                 h/x=921
> c                 500 g pu total
9c16
<   1    1  -0.1    1 -2 3 -4 71 -6                           imp:n=1
---
>   1    0          1 -2 3 -4 20 -6                           imp:n=1
23c30,41
<   8    20 -1.003918  1 -2 3 -4  70 -71                      imp:n=1
---
> c      bowl
>   8    3  -1.0431  ((63 -28):(-63 -61 69)) -32              imp:n=1
> c      bowl water reflection
>   9    1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                   (-69 70 -62)) -2 1  103                   imp:n=1
>  10    0          -33 -63 70 62 -2 1  103                   imp:n=1
> c      bowl
>  11    3  -1.0431  ((63 -28):(-63 -58 69)) -34              imp:n=1
> c      bowl water reflection
>  12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                   (-69 70 -60)) -2 1 -103                   imp:n=1
>  13    0          -35 -63 70 60 -2 1 -103                   imp:n=1
25,26c43,44
<  22    1  -1.0     70 -28 -53                               imp:n=1
<  23    1  -1.0    70 -28 53 64 -65 41 66 -1                 imp:n=1
---
>  22    1  -1.0    70 -28 -53                                imp:n=1
>  23    1  -1.0    70 -28 53 64 -65 41 66 -1                 imp:n=1
28c46,72
<  24    20 -1.003918 5 -70 1 -4 -2 3                         imp:n=1
---
>  24    8  -5.562 5 -70 1 -4 -2 3                            imp:n=1
> c      filled cans
>  25    0  1 3 -433 -444 70 -20 33 35
>           fill=1 (7.035 7.035 0)                            imp:n=1
>  26    0    -331 334 -330 333 -329 332  u=1 lat=2
>        fill= -5:12 -1:10 0:0
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>        4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                             imp:n=1
> 201    4  -1.098   -201 -28 u=2                             imp:n=1
> 202    1  -1.0      28      u=2                             imp:n=1
> 203    0            201 -28 u=2                             imp:n=1
> 204    10 -2.911   -201 -28 u=3                             imp:n=1
> 205    1  -1.0      28      u=3                             imp:n=1
> 206    0            201 -28 u=3                             imp:n=1
> 207    0            777     u=4                            imp:n=1
>  28    0            1 -2 3 -4 (433:444) 70 -20 33 35        imp:n=1
117a162,163
```

```
> 433   px  154.770
> 444   py  124.613
124,161d169
< 120   c/z 56.280 125.045 6.985
< 121   c/z 56.280 125.045 9.525
< 122   c/z 70.350 125.045 6.985
< 123   c/z 70.350 125.045 9.525
< 124   c/z 49.245 112.860 6.985
< 125   c/z 49.245 112.860 9.525
< 126   c/z 63.315 112.860 6.985
< 127   c/z 63.315 112.860 9.525
< 128   c/z 77.385 112.860 6.985
< 129   c/z 77.385 112.860 9.525
< 130   c/z 56.280 100.675 6.985
< 131   c/z 56.280 100.675 9.525
< 132   c/z 70.350 100.675 6.985
< 133   c/z 70.350 100.675 9.525
< 134   c/z 63.315 112.860 12.185
< 135   px  70.350
< 136   px  56.280
< 137   py  125.045
< 138   c/z 63.315 59.131 9.1091
< 139   c/z 63.315 59.131 11.6491
< 420   c/z 123.890 125.045 6.985
< 421   c/z 123.890 125.045 9.525
< 422   c/z 137.960 125.045 6.985
< 423   c/z 137.960 125.045 9.525
< 424   c/z 116.855 112.860 6.985
< 425   c/z 116.855 112.860 9.525
< 426   c/z 130.925 112.860 6.985
< 427   c/z 130.925 112.860 9.525
< 428   c/z 144.995 112.860 6.985
< 429   c/z 144.995 112.860 9.525
< 430   c/z 123.890 100.675 6.985
< 431   c/z 123.890 100.675 9.525
< 432   c/z 137.960 100.675 6.985
< 433   c/z 137.960 100.675 9.525
< 434   c/z 130.925 112.860 12.185
< 435   px  137.960
< 436   px  123.890
< 437   py  125.045
172c180
< m7    94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
182,183d189
< m20   94239.55 -0.003786 8016.50 -0.888274 1001.50 -0.111859  $pu + water
< mt20   lwtr.01
185,186c191,199
< ksrc  56 125 2
<       -23. 121. 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
>       10. 122. 10
>       10. 101. 10

***************************************************************************************
diff c0001f1f4.i c0001f1b7b.i >diff1f4b7b
1,6c1,3
< glovebox ha20mb cementation model - flooding case 1200 g pu - c0001f1f4
< c     base case 900g +300g holdup
< c     glovebox - full water reflection on all sides
< c
< c     1200 g pu in 2" slab on floor mixed with water, 10% water spray
< c     150 g/cc pu with water above
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
> c     glovebox - full water reflection on all sides, cement can refl
```

```
7a5,13
> c      bowls -  two bowls in corner 10" from cans
> c              0.04167 g pu/cc pu
> c              0.200 kg pu/bowl
> c              h/x=634
> c              sides, bottom of bowls not included
> c      containers - 7 2.76 L cans 90% water 10% carbon
> c                    0.02585 g pu/cc
> c                    h/x=921
> c                    500 g pu total
10c16
<   1    1  -0.1    1 -2 3 -4 71 -6                                 imp:n=1
---
>   1    0          1 -2 3 -4 20 -6                                 imp:n=1
24,25c30,41
<   8    20 -1.155242  1 -2 3 -4  70 -72                            imp:n=1
<   9    1  -1.0       1 -2 3 -4  72 -71                            imp:n=1
---
> c      bowl
>   8    3  -1.0431  ((63 -28):(-63 -61 69)) -32                    imp:n=1
> c      bowl water reflection
>   9    1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                   (-69 70 -62)) -2 1  103                         imp:n=1
>  10    0          -33 -63 70 62 -2 1  103                         imp:n=1
> c      bowl
>  11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                    imp:n=1
> c      bowl water reflection
>  12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                   (-69 70 -60)) -2 1 -103                         imp:n=1
>  13    0          -35 -63 70 60 -2 1 -103                         imp:n=1
27,28c43,44
<  22    5  -1.0749 70 -28 -53                                      imp:n=1
<  23    0          70 -28 53 64 -65 41 66 -1                       imp:n=1
---
>  22    1  -1.0    70 -28 -53                                      imp:n=1
>  23    1  -1.0    70 -28 53 64 -65 41 66 -1                       imp:n=1
30c46,72
<  24    20 -1.155242 5 -70 1 -4 -2 3                               imp:n=1
---
>  24    8  -5.562 5 -70 1 -4 -2 3                                  imp:n=1
> c      filled cans
>  25    0  1 3 -433 -444 70 -20 33 35
>           fill=1 (7.035 7.035 0)                                  imp:n=1
>  26    0     -331 334 -330 333 -329 332  u=1 lat=2
>        fill= -5:12 -1:10 0:0
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>        4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                   imp:n=1
> 201    4  -1.098   -201 -28 u=2                                   imp:n=1
> 202    1  -1.0      28       u=2                                  imp:n=1
> 203    0            201 -28 u=2                                   imp:n=1
> 204    10 -2.911   -201 -28 u=3                                   imp:n=1
> 205    1  -1.0      28       u=3                                  imp:n=1
> 206    0            201 -28 u=3                                   imp:n=1
> 207    0            777     u=4                                  imp:n=1
>  28    0            1 -2 3 -4 (433:444) 70 -20 33 35              imp:n=1
101d142
<  72    pz  0.128205
120a162,163
> 433    px  154.770
> 444    py  124.613
127,164d169
< 120    c/z 56.280 125.045 6.985
< 121    c/z 56.280 125.045 9.525
< 122    c/z 70.350 125.045 6.985
```

```
< 123    c/z 70.350 125.045 9.525
< 124    c/z 49.245 112.860 6.985
< 125    c/z 49.245 112.860 9.525
< 126    c/z 63.315 112.860 6.985
< 127    c/z 63.315 112.860 9.525
< 128    c/z 77.385 112.860 6.985
< 129    c/z 77.385 112.860 9.525
< 130    c/z 56.280 100.675 6.985
< 131    c/z 56.280 100.675 9.525
< 132    c/z 70.350 100.675 6.985
< 133    c/z 70.350 100.675 9.525
< 134    c/z 63.315 112.860 12.185
< 135    px  70.350
< 136    px  56.280
< 137    py  125.045
< 138    c/z 63.315 59.131 9.1091
< 139    c/z 63.315 59.131 11.6491
< 420    c/z 123.890 125.045 6.985
< 421    c/z 123.890 125.045 9.525
< 422    c/z 137.960 125.045 6.985
< 423    c/z 137.960 125.045 9.525
< 424    c/z 116.855 112.860 6.985
< 425    c/z 116.855 112.860 9.525
< 426    c/z 130.925 112.860 6.985
< 427    c/z 130.925 112.860 9.525
< 428    c/z 144.995 112.860 6.985
< 429    c/z 144.995 112.860 9.525
< 430    c/z 123.890 100.675 6.985
< 431    c/z 123.890 100.675 9.525
< 432    c/z 137.960 100.675 6.985
< 433    c/z 137.960 100.675 9.525
< 434    c/z 130.925 112.860 12.185
< 435    px  137.960
< 436    px  123.890
< 437    py  125.045
175c180
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
185,186d189
< m20   94239.55 -0.1500 8016.50 -0.895002 1001.50 -0.11024  $pu + water
< mt20   lwtr.01
188c191,199
< ksrc  56 125 0.1
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
>       10. 122. 10
>       10. 101. 10

*****************************************************************************************
diff c0001f1s3.i c0001f1b7b.i >diff1s3b7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1s3
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
5,6c5
< c     bowls -  one bowl in corner 10" from cans
< c              one bowl stacked on cans
---
> c     bowls -  two bowls in corner 10" from cans
17c16
<   1    0        1 -2 3 -4 20 -6 #14 #15                       imp:n=1
---
>   1    0        1 -2 3 -4 20 -6                               imp:n=1
35,36c34,35
<                 (-69 70 -62)) -2 1                            imp:n=1
<  10    0        -33 -63 70 62 -2 1                            imp:n=1
---
>                 (-69 70 -62)) -2 1  103                       imp:n=1
```

```
> 10   0          -33 -63 70 62 -2 1  103                          imp:n=1
38,41c37,41
< c     container stacked
< 14    3  -1.0431 -110 28 -29 ((59 -29):(-59 -111)) -110          imp:n=1
< c     container water reflection
< 15    1  -1.0   20 -30 ((59 -109 (110:29)):(-59 111 -112))       imp:n=1
---
> 11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                    imp:n=1
> c     bowl water reflection
> 12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                         imp:n=1
> 13    0          -35 -63 70 60 -2 1 -103                         imp:n=1
48c48
< 25    0  1 3 -433 -444 70 -20 33 (111:-28)
---
> 25    0  1 3 -433 -444 70 -20 33 35
72c72
< 28    0            1 -2 3 -4 (433:444) 70 -20 33                 imp:n=1
---
> 28    0            1 -2 3 -4 (433:444) 70 -20 33 35              imp:n=1
151,154c151,154
< 109   c/z 91.455 55.775 12.70
< 110   c/z 91.455 55.775 10.16
< 111   s   91.455 55.775 27.68 10.16
< 112   s   91.455 55.775 27.68 12.70
---
> 109   c/z 17.465 13.0353 12.70
> 110   c/z 17.465 13.0353 10.16
> 111   s   17.465 13.0353 27.68 10.16
> 112   s   17.465 13.0353 27.68 12.70
199c199
<       91. 55. 30
---
>       10. 101. 10

*************************************************************************************
diff c0001f1s4.i c0001f1b7b.i >diff1s4b7b
1c1
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1s4
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
5,6c5
< c     bowls -  one bowl in corner 10" from cans
< c              one bowl stacked on cans
---
> c     bowls -  two bowls in corner 10" from cans
17c16
<  1    0          1 -2 3 -4 20 -6 #14 #15                         imp:n=1
---
>  1    0          1 -2 3 -4 20 -6                                 imp:n=1
35,36c34,35
<                (-69 70 -62)) -2 1                                imp:n=1
< 10    0          -33 -63 70 62 -2 1                              imp:n=1
---
>                (-69 70 -62)) -2 1  103                           imp:n=1
> 10    0          -33 -63 70 62 -2 1  103                         imp:n=1
38,41c37,41
< c     container stacked
< 14    3  -1.0431 -110 28 -29 ((59 -29):(-59 -111)) -110          imp:n=1
< c     container water reflection
< 15    1  -1.0   20 -30 ((59 -109 (110:29)):(-59 111 -112))       imp:n=1
---
> 11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                    imp:n=1
> c     bowl water reflection
> 12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                         imp:n=1
> 13    0          -35 -63 70 60 -2 1 -103                         imp:n=1
48,49c48,49
< 25    0  1 3 -433 -444 70 -20 33 (111:-28)
<           fill=1 (0 7.035 0)                                 imp:n=1
---
> 25    0  1 3 -433 -444 70 -20 33 35
>           fill=1 (7.035 7.035 0)                               imp:n=1
53,58c53,58
<       4 4 4 4 4 4 2 2 3 3 3 3 3 3 3 3 4 4
```

```
<        4 4 4 4 4 2 2 2 3 3 3 3 3 3 3 4 4 4
<        4 4 4 4 4 2 2 3 3 3 3 3 3 3 3 4 4 4
<        4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4
<        4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4
<        4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
---
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>        4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
72c72
<  28    0           1 -2 3 -4 (433:444) 70 -20 33              imp:n=1
---
>  28    0           1 -2 3 -4 (433:444) 70 -20 33 35           imp:n=1
151,154c151,154
< 109    c/z 21.105 19.220 12.70
< 110    c/z 21.105 19.220 10.16
< 111    s   21.105 19.220 27.68 10.16
< 112    s   21.105 19.220 27.68 12.70
---
> 109    c/z 17.465 13.0353 12.70
> 110    c/z 17.465 13.0353 10.16
> 111    s   17.465 13.0353 27.68 10.16
> 112    s   17.465 13.0353 27.68 12.70
191,197c191,197
< ksrc  14. 7. 10
<       28. 7. 10
<       7. 19. 10
<       21. 19. 10
<       35. 19. 10
<       14. 31. 10
<       28. 31. 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
199c199
<       21. 19. 30
---
>       10. 101. 10

*************************************************************************************
diff c0001fls1.i c0001flb7b.i >difflslb7b
1c1
< glovebox ha20mb cementation model - stacked bowl 1200 g pu - c0001fls1
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001flb7b
5,6c5
< c     bowls -  one bowl in corner 10" from cans
< c              one bowl stacked on cans
---
> c     bowls -  two bowls in corner 10" from cans
11,13c10,12
< c     containers - 5 2.76 L cans 90% water 10% carbon
< c                  0.03619 g pu/cc
< c                  h/x=657
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
> c                  0.02585 g pu/cc
> c                  h/x=921
17c16
<   1   0         1 -2 3 -4 20 -6 #14 #15                       imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                               imp:n=1
35,40c34,41
<                 (-69 70 -62)) -2 1                            imp:n=1
<  10   0         -33 -63 70 62 -2 1                            imp:n=1
< c     container stacked
<  14   3  -1.0431 -110 28 -29 ((59 -29):(-59 -111)) -110       imp:n=1
```

```
< c     container water reflection
< 15    1  -1.0    20 -30 ((59 -109 (110:29)):(-59 111 -112))      imp:n=1
---
>                  (-69 70 -62)) -2 1  103                         imp:n=1
> 10    0          -33 -63 70 62 -2 1  103                         imp:n=1
> c     bowl
> 11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                    imp:n=1
> c     bowl water reflection
> 12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                         imp:n=1
> 13    0          -35 -63 70 60 -2 1 -103                         imp:n=1
47c48
< 25    0  1 3 -433 -444 70 -20 33 (111:-28)
---
> 25    0  1 3 -433 -444 70 -20 33 35
55,57c56,58
<       4 4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
<       4 4 4 3 3 3 3 3 3 2 2 3 3 3 3 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4 4
---
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
64c65
< 201   4  -1.108  -201 -28 u=2                                    imp:n=1
---
> 201   4  -1.098  -201 -28 u=2                                    imp:n=1
71c72
< 28    0            1 -2 3 -4 (433:444) 70 -20 33                 imp:n=1
---
> 28    0            1 -2 3 -4 (433:444) 70 -20 33 35              imp:n=1
150,153c151,154
< 109   c/z 84.420 49.6825 12.70
< 110   c/z 84.420 49.6825 10.16
< 111   s   84.420 49.6825 27.68 10.16
< 112   s   84.420 49.6825 27.68 12.70
---
> 109   c/z 17.465 13.0353 12.70
> 110   c/z 17.465 13.0353 10.16
> 111   s   17.465 13.0353 27.68 10.16
> 112   s   17.465 13.0353 27.68 12.70
174c175
< m4   94239.55 -0.03619 8016.50 -0.80095 1001.50 -0.10031
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
190,191c191
< ksrc  70. 43. 10
<       84. 43. 10
---
> ksrc  84. 43. 10
194a195,197
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
197d199
<       84. 49.  30.

*******************************************************************************************
diff c0001f1s2.i c0001f1b7b.i >diff1s2b7b
1c1
< glovebox ha20mb cementation model - stacked bowl 1200 g pu - c0001f1s2
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
5,6c5
< c     bowls -  one bowl in corner 10" from cans
< c              one bowl stacked on cans
---
> c     bowls -  two bowls in corner 10" from cans
11,13c10,12
< c     containers - 5 2.76 L cans 90% water 10% carbon
< c                    0.03619 g pu/cc
< c                    h/x=657
---
> c     containers - 7 2.76 L cans 90% water 10% carbon
> c                    0.02585 g pu/cc
```

```
> c                 h/x=921
17c16
<   1    0         1 -2 3 -4 20 -6 #14 #15                          imp:n=1
---
>   1    0         1 -2 3 -4 20 -6                                  imp:n=1
35,40c34,41
<                  (-69 70 -62)) -2 1                               imp:n=1
<  10    0         -33 -63 70 62 -2 1                               imp:n=1
< c      container stacked
<  14    3  -1.0431 -110 28 -29 ((59 -29):(-59 -111)) -110          imp:n=1
< c      container water reflection
<  15    1  -1.0   20 -30 ((59 -109 (110:29)):(-59 111 -112)) 1 3 imp:n=1
---
>                  (-69 70 -62)) -2 1  103                          imp:n=1
>  10    0         -33 -63 70 62 -2 1  103                          imp:n=1
> c      bowl
>  11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                    imp:n=1
> c      bowl water reflection
>  12    1  -1.0   ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                          imp:n=1
>  13    0         -35 -63 70 60 -2 1 -103                          imp:n=1
47c48
<  25    0  1 3 -433 -444 70 -20 33 (111:-28)
---
>  25    0  1 3 -433 -444 70 -20 33 35
52,53c53,54
<        4 4 4 4 4 2 2 2 3 3 3 3 3 3 3 3 4 4
<        4 4 4 4 4 2 2 3 3 3 3 3 3 3 3 4 4 4
---
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
55,57c56,58
<        4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4
<        4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4
<        4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
---
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>        4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
64c65
< 201    4  -1.108  -201 -28 u=2                                    imp:n=1
---
> 201    4  -1.098  -201 -28 u=2                                    imp:n=1
71c72
<  28    0            1 -2 3 -4 (433:444) 70 -20 33                  imp:n=1
---
>  28    0            1 -2 3 -4 (433:444) 70 -20 33 35               imp:n=1
150,153c151,154
< 109   c/z 21.105 11.0967 12.70
< 110   c/z 21.105 11.0967 10.16
< 111   s   21.105 11.0967 27.68 10.16
< 112   s   21.105 11.0967 27.68 12.70
---
> 109   c/z 17.465 13.0353 12.70
> 110   c/z 17.465 13.0353 10.16
> 111   s   17.465 13.0353 27.68 10.16
> 112   s   17.465 13.0353 27.68 12.70
174c175
< m4   94239.55 -0.03619 8016.50 -0.80095 1001.50 -0.10031
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
190,194c191,197
< ksrc  7. 7. 10
<       21. 7. 10
<       35. 7. 10
<       14. 19. 10
<       28. 19. 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
```

```
197d199
<       21. 11.  30.

*************************************************************************************
diff c0001f1s6.i c0001f1b7b.i >diff1s6b7b
1,2c1,2
< glovebox ha20mb cementation model - stacked case 1200 g pu - c0001f1s6
< c     base case 900g + 0 g conveyor + 300g holdup + 200g outside
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
5,6c5
< c     bowls -  one bowl in corner 10" from cans
< c              one bowl stacked on other bowl
---
> c     bowls -  two bowls in corner 10" from cans
15,16d13
< c     room - 1 2.76 L can 6" spacing from glovebox wall
< c             0.200 kg pu + water
19c16
<   1   0         1 -2 3 -4 20 -6 #14 #15                           imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                                   imp:n=1
37,42c34,41
<                 (-69 70 -62)) -2 1 111                            imp:n=1
<  10   0         -33 -63 70 62 -2 1                                imp:n=1
< c     container stacked
<  14   3  -1.0431 -110 28 -29 ((59 -29):(-59 -111)) -110          imp:n=1
< c     container water reflection
<  15   1  -1.0   20 -30 ((59 -109 (110:29)):(-59 111 -112)) 1 -2 imp:n=1
---
>                 (-69 70 -62)) -2 1  103                           imp:n=1
>  10   0         -33 -63 70 62 -2 1  103                           imp:n=1
> c     bowl
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                     imp:n=1
> c     bowl water reflection
>  12   1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                 (-69 70 -60)) -2 1 -103                           imp:n=1
>  13   0         -35 -63 70 60 -2 1 -103                           imp:n=1
44,45c43,44
<  22   5  -1.0749   70 -28 -53                                     imp:n=1
<  23   0         70 -28 53 64 -65 41 66 -1                         imp:n=1
---
>  22   1  -1.0    70 -28 -53                                       imp:n=1
>  23   1  -1.0    70 -28 53 64 -65 41 66 -1                        imp:n=1
49c48
<  25   0  1 3 -433 -444 70 -20 33  (111:-28)
---
>  25   0  1 3 -433 -444 70 -20 33 35
73c72
<  28   0           1 -2 3 -4 (433:444) 70 -20 33                   imp:n=1
---
>  28   0           1 -2 3 -4 (433:444) 70 -20 33 35                imp:n=1
152,155c151,154
< 109   c/z 10.21 121.87 12.70
< 110   c/z 10.21 121.87 10.16
< 111   s   10.21 121.87 27.68 10.16
< 112   s   10.21 121.87 27.68 12.70
---
> 109   c/z 17.465 13.0353 12.70
> 110   c/z 17.465 13.0353 10.16
> 111   s   17.465 13.0353 27.68 10.16
> 112   s   17.465 13.0353 27.68 12.70
200,201c199
<       10. 122. 30
<       -23. 121. 10
---
>       10. 101. 10

*************************************************************************************
diff c0001f1s5.i c0001f1b7b.i >diff1s5b7b
1,2c1,2
< glovebox ha20mb cementation model - stacked case 1200 g pu - c0001f1s5
< c     base case 900g + 0 g conveyor + 300g holdup + 0g outside +200g stacked
---
```

```
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
14,15d13
< c                      1 2.76 L can 90% water 10% carbon stacked
< c                      200 g pu total
18c16
<   1   0         1 -2 3 -4 20 -6 #14 #15                        imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                                imp:n=1
44,47d41
< c     container stacked
<  14    12  -1.146  -113 28 -29                                 imp:n=1
< c     container water reflection
<  15   1  -1.0   20 -30 -114 (113:29)                            imp:n=1
54c48
<  25    0  1 3 -433 -444 70 -20 33 35 (-28:113)
---
>  25    0  1 3 -433 -444 70 -20 33 35
176,177d169
< 113   c/z 91.455 55.775 6.985
< 114   c/z 91.455 55.775 9.525
198,200d189
< m12   94239.55 -0.07237 8016.50 -0.80262 1001.50 -0.09991
<       6012.50 -0.17100                              $pu + carbon +water
< mt12  lwtr.01
211d199
<       91. 55. 30

*************************************************************************************
diff c0001f1w1.i c0001f1b13a.i >diff1w1b13a
1,2c1,2
< glovebox ha20mb cementation model - wagon case 1200 g pu - c0001f1w1
< c     base case 900g +400 g conveyor +300g holdup +200g outside
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b13a
> c     base case 900g + 400 g conveyor + 300g holdup + 200g outside
20d19
< c          - 5 position wagon with 5 2.7 L cans 400 g pu + water
30,34c29,32
<    6   1  -1.0  (((-10:11:-12:4:6)(13 -14 15 -16 5 -18)):
<                 (-13 -67 -68 17))  #22 #23                      imp:n=1
<   60   1  -1.0  ((13 -14 15 -16 -5 17 #512) (-8:9:-24:25)):
<                 ((-23 22 -27 26 21 -17 21) (-8:-7:9:-24:25))
<                 (516:-517:-518:519)                              imp:n=1
---
>    6   1  -1.0   (((((-10:11:-12:4:6)(13 -14 15 -16 5 -18 #23)):
>                  ((13 -14 15 -16 -5 21) (17:(-23 22 -27 26))
>                 (-8:-7:9:-24:25))) (53:-70:28))):(-13 -67 -68 17)
>                                                                  imp:n=1
36,38c34,35
<    7   0         14:(-13 (67:68:-17)):-15:16:18:-504            imp:n=0
< 570   0         (-14 15 -17 13 -16 504) (-22:23:27:-26:-21)
<                 (520:-521:-522:523)                              imp:n=1
---
>    7   0         14:(-13 (67:68)):-15:16:18:-21:
>                  ((-22:23:27:-26) -17)                           imp:n=0
52c49
<  20    7  -1.088  70 -28 -138                                   imp:n=1
---
>  20    7  -1.088  70 -28 -138                                  imp:n=1
76,92d72
< c     5 position wagon under glovebox
< c
< 501   50 -1.153  -505 503 -502                                  imp:n=1
< 502   1  -1.0    -506 503 -501 (502:505) 518                     imp:n=1
< 503   50 -1.153  -507 503 -502                                  imp:n=1
< 504   1  -1.0    -508 503 -501 (502:507)                         imp:n=1
< 505   50 -1.153  -509 503 -502                                  imp:n=1
< 506   1  -1.0    -510 503 -501 (502:509) -519                    imp:n=1
< 507   50 -1.153  -511 503 -502                                  imp:n=1
< 508   1  -1.0    -512 503 -501 (502:511)                         imp:n=1
< 509   50 -1.153  -513 503 -502                                  imp:n=1
< 510   1  -1.0    -514 503 -501 (502:513)                         imp:n=1
< 511   0           503 -501 -516 517 518 -519
<                   506 508 510 512 514                            imp:n=1
```

```
< 512   0           501 -516 517 518 -519 -5                      imp:n=1
< 513   1  -1.0     ((504 -520 521 522 -523)
<                   (-503:516:-517:-518:519)) -17 (27:-21:-22)    imp:n=1
114c94
< 21    pz  -63.224
---
> 21    pz  -66.04
181a162,163
> 433   px  154.770
> 444   py  124.613
207,247c189
< 139   c/z 63.315 59.131 11.6491
< 420   c/z 123.890 125.045 6.985
< 421   c/z 123.890 125.045 9.525
< 422   c/z 137.960 125.045 6.985
< 423   c/z 137.960 125.045 9.525
< 424   c/z 116.855 112.860 6.985
< 425   c/z 116.855 112.860 9.525
< 426   c/z 130.925 112.860 6.985
< 427   c/z 130.925 112.860 9.525
< 428   c/z 144.995 112.860 6.985
< 429   c/z 144.995 112.860 9.525
< 430   c/z 123.890 100.675 6.985
< 431   c/z 123.890 100.675 9.525
< 432   c/z 137.960 100.675 6.985
< 433   c/z 137.960 100.675 9.525
< 434   c/z 130.925 112.860 12.185
< 435   px  137.960
< 436   px  123.890
< 437   py  125.045
< 501   pz  -39.37
< 502   pz  -41.91
< 503   pz  -63.224
< 504   pz  -93.704
< 505   c/z 39.157 120.538 6.350
< 506   c/z 39.157 120.538 8.890
< 507   c/z 63.315 120.538 6.350
< 508   c/z 63.315 120.538 8.890
< 509   c/z 87.473 120.538 6.350
< 510   c/z 87.473 120.538 8.890
< 511   c/z 51.236 105.183 6.350
< 512   c/z 51.236 105.183 8.890
< 513   c/z 75.394 105.183 6.350
< 514   c/z 75.394 105.183 8.890
< 516   py  131.81
< 517   py  93.91
< 518   px  30.628
< 519   px  96.002
< 520   py  162.29
< 521   py  63.43
< 522   px  0.148
< 523   px  126.482
---
> 139   c/z 63.325 59.131 11.6491
268,269d209
< m50   94239.55 -0.14815 8016.50 -0.89492 1001.50 -0.11026   $pu + water
< mt50   lwtr.01
282,286d221
<       39 120 -50
<       63 120 -50
<       87 120 -50
<       51 105 -50
<       75 105 -50

*************************************************************************************
diff c0001f1b7h.i c0001f1b7b.i >diff1b7hb7b
1,2c1,2
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7h
< c     base case 900g + 0 g conveyor + 300g holdup + 200g outside
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
14,15d13
< c     room - 1 2.76 L can 6" spacing from glovebox wall
< c            0.200 kg pu + water
```

```
22c20
<   4   1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #22 #23          imp:n=1
---
>   4   1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #23              imp:n=1
45,46c43,44
<  22   5  -1.0749   70 -28 -53                                     imp:n=1
<  23   0            70 -28 53 64 -65 41 66 -1                      imp:n=1
---
>  22   1  -1.0    70 -28 -53                                       imp:n=1
>  23   1  -1.0    70 -28 53 64 -65 41 66 -1                        imp:n=1
51c49
<          fill=1 (0 7.035 0)                                       imp:n=1
---
>          fill=1 (7.035 7.035 0)                                   imp:n=1
55,59c53,58
<       4 4 4 4 4 2 2 3 3 3 3 3 3 3 3 4 4
<       4 4 4 4 4 2 2 2 3 3 3 3 3 3 4 4 4
<       4 4 4 4 4 2 2 3 3 3 3 3 3 3 4 4 4
<       4 4 4 4 3 3 3 3 3 3 3 3 3 4 4 4 4
<       4 4 4 4 3 3 3 3 3 3 3 3 3 4 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
61d59
<       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
126c124
<  53   c/z -7.035 19.220 6.985
---
>  53   c/z -23.495 121.87 6.985
137,140c135,138
<  64   py  12.235
<  65   py  26.205
<  66   px  -7.035
<  67   c/z -23.495 19.220 37.465
---
>  64   py  114.885
>  65   py  128.855
>  66   px  -23.495
>  67   c/z -23.495 121.87 37.465
177c175
< m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.1004
---
> m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
193,199c191,197
< ksrc  14. 7. 10
<       28. 7. 10
<       7. 19. 10
<       21. 19. 10
<       35. 19. 10
<       14. 31. 10
<       28. 31. 10
---
> ksrc  84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       105. 55. 10
>       84. 68. 10
>       98. 68. 10
202d199
<       -7. 19. 10

*********************************************************************************************
diff c0001f1b7g.i c0001f1b7b.i >diff1b7gb7b
1,2c1,2
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7g
< c     base case 900g + 0 g conveyor + 300g holdup + 200g outside
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
14,15d13
```

```
< c     room - 1 2.76 L can 6" spacing from glovebox wall
< c             0.200 kg pu + water
22c20
<   4   1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #22 #23          imp:n=1
---
>   4   1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #23              imp:n=1
45,46c43,44
<  22   5  -1.0749   70 -28 -53                                    imp:n=1
<  23   0           70 -28 53 64 -65 41 66 -1                      imp:n=1
---
>  22   1  -1.0   70 -28 -53                                       imp:n=1
>  23   1  -1.0   70 -28 53 64 -65 41 66 -1                        imp:n=1
126c124
<  53   c/z -7.035 121.87 6.985
---
>  53   c/z -23.495 121.87 6.985
139c137
<  66   px  -7.035
---
>  66   px  -23.495
202d199
<       -7. 121. 10

***************************************************************************************
diff c0001f1b17.i c0001f1b7b.i >diff1b17b7b
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f1b17
< c     base case 900g + 400 g conveyor + 300g holdup + 0g outside
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f1b7b
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
14,17d13
< c     conveyor container - 1 4.7 L can pu + water next to cans
< c                 0.08511 g pu/cc
< c                 h/x=309
< c                 400 g pu total
46,49d41
< c     container on conveyor
<  19   7  -1.088    70 -28 -138                                     imp:n=1
<  20   1  -1.0      70 -20 138 -139 (-142)                          imp:n=1
<  21   1  -1.0      28 -20 -138                                     imp:n=1
56c48
<  25   0  1 3 -433 -444 70 -20 33 35 #19 #20 #21
---
>  25   0  1 3 -433 -444 70 -20 33 35
61,67c53,59
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 3 2 2 4 4 4 4 4 4 4
<       4 4 4 3 3 3 3 3 2 2 2 4 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 2 2 3 3 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 4 4 4 4
>       4 4 4 3 3 3 3 3 2 2 2 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 2 2 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 4 4 4 4 4
178,180d169
< 138   c/z 114.6 42.446 9.1091
< 139   c/z 114.6 42.446 11.6491
< 142   c/z 133.665 31.405 30.25
191c180
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
211d199
<       114. 42. 10

***************************************************************************************
c0001f2b4.i
```

```
glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
c      base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
c      glovebox - full water reflection on all sides, cement can refl
c
c      bowls -  two bowls in corner 10" from cans
c              0.04167 g pu/cc pu
c              0.200 kg pu/bowl
c              h/x=634
c              sides, bottom of bowls not included
c      containers - 7 2.76 L cans 90% water 10% sio2
c                   0.02585 g pu/cc
c                   h/x=921
c                   500 g pu total
c                       7 2.76 L cans pu+water+carbon+sio2
c                       0.04652 g/cc pu
c                       h/x=20
c                       900g pu total
c      room - 1 2.76 L can 6" spacing from glovebox wall
c             0.200 kg pu + water
c
c      glovebox
  1    0          1 -2 3 -4 20 -6                                   imp:n=1
c      glovebox floor conveyor box
  2    1  -1.0 24 -25 7 -5 8 -9                                     imp:n=1
c      glovebox lead sidewall and window
  4    1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #23                imp:n=1
  5    1  -1.0    (-1:2:-3) (10 -11 12 -4 19 -6)                    imp:n=1
c      full water reflection
  6    1  -1.0    (((((-10:11:-12:4:6)(13 -14 15 -16 5 -18 #23)):
                  ((13 -14 15 -16 -5 21) (17:(-23 22 -27 26))
                 (-8:-7:9:-24:25))) (53:-70:28))):(-13 -67 -68 17)
                                                                    imp:n=1
c      outside world
  7    0          14:(-13 (67:68)):-15:16:18:-21:
                  ((-22:23:27:-26) -17)                             imp:n=0
c      bowl
  8    3  -1.0431  ((63 -28):(-63 -61 69)) -32                      imp:n=1
c      bowl water reflection
  9    1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
                  (-69 70 -62)) -2 1  103                           imp:n=1
 10    0          -33 -63 70 62 -2 1  103                           imp:n=1
c      bowl
 11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                      imp:n=1
c      bowl water reflection
 12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
                  (-69 70 -60)) -2 1 -103                           imp:n=1
 13    0          -35 -63 70 60 -2 1 -103                           imp:n=1
c      container in drum outside glovebox
 22    5  -1.0749    70 -28 -53                                     imp:n=1
 23    0          70 -28 53 64 -65 41 66 -1                         imp:n=1
c      holdup on floor
 24    8  -5.562 5 -70 1 -4 -2 3                                    imp:n=1
c      filled cans
 25    0  1 3 -433 -444 70 -20 33 35
          fill=1 (7.035 7.035 0)                                    imp:n=1
 26    0     -331 334 -330 333 -329 332  u=1 lat=2
       fill= -5:14 -1:10 0:0
       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
       4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
       4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
       4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
       4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
       4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
                                                                    imp:n=1
201    4  -1.167   -201 -28 u=2                                     imp:n=1
202    1  -1.0      28      u=2                                     imp:n=1
203    0            201 -28 u=2                                     imp:n=1
204    10 -2.911   -201 -28 u=3                                     imp:n=1
205    1  -1.0      28      u=3                                     imp:n=1
```

```
206   0           201 -28 u=3                                   imp:n=1
207   0           777    u=4                                   imp:n=1
208   11 -2.1739 -201 -28 u=5                                   imp:n=1
209   1  -1.0     28       u=5                                  imp:n=1
210   0           201 -28 u=5                                   imp:n=1
 28   0           1 -2 3 -4 (433:444) 70 -20 33 35              imp:n=1

  1   px  0.0
  2   py  132.08
  3   py  0.0
  4   px  518.16
  5   pz  0.0
  6   pz  91.44
  7   pz  -35.56
  8   px  60.96
  9   px  411.48
 10   px  -1.27
 11   py  133.35
 12   py  -1.27
 13   px  -30.48
 14   py  162.56
 15   py  -30.48
 16   px  548.64
 17   pz  -30.48
 18   pz  121.92
 19   pz  41.91
 20   pz  20.57
 21   pz  -66.04
 22   px  30.48
 23   px  441.96
 24   py  50.80
 25   py  81.28
 26   py  20.32
 27   py  111.76
 28   pz  18.03
 29   pz  35.733
 30   pz  38.273
 32   c/z 10.21 121.87 10.16
 33   c/z 10.21 121.87 12.70
 34   c/z 10.21 101.45 10.16
 35   c/z 10.21 101.45 12.70
 36   c/z 281.94 10.16 6.985
 37   c/z 281.94 10.16 9.525
 38   c/z 113.344 79.375 6.985
 39   c/z 127.316 79.375 6.985
 40   c/z 34.99 125.09 6.985
 41   c/z 113.344 65.405 6.985
 42   c/z 127.316 65.405 6.985
 43   c/z 34.99 111.11 6.985
 44   c/z 6.99 125.09 9.525
 45   c/z 6.99 111.11 9.525
 46   c/z 20.99 111.11 9.525
 47   c/z 34.99 111.11 9.525
 48   c/z 34.99 125.09 9.525
 49   c/z 20.99 125.09 9.525
 51   py  101.585
 52   px  30.515
 53   c/z -23.495 121.87 6.985
 54   px  6.986
 55   px  20.958
 56   py  125.094
 57   py  111.122
 58   s   10.21 101.45 9.98 10.16
 59   pz  27.68
 60   s   10.21 101.45 9.98 12.70
 61   s   10.21 121.87 9.98 10.16
 62   s   10.21 121.87 9.98 12.70
 63   pz  9.98
 64   py  114.885
 65   py  128.855
 66   px  -23.495
 67   c/z -23.495 121.87 37.465
 68   pz  48.514
 69   pz  0.33
 70   pz  0.001
```

```
 71    pz  5.080
101    py  104.136
102    c/z 130.49 121.918 35.56
103    py  111.66
104    px  30.48
105    py  132.08
106    px  106.35
107    py 121.918
108    px 130.49
109    c/z 17.465 13.0353 12.70
110    c/z 17.465 13.0353 10.16
111    s   17.465 13.0353 27.68 10.16
112    s   17.465 13.0353 27.68 12.70
201    cz  6.985
329    p  -0.5  0.866025 0 7.035
330    p   0.5  0.866025 0 7.035
331    px  7.035
332    p  -0.5  0.866025 0 -7.035
333    p   0.5  0.866025 0 -7.035
334    px  -7.035
433    px  196.980
444    py  124.613
202    c/z 70.350 86.577 6.985
203    c/z 84.0797 89.5674 6.985
204    c/z 95.4726 81.3125 6.985
205    c/z 56.6203 89.5674 6.985
206    c/z 45.2274 81.3125 6.985
777    pz   -777.   $ redundant surface to put on cell cards with none

m1     1001.5  2  8016.5 1                                  $water
mt1    lwtr.01
m3    94239.55 -0.04167 8016.50 -0.89002 1001.50 -0.11144   $pu + water
mt3    lwtr.01
m4    94239.55 -0.02585 8016.50 -0.92848 1001.50 -0.10042
      14000.50 -0.11200                                   $pu + carbon +water
mt4    lwtr.01
m5    94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110   $pu + water
mt5    lwtr.01
m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
mt7    lwtr.01
m8    94239.55 -4.80769 8016.50 -0.67026 1001.50 -0.08445   $pu + water
mt8    lwtr.01
m10   20000.50 -0.40973 14000.50 -0.09782 13027.50 -0.03853
      12000.50 -0.03293  8016.50 -0.41092  1001.50 -0.01007 $cement 9% h2o
mt10  lwtr.01
m11   94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
       6012.50 -0.68842 14000.50 -0.65338                   $pu +c+sio2+ water
mt11  lwtr.01
kcode 5000 1.0 10 200
ksrc   70. 43. 10
       84. 43. 10
       98. 43. 10
       77. 55. 10
       91. 55. 10
       70. 31. 10
       84. 31. 10
       10. 122. 10
       10. 101. 10
       126. 68. 10
       140. 68. 10
       119. 80. 10
       133. 80. 10
       147. 80. 10
       126. 92. 10
       140. 92. 10
       -23. 121. 10
ctme 240
print 10 40 50
prdmp j j j 3


*****************************************************************************************
diff c0001f2b3.i c0001f2b4.i >diff2b3b4
1c1
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b3
```

```
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
14,15c14,15
< c                      5 2.76 L cans pu+water+carbon+sio2
< c                      0.06513 g/cc pu
---
> c                      7 2.76 L cans pu+water+carbon+sio2
> c                      0.04652 g/cc pu
65a66
>       4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
67d67
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
78c78
< 208   11 -2.1746 -201 -28 u=5                                   imp:n=1
---
> 208   11 -2.1739 -201 -28 u=5                                   imp:n=1
196,197c196,197
< m11  94239.55 -0.06513 8016.50 -0.78435 1001.50 -0.00549
<       6012.50 -0.67704 14000.50 -0.64258                     $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>       6012.50 -0.68842 14000.50 -0.65338                     $pu +c+sio2+ water
213a214,215
>       126. 92. 10
>       140. 92. 10

*************************************************************************************
diff c0001f2b1.i c0001f2b4.i >diff2b1b4
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b1
< c     base case 900g + 0 g conveyor + 300g holdup + 0g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
10,12c10,12
< c     containers - 5 2.76 L cans 90% water 10% sio2
< c                  0.03619 g pu/cc
< c                  h/x=657
---
> c     containers - 7 2.76 L cans 90% water 10% sio2
> c                  0.02585 g pu/cc
> c                  h/x=921
14,15c14,15
< c                      5 2.76 L cans pu+water+carbon+sio2
< c                      0.06513 g/cc pu
---
> c                      7 2.76 L cans pu+water+carbon+sio2
> c                      0.04652 g/cc pu
17a18,19
> c     room - 1 2.76 L can 6" spacing from glovebox wall
> c              0.200 kg pu + water
47,48c49,50
<  22   1  -1.0    70 -28 -53                                       imp:n=1
<  23   1  -1.0    70 -28 53 64 -65 41 66 -1                        imp:n=1
---
>  22   5  -1.0749   70 -28 -53                                     imp:n=1
>  23   0            70 -28 53 64 -65 41 66 -1                      imp:n=1
59c61
<       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
---
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
63a66
>       4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
65d67
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
69c71
< 201   4  -1.177  -201 -28 u=2                                   imp:n=1
---
> 201   4  -1.167  -201 -28 u=2                                   imp:n=1
76c78
< 208   11 -2.1746 -201 -28 u=5                                   imp:n=1
---
> 208   11 -2.1739 -201 -28 u=5                                   imp:n=1
182c184
< m4   94239.55 -0.03619 8016.50 -0.92895 1001.50 -0.10031
```

```
---
> m4   94239.55 -0.02585 8016.50 -0.92848 1001.50 -0.10042
194,195c196,197
< m11  94239.55 -0.06513 8016.50 -0.78435 1001.50 -0.00549
<        6012.50 -0.67704 14000.50 -0.64258                 $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>        6012.50 -0.68842 14000.50 -0.65338                 $pu +c+sio2+ water
202a205,206
>        70. 31. 10
>        84. 31. 10
209a214,216
>        126. 92. 10
>        140. 92. 10
>        -23. 121. 10

*******************************************************************************
diff c0001f2b2.i c0001f2b4.i >diff2b2b4
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b2
< c      base case 900g + 0 g conveyor + 300g holdup + 0g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c      base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
10,12c10,12
< c      containers - 5 2.76 L cans 90% water 10% sio2
< c                  0.03619 g pu/cc
< c                  h/x=657
---
> c      containers - 7 2.76 L cans 90% water 10% sio2
> c                  0.02585 g pu/cc
> c                  h/x=921
14,15c14,15
< c                      6 2.76 L cans pu+water+carbon+sio2
< c                      0.05428 g/cc pu
---
> c                      7 2.76 L cans pu+water+carbon+sio2
> c                      0.04652 g/cc pu
17a18,19
> c      room - 1 2.76 L can 6" spacing from glovebox wall
> c            0.200 kg pu + water
47,48c49,50
<  22   1  -1.0    70 -28 -53                                 imp:n=1
<  23   1  -1.0    70 -28 53 64 -65 41 66 -1                  imp:n=1
---
>  22   5  -1.0749   70 -28 -53                               imp:n=1
>  23   0          70 -28 53 64 -65 41 66 -1                  imp:n=1
59c61
<        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
---
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 4 4
61c63
<        4 4 4 3 3 3 3 3 2 2 3 3 5 3 3 3 3 4 4 4
---
>        4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
63a66
>        4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
65d67
<        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
69c71
< 201    4  -1.177  -201 -28 u=2                               imp:n=1
---
> 201    4  -1.167  -201 -28 u=2                               imp:n=1
76c78
< 208    11 -2.1742 -201 -28 u=5                               imp:n=1
---
> 208    11 -2.1739 -201 -28 u=5                               imp:n=1
182,183c184,185
< m4    94239.55 -0.03619 8016.50 -0.92895 1001.50 -0.10031
<       14000.50 -0.11200                               $pu + sio2 +water
---
> m4    94239.55 -0.02585 8016.50 -0.92848 1001.50 -0.10042
>       14000.50 -0.11200                               $pu + carbon +water
194,195c196,197
< m11  94239.55 -0.05428 8016.50 -0.78280 1001.50 -0.00458
```

```
<       6012.50 -0.68368 14000.50 -0.64888              $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>       6012.50 -0.68842 14000.50 -0.65338              $pu +c+sio2+ water
202a205,206
>       70. 31. 10
>       84. 31. 10
210c214,216
<       133. 55. 10
---
>       126. 92. 10
>       140. 92. 10
>       -23. 121. 10

*************************************************************************************
diff c0001f2b5.i c0001f2b4.i >diff2b5b4
1c1
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b5
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
3c3
< c     glovebox - full water reflection on all sides, water can refl
---
> c     glovebox - full water reflection on all sides, cement can refl
74c74
< 204   1  -1.0    -201 -28 u=3                            imp:n=1
---
> 204   10 -2.911  -201 -28 u=3                            imp:n=1

*************************************************************************************
diff c0001f2b8.i c0001f2b4.i >diff2b8b4
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b8
< c     base case 900g + 400g conveyor + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
20,23d19
< c     conveyor container - 1 4.7 L can pu + water next to cans
< c                 0.08511 g pu/cc
< c                 h/x=309
< c                 400 g pu total
52,55d47
< c     container on conveyor
<  19   7  -1.088   70 -28 -138                            imp:n=1
<  20   1  -1.0     70 -20 138 -139                        imp:n=1
<  21   1  -1.0     28 -20 -138                            imp:n=1
62c54
<  25   0  1 3 -433 -444 70 -20 33 35 #19 #20 #21
---
>  25   0  1 3 -433 -444 70 -20 33 35
67,71c59,63
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 3 2 2 4 4 4 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 2 2 2 4 4 4 4 4 4 4 4 4
<       4 4 4 3 3 3 3 3 2 2 3 4 4 4 3 3 3 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>       4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
187,188d178
< 138   c/z 136.4 26.4 9.1091
< 139   c/z 136.4 26.4 11.6491
199c189
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
227d216
<       136. 26. 10

*************************************************************************************
diff c0001f2b6a.i c0001f2b4.i >diff2b6ab4
```

```
1,3c1,3
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b6a
< c      base case 900g +400 g conveyor +300g holdup +200g outside +900g h/x=20
< c      glovebox - full water reflection on all sides, 1" water refl
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c      base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
> c      glovebox - full water reflection on all sides, cement can refl
18,21d17
< c      conveyor container - 1 4.7 L can pu + water 10" from cans
< c                     0.08511 g pu/cc
< c                     h/x=309
< c                     400 g pu total
52,54d47
< c      container on conveyor
<  20    7  -1.088  70 -28 -138                                  imp:n=1
<  21    1  -1.0     70 -20 (138:28) -139                        imp:n=1
56c49
<  22    5  -1.0749 70 -28 -53                                   imp:n=1
---
>  22    5  -1.0749   70 -28 -53                                 imp:n=1
61,92c54,81
< 201    4  -1.167  -120 70 -28                                  imp:n=1
< 202    4  -1.167  -122 70 -28                                  imp:n=1
< 203    4  -1.167  -124 70 -28                                  imp:n=1
< 204    4  -1.167  -126 70 -28                                  imp:n=1
< 205    4  -1.167  -128 70 -28                                  imp:n=1
< 206    4  -1.167  -130 70 -28                                  imp:n=1
< 207    4  -1.167  -132 70 -28                                  imp:n=1
< 208    1  -1.0    ((-121:-123:-125:-129:-131:-133)
<                   (120 122 124 128 130 132 134)) 134 -28 70 -2
<                   (135:-136:-137)                              imp:n=1
< 209    1  -1.0 ((-121:-123:-125:-127:-129:-131:-133) 28 -20 -2) imp:n=1
< 210    0          120 122 124 126 128 130 132 -134 -28 70      imp:n=1
< 211    0          121 123 125 127 129 131 133 -134 28 -20      imp:n=1
< 212    0          -135 136 137 120 122 -2 -28 70               imp:n=1
< c      filled cans
< 401    11 -2.1739 -420 70 -28                                  imp:n=1
< 402    11 -2.1739 -422 70 -28                                  imp:n=1
< 403    11 -2.1739 -424 70 -28                                  imp:n=1
< 404    11 -2.1739 -426 70 -28                                  imp:n=1
< 405    11 -2.1739 -428 70 -28                                  imp:n=1
< 406    11 -2.1739 -430 70 -28                                  imp:n=1
< 407    11 -2.1739 -432 70 -28                                  imp:n=1
< 408    1  -1.0    ((-421:-423:-425:-429:-431:-433)
<                   (420 422 424 428 430 432 434)) 434 -28 70 -2
<                   (435:-436:-437)                              imp:n=1
< 409    1  -1.0 ((-421:-423:-425:-427:-429:-431:-433) 28 -20 -2) imp:n=1
< 410    0          420 422 424 426 428 430 432 -434 -28 70      imp:n=1
< 411    0          421 423 425 427 429 431 433 -434 28 -20      imp:n=1
< 412    0          -435 436 437 420 422 -2 -28 70               imp:n=1
<  28    0   1 -2 3 -4 121 123 125 127 129 131 133 134 70 -20 33 35
<            (-136:135:-137:28) 139 421 423 425 427 429 431 433 434
<            (-436:435:-437:28)                                  imp:n=1
---
>  25    0  1 3 -433 -444 70 -20 33 35
>           fill=1 (7.035 7.035 0)                               imp:n=1
>  26    0    -331 334 -330 333 -329 332  u=1 lat=2
>        fill= -5:14 -1:10 0:0
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>        4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                imp:n=1
> 201    4   -1.167  -201 -28 u=2                                imp:n=1
> 202    1   -1.0     28      u=2                                imp:n=1
> 203    0            201 -28 u=2                                imp:n=1
```

```
> 204    10 -2.911   -201 -28 u=3                                        imp:n=1
> 205    1  -1.0      28       u=3                                       imp:n=1
> 206    0            201 -28 u=3                                        imp:n=1
> 207    0            777     u=4                                       imp:n=1
> 208    11 -2.1739 -201 -28 u=5                                         imp:n=1
> 209    1  -1.0      28       u=5                                       imp:n=1
> 210    0            201 -28 u=5                                        imp:n=1
>  28    0            1 -2 3 -4 (433:444) 70 -20 33 35                   imp:n=1
181a171,172
> 433    px  196.980
> 444    py  124.613
188,225d178
< 120    c/z 56.280 125.045 6.985
< 121    c/z 56.280 125.045 9.525
< 122    c/z 70.350 125.045 6.985
< 123    c/z 70.350 125.045 9.525
< 124    c/z 49.245 112.860 6.985
< 125    c/z 49.245 112.860 9.525
< 126    c/z 63.315 112.860 6.985
< 127    c/z 63.315 112.860 9.525
< 128    c/z 77.385 112.860 6.985
< 129    c/z 77.385 112.860 9.525
< 130    c/z 56.280 100.675 6.985
< 131    c/z 56.280 100.675 9.525
< 132    c/z 70.350 100.675 6.985
< 133    c/z 70.350 100.675 9.525
< 134    c/z 63.315 112.860 12.185
< 135    px  70.350
< 136    px  56.280
< 137    py  125.045
< 138    c/z 63.315 59.131 9.1091
< 139    c/z 63.315 59.131 11.6491
< 420    c/z 123.890 125.045 6.985
< 421    c/z 123.890 125.045 9.525
< 422    c/z 137.960 125.045 6.985
< 423    c/z 137.960 125.045 9.525
< 424    c/z 116.855 112.860 6.985
< 425    c/z 116.855 112.860 9.525
< 426    c/z 130.925 112.860 6.985
< 427    c/z 130.925 112.860 9.525
< 428    c/z 144.995 112.860 6.985
< 429    c/z 144.995 112.860 9.525
< 430    c/z 123.890 100.675 6.985
< 431    c/z 123.890 100.675 9.525
< 432    c/z 137.960 100.675 6.985
< 433    c/z 137.960 100.675 9.525
< 434    c/z 130.925 112.860 12.185
< 435    px  137.960
< 436    px  123.890
< 437    py  125.045
232c185
<       14000.50 -0.11200                                         $pu + sio2 +water
---
>       14000.50 -0.11200                                         $pu + carbon +water
236c189
< m7    94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
247,253c200,206
< ksrc   56 125 10
<        70 125 10
<        49 112 10
<        63 112 10
<        77 112 10
<        56 100 10
<        70 100 10
---
> ksrc   70. 43. 10
>        84. 43. 10
>        98. 43. 10
>        77. 55. 10
>        91. 55. 10
>        70. 31. 10
>        84. 31. 10
256c209,215
```

```
<       63. 59. 10
---
>       126. 68. 10
>       140. 68. 10
>       119. 80. 10
>       133. 80. 10
>       147. 80. 10
>       126. 92. 10
>       140. 92. 10
258,264d216
<       123 125 10
<       137 125 10
<       116 112 10
<       130 112 10
<       144 112 10
<       123 100 10
<       137 100 10

*************************************************************************************
diff c0001f2bh2.i c0001f2b4.i >diff2bh2b4
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2bh2
< c     base case 0g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
10c10
< c     containers - 0 2.76 L cans 90% water 10% sio2
---
> c     containers - 7 2.76 L cans 90% water 10% sio2
14,15c14,15
< c                     5 2.76 L cans pu+water+carbon+sio2
< c                     0.06513 g/cc pu
---
> c                     7 2.76 L cans pu+water+carbon+sio2
> c                     0.04652 g/cc pu
61,63c61,63
<       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
<       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
<       4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
---
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 4 4 4
>       4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 4 4 4
65a66
>       4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
67d67
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
78c78
< 208   11 -2.1746 -201 -28 u=5                                 imp:n=1
---
> 208   11 -2.1739 -201 -28 u=5                                 imp:n=1
196,197c196,197
< m11  94239.55 -0.06513 8016.50 -0.78435 1001.50 -0.00549
<       6012.50 -0.67704 14000.50 -0.64258               $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>       6012.50 -0.68842 14000.50 -0.65338               $pu +c+sio2+ water
213a214,215
>       126. 92. 10
>       140. 92. 10

*************************************************************************************
diff c0001f2bh3.i c0001f2b4.i >diff2bh3b4
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2bh3
< c     base case 0g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
10c10
< c     containers - 0 2.76 L cans 90% water 10% sio2
---
> c     containers - 7 2.76 L cans 90% water 10% sio2
14,15c14,15
```

```
< c                         6 2.76 L cans pu+water+carbon+sio2
< c                         0.055428 g/cc pu
---
> c                         7 2.76 L cans pu+water+carbon+sio2
> c                         0.04652 g/cc pu
61,63c61,64
<        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
<        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
<        4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
---
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>        4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
65,66c66
<        4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
<        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
---
>        4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
78c78
< 208    11 -2.1742 -201 -28 u=5                                 imp:n=1
---
> 208    11 -2.1739 -201 -28 u=5                                 imp:n=1
196,197c196,197
< m11  94239.55 -0.05428 8016.50 -0.78280 1001.50 -0.00458
<        6012.50 -0.68368 14000.50 -0.64888                 $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>        6012.50 -0.68842 14000.50 -0.65338                 $pu +c+sio2+ water
209d208
<        112. 68. 10
214a214,215
>        126. 92. 10
>        140. 92. 10

*************************************************************************************
diff c0001f2bh1.i c0001f2b4.i >diff2bh1b4
1,2c1,2
< glovebox ha20mb cementation model - sensitivity case 2100 g pu - c0001f2bh1
< c     base case 0g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
10c10
< c     containers - 0 2.76 L cans 90% water 10% sio2
---
> c     containers - 7 2.76 L cans 90% water 10% sio2
61,63c61,63
<        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
<        4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
<        4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
---
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>        4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4

*************************************************************************************
diff c0001f2bh4.i c0001f2b4.i >diff2bh4b4
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2bh4
< c     base case 0g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
10c10
< c     containers - 0 2.76 L cans 90% water 10% sio2
---
> c     containers - 7 2.76 L cans 90% water 10% sio2
14,15c14,15
< c                        10 2.76 L cans pu+water+carbon+sio2
< c                        0.03257 g/cc pu
---
> c                        7 2.76 L cans pu+water+carbon+sio2
> c                        0.04652 g/cc pu
61,65c61,66
```

```
<       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
<       4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4
<       4 4 4 3 3 3 3 3 3 3 5 5 5 3 3 3 3 4 4 4
<       4 4 4 4 4 3 3 3 3 5 5 5 5 3 3 3 4 4 4 4
<       4 4 4 4 4 3 3 3 3 5 5 5 3 3 3 3 4 4 4 4
---
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>       4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
67d67
<       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
78c78
< 208   11 -2.17345 -201 -28 u=5                                  imp:n=1
---
> 208   11 -2.1739 -201 -28 u=5                                  imp:n=1
196,197c196,197
< m11  94239.55 -0.03257 8016.50 -0.77971 1001.50 -0.00275
<       6012.50 -0.69695 14000.50 -0.66147                 $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>       6012.50 -0.68842 14000.50 -0.65338                 $pu +c+sio2+ water
209d208
<       112. 68. 10
212d210
<       105. 80. 10
216d213
<       112. 92. 10

*************************************************************************************
diff c0001f2q1.i c0001f2b4.i >diff2q1b4
1,2c1,2
< glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
< c     base case 900g + 0 g conveyor + 300g holdup + 0g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
4d3
< c     2" water flooded, 10% water spray
6c5
< c     bowls -  two bowls next to cans
---
> c     bowls -  two bowls in corner 10" from cans
11,13c10,12
< c     containers - 4 2.725 L cans 90% water 10% sio2
< c                  0.04523 g pu/cc
< c                  h/x=525
---
> c     containers - 7 2.76 L cans 90% water 10% sio2
> c                  0.02585 g pu/cc
> c                  h/x=921
15c14
< c                      7 2.725 L cans pu+water+c
---
> c                      7 2.76 L cans pu+water+carbon+sio2
18a18,19
> c     room - 1 2.76 L can 6" spacing from glovebox wall
> c            0.200 kg pu + water
21c22
<  1    1  -0.1   1 -2 3 -4 20 -6                               imp:n=1
---
>  1    0         1 -2 3 -4 20 -6                               imp:n=1
35d35
< c     containers
38,39c38,41
<  9    1  -0.1    -32 -63 61 71                               imp:n=1
<  10   1  -1.0    -32 70 -71 (61:-69)                         imp:n=1
---
> c     bowl water reflection
>  9    1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                  (-69 70 -62)) -2 1  103                      imp:n=1
>  10   0          -33 -63 70 62 -2 1  103                      imp:n=1
42,49c44,47
```

```
<  12    1  -0.1     -34 -63 58 71                                  imp:n=1
<  13    1  -1.0     -34 70 -71 (58:-69)                            imp:n=1
< c      can
<  14    10 -2.911 -202 70 -28                                      imp:n=1
<  15    10 -2.911 -203 70 -28                                      imp:n=1
<  16    10 -2.911 -204 70 -28                                      imp:n=1
<  17    10 -2.911 -205 70 -28                                      imp:n=1
<  18    10 -2.911 -206 70 -28                                      imp:n=1
---
> c      bowl water reflection
>  12    1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                   (-69 70 -60)) -2 1 -103                         imp:n=1
>  13    0          -35 -63 70 60 -2 1 -103                         imp:n=1
51,52c49,50
<  22    1  -1.0    70 -28 -53                                      imp:n=1
<  23    1  -1.0    70 -28 53 64 -65 41 66 -1                       imp:n-1
---
>  22    5  -1.0749    70 -28 -53                                   imp:n=1
>  23    0            70 -28 53 64 -65 41 66 -1                     imp:n=1
56c54
<  25    0  1 3 -433 -444 70 -28 32 34 202 203 204 205 206
---
>  25    0  1 3 -433 -444 70 -20 33 35
59,71c57,69
<        fill= -5:12 -1:10 0:0
<        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
<        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
<        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
<        4 4 4 4 3 3 3 5 5 5 3 3 3 3 3 4 4 4
<        4 4 4 4 3 3 5 2 2 5 3 3 3 3 4 4 4 4
<        4 4 4 3 3 3 5 2 2 5 3 3 3 3 4 4 4 4
<        4 4 4 3 3 3 4 4 4 3 3 3 3 4 4 4 4 4
<        4 4 3 3 3 4 4 4 4 3 3 3 3 4 4 4 4 4
<        4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
<        4 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
<        4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4
<        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
---
>        fill= -5:14 -1:10 0:0
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>        4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
73,86c71,81
< 201    4  -1.187   -201   u=2                                     imp:n=1
< 202    1  -0.1      201 71  u=2                                   imp:n=1
< 203    1  -1.0      201 -71 u=2                                   imp:n=1
< 204    10 -2.911   -201   u=3                                     imp:n=1
< 205    1  -0.1      201 71  u=3                                   imp:n=1
< 206    1  -1.0      201 -71 u=3                                   imp:n=1
< 207    1  -0.1      71  u=4                                       imp:n=1
< 208    1  -1.0     -71  u=4                                       imp:n=1
< 209    11 -2.1739   -201  u=5                                     imp:n=1
< 210    1  -0.1      201 71 u=5                                    imp:n=1
< 211    1  -1.0      201 -71 u=5                                   imp:n=1
<  27    1  -0.1      1  3 -433 -444 28 -20                         imp:n=1
<  28    1  -0.1      1 -2 3 -4 (433:444) 71 -20                    imp:n=1
<  29    1  -1.0      1 -2 3 -4 (433:444) 70 -71                    imp:n=1
---
> 201    4  -1.167   -201 -28 u=2                                   imp:n=1
> 202    1  -1.0      28       u=2                                  imp:n=1
> 203    0            201 -28 u=2                                   imp:n=1
> 204    10 -2.911   -201 -28 u=3                                   imp:n=1
> 205    1  -1.0      28       u=3                                  imp:n=1
> 206    0            201 -28 u=3                                   imp:n=1
> 207    0            777     u=4                                  imp:n=1
> 208    11 -2.1739 -201 -28 u=5                                    imp:n=1
```

```
> 209   1  -1.0       28       u=5                                      imp:n=1
> 210   0             201 -28 u=5                                       imp:n=1
>  28   0             1 -2 3 -4 (433:444) 70 -20 33 35                  imp:n=1
118,121c113,116
<  32   c/z 60.162 72.690 10.16
<  33   c/z 60.162 72.690 12.70
<  34   c/z 80.538 72.690 10.16
<  35   c/z 80.538 72.690 12.70
---
>  32   c/z 10.21 121.87 10.16
>  33   c/z 10.21 121.87 12.70
>  34   c/z 10.21 101.45 10.16
>  35   c/z 10.21 101.45 12.70
138c133
<  53   c/z -23.495 111.11 6.985
---
>  53   c/z -23.495 121.87 6.985
143c138
<  58   s   80.538 72.690 9.98 10.16
---
>  58   s   10.21 101.45 9.98 10.16
145,147c140,142
<  60   s   80.538 72.690 9.98 12.70
<  61   s   60.162 72.690 9.98 10.16
<  62   s   60.162 72.690 9.98 12.70
---
>  60   s   10.21 101.45 9.98 12.70
>  61   s   10.21 121.87 9.98 10.16
>  62   s   10.21 121.87 9.98 12.70
149,150c144,145
<  64   py  104.125
<  65   py  118.095
---
>  64   py  114.885
>  65   py  128.855
152c147
<  67   c/z -23.495 111.11 37.465
---
>  67   c/z -23.495 121.87 37.465
159c154
< 103   px  120.33
---
> 103   py  111.66
176c171
< 433   px  155.870
---
> 433   px  196.980
189,190c184,185
< m4    94239.55 -0.04523 8016.50 -0.92937 1001.50 -0.10021
<      14000.50 -0.11200                                          $pu + sio2 +water
---
> m4    94239.55 -0.02585 8016.50 -0.92848 1001.50 -0.10042
>      14000.50 -0.11200                                          $pu + carbon +water
192c187
< m5    94239.55 -0.07339 8016.50 -0.89148 1001.50 -0.11109   $pu + water
---
> m5    94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110   $pu + water
205,206c200
< ksrc  56. 43. 10
<       70. 43. 10
---
> ksrc  70. 43. 10
208c202
<       63. 55. 10
---
>       98. 43. 10
211,217c205,216
<       49. 31. 10
<       63. 31. 10
<       77. 31. 10
<       42. 43. 10
<       49. 55. 10
<       60. 72. 10
<       80. 72. 10
---
```

```
>       70. 31. 10
>       84. 31. 10
>       10. 122. 10
>       10. 101. 10
>       126. 68. 10
>       140. 68. 10
>       119. 80. 10
>       133. 80. 10
>       147. 80. 10
>       126. 92. 10
>       140. 92. 10
>       -23. 121. 10

***************************************************************************************
diff c0001f2q2.i c0001f2q1.i >diff2q2q1
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f2q2
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
3c3
< c     glovebox - full water reflection on all sides, water can refl
---
> c     glovebox - full water reflection on all sides, cement can refl
45,49c45,49
<  14   1  -1.0   -202 70 -28                                    imp:n=1
<  15   1  -1.0   -203 70 -28                                    imp:n=1
<  16   1  -1.0   -204 70 -28                                    imp:n=1
<  17   1  -1.0   -205 70 -28                                    imp:n=1
<  18   1  -1.0   -206 70 -28                                    imp:n=1
---
>  14   10 -2.911 -202 70 -28                                    imp:n=1
>  15   10 -2.911 -203 70 -28                                    imp:n=1
>  16   10 -2.911 -204 70 -28                                    imp:n=1
>  17   10 -2.911 -205 70 -28                                    imp:n=1
>  18   10 -2.911 -206 70 -28                                    imp:n=1
76c76
< 204   1  -1.0    -201  u=3                                     imp:n=1
---
> 204   10 -2.911  -201  u=3                                     imp:n=1

***************************************************************************************
diff c0001f2q1a.i c0001f2q1.i >diff2q1aq1
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f2q1a
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
11,13c11,13
< c     containers - 5 2.76 L cans 90% water 10% sio2
< c                  0.03619 g pu/cc
< c                  h/x=627
---
> c     containers - 4 2.725 L cans 90% water 10% sio2
> c                  0.04523 g pu/cc
> c                  h/x=525
15,16c15,16
< c                       5 2.76 L cans pu+water+carbon+sio2
< c                       0.06513 g/cc pu
---
> c                       7 2.725 L cans pu+water+c
> c                       0.04652 g/cc pu
20d19
< c
38c37
<   8   3  -1.0431  ((63 -28):(-63 -61 69)) -32                   imp:n=1
---
>   8   3  -1.0431  ((63 -28):(-63 -61 69)) -32                  imp:n=1
42c41
<  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                   imp:n=1
---
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                  imp:n=1
62,66c61,65
<       4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
<       4 4 3 3 4 3 3 3 3 3 3 3 3 3 3 3 4 4 4
<       4 4 3 3 3 3 3 5 5 5 3 3 3 3 3 3 4 4 4
<       4 4 3 4 3 3 3 2 2 5 3 3 3 3 4 4 4 4
```

```
<       4 4 3 3 3 3 2 2 2 5 3 3 3 3 4 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 4 4 4 4
>       4 4 4 4 3 3 3 5 5 5 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 5 2 2 5 3 3 3 3 4 4 4 4
>       4 4 4 3 3 3 5 2 2 5 3 3 3 3 4 4 4 4
74c73
< 201   4  -1.177  -201  u=2                                      imp:n=1
---
> 201   4  -1.187  -201  u=2                                      imp:n=1
82,83c81,82
< 209   11 -2.1746 -201  u=5                                      imp:n=1
< 210   1  -0.1     201 71  u=5                                   imp:n=1
---
> 209   11 -2.1739  -201  u=5                                     imp:n=1
> 210   1  -0.1     201 71 u=5                                    imp:n=1
139c138
<  53   c/z -23.495 121.87 6.985
---
>  53   c/z -23.495 111.11 6.985
150,151c149,150
<  64   py  114.885
<  65   py  128.855
---
>  64   py  104.125
>  65   py  118.095
153c152
<  67   c/z -23.495 121.87 37.465
---
>  67   c/z -23.495 111.11 37.465
190c189
< m4   94239.55 -0.03619 8016.50 -0.92895 1001.50 -0.10031
---
> m4   94239.55 -0.04523 8016.50 -0.92937 1001.50 -0.10021
202,203c201,202
< m11  94239.55 -0.06513 8016.50 -0.78435 1001.50 -0.00549
<       6012.50 -0.67704 14000.50 -0.64258                  $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>       6012.50 -0.68842 14000.50 -0.65338                  $pu +c+sio2+ water

*************************************************************************************
diff c0001f2q4.i c0001f2q1.i >diff2q4q1
1,6c1,4
< glovebox ha20mb cementation model - seismic case 2100 g pu - c0001f2q4
< c     base case 1800g + +300g holdup +200g outside
< c     glovebox - full water reflection on all sides
< c
< c     2100 g pu mixed with water in glovebox conveyor housing under floor,
< c     2" water on floor, 10% water spray
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside +900g h/x=20
> c     glovebox - full water reflection on all sides, cement can refl
> c     2" water flooded, 10% water spray
8,9c6,18
< c     room - 1 2.76 L can 6" spacing from glovebox wall
< c            0.200 kg pu + water
---
> c     bowls -  two bowls next to cans
> c             0.04167 g pu/cc pu
> c             0.200 kg pu/bowl
> c             h/x=634
> c             sides, bottom of bowls not included
> c     containers - 4 2.725 L cans 90% water 10% sio2
> c                  0.04523 g pu/cc
> c                  h/x=525
> c                  500 g pu total
> c                      7 2.725 L cans pu+water+c
> c                      0.04652 g/cc pu
> c                      h/x=20
> c                      900g pu total
12c21
<   1   1  -0.1   1 -2 3 -4 71 -6                                 imp:n=1
```

```
---
>   1    1  -0.1    1 -2 3 -4 20 -6                              imp:n=1
14c23
<   2    20  -1.005721 24 -25 7 -5 8 -9                          imp:n=1
---
>   2    1  -1.0 24 -25 7 -5 8 -9                                imp:n=1
26,27c35,49
< c      2 inch layer on floor
<   8    1  -1.0       1 -2 3 -4  70 -71                         imp:n=1
---
> c      containers
> c      bowl
>   8    3  -1.0431  ((63 -28):(-63 -61 69)) -32                 imp:n=1
>   9    1  -0.1     -32 -63 61 71                               imp:n=1
>  10    1  -1.0     -32 70 -71 (61:-69)                         imp:n=1
> c      bowl
>  11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                 imp:n=1
>  12    1  -0.1     -34 -63 58 71                               imp:n=1
>  13    1  -1.0     -34 70 -71 (58:-69)                         imp:n=1
> c      can
>  14    10 -2.911 -202 70 -28                                   imp:n=1
>  15    10 -2.911 -203 70 -28                                   imp:n=1
>  16    10 -2.911 -204 70 -28                                   imp:n=1
>  17    10 -2.911 -205 70 -28                                   imp:n=1
>  18    10 -2.911 -206 70 -28                                   imp:n=1
29,30c51,52
<  22    5  -1.0749 70 -28 -53                                   imp:n=1
<  23    0          70 -28 53 64 -65 41 66 -1                    imp:n=1
---
>  22    1  -1.0    70 -28 -53                                   imp:n=1
>  23    1  -1.0    70 -28 53 64 -65 41 66 -1                    imp:n=1
32c54,86
<  24    1  -1.0       5 -70 1 -4 -2 3                           imp:n=1
---
>  24    8  -5.562 5 -70 1 -4 -2 3                               imp:n=1
> c      filled cans
>  25    0  1 3 -433 -444 70 -28 32 34 202 203 204 205 206
>           fill=1 (7.035 7.035 0)                               imp:n=1
>  26    0    -331 334 -330 333 -329 332  u=1 lat=2
>        fill= -5:12 -1:10 0:0
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 5 5 5 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 5 2 2 5 3 3 3 3 4 4 4 4
>        4 4 4 3 3 3 5 2 2 5 3 3 3 3 4 4 4 4
>        4 4 4 3 3 3 4 4 4 3 3 3 3 4 4 4 4 4
>        4 4 3 3 3 4 4 4 4 3 3 3 3 4 4 4 4 4
>        4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                imp:n=1
> 201    4  -1.187   -201  u=2                                   imp:n=1
> 202    1  -0.1      201 71  u=2                                imp:n=1
> 203    1  -1.0      201 -71 u=2                                imp:n=1
> 204    10 -2.911  -201  u=3                                    imp:n=1
> 205    1  -0.1      201 71  u=3                                imp:n=1
> 206    1  -1.0      201 -71 u=3                                imp:n=1
> 207    1  -0.1      71  u=4                                    imp:n=1
> 208    1  -1.0     -71  u=4                                    imp:n=1
> 209    11 -2.1739  -201  u=5                                   imp:n=1
> 210    1  -0.1      201 71 u=5                                 imp:n=1
> 211    1  -1.0      201 -71 u=5                                imp:n=1
>  27    1  -0.1      1  3 -433 -444 28 -20                      imp:n=1
>  28    1  -0.1      1 -2 3 -4 (433:444) 71 -20                 imp:n=1
>  29    1  -1.0      1 -2 3 -4 (433:444) 70 -71                 imp:n=1
64,67c118,121
<  32    c/z 10.21 121.87 10.16
<  33    c/z 10.21 121.87 12.70
<  34    c/z 10.21 101.45 10.16
<  35    c/z 10.21 101.45 12.70
---
>  32    c/z 60.162 72.690 10.16
>  33    c/z 60.162 72.690 12.70
```

```
> 34   c/z 80.538 72.690 10.16
> 35   c/z 80.538 72.690 12.70
84c138
< 53   c/z -23.495 121.87 6.985
---
> 53   c/z -23.495 111.11 6.985
89c143
< 58   s   10.21 101.45 9.98 10.16
---
> 58   s   80.538 72.690 9.98 10.16
91,93c145,147
< 60   s   10.21 101.45 9.98 12.70
< 61   s   10.21 121.87 9.98 10.16
< 62   s   10.21 121.87 9.98 12.70
---
> 60   s   80.538 72.690 9.98 12.70
> 61   s   60.162 72.690 9.98 10.16
> 62   s   60.162 72.690 9.98 12.70
95,96c149,150
< 64   py  114.885
< 65   py  128.855
---
> 64   py  104.125
> 65   py  118.095
98c152
< 67   c/z -23.495 121.87 37.465
---
> 67   c/z -23.495 111.11 37.465
105c159
< 103  py  111.66
---
> 103  px  120.33
121a176,177
> 433  px  155.870
> 444  py  124.613
128,165d183
< 120  c/z 56.280 125.045 6.985
< 121  c/z 56.280 125.045 9.525
< 122  c/z 70.350 125.045 6.985
< 123  c/z 70.350 125.045 9.525
< 124  c/z 49.245 112.860 6.985
< 125  c/z 49.245 112.860 9.525
< 126  c/z 63.315 112.860 6.985
< 127  c/z 63.315 112.860 9.525
< 128  c/z 77.385 112.860 6.985
< 129  c/z 77.385 112.860 9.525
< 130  c/z 56.280 100.675 6.985
< 131  c/z 56.280 100.675 9.525
< 132  c/z 70.350 100.675 6.985
< 133  c/z 70.350 100.675 9.525
< 134  c/z 63.315 112.860 12.185
< 135  px  70.350
< 136  px  56.280
< 137  py  125.045
< 138  c/z 63.315 59.131 9.1091
< 139  c/z 63.315 59.131 11.6491
< 420  c/z 123.890 125.045 6.985
< 421  c/z 123.890 125.045 9.525
< 422  c/z 137.960 125.045 6.985
< 423  c/z 137.960 125.045 9.525
< 424  c/z 116.855 112.860 6.985
< 425  c/z 116.855 112.860 9.525
< 426  c/z 130.925 112.860 6.985
< 427  c/z 130.925 112.860 9.525
< 428  c/z 144.995 112.860 6.985
< 429  c/z 144.995 112.860 9.525
< 430  c/z 123.890 100.675 6.985
< 431  c/z 123.890 100.675 9.525
< 432  c/z 137.960 100.675 6.985
< 433  c/z 137.960 100.675 9.525
< 434  c/z 130.925 112.860 12.185
< 435  px  137.960
< 436  px  123.890
< 437  py  125.045
171,172c189,190
```

```
< m4    94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
<         6012.50 -0.17100                              $pu + carbon +water
---
> m4    94239.55 -0.04523 8016.50 -0.92937 1001.50 -0.10021
>       14000.50 -0.11200                               $pu + sio2 +water
174c192
< m5    94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110   $pu + water
---
> m5    94239.55 -0.07339 8016.50 -0.89148 1001.50 -0.11109   $pu + water
176c194
< m7    94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
186,187d203
< m20     94239.55 -0.005528 8016.50 -0.887614 1001.50 -0.111839  $pu + water
< mt20    lwtr.01
189,190c205,217
< ksrc  235. 66. -17.
<         -23. 121. 10
---
> ksrc  56. 43. 10
>         70. 43. 10
>         84. 43. 10
>         63. 55. 10
>         77. 55. 10
>         91. 55. 10
>         49. 31. 10
>         63. 31. 10
>         77. 31. 10
>         42. 43. 10
>         49. 55. 10
>         60. 72. 10
>         80. 72. 10

**************************************************************************************
diff c0001f2q4a.i c0001f2q1.i >diff2q4aq1
1,6c1,4
< glovebox ha20mb cementation model - seismic case 2100 g pu - c0001f2q4a
< c       base case 1800g + +300g holdup +200g outside
< c       glovebox - full water reflection on all sides
< c
< c       2100 g pu at 30 g/L in water in glovebox conveyor housing under floor,
< c       2" water on floor, 10% water spray
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
> c       base case 900g + 0 g conveyor + 300g holdup + 0g outside +900g h/x=20
> c       glovebox - full water reflection on all sides, cement can refl
> c       2" water flooded, 10% water spray
8,9c6,18
< c       room - 1 2.76 L can 6" spacing from glovebox wall
< c               0.200 kg pu + water
---
> c       bowls -  two bowls next to cans
> c                0.04167 g pu/cc pu
> c                0.200 kg pu/bowl
> c                h/x=634
> c                sides, bottom of bowls not included
> c       containers - 4 2.725 L cans 90% water 10% sio2
> c                     0.04523 g pu/cc
> c                     h/x=525
> c                     500 g pu total
> c                         7 2.725 L cans pu+water+c
> c                         0.04652 g/cc pu
> c                         h/x=20
> c                         900g pu total
12c21
<    1    1  -0.1    1 -2 3 -4 71 -6                              imp:n=1
---
>    1    1  -0.1    1 -2 3 -4 20 -6                              imp:n=1
14,15c23
<    2    20 -1.031048  24 -25 7 -72 8 -9                         imp:n=1
<    3    1  -1.0       24 -25 72 -5 8 -9                         imp:n=1
---
>    2    1  -1.0 24 -25 7 -5 8 -9                                imp:n=1
27,28c35,49
```

```
< c     2 inch layer on floor
<   8   1  -1.0       1 -2 3 -4  70 -71                                  imp:n=1
---
> c     containers
> c     bowl
>   8   3  -1.0431  ((63 -28):(-63 -61 69)) -32                         imp:n=1
>   9   1  -0.1     -32 -63 61 71                                       imp:n=1
>  10   1  -1.0     -32 70 -71 (61:-69)                                 imp:n=1
> c     bowl
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                         imp:n=1
>  12   1  -0.1     -34 -63 58 71                                       imp:n=1
>  13   1  -1.0     -34 70 -71 (58:-69)                                 imp:n=1
> c     can
>  14   10 -2.911 -202 70 -28                                           imp:n=1
>  15   10 -2.911 -203 70 -28                                           imp:n=1
>  16   10 -2.911 -204 70 -28                                           imp:n=1
>  17   10 -2.911 -205 70 -28                                           imp:n=1
>  18   10 -2.911 -206 70 -28                                           imp:n=1
30,31c51,52
<  22   5  -1.0749 70 -28 -53                                           imp:n=1
<  23   0         70 -28 53 64 -65 41 66 -1                             imp:n=1
---
>  22   1  -1.0   70 -28 -53                                            imp:n=1
>  23   1  -1.0   70 -28 53 64 -65 41 66 -1                             imp:n=1
33c54,86
<  24   1  -1.0      5 -70 1 -4 -2 3                                    imp:n=1
---
>  24   8  -5.562 5 -70 1 -4 -2 3                                       imp:n=1
> c     filled cans
>  25   0  1 3 -433 -444 70 -28 32 34 202 203 204 205 206
>          fill=1 (7.035 7.035 0)                                       imp:n=1
>  26   0    -331 334 -330 333 -329 332  u=1 lat=2
>       fill= -5:12 -1:10 0:0
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 3 5 5 5 3 3 3 3 3 4 4 4
>       4 4 4 4 3 3 5 2 2 5 3 3 3 3 4 4 4 4
>       4 4 4 3 3 3 5 2 2 5 3 3 3 3 4 4 4 4
>       4 4 4 3 3 3 4 4 4 3 3 3 3 4 4 4 4 4
>       4 4 3 3 3 4 4 4 4 3 3 3 3 4 4 4 4 4
>       4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                       imp:n=1
> 201   4  -1.187   -201  u=2                                           imp:n=1
> 202   1  -0.1      201 71  u=2                                        imp:n=1
> 203   1  -1.0      201 -71 u=2                                        imp:n=1
> 204   10 -2.911  -201  u=3                                            imp:n=1
> 205   1  -0.1      201 71  u=3                                        imp:n=1
> 206   1  -1.0      201 -71 u=3                                        imp:n=1
> 207   1  -0.1      71  u=4                                            imp:n=1
> 208   1  -1.0     -71  u=4                                            imp:n=1
> 209   11 -2.1739  -201  u=5                                           imp:n=1
> 210   1  -0.1      201 71 u=5                                         imp:n=1
> 211   1  -1.0      201 -71 u=5                                        imp:n=1
>  27   1  -0.1      1  3 -433 -444 28 -20                              imp:n=1
>  28   1  -0.1      1 -2 3 -4 (433:444) 71 -20                         imp:n=1
>  29   1  -1.0      1 -2 3 -4 (433:444) 70 -71                         imp:n=1
65,68c118,121
<  32    c/z 10.21 121.87 10.16
<  33    c/z 10.21 121.87 12.70
<  34    c/z 10.21 101.45 10.16
<  35    c/z 10.21 101.45 12.70
---
>  32    c/z 60.162 72.690 10.16
>  33    c/z 60.162 72.690 12.70
>  34    c/z 80.538 72.690 10.16
>  35    c/z 80.538 72.690 12.70
85c138
<  53    c/z -23.495 121.87 6.985
---
>  53    c/z -23.495 111.11 6.985
90c143
```

```
<  58    s    10.21 101.45 9.98 10.16
---
>  58    s    80.538 72.690 9.98 10.16
92,94c145,147
<  60    s    10.21 101.45 9.98 12.70
<  61    s    10.21 121.87 9.98 10.16
<  62    s    10.21 121.87 9.98 12.70
---
>  60    s    80.538 72.690 9.98 12.70
>  61    s    60.162 72.690 9.98 10.16
>  62    s    60.162 72.690 9.98 12.70
96,97c149,150
<  64    py   114.885
<  65    py   128.855
---
>  64    py   104.125
>  65    py   118.095
99c152
<  67    c/z -23.495 121.87 37.465
---
>  67    c/z -23.495 111.11 37.465
104d156
<  72    pz   -29.008
107c159
< 103    py   111.66
---
> 103    px   120.33
123a176,177
> 433    px   155.870
> 444    py   124.613
130,167d183
< 120    c/z 56.280 125.045 6.985
< 121    c/z 56.280 125.045 9.525
< 122    c/z 70.350 125.045 6.985
< 123    c/z 70.350 125.045 9.525
< 124    c/z 49.245 112.860 6.985
< 125    c/z 49.245 112.860 9.525
< 126    c/z 63.315 112.860 6.985
< 127    c/z 63.315 112.860 9.525
< 128    c/z 77.385 112.860 6.985
< 129    c/z 77.385 112.860 9.525
< 130    c/z 56.280 100.675 6.985
< 131    c/z 56.280 100.675 9.525
< 132    c/z 70.350 100.675 6.985
< 133    c/z 70.350 100.675 9.525
< 134    c/z 63.315 112.860 12.185
< 135    px  70.350
< 136    px  56.280
< 137    py  125.045
< 138    c/z 63.315 59.131 9.1091
< 139    c/z 63.315 59.131 11.6491
< 420    c/z 123.890 125.045 6.985
< 421    c/z 123.890 125.045 9.525
< 422    c/z 137.960 125.045 6.985
< 423    c/z 137.960 125.045 9.525
< 424    c/z 116.855 112.860 6.985
< 425    c/z 116.855 112.860 9.525
< 426    c/z 130.925 112.860 6.985
< 427    c/z 130.925 112.860 9.525
< 428    c/z 144.995 112.860 6.985
< 429    c/z 144.995 112.860 9.525
< 430    c/z 123.890 100.675 6.985
< 431    c/z 123.890 100.675 9.525
< 432    c/z 137.960 100.675 6.985
< 433    c/z 137.960 100.675 9.525
< 434    c/z 130.925 112.860 12.185
< 435    px  137.960
< 436    px  123.890
< 437    py  125.045
173,174c189,190
< m4    94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
<        6012.50 -0.17100                                    $pu + carbon +water
---
> m4    94239.55 -0.04523 8016.50 -0.92937 1001.50 -0.10021
>       14000.50 -0.11200                                    $pu + sio2 +water
```

```
176c192
< m5    94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110    $pu + water
---
> m5    94239.55 -0.07339 8016.50 -0.89148 1001.50 -0.11109    $pu + water
178c194
< m7    94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096    $pu + water
---
> m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028    $pu + water
188,189d203
< m20    94239.55 -0.0300 8016.50 -0.88948 1001.50 -0.111568  $pu + water
< mt20   lwtr.01
191,192c205,217
< ksrc  235. 66. -30.
<       -23. 121. 10
---
> ksrc  56. 43. 10
>       70. 43. 10
>       84. 43. 10
>       63. 55. 10
>       77. 55. 10
>       91. 55. 10
>       49. 31. 10
>       63. 31. 10
>       77. 31. 10
>       42. 43. 10
>       49. 55. 10
>       60. 72. 10
>       80. 72. 10

***************************************************************************************
diff c0001f2q4b.i c0001f2q1.i >diff2q4bq1
1,6c1,4
< glovebox ha20mb cementation model - seismic case 2100 g pu - c0001f2q4b
< c     base case 1800g + +300g holdup +200g outside
< c     glovebox - full water reflection on all sides
< c
< c     2100 g pu at 150 g/L in water in glovebox conveyor housing under floor,
< c     2" water on floor, 10% water spray
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside +900g h/x=20
> c     glovebox - full water reflection on all sides, cement can refl
> c     2" water flooded, 10% water spray
8,9c6,18
< c     room - 1 2.76 L can 6" spacing from glovebox wall
< c            0.200 kg pu + water
---
> c     bowls -  two bowls next to cans
> c             0.04167 g pu/cc pu
> c             0.200 kg pu/bowl
> c             h/x=634
> c             sides, bottom of bowls not included
> c     containers - 4 2.725 L cans 90% water 10% sio2
> c                  0.04523 g pu/cc
> c                  h/x=525
> c                  500 g pu total
> c                      7 2.725 L cans pu+water+c
> c                      0.04652 g/cc pu
> c                      h/x=20
> c                      900g pu total
12c21
<   1   1  -0.1   1 -2 3 -4 71 -6                              imp:n=1
---
>   1   1  -0.1   1 -2 3 -4 20 -6                              imp:n=1
14,15c23
<   2   20 -1.155242  24 -25 7 -72 8 -9                        imp:n=1
<   3   1  -1.0       24 -25 72 -5 8 -9                        imp:n=1
---
>   2   1  -1.0 24 -25 7 -5 8 -9                               imp:n=1
27,28c35,49
< c     2 inch layer on floor
<   8   1  -1.0       1 -2 3 -4  70 -71                        imp:n=1
---
> c     containers
> c     bowl
```

```
>   8    3  -1.0431  ((63 -28):(-63 -61 69)) -32                imp:n=1
>   9    1  -0.1     -32 -63 61 71                              imp:n=1
>  10    1  -1.0     -32 70 -71 (61:-69)                        imp:n=1
> c      bowl
>  11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                imp:n=1
>  12    1  -0.1     -34 -63 58 71                              imp:n=1
>  13    1  -1.0     -34 70 -71 (58:-69)                        imp:n=1
> c      can
>  14    10 -2.911 -202 70 -28                                  imp:n=1
>  15    10 -2.911 -203 70 -28                                  imp:n=1
>  16    10 -2.911 -204 70 -28                                  imp:n=1
>  17    10 -2.911 -205 70 -28                                  imp:n=1
>  18    10 -2.911 -206 70 -28                                  imp:n=1
30,31c51,52
<  22    5  -1.0749 70 -28 -53                                  imp:n=1
<  23    0          70 -28 53 64 -65 41 66 -1                   imp:n=1
---
>  22    1  -1.0    70 -28 -53                                  imp:n=1
>  23    1  -1.0    70 -28 53 64 -65 41 66 -1                   imp:n=1
33c54,86
<  24    1  -1.0       5 -70 1 -4 -2 3                          imp:n=1
---
>  24    8  -5.562 5 -70 1 -4 -2 3                              imp:n=1
> c      filled cans
>  25    0  1 3 -433 -444 70 -28 32 34 202 203 204 205 206
>           fill=1 (7.035 7.035 0)                              imp:n=1
>  26    0     -331 334 -330 333 -329 332  u=1 lat=2
>        fill= -5:12 -1:10 0:0
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 3 5 5 5 3 3 3 3 3 4 4 4
>        4 4 4 4 3 3 5 2 2 5 3 3 3 3 4 4 4 4
>        4 4 4 3 3 3 5 2 2 5 3 3 3 3 4 4 4 4
>        4 4 4 3 3 3 4 4 4 3 3 3 3 4 4 4 4 4
>        4 4 3 3 3 4 4 4 4 3 3 3 3 4 4 4 4 4
>        4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                               imp:n=1
> 201    4  -1.187   -201  u=2                                  imp:n=1
> 202    1  -0.1      201 71  u=2                               imp:n=1
> 203    1  -1.0      201 -71 u=2                               imp:n=1
> 204    10 -2.911   -201  u=3                                  imp:n=1
> 205    1  -0.1      201 71  u=3                               imp:n=1
> 206    1  -1.0      201 -71 u=3                               imp:n=1
> 207    1  -0.1      71  u=4                                   imp:n=1
> 208    1  -1.0     -71  u=4                                   imp:n=1
> 209    11 -2.1739  -201  u=5                                  imp:n=1
> 210    1  -0.1      201 71 u=5                                imp:n=1
> 211    1  -1.0      201 -71 u=5                               imp:n=1
>  27    1  -0.1      1  3 -433 -444 28 -20                     imp:n=1
>  28    1  -0.1      1 -2 3 -4 (433:444) 71 -20                imp:n=1
>  29    1  -1.0      1 -2 3 -4 (433:444) 70 -71                imp:n=1
65,68c118,121
<  32    c/z 10.21 121.87 10.16
<  33    c/z 10.21 121.87 12.70
<  34    c/z 10.21 101.45 10.16
<  35    c/z 10.21 101.45 12.70
---
>  32    c/z 60.162 72.690 10.16
>  33    c/z 60.162 72.690 12.70
>  34    c/z 80.538 72.690 10.16
>  35    c/z 80.538 72.690 12.70
85c138
<  53    c/z -23.495 121.87 6.985
---
>  53    c/z -23.495 111.11 6.985
90c143
<  58    s    10.21 101.45 9.98 10.16
---
>  58    s    80.538 72.690 9.98 10.16
92,94c145,147
<  60    s    10.21 101.45 9.98 12.70
```

```
< 61    s    10.21 121.87 9.98 10.16
< 62    s    10.21 121.87 9.98 12.70
---
> 60    s    80.538 72.690 9.98 12.70
> 61    s    60.162 72.690 9.98 10.16
> 62    s    60.162 72.690 9.98 12.70
96,97c149,150
< 64    py  114.885
< 65    py  128.855
---
> 64    py  104.125
> 65    py  118.095
99c152
< 67    c/z -23.495 121.87 37.465
---
> 67    c/z -23.495 111.11 37.465
104d156
< 72    pz  -34.25
107c159
< 103   py  111.66
---
> 103   px  120.33
123a176,177
> 433   px  155.870
> 444   py  124.613
130,167d183
< 120   c/z 56.280 125.045 6.985
< 121   c/z 56.280 125.045 9.525
< 122   c/z 70.350 125.045 6.985
< 123   c/z 70.350 125.045 9.525
< 124   c/z 49.245 112.860 6.985
< 125   c/z 49.245 112.860 9.525
< 126   c/z 63.315 112.860 6.985
< 127   c/z 63.315 112.860 9.525
< 128   c/z 77.385 112.860 6.985
< 129   c/z 77.385 112.860 9.525
< 130   c/z 56.280 100.675 6.985
< 131   c/z 56.280 100.675 9.525
< 132   c/z 70.350 100.675 6.985
< 133   c/z 70.350 100.675 9.525
< 134   c/z 63.315 112.860 12.185
< 135   px  70.350
< 136   px  56.280
< 137   py  125.045
< 138   c/z 63.315 59.131 9.1091
< 139   c/z 63.315 59.131 11.6491
< 420   c/z 123.890 125.045 6.985
< 421   c/z 123.890 125.045 9.525
< 422   c/z 137.960 125.045 6.985
< 423   c/z 137.960 125.045 9.525
< 424   c/z 116.855 112.860 6.985
< 425   c/z 116.855 112.860 9.525
< 426   c/z 130.925 112.860 6.985
< 427   c/z 130.925 112.860 9.525
< 428   c/z 144.995 112.860 6.985
< 429   c/z 144.995 112.860 9.525
< 430   c/z 123.890 100.675 6.985
< 431   c/z 123.890 100.675 9.525
< 432   c/z 137.960 100.675 6.985
< 433   c/z 137.960 100.675 9.525
< 434   c/z 130.925 112.860 12.185
< 435   px  137.960
< 436   px  123.890
< 437   py  125.045
173,174c189,190
< m4    94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
<        6012.50 -0.17100                                    $pu + carbon +water
---
> m4    94239.55 -0.04523 8016.50 -0.92937 1001.50 -0.10021
>      14000.50 -0.11200                                     $pu + sio2 +water
176c192
< m5    94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110   $pu + water
---
> m5    94239.55 -0.07339 8016.50 -0.89148 1001.50 -0.11109   $pu + water
178c194
```

```
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
188,189d203
< m20   94239.55 -0.1500 8016.50 -0.895002 1001.50 -0.11024  $pu + water
< mt20   lwtr.01
191,192c205,217
< ksrc  235. 66. -30.
<       -23. 121. 10
---
> ksrc  56. 43. 10
>       70. 43. 10
>       84. 43. 10
>       63. 55. 10
>       77. 55. 10
>       91. 55. 10
>       49. 31. 10
>       63. 31. 10
>       77. 31. 10
>       42. 43. 10
>       49. 55. 10
>       60. 72. 10
>       80. 72. 10

****************************************************************************************
diff c0001f2q1b.i c0001f2q1.i >diff2q1bq1
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f2q1b
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
4c4
< c     2" water flooded, 0.01 g/cc water spray
---
> c     2" water flooded, 10% water spray
21c21
<   1    1  -0.01    1 -2 3 -4 20 -6                                 imp:n=1
---
>   1    1  -0.1    1 -2 3 -4 20 -6                                  imp:n=1
38c38
<   9    1  -0.01    -32 -63 61 71                                   imp:n=1
---
>   9    1  -0.1     -32 -63 61 71                                   imp:n=1
42c42
<  12    1  -0.01    -34 -63 58 71                                   imp:n=1
---
>  12    1  -0.1     -34 -63 58 71                                   imp:n=1
74c74
< 202    1  -0.01     201 71  u=2                                    imp:n=1
---
> 202    1  -0.1      201 71  u=2                                    imp:n=1
77c77
< 205    1  -0.01     201 71  u=3                                    imp:n=1
---
> 205    1  -0.1      201 71  u=3                                    imp:n=1
79c79
< 207    1  -0.01     71  u=4                                        imp:n=1
---
> 207    1  -0.1      71  u=4                                        imp:n=1
82c82
< 210    1  -0.01     201 71 u=5                                     imp:n=1
---
> 210    1  -0.1      201 71 u=5                                     imp:n=1
84,85c84,85
<  27    1  -0.01     1  3 -433 -444 28 -20                          imp:n=1
<  28    1  -0.01     1 -2 3 -4 (433:444) 71 -20                     imp:n=1
---
>  27    1  -0.1      1  3 -433 -444 28 -20                          imp:n=1
>  28    1  -0.1      1 -2 3 -4 (433:444) 71 -20                     imp:n=1

****************************************************************************************
diff c0001f2q1c.i c0001f2q1.i >diff2q1cq1
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f2q1c
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
```

```
4c4
< c      2" water flooded, 0.05 g/cc water spray
---
> c      2" water flooded, 10% water spray
21c21
<    1    1  -0.05    1 -2 3 -4 20 -6                           imp:n=1
---
>    1    1  -0.1    1 -2 3 -4 20 -6                            imp:n=1
38c38
<    9    1  -0.05    -32 -63 61 71                             imp:n=1
---
>    9    1  -0.1     -32 -63 61 71                             imp:n=1
42c42
<   12    1  -0.05    -34 -63 58 71                             imp:n=1
---
>   12    1  -0.1     -34 -63 58 71                             imp:n=1
74c74
< 202     1  -0.05     201 71  u=2                              imp:n=1
---
> 202     1  -0.1      201 71  u=2                              imp:n=1
77c77
< 205     1  -0.05     201 71  u=3                              imp:n=1
---
> 205     1  -0.1      201 71  u=3                              imp:n=1
79c79
< 207     1  -0.05     71  u=4                                  imp:n=1
---
> 207     1  -0.1      71  u=4                                  imp:n=1
82c82
< 210     1  -0.05     201 71 u=5                               imp:n=1
---
> 210     1  -0.1      201 71 u=5                               imp:n=1
84,85c84,85
<   27    1  -0.05     1  3 -433 -444 28 -20                    imp:n=1
<   28    1  -0.05     1 -2 3 -4 (433:444) 71 -20               imp:n=1
---
>   27    1  -0.1      1  3 -433 -444 28 -20                    imp:n=1
>   28    1  -0.1      1 -2 3 -4 (433:444) 71 -20               imp:n=1

*************************************************************************************
diff c0001f2q1d.i c0001f2q1.i >diff2q1dq1
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f2q1d
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
4c4
< c      2" water flooded, 0.15 g/cc water spray
---
> c      2" water flooded, 10% water spray
21c21
<    1    1  -0.15    1 -2 3 -4 20 -6                           imp:n=1
---
>    1    1  -0.1    1 -2 3 -4 20 -6                            imp:n=1
38c38
<    9    1  -0.15    -32 -63 61 71                             imp:n=1
---
>    9    1  -0.1     -32 -63 61 71                             imp:n=1
42c42
<   12    1  -0.15    -34 -63 58 71                             imp:n=1
---
>   12    1  -0.1     -34 -63 58 71                             imp:n=1
74c74
< 202     1  -0.15     201 71  u=2                              imp:n=1
---
> 202     1  -0.1      201 71  u=2                              imp:n=1
77c77
< 205     1  -0.15     201 71  u=3                              imp:n=1
---
> 205     1  -0.1      201 71  u=3                              imp:n=1
79c79
< 207     1  -0.15     71  u=4                                  imp:n=1
---
> 207     1  -0.1      71  u=4                                  imp:n=1
82c82
< 210     1  -0.15     201 71 u=5                               imp:n=1
```

```
---
> 210   1  -0.1      201 71 u=5                                      imp:n=1
84,85c84,85
<  27   1  -0.15     1  3 -433 -444 28 -20                           imp:n=1
<  28   1  -0.15     1 -2 3 -4 (433:444) 71 -20                      imp:n=1
---
>  27   1  -0.1      1  3 -433 -444 28 -20                           imp:n=1
>  28   1  -0.1      1 -2 3 -4 (433:444) 71 -20                      imp:n=1

*************************************************************************************
diff c0001f2q1e.i c0001f2q1.i >diff2q1eq1
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f2q1e
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
4c4
< c     2" water flooded, 0.001 g/cc water spray
---
> c     2" water flooded, 10% water spray
21c21
<   1   1  -0.001  1 -2 3 -4 20 -6                                   imp:n=1
---
>   1   1  -0.1   1 -2 3 -4 20 -6                                    imp:n=1
38c38
<   9   1  -0.001  -32 -63 61 71                                     imp:n=1
---
>   9   1  -0.1    -32 -63 61 71                                     imp:n=1
42c42
<  12   1  -0.001  -34 -63 58 71                                     imp:n=1
---
>  12   1  -0.1    -34 -63 58 71                                     imp:n=1
74c74
< 202   1  -0.001   201 71  u=2                                      imp:n=1
---
> 202   1  -0.1     201 71  u=2                                      imp:n=1
77c77
< 205   1  -0.001   201 71  u=3                                      imp:n=1
---
> 205   1  -0.1     201 71  u=3                                      imp:n=1
79c79
< 207   1  -0.001   71  u=4                                          imp:n=1
---
> 207   1  -0.1     71  u=4                                          imp:n=1
82c82
< 210   1  -0.001   201 71 u=5                                       imp:n=1
---
> 210   1  -0.1     201 71 u=5                                       imp:n=1
84,85c84,85
<  27   1  -0.001   1  3 -433 -444 28 -20                            imp:n=1
<  28   1  -0.001   1 -2 3 -4 (433:444) 71 -20                       imp:n=1
---
>  27   1  -0.1     1  3 -433 -444 28 -20                            imp:n=1
>  28   1  -0.1     1 -2 3 -4 (433:444) 71 -20                       imp:n=1

*************************************************************************************
diff c0001f2q5a.i c0001f2q1.i >diff2q5aq1
1c1
< glovebox ha20mb cementation model - seismic two bowls - c0001f2q5a
---
> glovebox ha20mb cementation model - seismic two bowls - c0001f2q1
45,49c45,49
<  14    10 -2.722 -202 70 -28                                       imp:n=1
<  15    10 -2.722 -203 70 -28                                       imp:n=1
<  16    10 -2.722 -204 70 -28                                       imp:n=1
<  17    10 -2.722 -205 70 -28                                       imp:n=1
<  18    10 -2.722 -206 70 -28                                       imp:n=1
---
>  14    10 -2.911 -202 70 -28                                       imp:n=1
>  15    10 -2.911 -203 70 -28                                       imp:n=1
>  16    10 -2.911 -204 70 -28                                       imp:n=1
>  17    10 -2.911 -205 70 -28                                       imp:n=1
>  18    10 -2.911 -206 70 -28                                       imp:n=1
76c76
< 204    10 -2.722  -201  u=3                                        imp:n=1
---
```

```
> 204   10 -2.911   -201  u=3                                        imp:n=1
198,199c198,199
< m10  20000.50 -0.36921 14000.50 -0.088147 13027.50 -0.034717
<      12000.50 -0.029669  8016.50 -0.458114  1001.50 -0.020142 $cement 18% h2o
---
> m10  20000.50 -0.40973 14000.50 -0.09782 13027.50 -0.03853
>      12000.50 -0.03293  8016.50 -0.41092  1001.50 -0.01007 $cement 9% h2o

**********************************************************************************************
diff c0001f2f1.i c0001f2b4.i >diff2f1b4
1,2c1,2
< glovebox ha20mb cementation model - fire case 2100 g pu - c0001f2f1
< c     base case 900g + 0 g conveyor + 300g holdup + 0g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
6c6
< c            0.04228 g pu/cc pu
---
> c            0.04167 g pu/cc pu
8c8
< c            h/x
---
> c            h/x=634
22c22
<   1   1  -0.1   1 -2 3 -4 20 -6                                    imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                                    imp:n=1
36d35
< c     containers
39,41c38,41
<   9   1  -0.1    -32 -63 61 71                                     imp:n=1
<  10   1  -1.0    -32 70 -71 (61:-69)                               imp:n=1
<  11   1  -0.1    -32 28 -20                                        imp:n=1
---
> c     bowl water reflection
>   9   1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                  (-69 70 -62)) -2 1  103                             imp:n=1
>  10   0          -33 -63 70 62 -2 1  103                             imp:n=1
43,46c43,47
<  12   3  -1.0431  ((63 -28):(-63 -58 69)) -34                        imp:n=1
<  13   1  -0.1    -34 -63 58 71                                      imp:n=1
<  14   1  -1.0    -34 70 -71 (58:-69)                                imp:n=1
<  15   1  -0.1    -34 28 -20                                         imp:n=1
---
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                        imp:n=1
> c     bowl water reflection
>  12   1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                             imp:n=1
>  13   0          -35 -63 70 60 -2 1 -103                             imp:n=1
48c49
<  22   5  -1.0749 70 -28 -53                                         imp:n=1
---
>  22   5  -1.0749   70 -28 -53                                        imp:n=1
53c54
<  25   0  1 3 -433 -444 70 -20 32 34
---
>  25   0  1 3 -433 -444 70 -20 33 35
71,85c72,81
< 202   1  -0.1    -201 28  u=2                                        imp:n=1
< 203   1  -0.1     201 71  u=2                                        imp:n=1
< 204   1  -1.0     201 -71 u=2                                        imp:n=1
< 205   10 -2.911  -201 -28 u=3                                        imp:n=1
< 206   1  -0.1    -201 28  u=3                                        imp:n=1
< 207   1  -0.1     201 71  u=3                                        imp:n=1
< 208   1  -1.0     201 -71 u=3                                        imp:n=1
< 209   1  -0.1     71  u=4                                            imp:n=1
< 210   1  -1.0    -71  u=4                                            imp:n=1
< 211   11 -2.1739 -201 -28 u=5                                        imp:n=1
< 212   1  -0.1    -201 28  u=5                                        imp:n=1
< 213   1  -0.1     201 71  u=5                                        imp:n=1
< 214   1  -1.0     201 -71 u=5                                        imp:n=1
<  28   1  -0.1     1 -2 3 -4 (433:444) 71 -20 32 34                   imp:n=1
<  29   1  -1.0     1 -2 3 -4 (433:444) 70 -71 32 34                   imp:n=1
---
```

```
> 202   1  -1.0      28       u=2                                          imp:n=1
> 203   0            201 -28 u=2                                           imp:n=1
> 204   10 -2.911   -201 -28 u=3                                           imp:n=1
> 205   1  -1.0      28       u=3                                          imp:n=1
> 206   0            201 -28 u=3                                           imp:n=1
> 207   0            777    u=4                                            imp:n=1
> 208   11 -2.1739 -201 -28 u=5                                            imp:n=1
> 209   1  -1.0      28       u=5                                          imp:n=1
> 210   0            201 -28 u=5                                           imp:n=1
>  28   0            1 -2 3 -4 (433:444) 70 -20 33 35                      imp:n=1
158c154
< 103   py 111.66
---
> 103   py  111.66
189c185
<       14000.50 -0.11200                                  $pu + sio2 +water
---
>       14000.50 -0.11200                                  $pu + carbon +water

*****************************************************************************************
diff c0001f2f2a.i c0001f2b5.i >diff2f2ab5
1,4c1,3
< glovebox ha20mb cementation model - flooding case 2100 g pu - c0001f2f2a
< c     base case 900g +400 g conveyor +300g holdup +200g outside +900g h/x=20
< c     glovebox - full water reflection on all sides, no can reflection
< c     glovebox flooded to 2", 10% water spray
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b5
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
> c     glovebox - full water reflection on all sides, water can refl
19,22d17
< c     conveyor container - 1 4.7 L can pu + water 10" from cans
< c                  0.08511 g pu/cc
< c                  h/x=309
< c                  400 g pu total
27c22
<   1   2  -0.10  1 -2 3 -4 20 -6                                         imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                                          imp:n=1
44,47c39,41
<   9   2  -0.1   ((63 -33 -20 (32:28)):(-63 61 -62 71)) -2 1 103 imp:n=1
<  10   1  -1.0    70 -71 -62 (61:-69)  -2 1  103                          imp:n=1
<  11   2  -0.1   -33 -63 71 62 -2 1  103                                  imp:n=1
<  12   1  -1.0   -33 -71 70 62 -2 1  103                                  imp:n=1
---
>   9   1  -1.0   ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                 (-69 70 -62)) -2 1  103                                  imp:n=1
>  10   0         -33 -63 70 62 -2 1  103                                  imp:n=1
49c43
<  13   3  -1.0431  ((63 -28):(-63 -58 69)) -34                            imp:n=1
---
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                            imp:n=1
51,58c45,47
<  14   2  -0.1   ((63 -35 -20 (34:28)):(-63 58 -60 71)) -2 1 -103 imp:n=1
<  15   1  -1.0    70 -71 -60 (58:-69) -2 1 -103                           imp:n=1
<  16   2  -0.1   -35 -63 71 60 -2 1 -103                                  imp:n=1
<  17   1  -1.0   -35 -71 70 60 -2 1 -103                                  imp:n=1
< c     container on conveyor
<  19   1  -1.0      70 -71 138 -139                                      imp:n=1
<  20   7  -1.088  70 -28 -138                                             imp:n=1
<  21   2  -0.1      71 -20 (138:28) -139                                 imp:n=1
---
>  12   1  -1.0   ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                 (-69 70 -60)) -2 1 -103                                  imp:n=1
>  13   0         -35 -63 70 60 -2 1 -103                                  imp:n=1
60c49
<  22   5  -1.0749 70 -28 -53                                             imp:n=1
---
>  22   5  -1.0749   70 -28 -53                                           imp:n=1
65,109c54,81
< 201   4  -1.167  -120 70 -28                                             imp:n=1
< 202   4  -1.167  -122 70 -28                                             imp:n=1
< 203   4  -1.167  -124 70 -28                                             imp:n=1
< 204   4  -1.167  -126 70 -28                                             imp:n=1
< 205   4  -1.167  -128 70 -28                                             imp:n=1
```

```
< 206   4  -1.167   -130 70 -28                                   imp:n=1
< 207   4  -1.167   -132 70 -28                                   imp:n=1
< 208   2  -0.1     ((-121:-123:-125:-129:-131:-133)
<                   (120 122 124 128 130 132 134)) 134 -28 71 -2
<                   (135:-136:-137)                               imp:n=1
< 209   2  -0.1 ((-121:-123:-125:-127:-129:-131:-133) 28 -20 -2)  imp:n=1
< 210   2  -0.1     120 122 124 126 128 130 132 -134 -28 71       imp:n=1
< 211   2  -0.1     121 123 125 127 129 131 133 -134 28 -20       imp:n=1
< 212   2  -0.1     -135 136 137 120 122 -2 -28 71                imp:n=1
< 213   1  -1.0     ((-121:-123:-125:-129:-131:-133)
<                   (120 122 124 128 130 132 134)) 134 -71 70 -2
<                   (135:-136:-137)                               imp:n=1
< 214   1  -1.0     120 122 124 126 128 130 132 -134 -71 70       imp:n=1
< 215   1  -1.0     -135 136 137 120 122 -2 -71 70                imp:n=1
< c     filled cans
< 401   11 -2.1739 -420 70 -28                                    imp:n=1
< 402   11 -2.1739 -422 70 -28                                    imp:n=1
< 403   11 -2.1739 -424 70 -28                                    imp:n=1
< 404   11 -2.1739 -426 70 -28                                    imp:n=1
< 405   11 -2.1739 -428 70 -28                                    imp:n=1
< 406   11 -2.1739 -430 70 -28                                    imp:n=1
< 407   11 -2.1739 -432 70 -28                                    imp:n=1
< 408   2  -0.1     ((-421:-423:-425:-429:-431:-433)
<                   (420 422 424 428 430 432 434)) 434 -28 71 -2
<                   (435:-436:-437)                               imp:n=1
< 409   2  -0.1 ((-421:-423:-425:-427:-429:-431:-433) 28 -20 -2)  imp:n=1
< 410   2  -0.1     420 422 424 426 428 430 432 -434 -28 71       imp:n=1
< 411   2  -0.1     421 423 425 427 429 431 433 -434 28 -20       imp:n=1
< 412   2  -0.1     -435 436 437 420 422 -2 -28 71                imp:n=1
< 413   1  -1.0     ((-421:-423:-425:-429:-431:-433)
<                   (420 422 424 428 430 432 434)) 434 -71 70 -2
<                   (435:-436:-437)                               imp:n=1
< 414   1  -1.0     420 422 424 426 428 430 432 -434 -71 70       imp:n=1
< 415   1  -1.0     -435 436 437 420 422 -2 -71 70                imp:n=1
<  28   2  -0.1 1 -2 3 -4 121 123 125 127 129 131 133 134 71 -20 33 35
<           (-136:135:-137:28) 139 421 423 425 427 429 431 433 434
<           (-436:435:-437:28)                                    imp:n=1
<  29   1  -1.0 1 -2 3 -4 121 123 125 127 129 131 133 134 70 -71 33 35
<           (-136:135:-137:28) 139 421 423 425 427 429 431 433 434
<           (-436:435:-437:28)                                    imp:n=1
---
>  25   0  1 3 -433 -444 70 -20 33 35
>          fill=1 (7.035 7.035 0)                                 imp:n=1
>  26   0    -331 334 -330 333 -329 332  u=1 lat=2
>       fill= -5:14 -1:10 0:0
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>       4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                 imp:n=1
> 201   4  -1.167   -201 -28 u=2                                  imp:n=1
> 202   1  -1.0      28      u=2                                  imp:n=1
> 203   0            201 -28 u=2                                  imp:n=1
> 204   1  -1.0     -201 -28 u=3                                  imp:n=1
> 205   1  -1.0      28      u=3                                  imp:n=1
> 206   0            201 -28 u=3                                  imp:n=1
> 207   0            777    u=4                                   imp:n=1
> 208   11 -2.1739 -201 -28 u=5                                   imp:n=1
> 209   1  -1.0      28      u=5                                  imp:n=1
> 210   0            201 -28 u=5                                  imp:n=1
>  28   0            1 -2 3 -4 (433:444) 70 -20 33 35             imp:n=1
198a171,172
> 433   px  196.980
> 444   py  124.613
205,242d178
< 120   c/z 56.280 125.045 6.985
< 121   c/z 56.280 125.045 9.525
```

```
< 122    c/z 70.350 125.045 6.985
< 123    c/z 70.350 125.045 9.525
< 124    c/z 49.245 112.860 6.985
< 125    c/z 49.245 112.860 9.525
< 126    c/z 63.315 112.860 6.985
< 127    c/z 63.315 112.860 9.525
< 128    c/z 77.385 112.860 6.985
< 129    c/z 77.385 112.860 9.525
< 130    c/z 56.280 100.675 6.985
< 131    c/z 56.280 100.675 9.525
< 132    c/z 70.350 100.675 6.985
< 133    c/z 70.350 100.675 9.525
< 134    c/z 63.315 112.860 12.185
< 135    px  70.350
< 136    px  56.280
< 137    py  125.045
< 138    c/z 63.315 59.131 9.1091
< 139    c/z 63.315 59.131 11.6491
< 420    c/z 123.890 125.045 6.985
< 421    c/z 123.890 125.045 9.525
< 422    c/z 137.960 125.045 6.985
< 423    c/z 137.960 125.045 9.525
< 424    c/z 116.855 112.860 6.985
< 425    c/z 116.855 112.860 9.525
< 426    c/z 130.925 112.860 6.985
< 427    c/z 130.925 112.860 9.525
< 428    c/z 144.995 112.860 6.985
< 429    c/z 144.995 112.860 9.525
< 430    c/z 123.890 100.675 6.985
< 431    c/z 123.890 100.675 9.525
< 432    c/z 137.960 100.675 6.985
< 433    c/z 137.960 100.675 9.525
< 434    c/z 130.925 112.860 12.185
< 435    px  137.960
< 436    px  123.890
< 437    py  125.045
246,247d181
< m2     1001.5  2  8016.5 1                                          $water
< mt2    lwtr.01
251c185
<       14000.50 -0.11200                                           $pu + sio2 +water
---
>       14000.50 -0.11200                                           $pu + carbon +water
255c189
< m7    94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
266,272c200,206
< ksrc   56 125 10
<        70 125 10
<        49 112 10
<        63 112 10
<        77 112 10
<        56 100 10
<        70 100 10
---
> ksrc   70. 43. 10
>        84. 43. 10
>        98. 43. 10
>        77. 55. 10
>        91. 55. 10
>        70. 31. 10
>        84. 31. 10
275c209,215
<        63. 59. 10
---
>        126. 68. 10
>        140. 68. 10
>        119. 80. 10
>        133. 80. 10
>        147. 80. 10
>        126. 92. 10
>        140. 92. 10
277,283d216
<        123 125 10
```

```
<       137 125 10
<       116 112 10
<       130 112 10
<       144 112 10
<       123 100 10
<       137 100 10

*************************************************************************************
diff c0001f2f3.i c0001f2b4.i >diff2f3b4
1,5c1,3
< glovebox ha20mb cementation model - flooding case 2100 g pu - c0001f2f3
< c     base case 1800g + +300g holdup +200g outside
< c     glovebox - full water reflection on all sides
< c
< c     2100 g pu in 2" slab on floor mixed with water, 10% water spray
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
> c     glovebox - full water reflection on all sides, cement can refl
6a5,17
> c     bowls -  two bowls in corner 10" from cans
> c             0.04167 g pu/cc pu
> c             0.200 kg pu/bowl
> c             h/x=634
> c             sides, bottom of bowls not included
> c     containers - 7 2.76 L cans 90% water 10% sio2
> c                  0.02585 g pu/cc
> c                  h/x=921
> c                  500 g pu total
> c                      7 2.76 L cans pu+water+carbon+sio2
> c                      0.04652 g/cc pu
> c                      h/x=20
> c                      900g pu total
11c22
<   1   1  -0.1    1 -2 3 -4 71 -6                              imp:n=1
---
>   1   0          1 -2 3 -4 20 -6                              imp:n=1
25c36,47
<   8   20 -1.006856  1 -2 3 -4  70 -71                         imp:n=1
---
> c     bowl
>   8   3  -1.0431  ((63 -28):(-63 -61 69)) -32                 imp:n=1
> c     bowl water reflection
>   9   1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                  (-69 70 -62)) -2 1  103                      imp:n=1
>  10   0          -33 -63 70 62 -2 1  103                      imp:n=1
> c     bowl
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                 imp:n=1
> c     bowl water reflection
>  12   1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                      imp:n=1
>  13   0          -35 -63 70 60 -2 1 -103                      imp:n=1
27,28c49,50
<  22   5  -1.0749 70 -28 -53                                   imp:n=1
<  23   0          70 -28 53 64 -65 41 66 -1                    imp:n=1
---
>  22   5  -1.0749   70 -28 -53                                 imp:n=1
>  23   0          70 -28 53 64 -65 41 66 -1                    imp:n=1
30c52,81
<  24   20 -1.006856 5 -70 1 -4 -2 3                            imp:n=1
---
>  24   8  -5.562 5 -70 1 -4 -2 3                               imp:n=1
> c     filled cans
>  25   0  1 3 -433 -444 70 -20 33 35
>           fill=1 (7.035 7.035 0)                              imp:n=1
>  26   0     -331 334 -330 333 -329 332  u=1 lat=2
>       fill= -5:14 -1:10 0:0
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>       4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
```

```
>        4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                     imp:n=1
> 201    4  -1.167   -201 -28 u=2                                     imp:n=1
> 202    1  -1.0      28      u=2                                     imp:n=1
> 203    0            201 -28 u=2                                     imp:n=1
> 204    10 -2.911   -201 -28 u=3                                     imp:n=1
> 205    1  -1.0      28      u=3                                     imp:n=1
> 206    0            201 -28 u=3                                     imp:n=1
> 207    0            777    u=4                                     imp:n=1
> 208    11 -2.1739 -201 -28 u=5                                      imp:n=1
> 209    1  -1.0      28      u=5                                     imp:n=1
> 210    0            201 -28 u=5                                     imp:n=1
>  28    0            1 -2 3 -4 (433:444) 70 -20 33 35                imp:n=1
119a171,172
> 433    px  196.980
> 444    py  124.613
126,163d178
< 120    c/z 56.280 125.045 6.985
< 121    c/z 56.280 125.045 9.525
< 122    c/z 70.350 125.045 6.985
< 123    c/z 70.350 125.045 9.525
< 124    c/z 49.245 112.860 6.985
< 125    c/z 49.245 112.860 9.525
< 126    c/z 63.315 112.860 6.985
< 127    c/z 63.315 112.860 9.525
< 128    c/z 77.385 112.860 6.985
< 129    c/z 77.385 112.860 9.525
< 130    c/z 56.280 100.675 6.985
< 131    c/z 56.280 100.675 9.525
< 132    c/z 70.350 100.675 6.985
< 133    c/z 70.350 100.675 9.525
< 134    c/z 63.315 112.860 12.185
< 135    px  70.350
< 136    px  56.280
< 137    py  125.045
< 138    c/z 63.315 59.131 9.1091
< 139    c/z 63.315 59.131 11.6491
< 420    c/z 123.890 125.045 6.985
< 421    c/z 123.890 125.045 9.525
< 422    c/z 137.960 125.045 6.985
< 423    c/z 137.960 125.045 9.525
< 424    c/z 116.855 112.860 6.985
< 425    c/z 116.855 112.860 9.525
< 426    c/z 130.925 112.860 6.985
< 427    c/z 130.925 112.860 9.525
< 428    c/z 144.995 112.860 6.985
< 429    c/z 144.995 112.860 9.525
< 430    c/z 123.890 100.675 6.985
< 431    c/z 123.890 100.675 9.525
< 432    c/z 137.960 100.675 6.985
< 433    c/z 137.960 100.675 9.525
< 434    c/z 130.925 112.860 12.185
< 435    px  137.960
< 436    px  123.890
< 437    py  125.045
169,170c184,185
< m4    94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
<        6012.50 -0.17100                                      $pu + carbon +water
---
> m4    94239.55 -0.02585 8016.50 -0.92848 1001.50 -0.10042
>       14000.50 -0.11200                                      $pu + carbon +water
174c189
< m7    94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
184,185d198
< m20    94239.55 -0.006625 8016.50 -0.888404 1001.50 -0.111827  $pu + water
< mt20   lwtr.01
187c200,215
< ksrc   56 125 2
---
> ksrc   70. 43. 10
```

```
>       84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       70. 31. 10
>       84. 31. 10
>       10. 122. 10
>       10. 101. 10
>       126. 68. 10
>       140. 68. 10
>       119. 80. 10
>       133. 80. 10
>       147. 80. 10
>       126. 92. 10
>       140. 92. 10

*******************************************************************************************
diff c0001f2f4.i c0001f2b4.i >diff2f4b4
1,6c1,3
< glovebox ha20mb cementation model - flooding case 2100 g pu - c0001f2f4
< c      base case 1800g + +300g holdup +200g outside
< c      glovebox - full water reflection on all sides
< c
< c      2100 g pu in 2" slab on floor mixed with water, 10% water spray
< c      150 g/cc pu with water above
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c      base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
> c      glovebox - full water reflection on all sides, cement can refl
7a5,17
> c      bowls -  two bowls in corner 10" from cans
> c              0.04167 g pu/cc pu
> c              0.200 kg pu/bowl
> c              h/x=634
> c              sides, bottom of bowls not included
> c      containers - 7 2.76 L cans 90% water 10% sio2
> c                  0.02585 g pu/cc
> c                  h/x=921
> c                  500 g pu total
> c                      7 2.76 L cans pu+water+carbon+sio2
> c                      0.04652 g/cc pu
> c                      h/x=20
> c                      900g pu total
12c22
<   1   1  -0.1    1 -2 3 -4 71 -6                                    imp:n=1
---
>   1   0          1 -2 3 -4 20 -6                                    imp:n=1
26,27c36,47
<   8   20 -1.155242  1 -2 3 -4  70 -72                               imp:n=1
<   9   1  -1.0       1 -2 3 -4  72 -71                               imp:n=1
---
> c      bowl
>   8   3  -1.0431  ((63 -28):(-63 -61 69)) -32                       imp:n=1
> c      bowl water reflection
>   9   1  -1.0    ((63 -33 -20 (32:28)):(-63 61 -62 69):
>                  (-69 70 -62)) -2 1  103                            imp:n=1
>  10   0          -33 -63 70 62 -2 1  103                            imp:n=1
> c      bowl
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                       imp:n=1
> c      bowl water reflection
>  12   1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                            imp:n=1
>  13   0          -35 -63 70 60 -2 1 -103                            imp:n=1
29,30c49,50
<  22   5  -1.0749 70 -28 -53                                         imp:n=1
<  23   0          70 -28 53 64 -65 41 66 -1                          imp:n=1
---
>  22   5  -1.0749   70 -28 -53                                       imp:n=1
>  23   0           70 -28 53 64 -65 41 66 -1                         imp:n=1
32c52,81
<  24   20 -1.155242 5 -70 1 -4 -2 3                                  imp:n=1
---
>  24   8  -5.562 5 -70 1 -4 -2 3                                     imp:n=1
> c      filled cans
>  25   0  1 3 -433 -444 70 -20 33 35
```

```
>          fill=1 (7.035 7.035 0)                                        imp:n=1
>  26    0     -331 334 -330 333 -329 332  u=1 lat=2
>       fill= -5:14 -1:10 0:0
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>       4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 5 5 3 3 3 4 4 4 4 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
>       4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>       4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                       imp:n=1
> 201   4  -1.167   -201 -28 u=2                                        imp:n=1
> 202   1  -1.0      28      u=2                                        imp:n=1
> 203   0            201 -28 u=2                                        imp:n=1
> 204   10 -2.911   -201 -28 u=3                                        imp:n=1
> 205   1  -1.0      28      u=3                                        imp:n=1
> 206   0            201 -28 u=3                                        imp:n=1
> 207   0            777     u=4                                       imp:n=1
> 208   11 -2.1739 -201 -28 u=5                                         imp:n=1
> 209   1  -1.0      28      u=5                                        imp:n=1
> 210   0            201 -28 u=5                                        imp:n=1
>  28   0            1 -2 3 -4 (433:444) 70 -20 33 35                   imp:n=1
103d151
<  72    pz  0.22436
122a171,172
> 433    px  196.980
> 444    py  124.613
129,166d178
< 120    c/z 56.280 125.045 6.985
< 121    c/z 56.280 125.045 9.525
< 122    c/z 70.350 125.045 6.985
< 123    c/z 70.350 125.045 9.525
< 124    c/z 49.245 112.860 6.985
< 125    c/z 49.245 112.860 9.525
< 126    c/z 63.315 112.860 6.985
< 127    c/z 63.315 112.860 9.525
< 128    c/z 77.385 112.860 6.985
< 129    c/z 77.385 112.860 9.525
< 130    c/z 56.280 100.675 6.985
< 131    c/z 56.280 100.675 9.525
< 132    c/z 70.350 100.675 6.985
< 133    c/z 70.350 100.675 9.525
< 134    c/z 63.315 112.860 12.185
< 135    px  70.350
< 136    px  56.280
< 137    py  125.045
< 138    c/z 63.315 59.131 9.1091
< 139    c/z 63.315 59.131 11.6491
< 420    c/z 123.890 125.045 6.985
< 421    c/z 123.890 125.045 9.525
< 422    c/z 137.960 125.045 6.985
< 423    c/z 137.960 125.045 9.525
< 424    c/z 116.855 112.860 6.985
< 425    c/z 116.855 112.860 9.525
< 426    c/z 130.925 112.860 6.985
< 427    c/z 130.925 112.860 9.525
< 428    c/z 144.995 112.860 6.985
< 429    c/z 144.995 112.860 9.525
< 430    c/z 123.890 100.675 6.985
< 431    c/z 123.890 100.675 9.525
< 432    c/z 137.960 100.675 6.985
< 433    c/z 137.960 100.675 9.525
< 434    c/z 130.925 112.860 12.185
< 435    px  137.960
< 436    px  123.890
< 437    py  125.045
172,173c184,185
< m4   94239.55 -0.02585 8016.50 -0.80048 1001.50 -0.10042
<        6012.50 -0.17100                                 $pu + carbon +water
---
```

```
> m4    94239.55 -0.02585 8016.50 -0.92848 1001.50 -0.10042
>       14000.50 -0.11200                                  $pu + carbon +water
177c189
< m7    94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096    $pu + water
---
> m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028    $pu + water
187,188d198
< m20   94239.55 -0.1500 8016.50 -0.895002 1001.50 -0.11024  $pu + water
< mt20   lwtr.01
190c200,215
< ksrc  56 125 0.1
---
> ksrc  70. 43. 10
>       84. 43. 10
>       98. 43. 10
>       77. 55. 10
>       91. 55. 10
>       70. 31. 10
>       84. 31. 10
>       10. 122. 10
>       10. 101. 10
>       126. 68. 10
>       140. 68. 10
>       119. 80. 10
>       133. 80. 10
>       147. 80. 10
>       126. 92. 10
>       140. 92. 10

****************************************************************************************
diff c0001f2f5a.i c0001f2f1.i >diff2f5af1
1,2c1,2
< glovebox ha20mb cementation model - fire case 2100 g pu - c0001f2f5a
< c     base case 900g + 300g holdup + 200g outside +700g h/x=20 +200g h/x=364
---
> glovebox ha20mb cementation model - fire case 2100 g pu - c0001f2f1
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside +900g h/x=20
8c8
< c             h/x =625
---
> c             h/x
14,15c14,15
< c                      6 2.76 L cans pu+water+carbon+sio2
< c                      0.04222 g/cc pu
---
> c                      7 2.76 L cans pu+water+carbon+sio2
> c                      0.04652 g/cc pu
17,21c17
< c                      700g pu total
< c                        1 2.76 L cans pu+water
< c                        0.07237 g/cc pu
< c                        h/x=364
< c                        200g pu total
---
> c                      900g pu total
68c64
<       4 4 4 4 4 3 3 3 3 3 5 6 5 3 3 3 4 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
84c80
< 211   11 -2.1738 -201 -28 u=5                               imp:n=1
---
> 211   11 -2.1739 -201 -28 u=5                               imp:n=1
88,91d83
< 215   12 -1.075  -201 -28 u=6                               imp:n=1
< 216   1  -0.1    -201 28  u=6                               imp:n=1
< 217   1  -0.1     201 71  u=6                               imp:n=1
< 218   1  -1.0     201 -71 u=6                               imp:n=1
208,209c200,201
< m11  94239.55 -0.04222 8016.50 -0.78108 1001.50 -0.00356
<       6012.50 -0.69105 14000.50 -0.65587                 $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>       6012.50 -0.68842 14000.50 -0.65338                 $pu +c+sio2+ water
211,212d202
```

```
< m12  94239.55 -0.07237 8016.50 -0.89143 1001.50 -0.11110   $pu + water
< mt12  lwtr.01

*********************************************************************************
diff c0001f2s1.i c0001f2b4.i >diff2s1b4
1c1
< glovebox ha20mb cementation model - stacked bowl 2100 g pu - c0001f2s1
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
5,6c5
< c     bowls -  one bowl in corner 10" from cans
< c              one bowl stacked on cans
---
> c     bowls -  two bowls in corner 10" from cans
23c22
<   1   0         1 -2 3 -4 20 -6  #14 #15                    imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                             imp:n=1
41,42c40,41
<                (-69 70 -62)) -2 1                           imp:n=1
<  10   0        -33 -63 70 62 -2 1                           imp:n=1
---
>                (-69 70 -62)) -2 1  103                      imp:n=1
>  10   0        -33 -63 70 62 -2 1  103                      imp:n=1
44,47c43,47
< c     container stacked
<  14   3  -1.0431 -110 28 -29 ((59 -29):(-59 -111)) -110     imp:n=1
< c     container water reflection
<  15   1  -1.0   20 -30 ((59 -109 (110:29)):(-59 111 -112))   imp:n=1
---
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34               imp:n=1
> c     bowl water reflection
>  12   1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                (-69 70 -60)) -2 1 -103                      imp:n=1
>  13   0        -35 -63 70 60 -2 1 -103                      imp:n=1
54c54
<  25   0  1 3 -433 -444 70 -20 33 (111:-28)
---
>  25   0  1 3 -433 -444 70 -20 33 35
81c81
<  28   0           1 -2 3 -4 (433:444) 70 -20 33             imp:n=1
---
>  28   0           1 -2 3 -4 (433:444) 70 -20 33 35          imp:n=1
160,163c160,163
< 109   c/z 84.42 43.59 12.70
< 110   c/z 84.42 43.59 10.16
< 111   s   84.42 43.59 27.68 10.16
< 112   s   84.42 43.59 27.68 12.70
---
> 109   c/z 17.465 13.0353 12.70
> 110   c/z 17.465 13.0353 10.16
> 111   s   17.465 13.0353 27.68 10.16
> 112   s   17.465 13.0353 27.68 12.70
208c208
<       84. 43. 30
---
>       10. 101. 10

*********************************************************************************
diff c0001f2s2.i c0001f2b4.i >diff2s2b4
1c1
< glovebox ha20mb cementation model - stacked bowl 2100 g pu - c0001f2s2
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
5,6c5
< c     bowls -  one bowls in corner 10" from cans
< c              one bowl stacked on other bowl
---
> c     bowls -  two bowls in corner 10" from cans
23c22
<   1   0         1 -2 3 -4 20 -6 #14 #15                     imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                             imp:n=1
41,46c40,47
<                (-69 70 -62)) -2 1 111                       imp:n=1
```

```
<  10   0          -33 -63 70 62 -2 1                             imp:n=1
< c     container stacked
<  14   3  -1.0431 -110 28 -29 ((59 -29):(-59 -111)) -110         imp:n=1
< c     container water reflection
<  15   1  -1.0    20 -30 ((59 -109 (110:29)):(-59 111 -112)) 1 -2 imp:n=1
---
>                  (-69 70 -62)) -2 1  103                        imp:n=1
>  10   0          -33 -63 70 62 -2 1  103                        imp:n=1
> c     bowl
>  11   3  -1.0431  ((63 -28):(-63 -58 69)) -34                   imp:n=1
> c     bowl water reflection
>  12   1  -1.0    ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                        imp:n=1
>  13   0          -35 -63 70 60 -2 1 -103                        imp:n=1
53c54
<  25   0  1 3 -433 -444 70 -20 33 (111:-28)
---
>  25   0  1 3 -433 -444 70 -20 33 35
80c81
<  28   0           1 -2 3 -4 (433:444) 70 -20 33                 imp:n=1
---
>  28   0           1 -2 3 -4 (433:444) 70 -20 33 35              imp:n=1
159,162c160,163
< 109   c/z 10.21 121.87 12.70
< 110   c/z 10.21 121.87 10.16
< 111   s   10.21 121.87 27.68 10.16
< 112   s   10.21 121.87 27.68 12.70
---
> 109   c/z 17.465 13.0353 12.70
> 110   c/z 17.465 13.0353 10.16
> 111   s   17.465 13.0353 27.68 10.16
> 112   s   17.465 13.0353 27.68 12.70
207c208
<       10. 122. 30
---
>       10. 101. 10

***************************************************************************************
diff c0001f2s3.i c0001f2b4.i >diff2s3b4
1,2c1,2
< glovebox ha20mb cementation model - stacked can 2100 g pu - c0001f2s3
< c     base case 900g + 200g can + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
18,19d17
< c                       1 2.76 L can 90% water 10% sio2 stacked
< c                       200 g pu total
24c22
<   1   0          1 -2 3 -4 20 -6  #14 #15                       imp:n=1
---
>   1   0          1 -2 3 -4 20 -6                                imp:n=1
42,43c40,41
<                  (-69 70 -62)) -2 1 103                         imp:n=1
<  10   0          -33 -63 70 62 -2 1 103                         imp:n=1
---
>                  (-69 70 -62)) -2 1  103                        imp:n=1
>  10   0          -33 -63 70 62 -2 1  103                        imp:n=1
50,53d47
< c     container stacked
<  14    12  -1.215  -113 28 -29                                  imp:n=1
< c     container water reflection
<  15   1  -1.0    20 -30 -114 (113:29)                           imp:n=1
60c54
<  25   0  1 3 -433 -444 70 -20 33 35 (113:-28)
---
>  25   0  1 3 -433 -444 70 -20 33 35
166,169c160,163
< 109   c/z 84.42 43.59 12.70
< 110   c/z 84.42 43.59 10.16
< 111   s   84.42 43.59 27.68 10.16
< 112   s   84.42 43.59 27.68 12.70
---
> 109   c/z 17.465 13.0353 12.70
> 110   c/z 17.465 13.0353 10.16
```

```
> 111    s    17.465 13.0353 27.68 10.16
> 112    s    17.465 13.0353 27.68 12.70
185,186d178
< 113    c/z 84.420 43.590 6.985
< 114    c/z 84.420 43.590 9.525
207,209d198
< m12    94239.55 -0.07237 8016.50 -0.93062 1001.50 -0.09991
<        14000.50 -0.11200                               $pu + sio2 +water
< mt12   lwtr.01
219c208
<        84. 43. 30
---
>        10. 101. 10

*******************************************************************************************
diff c0001f2s4.i c0001f2b4.i >diff2s4b4
1c1
< glovebox ha20mb cementation model - stacked bowl 2100 g pu - c0001f2s4
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
5,6c5
< c      bowls -  one bowl in corner 10" from cans
< c               one bowl stacked on 900 g cans
---
> c      bowls -  two bowls in corner 10" from cans
23c22
<   1    0         1 -2 3 -4 20 -6  #14 #15                     imp:n=1
---
>   1    0         1 -2 3 -4 20 -6                              imp:n=1
41,42c40,41
<                  (-69 70 -62)) -2 1                           imp:n=1
<  10    0         -33 -63 70 62 -2 1                           imp:n=1
---
>                  (-69 70 -62)) -2 1  103                      imp:n=1
>  10    0         -33 -63 70 62 -2 1  103                      imp:n=1
44,47c43,47
< c      container stacked
<  14    3  -1.0431 -110 28 -29 ((59 -29):(-59 -111)) -110      imp:n=1
< c      container water reflection
<  15    1  -1.0   20 -30 ((59 -109 (110:29)):(-59 111 -112))   imp:n=1
---
>  11    3  -1.0431  ((63 -28):(-63 -58 69)) -34                imp:n=1
> c      bowl water reflection
>  12    1  -1.0   ((63 -35 -20 (34:28)):(-63 58 -60 69):
>                  (-69 70 -60)) -2 1 -103                      imp:n=1
>  13    0         -35 -63 70 60 -2 1 -103                      imp:n=1
54c54
<  25    0  1 3 -433 -444 70 -20 33 (111:-28)
---
>  25    0  1 3 -433 -444 70 -20 33 35
81c81
<  28    0           1 -2 3 -4 (433:444) 70 -20 33              imp:n=1
---
>  28    0           1 -2 3 -4 (433:444) 70 -20 33 35           imp:n=1
160,163c160,163
< 109    c/z 133.665 80.145 12.70
< 110    c/z 133.665 80.145 10.16
< 111    s   133.665 80.145 27.68 10.16
< 112    s   133.665 80.145 27.68 12.70
---
> 109    c/z 17.465 13.0353 12.70
> 110    c/z 17.465 13.0353 10.16
> 111    s   17.465 13.0353 27.68 10.16
> 112    s   17.465 13.0353 27.68 12.70
208c208
<        133. 80. 30
---
>        10. 101. 10

*******************************************************************************************
diff c0001f2s5.i c0001f2b4.i >diff2s5b4
1,2c1,2
< glovebox ha20mb cementation model - stacked can 2100 g pu - c0001f2s5
< c      base case 900g + 200g can + 300g holdup + 200g outside +900g h/x=20
---
```

```
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c      base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
18,19d17
< c                       1 2.76 L can 90% water 10% sio2 stacked
< c                       200 g pu total
24c22
<   1   0         1 -2 3 -4 20 -6  #14 #15                        imp:n=1
---
>   1   0         1 -2 3 -4 20 -6                                 imp:n=1
42,43c40,41
<                 (-69 70 -62)) -2 1 103                          imp:n=1
<  10   0         -33 -63 70 62 -2 1 103                          imp:n=1
---
>                 (-69 70 -62)) -2 1  103                         imp:n=1
>  10   0         -33 -63 70 62 -2 1  103                         imp:n=1
50,53d47
< c     container stacked
<  14    12  -1.215  -113 28 -29                                  imp:n=1
< c     container water reflection
<  15   1  -1.0   20 -30 -114 (113:29)                             imp:n=1
60c54
<  25   0  1 3 -433 -444 70 -20 33 35 (113:-28)
---
>  25   0  1 3 -433 -444 70 -20 33 35
166,169c160,163
< 109   c/z 84.42 43.59 12.70
< 110   c/z 84.42 43.59 10.16
< 111   s   84.42 43.59 27.68 10.16
< 112   s   84.42 43.59 27.68 12.70
---
> 109   c/z 17.465 13.0353 12.70
> 110   c/z 17.465 13.0353 10.16
> 111   s   17.465 13.0353 27.68 10.16
> 112   s   17.465 13.0353 27.68 12.70
185,186d178
< 113   c/z 133.665 80.145 6.985
< 114   c/z 133.665 80.145 9.525
207,209d198
< m12   94239.55 -0.07237 8016.50 -0.93062 1001.50 -0.09991
<       14000.50 -0.11200                                   $pu + sio2 +water
< mt12  lwtr.01
219c208
<       133. 80. 30
---
>       10. 101. 10

*************************************************************************************
diff c0001f2w1.i c0001f2b3.i >diff2w1b3
1,3c1,3
< glovebox ha20mb cementation model - wagon case 2100 g pu - c0001f2w1
< c     base case 900g +400 g conveyor +300g holdup +200g outside +900g h/x=20
< c     glovebox - full water reflection on all sides, 1" water refl
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b3
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
> c     glovebox - full water reflection on all sides, cement can refl
14,15c14,15
< c                       7 2.76 L cans pu+water+carbon+sio2
< c                       0.04652 g/cc pu
---
> c                       5 2.76 L cans pu+water+carbon+sio2
> c                       0.06513 g/cc pu
18,21d17
< c     conveyor container - 1 4.7 L can pu + water 10" from cans
< c                   0.08511 g pu/cc
< c                   h/x=309
< c                   400 g pu total
24d19
< c          - 5 position wagon with 5 2.7 L cans 400 g pu + water
34,38c29,32
<   6   1  -1.0  (((-10:11:-12:4:6)(13 -14 15 -16 5 -18)):
<                (-13 -67 -68 17))  #22 #23                       imp:n=1
<  60   1  -1.0  ((13 -14 15 -16 -5 17 #512) (-8:9:-24:25)):
<                ((-23 22 -27 26 21 -17 21) (-8:-7:9:-24:25))
<                (516:-517:-518:519)                              imp:n=1
```

```
---
>   6   1  -1.0   (((((-10:11:-12:4:6)(13 -14 15 -16 5 -18 #23)):
>                 ((13 -14 15 -16 -5 21) (17:(-23 22 -27 26))
>                (-8:-7:9:-24:25))) (53:-70:28))):(-13 -67 -68 17)
>                                                                 imp:n=1
40,42c34,35
<   7   0         14:(-13 (67:68:-17)):-15:16:18:-504             imp:n=0
< 570   0        (-14 15 -17 13 -16 504) (-22:23:27:-26:-21)
<                (520:-521:-522:523)                              imp:n=1
---
>   7   0         14:(-13 (67:68)):-15:16:18:-21:
>                 ((-22:23:27:-26) -17)                           imp:n=0
55,57d47
< c     container on conveyor
<  20   7  -1.088  70 -28 -138                                    imp:n=1
<  21   1  -1.0     70 -20 (138:28) -139                          imp:n=1
59c49
<  22   5  -1.0749 70 -28 -53                                     imp:n=1
---
>  22   5  -1.0749   70 -28 -53                                   imp:n=1
64,112c54,81
< 201   4  -1.167  -120 70 -28                                    imp:n=1
< 202   4  -1.167  -122 70 -28                                    imp:n=1
< 203   4  -1.167  -124 70 -28                                    imp:n=1
< 204   4  -1.167  -126 70 -28                                    imp:n=1
< 205   4  -1.167  -128 70 -28                                    imp:n=1
< 206   4  -1.167  -130 70 -28                                    imp:n=1
< 207   4  -1.167  -132 70 -28                                    imp:n=1
< 208   1  -1.0     ((-121:-123:-125:-129:-131:-133)
<                   (120 122 124 128 130 132 134)) 134 -28 70 -2
<                   (135:-136:-137)                               imp:n=1
< 209   1  -1.0 ((-121:-123:-125:-127:-129:-131:-133) 28 -20 -2) imp:n=1
< 210   0           120 122 124 126 128 130 132 -134 -28 70       imp:n=1
< 211   0           121 123 125 127 129 131 133 -134 28 -20       imp:n=1
< 212   0           -135 136 137 120 122 -2 -28 70                imp:n=1
< c     filled cans
< 401   11 -2.1739 -420 70 -28                                    imp:n=1
< 402   11 -2.1739 -422 70 -28                                    imp:n=1
< 403   11 -2.1739 -424 70 -28                                    imp:n=1
< 404   11 -2.1739 -426 70 -28                                    imp:n=1
< 405   11 -2.1739 -428 70 -28                                    imp:n=1
< 406   11 -2.1739 -430 70 -28                                    imp:n=1
< 407   11 -2.1739 -432 70 -28                                    imp:n=1
< 408   1  -1.0     ((-421:-423:-425:-429:-431:-433)
<                   (420 422 424 428 430 432 434)) 434 -28 70 -2
<                   (435:-436:-437)                               imp:n=1
< 409   1  -1.0 ((-421:-423:-425:-427:-429:-431:-433) 28 -20 -2) imp:n=1
< 410   0           420 422 424 426 428 430 432 -434 -28 70       imp:n=1
< 411   0           421 423 425 427 429 431 433 -434 28 -20       imp:n=1
< 412   0           -435 436 437 420 422 -2 -28 70                imp:n=1
<  28   0    1 -2 3 -4 121 123 125 127 129 131 133 134 70 -20 33 35
<            (-136:135:-137:28) 139 421 423 425 427 429 431 433 434
<            (-436:435:-437:28)                                   imp:n=1
< c     5 position wagon under glovebox
< c
< 501   50 -1.153  -505 503 -502                                  imp:n=1
< 502   1  -1.0    -506 503 -501 (502:505) 518                    imp:n=1
< 503   50 -1.153  -507 503 -502                                  imp:n=1
< 504   1  -1.0    -508 503 -501 (502:507)                        imp:n=1
< 505   50 -1.153  -509 503 -502                                  imp:n=1
< 506   1  -1.0    -510 503 -501 (502:509) -519                   imp:n=1
< 507   50 -1.153  -511 503 -502                                  imp:n=1
< 508   1  -1.0    -512 503 -501 (502:511)                        imp:n=1
< 509   50 -1.153  -513 503 -502                                  imp:n=1
< 510   1  -1.0    -514 503 -501 (502:513)                        imp:n=1
< 511   0           503 -501 -516 517 518 -519
<                   506 508 510 512 514                           imp:n=1
< 512   0           501 -516 517 518 -519 -5                      imp:n=1
< 513   1  -1.0     ((504 -520 521 522 -523)
<                   (-503:516:-517:-518:519)) -17 (27:-21:-22)    imp:n=1
---
>  25   0  1 3 -433 -444 70 -20 33 35
>          fill=1 (7.035 7.035 0)                                 imp:n=1
>  26   0    -331 334 -330 333 -329 332  u=1 lat=2
>       fill= -5:14 -1:10 0:0
```

```
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 4 4 4
>        4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 5 5 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4
>        4 4 4 4 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4
>        4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
>                                                                   imp:n=1
> 201    4   -1.167   -201 -28 u=2                                  imp:n=1
> 202    1   -1.0      28      u=2                                  imp:n=1
> 203    0             201 -28 u=2                                  imp:n=1
> 204    10 -2.911   -201 -28 u=3                                   imp:n=1
> 205    1   -1.0      28      u=3                                  imp:n=1
> 206    0             201 -28 u=3                                  imp:n=1
> 207    0             777     u=4                                 imp:n=1
> 208    11 -2.1746 -201 -28 u=5                                    imp:n=1
> 209    1   -1.0      28      u=5                                  imp:n=1
> 210    0             201 -28 u=5                                  imp:n=1
>  28    0             1 -2 3 -4 (433:444) 70 -20 33 35             imp:n=1
134c103
<  21   pz  -63.224
---
>  21   pz  -66.04
201a171,172
> 433   px  196.980
> 444   py  124.613
208,267d178
< 120   c/z 56.280 125.045 6.985
< 121   c/z 56.280 125.045 9.525
< 122   c/z 70.350 125.045 6.985
< 123   c/z 70.350 125.045 9.525
< 124   c/z 49.245 112.860 6.985
< 125   c/z 49.245 112.860 9.525
< 126   c/z 63.315 112.860 6.985
< 127   c/z 63.315 112.860 9.525
< 128   c/z 77.385 112.860 6.985
< 129   c/z 77.385 112.860 9.525
< 130   c/z 56.280 100.675 6.985
< 131   c/z 56.280 100.675 9.525
< 132   c/z 70.350 100.675 6.985
< 133   c/z 70.350 100.675 9.525
< 134   c/z 63.315 112.860 12.185
< 135   px  70.350
< 136   px  56.280
< 137   py  125.045
< 138   c/z 63.315 59.131 9.1091
< 139   c/z 63.315 59.131 11.6491
< 420   c/z 123.890 125.045 6.985
< 421   c/z 123.890 125.045 9.525
< 422   c/z 137.960 125.045 6.985
< 423   c/z 137.960 125.045 9.525
< 424   c/z 116.855 112.860 6.985
< 425   c/z 116.855 112.860 9.525
< 426   c/z 130.925 112.860 6.985
< 427   c/z 130.925 112.860 9.525
< 428   c/z 144.995 112.860 6.985
< 429   c/z 144.995 112.860 9.525
< 430   c/z 123.890 100.675 6.985
< 431   c/z 123.890 100.675 9.525
< 432   c/z 137.960 100.675 6.985
< 433   c/z 137.960 100.675 9.525
< 434   c/z 130.925 112.860 12.185
< 435   px  137.960
< 436   px  123.890
< 437   py  125.045
< 501   pz  -39.37
< 502   pz  -41.91
< 503   pz  -63.224
< 504   pz  -93.704
< 505   c/z 39.157 120.538 6.350
```

```
< 506    c/z 39.157 120.538 8.890
< 507    c/z 63.315 120.538 6.350
< 508    c/z 63.315 120.538 8.890
< 509    c/z 87.473 120.538 6.350
< 510    c/z 87.473 120.538 8.890
< 511    c/z 51.236 105.183 6.350
< 512    c/z 51.236 105.183 8.890
< 513    c/z 75.394 105.183 6.350
< 514    c/z 75.394 105.183 8.890
< 516    py  131.81
< 517    py  93.91
< 518    px  30.628
< 519    px  96.002
< 520    py  162.29
< 521    py  63.43
< 522    px  0.148
< 523    px  126.482
274c185
<        14000.50 -0.11200                                 $pu + sio2 +water
---
>       14000.50 -0.11200                                 $pu + carbon +water
278c189
< m7    94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7    94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
285,286c196,197
< m11   94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
<        6012.50 -0.68842 14000.50 -0.65338                  $pu +c+sio2+ water
---
> m11   94239.55 -0.06513 8016.50 -0.78435 1001.50 -0.00549
>        6012.50 -0.67704 14000.50 -0.64258                  $pu +c+sio2+ water
288,289d198
< m50    94239.55 -0.14815 8016.50 -0.89492 1001.50 -0.11026   $pu + water
< mt50   lwtr.01
291,297c200,206
< ksrc   56 125 10
<        70 125 10
<        49 112 10
<        63 112 10
<        77 112 10
<        56 100 10
<        70 100 10
---
> ksrc   70. 43. 10
>        84. 43. 10
>        98. 43. 10
>        77. 55. 10
>        91. 55. 10
>        70. 31. 10
>        84. 31. 10
300c209,213
<        63. 59. 10
---
>        126. 68. 10
>        140. 68. 10
>        119. 80. 10
>        133. 80. 10
>        147. 80. 10
302,313d214
<        123 125 10
<        137 125 10
<        116 112 10
<        130 112 10
<        144 112 10
<        123 100 10
<        137 100 10
<        39 120 -50
<        63 120 -50
<        87 120 -50
<        51 105 -50
<        75 105 -50

******************************************************************************************
diff c0001f2b4h.i c0001f2b4.i >diff2b4hb4
1c1
```

```
< glovebox ha20mb cementation model - spacing case 2100 g pu - c0001f2b4h
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
18c18
< c     room - 1 2.76 L can 0" spacing from glovebox wall
---
> c     room - 1 2.76 L can 6" spacing from glovebox wall
26c26
<   4   1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #22 #23         imp:n=1
---
>   4   1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #23             imp:n=1
133c133
<  53   c/z -7.035 121.87 6.985
---
>  53   c/z -23.495 121.87 6.985
147c147
<  67   c/z -7.035 121.87 37.465
---
>  67   c/z -23.495 121.87 37.465
216c216
<       -7. 121. 10
---
>       -23. 121. 10

***************************************************************************************
diff c0001f2b9.i c0001f2b4.i >diff2b9b4
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b9
< c     base case 900g + 400g conveyor + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
20,23d19
< c     conveyor container - 1 4.7 L can pu + water next to cans
< c                 0.08511 g pu/cc
< c                 h/x=309
< c                 400 g pu total
52,55d47
< c     container on conveyor
<  19   7  -1.088   70 -28 -138                                     imp:n=1
<  20   1  -1.0     70 -20 138 -139 (-142)                          imp:n=1
<  21   1  -1.0     28 -20 -138                                     imp:n=1
62c54
<  25   0  1 3 -433 -444 70 -20 33 35 #19 #20 #21
---
>  25   0  1 3 -433 -444 70 -20 33 35
67,71c59,63
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 3 2 2 4 4 4 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 2 2 2 4 4 4 4 4 4 4 4 4
<       4 4 4 3 3 3 3 3 2 2 3 4 4 4 3 3 3 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
>       4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4 4
187,189d178
< 138   c/z 107.57 30.26 9.1091
< 139   c/z 107.57 30.26 11.6491
< 142   c/z 126.63 19.22 30.25
200c189
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
228d216
<       107. 30. 10

***************************************************************************************
diff c0001f2b7.i c0001f2b4.i >diff2b7b4
1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b7
< c     base case 900g +0g con +300g holdup +200g out +700g h/x=20 +200g h/x=200
---
```

```
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
14,15c14,15
< c                     6 2.76 L cans pu+water+carbon+sio2
< c                     0.04222 g/cc pu
---
> c                     7 2.76 L cans pu+water+carbon+sio2
> c                     0.04652 g/cc pu
17,21c17
< c                     700g pu total
< c                       1 2.76 L cans pu+water+carbon+sio2
< c                       0.07326 g/cc pu
< c                       h/x=200
< c                       200g pu total
---
> c                     900g pu total
69c65
<       4 4 4 4 4 3 3 3 3 3 5 6 5 3 3 3 4 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 5 5 5 3 3 3 4 4 4 4
82c78
< 208   11 -2.1738 -201 -28 u=5                                 imp:n=1
---
> 208   11 -2.1739 -201 -28 u=5                                 imp:n=1
85,87d80
< 211   12 -1.59223 -201 -28 u=6                                imp:n=1
< 212   1  -1.0     28      u=6                                 imp:n=1
< 213   0           201 -28 u=6                                 imp:n=1
203,204c196,197
< m11  94239.55 -0.04222 8016.50 -0.78108 1001.50 -0.00356
<       6012.50 -0.69105 14000.50 -0.65587               $pu +c+sio2+ water
---
> m11  94239.55 -0.04652 8016.50 -0.78170 1001.50 -0.00392
>       6012.50 -0.68842 14000.50 -0.65338               $pu +c+sio2+ water
206,208d198
< m12  94239.55 -0.07326 8016.50 -0.84168 1001.50 -0.06180
<       6012.50 -0.31578 14000.50 -0.29971               $pu +c+sio2+ water
< mt12  lwtr.01
```

```
*************************************************************************************
diff c0001f2b11a.i c0001f2b4.i >diff2b11ab4

1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b11a
< c     base case 900g + 2000g conveyor + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
20,23d19
< c     conveyor container - 1 2.2 L boat pu + water next to cans
< c                  0.9090 g pu/cc
< c                  h/x=28
< c                  2000 g pu total
52,55d47
< c     container on conveyor
<  19    13 -1.86271   605 -606 601 -602 603 -604                imp:n=1
<  20    1  -1.0        612 -611 607 -602 609 -610
<                      (-605:606:-601:602:-603:604)              imp:n=1
62c54
<  25    0  1 3 -433 -444 70 -20 33 35 #19 #20
---
>  25    0  1 3 -433 -444 70 -20 33 35
67,70c59,62
<       4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4
<       4 4 4 4 4 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 3 2 2 4 4 4 4 4 4 4 4 4
<       4 4 4 4 3 3 3 3 2 2 2 4 4 3 3 3 3 4 4 4
---
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>       4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>       4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
187,198d178
< 601 1  py  -6.35
< 602 1  py   6.35
< 603 1  px  -13.97
< 604 1  px   13.97
< 605 1  pz   5.915
< 606 1  pz   12.115
< 607 1  py  -8.89
< 608 1  py   8.89
< 609 1  px  -16.51
< 610 1  px   16.51
< 611 1  pz   14.655
< 612 1  pz   3.375
209c189
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
219,220d198
< m13  94239.55 -0.909091 8016.50 -0.84691 1001.50 -0.10671   $pu + water
< mt13  lwtr.01
239d216
<       106. 30. 3
243c220
< *tr1   106.56426 30.8050 0    60 330 90    150 60 90
---
>

*************************************************************************************
diff c0001f2b13.i c0001f2b4.i >diff2b13b4

1,2c1,2
< glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b13
< c     base case 900g + 2000g conveyor + 300g holdup + 200g outside +900g h/x=20
---
> glovebox ha20mb cementation model - base case 2100 g pu - c0001f2b4
> c     base case 900g + 0 g conveyor + 300g holdup + 200g outside +900g h/x=20
20,23d19
< c     conveyor container - 1 2.2 L boat pu metal button + water next to cans
< c                  19.6 g pu/cc
< c                  h/x=0
< c                  2000 g pu total
52,56d47
```

```
< c     container on conveyor
<  18   14 -19.6       620 -621 622 -602 605 -606                     imp:n=1
<  19   1  -1.0        605 -606 601 -602 603 -604 (621:-620:-622) imp:n=1
<  20   1  -1.0        612 -611 607 -602 609 -610
<                     (-605:606:-601:602:-603:604)                    imp:n=1
63c54
<  25    0  1 3 -433 -444 70 -20 33 35 #18 #19 #20
---
>  25    0  1 3 -433 -444 70 -20 33 35
68,71c59,62
<        4 4 4 4 4 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4
<        4 4 4 4 4 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4
<        4 4 4 4 3 3 3 3 3 2 2 4 4 4 4 4 4 4 4 4
<        4 4 4 4 3 3 3 3 2 2 2 4 4 3 3 3 3 4 4 4
---
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4
>        4 4 4 4 4 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 3 2 2 3 3 3 3 3 3 3 4 4
>        4 4 4 4 3 3 3 3 2 2 2 3 3 3 3 3 3 4 4 4
188,202d178
< 601 1  py   -6.35
< 602 1  py    6.35
< 603 1  px   -13.97
< 604 1  px    13.97
< 605 1  pz    5.915
< 606 1  pz    12.115
< 607 1  py   -8.89
< 608 1  py    8.89
< 609 1  px   -16.51
< 610 1  px    16.51
< 611 1  pz    14.655
< 612 1  pz    3.375
< 620 1  px   -9.0635
< 621 1  px   -5.0065
< 622 1  py    2.293
213c189
< m7   94239.55 -0.08511 8016.50 -0.89202 1001.50 -0.11096   $pu + water
---
> m7   94239.55 -0.14679 8016.50 -0.89485 1001.50 -0.11028   $pu + water
223,225d198
< m13  94239.55 -0.454545 8016.50 -0.86750 1001.50 -0.10931   $pu + water
< mt13  lwtr.01
< m14  94239.55 -19.6                                         $pu metal
244d216
<       98. 27. 3
248c220
< *tr1   106.56426 30.8050 0    60 330 90    150 60 90
---
>

**************************************************************************************
diff c0001f1s8.i c0001f1s4.i >diff2s8s4

1,2c1,2
< glovebox ha20mb cementation model - base case 1200 g pu - c0001f1s8
< c     base case 900g + 0 g conveyor + 300g holdup + 200g outside
---
> glovebox ha20mb cementation model - base case 1200 g pu - c0001f1s4
> c     base case 900g + 0 g conveyor + 300g holdup + 0g outside
15,16d14
< c     room - 1 2.76 L can no spacing from glovebox wall
< c            0.200 kg pu + water
23c21
<    4    1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #22 #23          imp:n=1
---
>    4    1  -1.0    (-1:2:-3) (10 -11 12 -4 5 -19) #23              imp:n=1
28c26
<                  (-8:-7:9:-24:25))) (53:-70:28))):(-15 -67 -68 17)
---
>                  (-8:-7:9:-24:25))) (53:-70:28))):(-13 -67 -68 17)
31c29
<    7   0          14:(-15 (67:68)):-13:16:18:-21:
---
>    7   0          14:(-13 (67:68)):-15:16:18:-21:
45,46c43,44
```

```
<  22    5  -1.0749    70 -28 -53                                          imp:n=1
<  23    0            70 -28 53 64 -65 66 -3                               imp:n=1
---
>  22    1  -1.0    70 -28 -53                                             imp:n=1
>  23    1  -1.0    70 -28 53 64 -65 41 66 -1                              imp:n=1
126c124
<  53    c/z 14.070 -7.035 6.985
---
>  53    c/z -23.495 121.87 6.985
137,140c135,138
<  64    px  7.035
<  65    px  21.105
<  66    py  -7.035
<  67    c/z 14.070 -23.495 37.465
---
>  64    py  114.885
>  65    py  128.855
>  66    px  -23.495
>  67    c/z -23.495 121.87 37.465
192c190
< kcode 5000 1.0 10 400
---
> kcode 5000 1.0 10 200
202d199
<        14. -7. 10
```

APPENDIX D

PRELIMINARY HAZARDS ANALYSIS

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D1.0 HA-20MB CEMENTATION GLOVEBOX CRITICALITY PRELIMINARY AZARDS ANALYSIS

D1.1 PURPOSE

The purpose of this Preliminary Hazard Analysis (PHA) is to identify the important process parameters and conditions that could impact the potential for the occurrence of a criticality in the PFP HA-20MB Glovebox. The results of this PHA will be used for input into the HA-20MB Glovebox Criticality Safety Evaluation Report (CSER).

D 2.0 HAZARDS EVALUATION

A PHA is a hazards identification/evaluation technique derived from the U.S. Military Standard System Safety Program Requirements (MIL-STD-882). A PHA is a structured discovery process involving a multi-disciplinary team and focuses on the hazardous materials and major process areas of a facility. The results of the PHA are recorded using a tabular format. Because of its military heritage, the PHA technique is useful for reviewing process areas where energy can be released in an uncontrolled manner. In general, the PHA formulates a list of hazards and hazardous situations by considering the following process characteristics:

- Raw materials, intermediate and final products, and their reactivity
- Plant equipment
- Facility layout
- Operating environment
- Operational activities (testing, maintenance, etc.)
- Interfaces among system components.

The American Institute of Chemical Engineers (AIChE) recognizes the PHA process as a creditable method of hazard evaluation. AIChE describes this process in their publication titled "Guidelines for Hazard Evaluation Procedures" (AIChE 1992).

The depth of a PHA is directly related to the experience and knowledge of the participants. A short resume of each team member is included (Section 3.0) to document the experience and knowledge of the PHA team.

D2.1 PHA EVALUATION STRUCTURE

The hazardous condition of concern for this PHA is a nuclear criticality. Criticality events are prevented by establishing limits for specific parameters. These parameters are referred to as controlled parameters. This PHA was structured to address the following controlled parameters:

- Mass
- Volume
- Geometry
- Moderation
- Reflection
- Interaction
- Enrichment
- Density
- Concentration
- Poisons

The process occurring in the HA-20MB Glovebox involves stabilization of Pu bearing materials in a Portland cement matrix. The PHA considered the controlled parameters in the context of the process steps that occur in the glovebox during the Pu cementation operation.

D2.2 PHA TABLE DESCRIPTION

The PHA table (Table A-1) was structured to ensure a systematic and thorough evaluation of the controlled parameters. The PHA table captured the following information:

ID: Item Identification; used to record a unique identifier for the hazardous condition

Process Condition: The process condition for which deviations of controlled parameters are being evaluated for the potential to cause a criticality in the HA-20MB Glovebox.

Controlled Parameter: Parameters that are controlled to prevent the occurrence of criticality events. Ten parameters are used: **mass, volume, moderation, interaction, reflection, geometry, enrichment, density, concentration, and poisons.**

General Cause: The general cause leading to the hazardous condition. In many cases, multiple hardware or operational faults are required to produce the hazardous condition. This column, in conjunction with the following column, identifies the sequence of hardware or operational faults postulated to produce the hazardous condition.

Detailed Causes: Specific causes within the general group of causes identified in the preceding column that can lead to the hazardous condition. This column is used to capture details that may be important in the analysis that will define the controls to prevent a criticality.

Existing Eng Safety: Hardware items identified by the PHA team that have the potential to mitigate or prevent the hazardous condition of concern

Existing Admin Safety: Administrative controls such as facility worker training and safety procedures identified by the PHA team that have the potential to mitigate or prevent the hazardous condition

Freq Cat NC: Frequency Category, No controls – The frequency ranking is a qualitative estimate of whether the hazardous condition is considered credible or not. Conditions considered not credible will not be evaluated further.

Remarks: Miscellaneous observations or clarifying comments for a given item. This column is also used to capture criticality analysis requirement decisions of the PHA team.

D2.3 PHA RESULTS

The results of this PHA are in the form of information to be considered as part of the Criticality Safety Evaluation Report (CSER). The raw data is presented in Table A1. The information contained in the PHA table is used to ensure that the CSER analysis addresses the appropriate conditions that may contribute to a criticality in the HA-20MB Glovebox. The following assumptions that are important to the CSER analysis were extracted from Table A1.

PFP Glovebox HA-20MB Criticality PHA Assumptions and Dispositions Derived from the PHA:

Assumptions Regarding Physical Configuration Outside Glovebox HA-20MB:

1. Assume lard can wagon, five position wagon, or waste drum can pass next to the north side of Glovebox HA-20MB. The criticality safety evaluation report (CSER) will assume that either are present as part of normal operations.

2. Only one waste drum at a time is allowed to be moved in Room 235B during normal operations.

3. The lard can or a five position wagon could pass underneath the glovebox. These will be considered as a contingency in the CSER.

4. Boats from HA-21I could, but would not normally, be moved past the glovebox on conveyor HA-28. The CSER will consider a container of 400 g of fully moderated material on the conveyor to bound this condition.

5. Material from Glovebox 23S could, but would not normally go by the glovebox on conveyor HA-28. The CSER will consider a container of 400 g of fully moderated material on the conveyor to bound this condition.

6. It will be assumed that no Hanford Convenience Cans (HCCs) will be present on Conveyor Glovebox HA-28 or in Room 235B. This is based on the current HA-28 Criticality Prevention Specifications (CPS) which does not allow this. Operations does not anticipate using Conveyor Glovebox HA-28 for HCCs in the future.

Assumptions Regarding Internal Glovebox Operations:

1. Several operators may be present during the cementation operations. Full reflection around the glovebox will be analyzed.

2. Multiple operations within the glovebox are anticipated to take place concurrently. The limits established in the CPS will accommodate this mode of operation.

3. The current anticipated feed is sand, slag and crucible (SSC). However, the CSER will consider future feed materials of sludge, ashes, fluorides, oxides (floor sweeps), and oxides < 30% Pu. The CSER analysis will bound these future feed materials by analyzing optimally water moderated Pu.

4. Moderators/reflectors better than water are not considered credible.

5. Access to the bottom of the glovebox is possible. This is bounded in the CSER by considering movement of material under the glovebox or personnel access under the glovebox.

6. Only 2 mixing bowls will be in use. It is anticipated that additional mixing bowls will be present but turned upside down so as not to be containers.

Assumptions Regarding Physical Configuration Inside Glovebox HA-20MB:

1. The glovebox is seismically qualified will remain upright and will not collapse during a seismic event (SE).

2. Equipment mountings inside the glovebox are not seismically qualified. Thus, equipment contents could be spilled in a seismic event.

3. A sealed metal plate covers a conveyer belt at the bottom of the glovebox. However, the seal is not qualified as a safety barrier and could fail and allow water, powder, or slurry to accumulate in the conveyor housing. This material will be analyzed as distributed along the floor.

4. The glovebox has no criticality drain. However, the maximum liquid depth in the glovebox is ~5.08 cm (~2 in.) due to a ledge between the glovebox and the HA-28 conveyor. Above this depth, liquids in HA-20MB drain into the HA-28 conveyor. The CSER will consider the ledge trapping water in the glovebox.

5. Liquid in the HA-28 conveyor drains into HA-21I which has a criticality drain.

6. It is desirable to simultaneously have in the glovebox at least 4 slip lid cans with a charge in them, a charge in reactor, a charge in mixer, an indeterminate number of feed cans, an indeterminate number of billet cans present, and material in the crusher and crusher pan. The Pu mass limit identified in the CSER will bound this condition.

7. When not in use the sieve assembly is turned upside down so that it is not a container.

8. Pu is assumed to be ^{239}Pu; it is not credible for uranium to exceed 50% ^{235}U enrichment in this glovebox.

9. Addition of fissile material into the glovebox feedwater tank will not be considered in the CSER. Purposeful introduction of fissile material into this tank will be procedurally prohibited. Accidental addition of fissile material into the tank is not credible based on the following considerations: storage of material is at a lower level than the tank; material movement does not occur over the tank; tubes block the opening of the tank; glovebox structural support blocks the opening in the top of the tank.

D3.0 PHA TEAM MEMBER BIOGRAPHIES

LaPriel Dayley – Project Enhancement Corporation, Project Engineer. Ms. Dayley has 15 years of experience working at the Hanford Site. She spent about 4 years as technical support for N Reactor and 7 years as Process Engineer at PFP. She was the Cementation process cog engineer for initial process start up in 1996. Her experience includes specifying equipment, acting as PIC for equipment installation, developing procedures and technical basis documents and shift technical support. Ms. Dayley has a Bachelor of Science degree in Chemical Engineering from the University of Washington.

Ken Dobbin - Fluor Federal Services, Inc, Criticality Safety Engineer - Mr. Dobbin has 25 years experience as a nuclear engineer, 20 of these years analyzing reactor physics and fuel management and 5 years in criticality safety. He is qualified as a Criticality Safety Engineer at the Plutonium Finishing Plant and has 20 months experience with PFP systems. During his PFP tenure, he contributed criticality safety expertise for the successful completion of an Operational Readiness Review to resume thermal stabilization of plutonium. Mr. Dobbin has both undergraduate and masters degrees in nuclear engineering.

David G. Erickson - Fluor Federal Services, Criticality Safety Engineer. Mr. Erickson has a B.S. in Physics, and has been at the Hanford Site for 16 years performing analysis in the fields of reactor physics and 13 years in criticality safety. He is familiar with the codes used in criticality analysis and has performed analysis and reviews of other PFP operations. He is a qualified Criticality Safety Specialist with FFS, and is the Technical Peer Reviewer for this project.

Brit E. Hey, Fluor Federal Services, Inc – Scribe for PHA. Mr. Brit Hey has over 18 years of combined engineering and management experience in the commercial and DOE nuclear industries. For the last 10 years Mr. Hey has performed safety analysis for numerous Hanford facilities and activities including tank farms, the waste encapsulation and storage facility, B-Plant, and the plutonium finishing plant. Mr. Hey has successfully completed the Process Hazard Analysis Leader training course offered by the ABS Group, Inc. Mr. Hey has both undergraduate and masters degrees in nuclear engineering from North Carolina State University.

Alan Ramble - B&W Hanford Company, PFP Facility Engineering - Mr. Ramble is currently the Criticality Safety Representative, the cognizant engineer for the Safety Analysis Report, and project manager for the Solution Stabilization Project at the Plutonium Finishing Plant. As Criticality Safety Representative, Mr. Ramble has responsibility for implementation of the criticality safety program at PFP, including approval of Criticality Safety Evaluation Reports, Criticality Prevention Specifications, operating procedures, initial training and annual retraining of fissile material handlers, and inspection for compliance with criticality safety requirements of PFP.

Robert F. Richard, Fluor Federal Services, Inc., Criticality Safety Engineer - B.S. Nuclear Engineering. Thirteen years experience at Hanford performing nuclear engineering analyses in fuel management, reactor physics, radiation shielding, and seven years in criticality safety.

Maria E. Shaw – B&W Federal Services – Nuclear Criticality Safety Representative – Nuclear Engineer. Ms. Shaw has worked as an engineer since 1991 and has been at the Hanford site since 1998. She has worked at the Plutonium Finishing Plant as a criticality safety representative and is plant certified as a Criticality Safety Representative. She has worked on the PFP thermal stabilization project. Ms. Shaw holds a B.S. in Math from Idaho State and M.S. in Chemistry from Univ. of Idaho. Prior to Hanford, she worked in the criticality safety field at Idaho National Engineering Laboratory and at the Navel Nuclear Fuel Facility (Lynchburg, VA.)

Milton V. Shultz, Jr. – Fluor Federal Services Inc., Safety Analysis and Risk Assessment. B.S. Nuclear Engineering Technology. Facilitator for Glovebox HA-20MB PHA. More than twenty-six years experience in a broad range of engineering and technical assignments at the Hanford Site. Experience includes leading PHAs and HAZOPs for a variety of TWRS and PFP projects, including several for the TWRS FSAR and BIO efforts, contributor to the hazards analysis work for the TWRS BIO. Has performed independent Nuclear Safety evaluations of reactor plant design and operation at Hanford's N Reactor.

Brian D. Skeels – Flour Hanford Company, PFP Stabilization Operations, Thermal Stabilization Support Team Leader. Mr. Skeels has 15 years experience at the Hanford Site. His experience has been at 100-KE/KW basins, 100N and PFP. Mr. Skeels has been at PFP for 12 years with 9 years as a First Line Supervisor/Manager. Mr. Skeels is currently the Team Leader for the Thermal Stabilization Support Team (TSST). Prior to being assigned as the TSST Team Leader, Mr. Skeels was a Shift Manager in charge of both the Cementation and Thermal Stabilization Processes during their operating campaigns. Mr. Skeels is currently qualified on the Cementation process as it was operated during the last campaign.

Alan D. Wilkinson, Fluor Federal Services, Inc, Criticality Safety Engineer, - Mr. Wilkinson has a B.S. Nuclear Engineering and M.S. Nuclear Engineering with an emphasis on Nuclear Criticality Safety. He has five years experience at Rocky Flats performing nuclear criticality safety analysis, and is now supporting PFP as a nuclear criticality safety engineer.

David W. Wootan, Fluor Federal Services, Inc, Criticality Safety Engineer, – Mr. Wootan has a B.S. Nuclear Engineering and M.S. Nuclear Engineering. He has twenty years experience at Hanford performing nuclear engineering analyses in the areas of reactor physics, shielding, and characterizing radiation environments, with 4 years experience in criticality safety.

D4.0 REFERENCES

AIChE, 1992, *Guidelines for Hazard Evaluation Procedures*, American Institute of Chemical Engineers, New York, New York.

MIL-STD-882B, 1977, *System Safety Program Requirements,* Department of Defense, Washington, DC

TABLE A1. PFP GLOVEBOX CRITICALITY PRELIMINARY HAZARDS ANALYSIS

Total Pages: 4 **Date: December 28, 1999**

Controlled Parameters: MASS, VOLUME, MODERATION, INTERACTION, REFLECTION, GEOMETRY, ENRICHMENT, DENSITY, CONCENTRATION, POISONS

Note: Fissile material is assumed to be present for all controlled parameters

ID	PROCESS CONDITION	CONTROLLED PARAMETER	GENERAL CAUSE (more, less, no, as well as, part of, reverse, other than)	DETAILED CAUSES	ENGINEERED SAFETY FEATURES	ADMINISTRATIVE SAFETY FEATURES	FREQ CAT NC	REMARKS
HA20MB-01	Seal in through airlock, conveyer, sphincter, bag-in port	Mass	More	Brought in the wrong container or too many containers (loss of mass tracking)	None	- Admin. procedures specify allowable materials - Operator training - Inventory control	C	- 2.5 kg Pu H/X < 2 - 1.5 kg Pu H/X < 20 - 400 g Pu unrestricted - 1 kg Pu unrestricted in 1/2 L - One entry point used at a time
HA20MB-02	Seal in through airlock, conveyer, sphincter, bag-in port	Mass	More	Brought in a full furnace boat	None	- Admin. procedures specify allowable materials - Operator training - Inventory control	C	Boats not likely to be in this section of Conveyor Glovebox HA-28 and therefore not likely to be inadvertently brought in
HA20MB-03	Seal in through airlock, conveyer, sphincter, bag-in port	Volume	More	Additional mixing bowl	None	- Admin. procedures - Operator training	C	Same mass in larger bowl volume
HA20MB-04	Seal in through airlock, conveyer, sphincter, bag-in port	Geometry	Stacking	Stacking	None	- Admin. procedures disallow stacking - Operator training	C	No stacking anywhere at the PFP

TABLE A1. PFP GLOVEBOX CRITICALITY PRELIMINARY HAZARDS ANALYSIS

Total Pages: 4 **Date: December 28, 1999**

Controlled Parameters: MASS, VOLUME, MODERATION, INTERACTION, REFLECTION, GEOMETRY, ENRICHMENT, DENSITY, CONCENTRATION, POISONS

Note: Fissile material is assumed to be present for all controlled parameters

ID	PROCESS CONDITION	CONTROLLED PARAMETER	GENERAL CAUSE (more, less, no, as well as, part of, reverse, other than)	DETAILED CAUSES	ENGINEERED SAFETY FEATURES	ADMINISTRATIVE SAFETY FEATURES	FREQ CAT NC	REMARKS
HA20MB-05	Seal in through airlock, conveyer, sphincter, bag-in port	Moderation, reflection	More	Non-water moderator, reflector (e.g., oil, plastic, solvents)	None	- Rag limit - Lubricant limit	C	- Trash intensive process - Consider reflection/ moderation in GB
HA20MB-06	Seal in through airlock, conveyer, sphincter, bag-in port	Density, concentration	Unspecified	Unspecified	None	None	NC	Optimum parameters considered in all analysis cases
HA20MB-07	Seal in through airlock, conveyer, sphincter, bag-in port	Poisons	Unspecified	Unspecified	None	None	NC	Poisons not credited for criticality control
HA20MB-08	Seal-out through airlock, conveyer, sphincter, bag-in port	No differences from seal-in	No differences from seal-in	No differences from seal-in	No differences from seal-in	Billets limited to < 2% Pu	C	Process of seal-out reduces reactivity
HA20MB-09	Seal-out through airlock, conveyer, sphincter, bag-in port	Interaction – see wagon evaluation below	Interaction – see wagon evaluation below	dropped billet which rolls under GB	None	See wagon evaluation below	C	Wagon will be the worst interaction case
HA20MB-10	Material movement outside GB	Interaction	Material brought near GB	Wagon moved underneath GB	None	Wagon location limitations (procedural and CPS)	C	- Must allow drums next to north end of GB (200 g max. Pu) - Wagons can be as close as 18 in
HA20MB-11	Material movement outside GB	Interaction	Material brought near GB	2 wagons moved near GB	None	Wagon location limitations (procedural and CPS)	NC	More than one wagon violating CPS not considered credible

TABLE A1. PFP GLOVEBOX CRITICALITY PRELIMINARY HAZARDS ANALYSIS

Total Pages: 4 **Date: December 28, 1999**

Controlled Parameters: MASS, VOLUME, MODERATION, INTERACTION, REFLECTION, GEOMETRY, ENRICHMENT, DENSITY, CONCENTRATION, POISONS

Note: Fissile material is assumed to be present for all controlled parameters

ID	PROCESS CONDITION	CONTROLLED PARAMETER	GENERAL CAUSE (more, less, no, as well as, part of, reverse, other than)	DETAILED CAUSES	ENGINEERED SAFETY FEATURES	ADMINISTRATIVE SAFETY FEATURES	FREQ CAT NC	REMARKS
HA20MB-12	Material accumulates outside GB	Interaction	material brought near GB	Uncounted waste left in proximity of GB	None	CPS postings require 3 ft for stored material and 18 in for material in motion	C	12 in water reflection around GB to be analysis basis which bounds all credible external reflection interactions
HA20MB-13	Process activities associated with any open container	None	NA	Spilled container	None	Clean up spills	C	No worse geometry than when container not spilled
HA20MB-14	Process activities associated with any open container	Moderation, geometry	More	Spilled container contents into 5 gal water tank	Tank opening high in glovebox with tubing obstructing part of opening	Fissile material not allowed in feedwater tank	NC	Not credible spilling container into 5 gallon water tank because opening to tank is high in glovebox and tubing arrangement inhibits objects from entering
HA20MB-15	Handling of containers in GB	Interaction, geometry	More	Passing one container over another	None	Procedure prohibits stacking	C	Stacking and passing over are equivalent
HA20MB-16	Handling of containers in GB	Interaction, geometry	More	Placing containers next to each other	None	None	C	Calculation will be performed to determine worst case fissile, water placement and personnel interaction
HA20MB-17	Transferring feed material	Mass	More	Putting all feed material in one container	None	500 g unrestricted volume and 200 g in each of two mixing bowls	C	Double batch mixing bowl

TABLE A1. PFP GLOVEBOX CRITICALITY PRELIMINARY HAZARDS ANALYSIS

Total Pages: 4 **Date: December 28, 1999**

Controlled Parameters: MASS, VOLUME, MODERATION, INTERACTION, REFLECTION, GEOMETRY, ENRICHMENT, DENSITY, CONCENTRATION, POISONS

Note: Fissile material is assumed to be present for all controlled parameters

ID	PROCESS CONDITION	CONTROLLED PARAMETER	GENERAL CAUSE (more, less, no, as well as, part of, reverse, other than)	DETAILED CAUSES	ENGINEERED SAFETY FEATURES	ADMINISTRATIVE SAFETY FEATURES	FREQ CAT NC	REMARKS
HA20MB-18	Handling water	Moderation	More, less	Add too much or too little	None	None	C	- Analysis will consider optimum moderation - Conveyor below HA-20MB can collect water
HA20MB-19	Chiller operation	Moderation	More	Tube leak overflows 5 gal tank	None	None	C	See fire analysis
HA20MB-20	Spill cleanup	Geometry	Other than	Process overflows`	None	procedure	C	Process requires immediate spill cleanup
HA20MB-21	Storage	Mass	More	Too many containers	None	900 g limit on feed in GB	C	Number of mixing bowls limited
HA20MB-22	External	Moderator	More	Fire in GB	Dry chemical suppression	None	C	Dry chemical does not alter reactivity
HA20MB-23	External	Moderator	More	Fire outside GB actuates room sprinklers	None	None	C	- Analysis will consider optimum moderation - Analysis assumes that GB damaged and water gets in - Glovebox holdup will be considered
HA20MB-24	External	Moderation, reflection	More	Seismic adds water	GB seismically qualified	None	C	- Analysis will consider optimum moderation - Conveyer could fill up

TABLE A1. PFP GLOVEBOX CRITICALITY PRELIMINARY HAZARDS ANALYSIS

Total Pages: 4 **Date: December 28, 1999**

Controlled Parameters: MASS, VOLUME, MODERATION, INTERACTION, REFLECTION, GEOMETRY, ENRICHMENT, DENSITY, CONCENTRATION, POISONS

Note: Fissile material is assumed to be present for all controlled parameters

ID	PROCESS CONDITION	CONTROLLED PARAMETER	GENERAL CAUSE (more, less, no, as well as, part of, reverse, other than)	DETAILED CAUSES	ENGINEERED SAFETY FEATURES	ADMINISTRATIVE SAFETY FEATURES	FREQ CAT NC	REMARKS
HA20MB-25	External	Interaction, geometry	More	Seismic re-arranges material	GB seismically qualified	None	C	- Slab geometry maintained - Inoperable HA-20MB conveyer could fill up
HA20MB-26	External	Interaction	Less	Loss of power	None	None	C	Loss of power to GB may cause premature work stoppage but reactivity is not increased

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APPENDIX E

MCNP MODEL FIGURES

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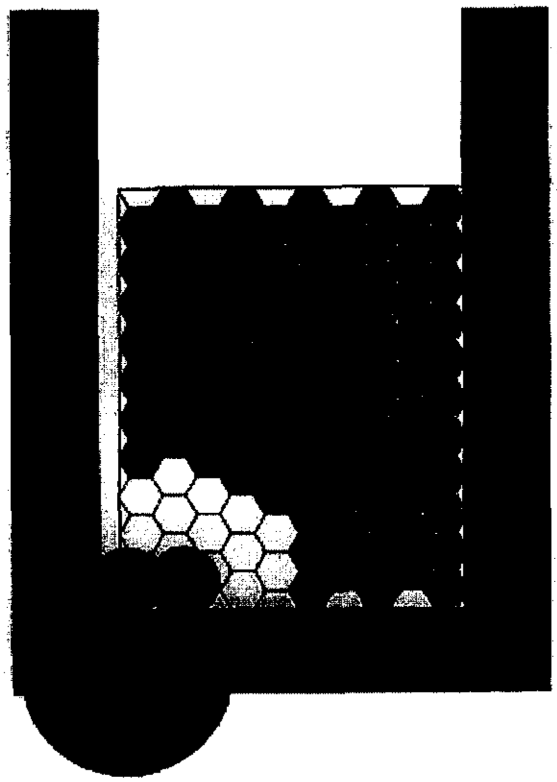

Figure 1 1200 g base case with cement can reflection Case c0001f1b7b

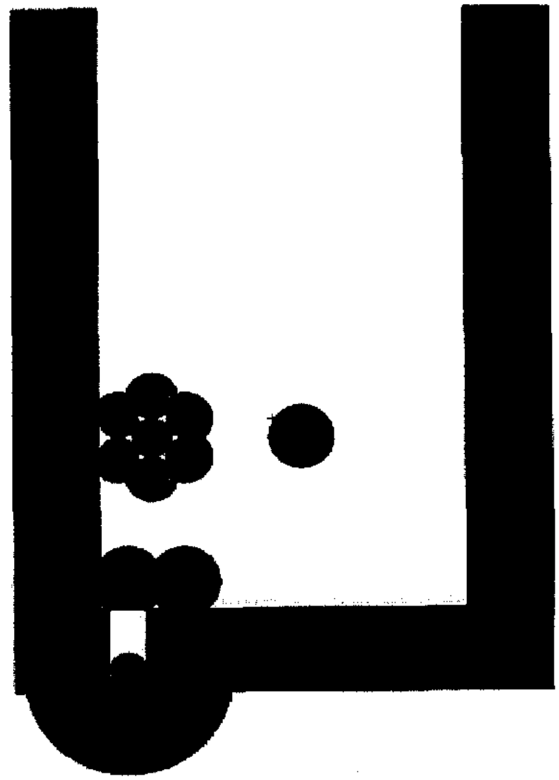

Figure 2 1200 g base case variation with nominal water reflection case c0001f1b13a

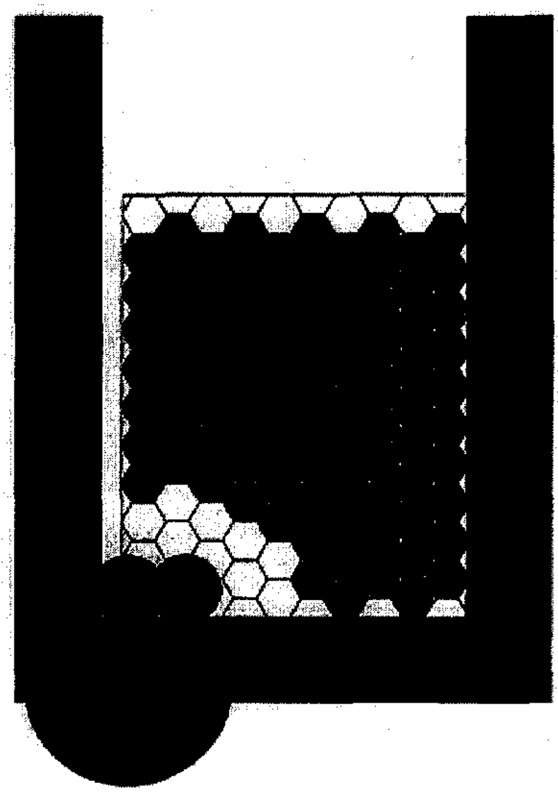

Figure 3 1200 g base case variation with cans in corner case c0001f1b7c

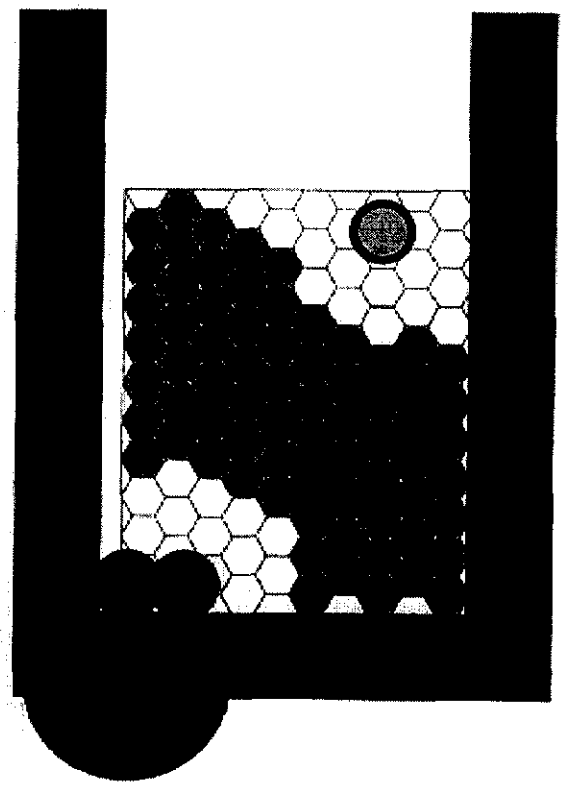

Figure 4 1200 g base case variation with conveyor container case c0001f1b18

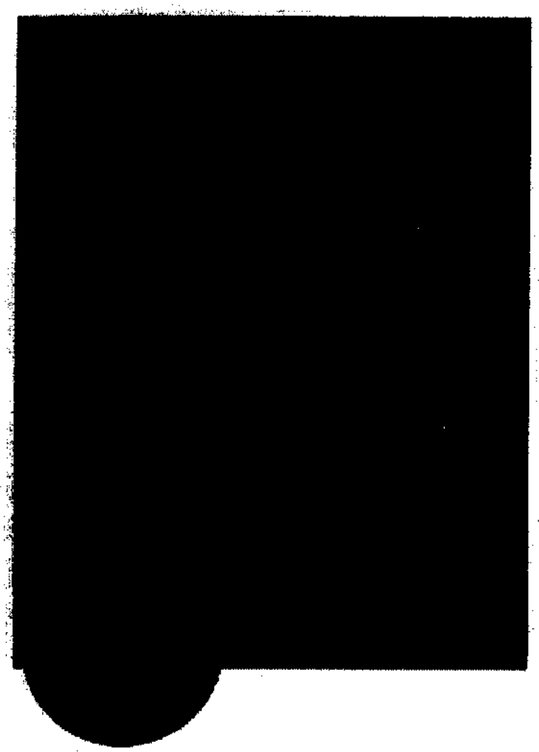

Figure 5 1200 g seismic case c0001f1q1a

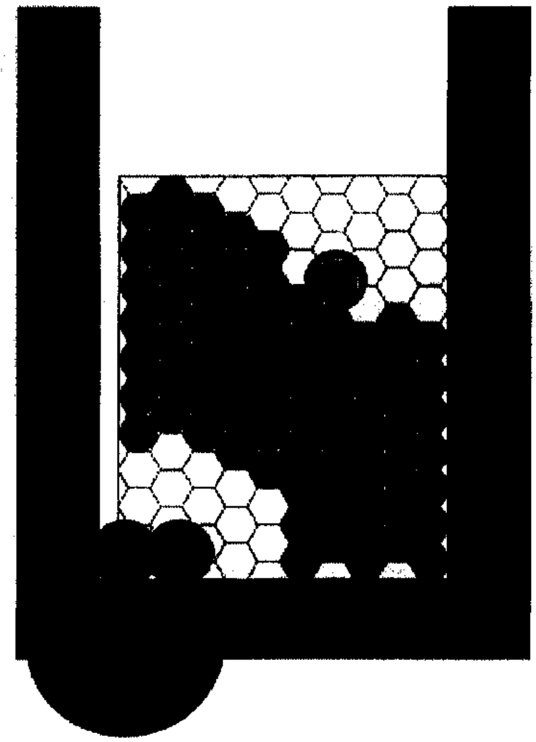

Figure 6 1200 g spacing case c0001f1b17

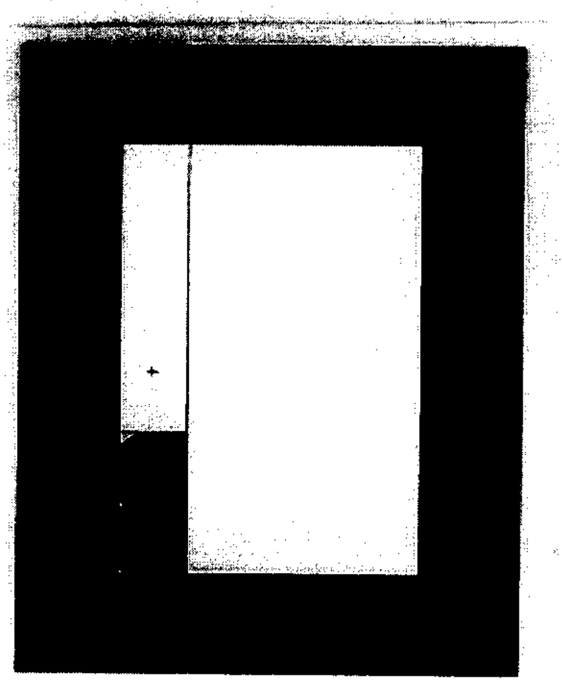

Figure 7 Verical Cross section of model showing two bowls

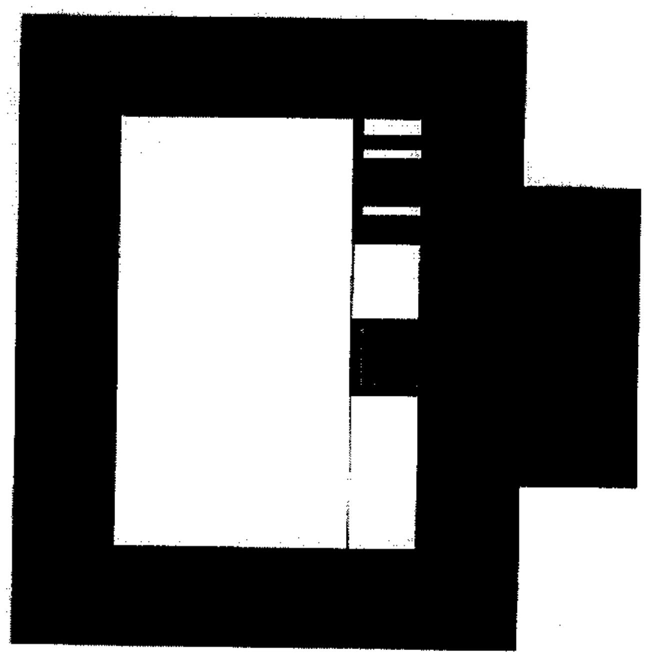

Figure 8 Vertical cross section showing cans and conveyor container case c0001f1b13a

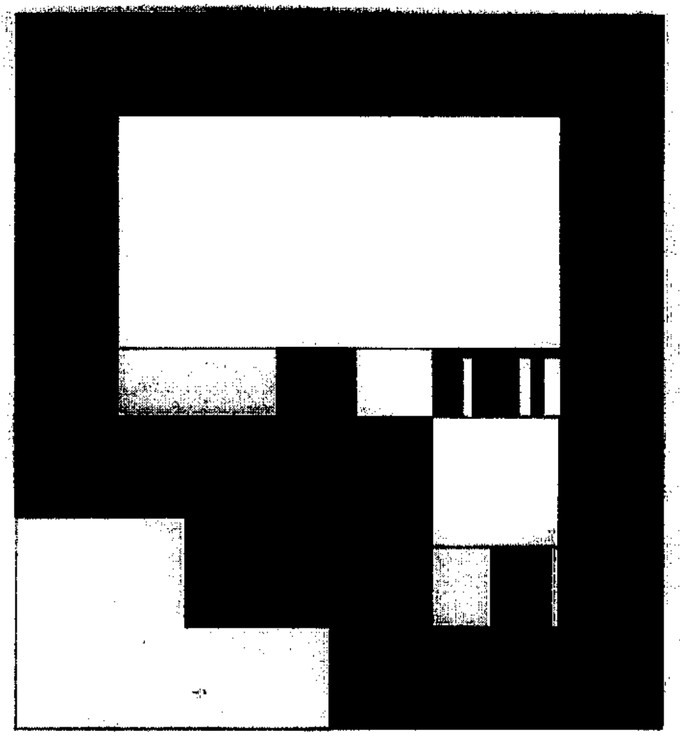

Figure 9 Verical cross ection showing canister in wagon under glovebox case c0001f1w1

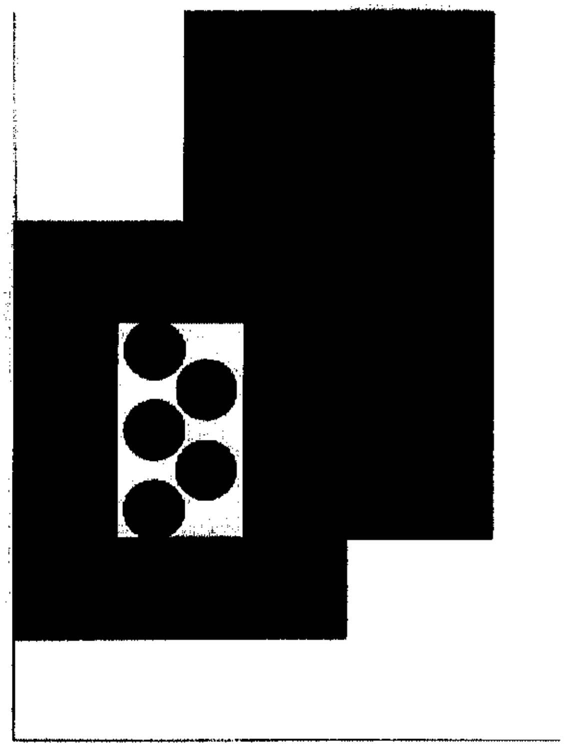

Figure 10 horizontal cross section showing wagon under glovebox case c0001f1w1

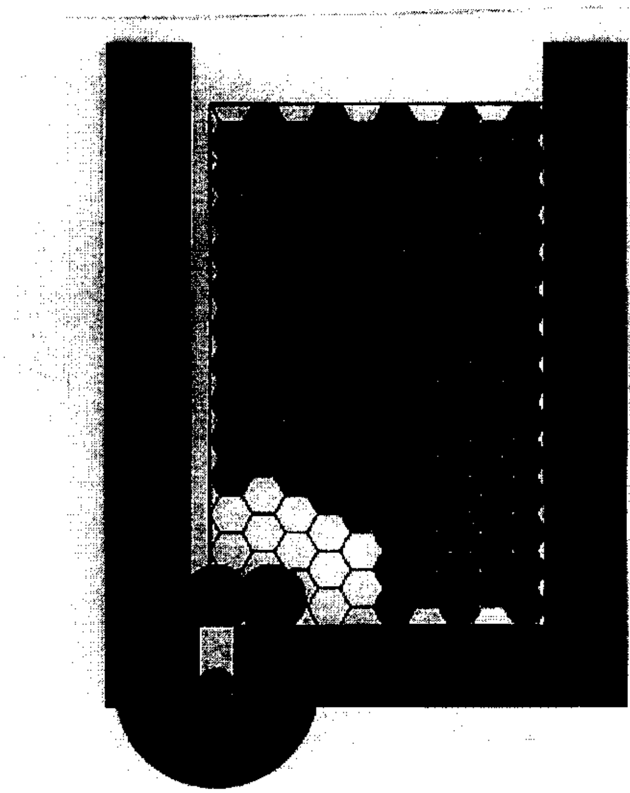

Figure 11 2100 g base case with cement can reflection Case c0001f2b4

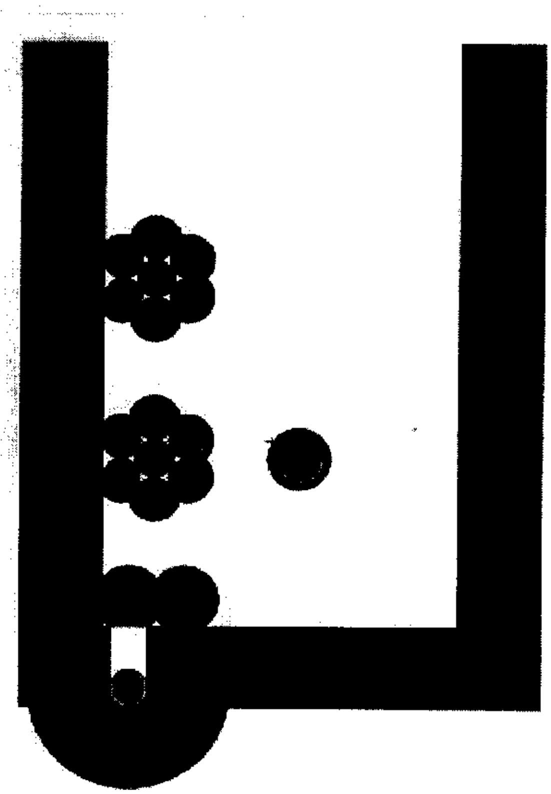

Figure 12 2100 g base case with nominal water reflectionCase c0001f2b6a

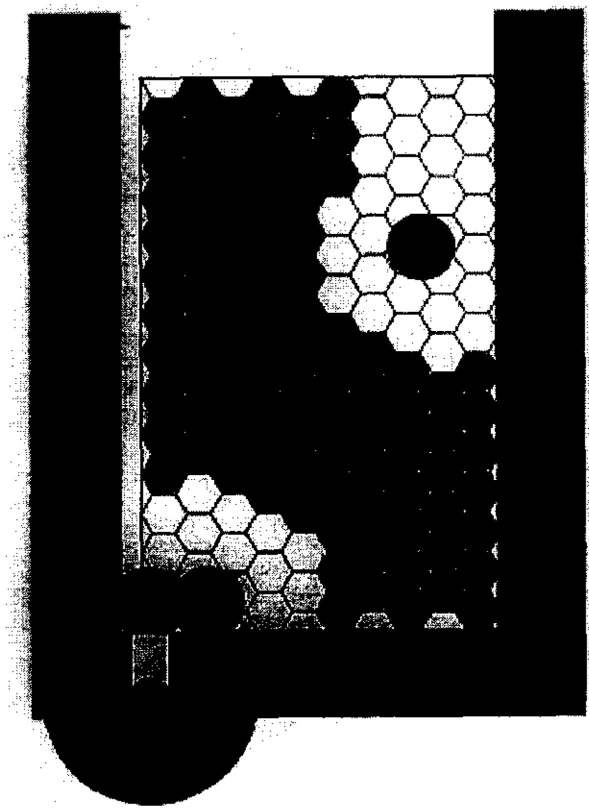

Figure 13 2100 g base case variation with conveyor container case c0001f2b8

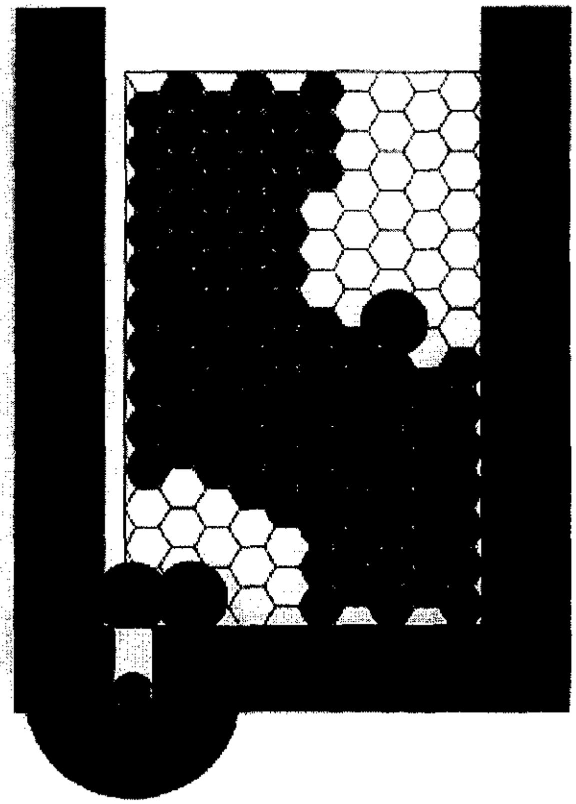

Figure 14 2100 g spacing case c0001f2b9

APPENDIX F

SAND, SLAG, AND CRUCIBLE CEMENTATION PROCESS FLOW AND STABILIZATION CEMENTATION DOCUMENTS

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PLUTONIUM FINISHING PLANT

PROCESS FLOW DOCUMENT

SAND, SLAG, AND CRUCIBLE CEMENTATION PROCESS FLOW DOCUMENT

PFD-Z-200-001

Prepared By:
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Engineer
PFP Process Engineering

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1. Introduction

A cementation process will be applied to immobilize material containing plutonium for eventual disposal to the Waste Isolation Pilot Plant (WIPP). Sand, Slag, and Crucible (SS&C) items specified for cementation were generated from past RMC production runs. Since this material contains calcium, which is reactive, steps will be taken in the process to render the material nonreactive before mixing with cement. SS&C items treated in this process will be packaged for WIPP/WAC[1] and TRU requirements per the Hanford Site Solid Waste Acceptance Criteria[4]. The cemented SS&C will then be shipped for long term storage. The PFP Stabilization Final Environmental Impact Statement (DOE/EIS-0244-F, APP-E) immobilization alternative evaluates the impacts of immobilizing this material[2].

2. Process Summary

SS&C which will be cemented is staged for introduction into the HA-20MB glovebox, where it is opened, weighed, sieved and processed through a particle size reduction unit. A measured amount of SS&C is mixed with chilled water in a mixer reactor to react residual calcium metal. This step will enable control of the exothermic reaction temperatures and hydrogen generation[3]. Following the calcium oxidation, cement, water, and SS&C are mixed to form a cement matrix. When the cemented can is cured, it is sealed out, packaged, and shipped.

3. Process Description

SS&C and other necessary cementation material is staged for introduction into glovebox HA-20MB. One SS&C container at a time is opened in the process area and weighed. Total unreacted SS&C in the glovebox is limited to ≤ 8,500 grams and is tracked through a running inventory. The SS&C is sieved to separate out the large pieces, then transferred to a size reduction unit to obtain an optimum particle size to assure reaction completeness. Optimum particle size was determined through laboratory testing to be 8 mesh[5]. Following this precementing activity, the SS&C is transferred into a hopper that feeds the variable speed auger prior to further processing (Figure One).

A nominal 3 liters of chilled process water is gravity fed into the mixer reactor bowl. SS&C is fed into the mixer reactor bowl under agitation at a rate ranging from 0-45 g/min to react calcium metal. The mixer reactor temperature is monitored using redundant infrared thermocouples and digital monitors. Additional chilled water may be added in 100 to 200mL amounts during the addition of the SS&C to offset any water loss from the water/calcium reaction. When the temperature reaches 80°C, the auger is automatically shut off using a temperature interlock to the auger. If the first interlock fails a redundant temperature interlock is activated at 90°C to stop the auger. When the calcium reaction is complete, the mixer reactor is manually stopped using switches located outside of the glovebox. The reactor bowl is removed from the mixer and a new reactor bowl is installed on the mixer and the process described above is repeated.

The solids are transferred to a holding container until enough is accumulated for a cementation batch (Figure 2).

The accumulated SS&C, cement, and water are mixed to form a cement matrix, allowed to cure, sealed out, and packaged for shipping. The proposed storage/shipping container is shown in Figure 3.

4. Process Technology

4.1 Feed Stock

The SS&C material being processed in the cementing operations was generated in the RMC button line operations. It consists of material left after the plutonium button was removed from the casting mold.

4.1.1 SS&C From RMC Operations

The SS&C material being processed originated from RMC button casting operations. Plutonium metal production required the mixing of plutonium fluoride, calcium metal, and other reactants. The mixture was placed into a magnesium oxide crucible (mold) and heated to 1093°C using an induction furnace. The high temperature caused the plutonium fluoride to be reduced to plutonium metal. The mold containing the plutonium was placed into the RMC line mold cutter. The mold cutter broke the mold, which released what was called a "button". The botton was then removed by hand from the adhering slag. The remaining solids were collected and processed through the hammer mill and placed into storage cans for future processing in PRF. The plutonium reduction process did not consume all the plutonium fluoride reduction reagents. A typical composition of SS&C is shown below.

Compound	Mole/Can	Wt%
MgO	18.36	46.42
CaF_2	6.57	41.97
Ca	3.49	8.78
CaI_2	0.09	1.65
Pu	0.03	0.46
PuF_4	0.01	0.20
PuO_2	0.01	0.17
SiO_2	0.12	0.45

Calcium Metal

Unreacted excess calcium metal leftover from plutonium metal production is still present. Calcium metal is highly reactive and when mixed with a matrixing agent such as cement and water, will react with the water and generate excess heat and hydrogen. An Unreviewed Safety Question Evaluation (USQ) was performed to bound potential accidents per the current PFP FSAR. The USQ analysis showed that by restricting the amount of unreacted SS&C to ≤8,500 grams, keeping all dispersable material covered, and allowing no more than 100 grams dispersable Pu per container, the process was bounded by the current PFP FSAR. The concentration of hydrogen in the glovebox during normal operation will be kept below flammablility limits by limiting the flow of SS&C into the mixer reactor to ≤50 grams/minute. This keeps the hydrogen concentration below the hydrogen flammability limit of 4% in the space above the mixer bowl. This is conservative as the calculation doesn't take into consideration that HA-20MB is ventilated at 59451 L/hr.

A material balance based on a feed rate of 50 grams/minute of SS&C containing 20% calcium is shown in Table 1.

Table 1 - SS&C Feed

Material Balance:
SS&C feeding in at a 50 g/min rate with 20% Ca Metal

Reactants			Products			
$2H_2O$	+ Ca^{+}	→	$Ca(OH)_2$	+ H_2	+	(△ at 24.74 kcal)
9g	10g		18.5 g	.5g		(3.3% above bowl)

5. Process Control

The instrumentation and controls for the process are located in Room 235-B inside and outside of HA-20MB.

5.1 Mixer Reactor Temperature Control

The mixer reactor operating temperature will be monitored using a temperature sensor. SS&C contains unreacted calcium metal from the reduction of plutonium fluoride to plutonium metal. Calcium metal reacts with water producing heat and hydrogen. The temperature of the mixer reactor will be monitored and is interlocked with the auger to stop feed addition when the reacting mixture reaches 80°C. This will allow the water to cool and limit the generation of water vapor and hydrogen. If the first temperature interlock fails, a second interlock is set to stop the auger at 90°C.

6. Off-Standard Conditions

Loss of the E-4 ventilation system would allow the possible build up of hydrogen within the glovebox. The operational procedures will instruct the operator to stop the SS&C auger feed. Ventilation loss during processing activities still would not generate hydrogen to the flammability limit of 4 percent. Hydrogen amounts calculated from average calcium amount weight concentrations in SS&C will produce 3.9 percent hydrogen in the glovebox even if the whole 2000 gram charge is fed into the mixer bowl with no air flow in the glovebox.

7. Equipment Description

The cementation process will be carried out in HA-20MB. The glovebox is located in Rm 235B. This section describes the location and type of equipment used in the cementation process.

7.1 Mixer Reactor

The commerical mixer reactor is a Hobart™ model number N-50 or equal. The commerical mixer reactor is capable of operating at three speeds. The speed control will be set at the correct speed, the mixer will be set to the on position, and a remote on/off switch, located on the outside of the glovebox near the mixer, will be used to start and stop the mixer.

7.2 Auger

The process feed auger has variable speed and can feed material to the mixer reactor at rates ranging from 0-45 g/min. Normal operating feed rate will be nominally 24 g/min. Since the maximum allowable feed rate is 50 g/min, this represents an engineered control. The auger is interlocked with temperature controllers to stop operation when the temperature is above the specified limit. The auger has a different plug and receptacle configuration to prevent overriding temperature interlocks.

7.3 Chiller

Process water cooler produces 3751 btu/hr of cooling to chill the water used to react the calcium metal and aid in process temperature control. The chiller unit is located on the mezzanine above the glovebox with the cooling coil tubing penetrating the glovebox wall and going into the process water reservoir.

Process water will be provided by a 94.5 liter capacity tank located on the mezzanine. Process water will be hand loaded to control the amount of water that could potentially enter the glovebox.

7.4 Scale

The scales have digital readouts and will be located in HA-20MB. Scales will be used to measure out charges into slip lid containers and to verify percent Pu in each cemented item.

7.5 Temperature Control System

The mixer reactor temperature will be controlled using infrared thermocouples and digital monitors. The controller will be interlocked to the SS&C auger. SS&C addition to the mixer reactor is stopped at 80°C through this interlock. A redundant auger stop loop is in place to stop the auger at 90°C if loop one fails to operate. Process restart is done manually when the temperature falls below 60°C.

Hobart is a trademark of the Hobart Corporation, Troy, Ohio.

7.6 Size Reduction

The SS&C will be reduced to the optimum particle size of 8 mesh using a general purpose crusher. The crusher is a standard 115VAC 1PH unit.

7.7 Sieve

A standard 8 mesh sieve is used to remove any particles larger than 8 mesh. The sieve screen can be from bulk 8 mesh material cut to fit or of custom manufacture.

8. Safety

The principle hazards associated with glovebox HA-20MB operations are heat of reaction, off-gas flammability, criticality, and radiation. The following sections will address these items.

8.1 Heat of Reaction

The reaction of calcium metal and water generates enough heat to boil water. Temperature controls are installed to control the amount of heat generated from the reaction by stopping the addition of SS&C. Further, the mixer reactor is continuously operated to dissipate heat of reaction.

8.2 Off-gas Flammability

Hydrogen is generated when calcium metal is reacted with water. Temperature controls are installed on the mixer reactor to limit the SS&C feed. Controlling the SS&C feed rate to ≤ 50 g/min limits the hydrogen generated above the bowl to 3% which is below the 4% flammability limit for hydrogen. Since the maximum auger feed rate is 45 g/min, this is a engineered control. Also, by limiting the charge sizes to ≤ 2000 grams unreacted SS&C, if the ventilation were to stop and all the material in the auger fed into the mixer reactor, the hydrogen level in the glovebox would be below the flammability limit (<4% hydrogen).

8.4 Glovebox Exhaust Flow

Glovebox ventilation is required to maintain glovebox airflow at specified values for prudent engineering control and defense in depth to prevent hydrogen buildup as discussed in section 8.2. The glovebox exhaust flow is maintained at greater than 20 scfm and is monitored on flow indicator FI-20MB-1.

The flow monitor is read as a prerequisite to startup and read periodically while processing per procedure ZO-160-060. This specification is required when reacting SS&C, other activities are permitted as long as glovebox to room dP requirements are satisfied.

8.5 Criticality

Plutonium is a fissile material and therefore, criticality limits are required. Criticality Prevention Specification CPS-Z-165-80030 (Glovebox HA-20MB in Room 235-B, 234-5Z Building) will be applicable during all operations in HA-20MB. Criticality specification limits fissile material to 500 grams in the airlock and 500 grams in the process area. Fissile material is limited to 180 grams in any liquid-bearing container (mixing bowl or cement can). No direct water lines will be connected to the glovebox, therefore limiting the total water available. Spacing of the fissile material is not required.

8.6 Radiation

Remote operation of equipment through placement of controls outside of the glovebox will reduce operator exposure. The mid-section of the glovebox has lead plates installed for dose reduction. However, this process is labor intensive and operations and maintenance activities in the glovebox will be minimized using ALARA principles of time, distance, and shielding will be used in developing procedures.

9. **Essential Material**

No essential material is required for this process. It is desirable that the same cement manufacturer be used to ensure consistent product.

10. **References**

(1) DOE, 1996a, Waste Acceptance Criteria for the Waste Isolation Pilot Plant, DOE/WIPP-069 Revision 5 Draft C, U.S. Department of Energy, Carlsbad Area Office, Carlsbad, New Mexico.

(2) DOE, 1996, Analysis of the Immobilization Alternative, DOE/EIS-0244-F, Appendix E Rev 3, U. S. Department Of Energy, Richland Area Office, Richland, Washington.

(3) Mortimer, Charles E., Chemistry, 5th Edition, 1983 Wadsworth Inc.

(4) WHC, 1993, Hanford Site Solid Waste Acceptance Criteria, Chapter 5, Transuranic Waste, Westinghouse Hanford Company, Richland, Washington

(5) Winstead, Michelle. L., July 1996, Internal Letter 15700-96-068, Results of Sand, Slag, and Cruible Testing for Cementation Process

FIGURE 1 - CEMENTATION PROCESS PREPARATION FLOW SHEET

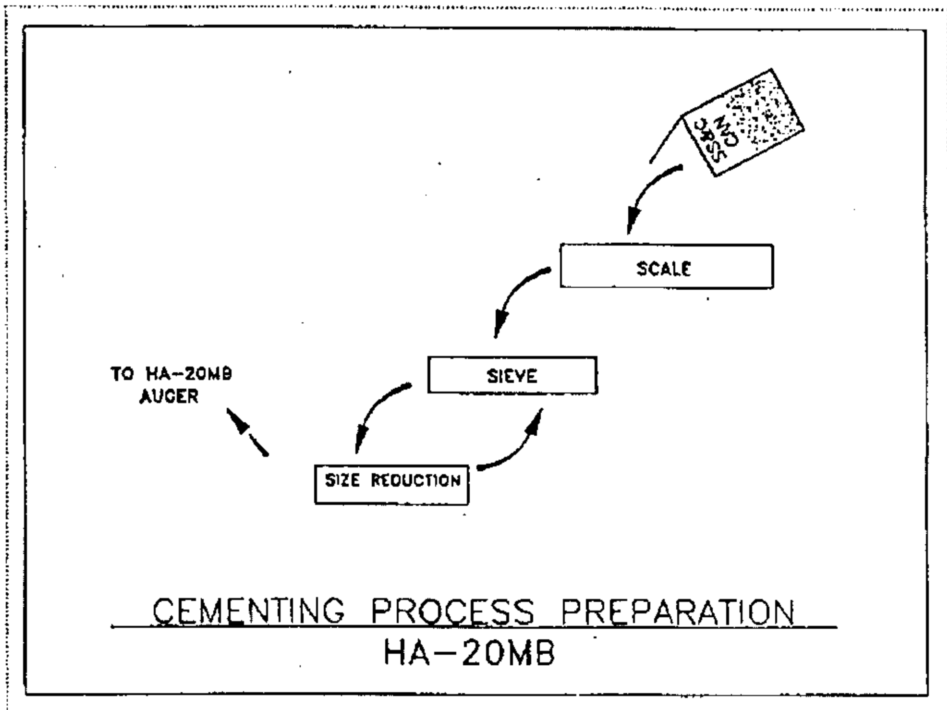


FIGURE 2 - SS&C CEMENTATION FLOW SHEET

Figure 2 – SS&C CEMENTATION FLOW SHEET

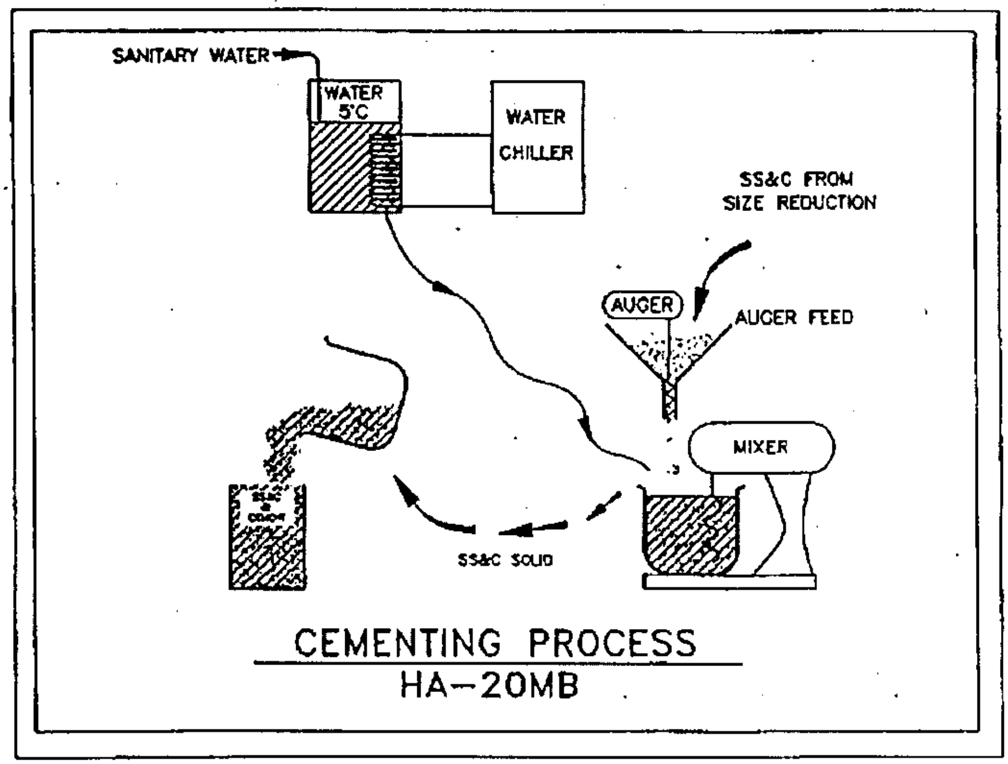
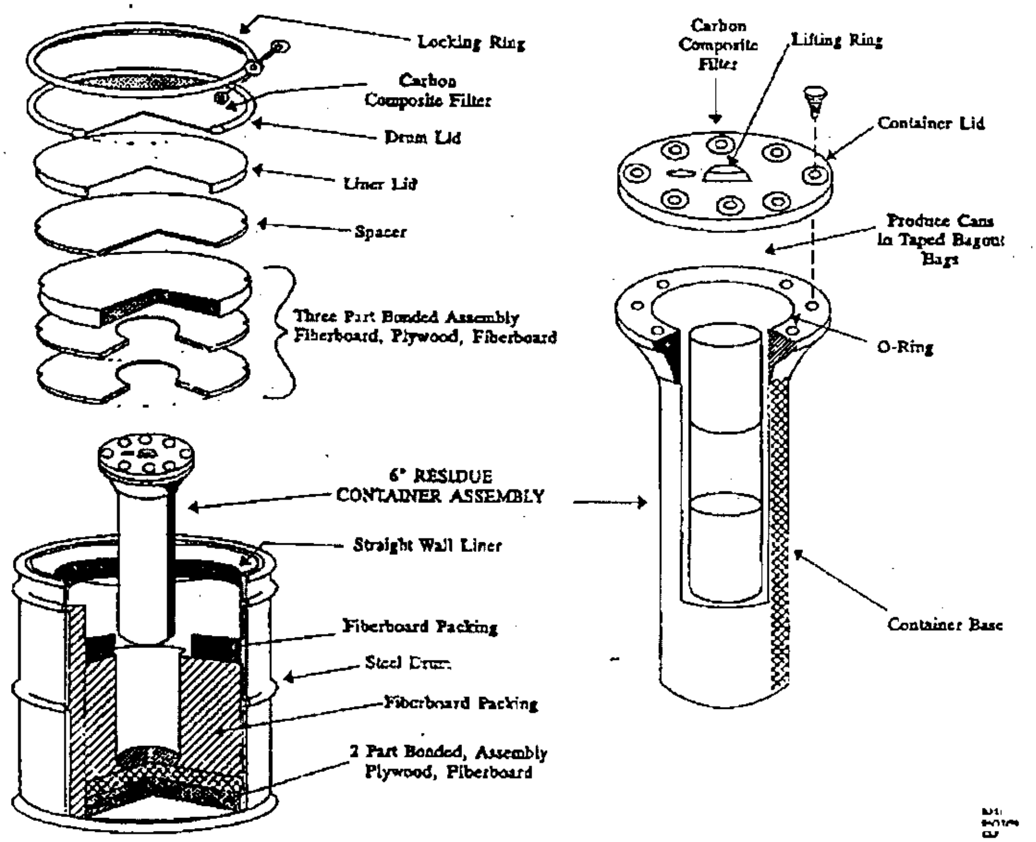


Figure 3 - Pipe-container-in-drum



PFP	DOCUMENT APPROVAL FORM	(1) Tracking No. DAF-97-786

(2) Document Number: PFD-Z-200-001 Rev: 0 Mod: 1 Charge Code/TPCN # K6178

Title: SAND, SALG, AND CRUCIBLE CEMENTATION PROCESS FLOW DOCUMENT

Originator: STUBBS, AM Phone: 3739380 Date: 8-13-96

Cognizant Engineer (print): FUNSTON,GA Phone: 373-1224

(3) Approval Designator: [ ]D [ ]S [ ]Q [ ]E [ ]RCO [ ]W [X]N/A [ ]CRIT [ ]OSR [ ]SGMC

(4) ACTION REQUESTED/AUTHORIZED: (Document the procedural basis for the requested action on page 2 section 9)

[ ] WRITE NEW DOCUMENT	[ ] REVISE DOCUMENT per description	[ ] CHANGE DOCUMENT STATUS
Please provide the following information, as a minimum, in Description OR Attach a draft if available:	(Check Appropriate Items):	[ ] CANCEL/VOID DOCUMENT
PRINT reviewers/approvers/validator names in APPROVAL/CONCURRENCE section below.	[ ] Temporary Change (approved for one shift only, extensions must be approved by approval authority on a shift by shift basis) (see 2nd page for signatures)	[ ] INACTIVATE DOCUMENT
OSR/TSR relationship and specifics.	[X] Technical Change	[ ] REACTIVATE DOCUMENT
Responsible Craft/Operator.	[ ] Administrative (Editorial) Change	[ ] Cancel DAF #
Equip. Name, Model, Series, Manufacturer, Etc.	[ ] Complete revision (requires complete review by original designated approvers)	Provide justification on page 2 of DAF.
Reference Drawings and Vendor Information.	[ ] CPS Change-expiration date:	
Facility Contacts.	[ ] USQ required?	
Level of detail	[ ] PH&S revision required?	
Priority/Milestone dates	[ ] JCS revision required?	
	[ ] Procedure Data Sheet revision required?	

(5) VALIDATION METHOD USED [ ]WALK-THROUGH (preferred) [ ]SIMULATOR [ ] FIRST USE

(Validation required for new procedures and complete revisions)

(6) Description: THE CHANGES BEING MADE TO THE PROCESS FLOW DOCMENT REFLECT HOW THE CURRENT PROCESS IS OPERATED. FOR USQ SEE USQ-96-007.

ATTCHED FOR CHANGES.

(7) APPROVAL/CONCURRENCE SIGNATURES.

	Printed Name	Signature	Date
Cog. Engineer:	Art Stubbs	[signature]	8/13/97
Cog. Manager:	Mark W. Gibson	[signature]	8/26/97
QA:			
Safety:			
Environmental:			
Crit. Safety:			
OSR Rep:			
Rad Con:			
Val. Contact: (or someone normally performing the task)			
OTHER:			
Administrative Change Approval:			
APPROVAL Approval Authority:	[signature]		8/26/97

(Approval Authority is not required for administrative changes.)

Procedural use: [ ]STEP BY STEP USE [ ]GENERAL USE [ ]ROUTINE USE [ ]NO CHANGE (ref: WHC-CM-5-8, 13.7)

PFP DOCUMENT APPROVAL FORM (CONTINUATION SHEET)

6) Description continued:

) Procedural Basis (Technical, Administrative or Design) for requested action:

CHANGE REQUIRED REFLECTS THE CURRENT OPERATION OF THE CEMENTATION PROCESS AS AGAINED THROUGH OPERATIONAL EXPERIENCE.

emporary Change (approved for one shift only, extensions must be approved by the approval uthority or delegate on a shift by shift basis)

	Printed Name	Signature	Date
Extension 1 Approval Authority:			
Extension 2 Approval Authority:			
Extension 3 Approval Authority:			
Extension 4 Approval Authority:			

STEP BY STEP USE

PLUTONIUM FINISHING PLANT

STABILIZATION OPERATIONS

STABILIZATION CEMENTATION

ZO-160-060
Revision G, Change 3
Page 1 of 29

Approval Designator SQ

ISSUE DATE 11/14/99

WORKING COPY VERIFIED BY: ______________ DATE: ______________

STABILIZATION CEMENTATION	ZO-160-060 Rev. G, Chg. 3 Page 2 of 29

REVISION STATUS

CHANGE	PAGE(S)	DESCRIPTION
REV. G-0 DAF-97-0173	ALL	COMPLETE REVISION
MOD. G-1 DAF-97-0464 DATE 5/1/97	7	IMPROVED WAY OF MEASURING OFF-GAS FLOW IN STEP 6.1.1.
MOD. G-2 DAF-97-0851 DATE 9/16/97	16	STEP 6.6.14.a. CHANGED "6.10.1" TO "6.11.1"
	17	STEP 6.6.16 CHANGED "6.5.19" TO "6.6.17"
	27	ATTACHMENT 2 REMOVED "6.5.26" FROM ATTACHMENT
Change 3 DAF-99-1284 11/14/99	1, 2, 5, 13, 20, 24, 26-28	Administrative change to update personnel and group titles to reflect those in the redesigned organization.

VALIDATED ON 02/20/97

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1. INTRODUCTION

1.1 Purpose

Provide instructions for cementing Sand, Slag, and Crucible (SS&C) in glovebox HA-20MB. The cemented SS&C shall be packaged in waste drum in preparation for shipment to Waste Isolation Pilot Plant (WIPP).

1.2 Scope

This procedure applies to SS&C with plutonium levels accepted for disposal. The SS&C contains calcium metal which does not meet WIPP reactivity requirements and will be reacted with water prior to cementing.

1.3 Applicability

Items with less than 60 grams plutonium that have been selected for disposal by this method. Sections are independent and may be performed simultaneously (except 6.1).

2. PRECAUTION AND LIMITATIONS

2.1 Criticality Statements

2.1.1 Amount of plutonium allowed in HA-20MB process area is not to be more than 500 grams above HA-20MB hold-up.

2.1.2 Amount of plutonium allowed in HA-20MB airlock is not to exceed 500 grams.

2.1.3 No more than 180 grams of plutonium in any one liquid bearing container.

2.1.4 Maximum container volume not to exceed a nominal 5 quarts (4.73 liters).

2.1.5 Stacking of containers is not allowed.

STABILIZATION CEMENTATION	Z0-160-060 Rev. G, Chg. 3 Page 5 of 29

2.2 Warning Statements

2.2.1 Total unreacted SS&C in open containers (including material held in slip-lid cans) is limited to less than 8500 grams in HA-20MB.

2.2.2 To limit dispersible Pu to 100 grams, maximum Pu for individual containers with dry SS&C is ≤100 grams.

2.3 Caution Statements

2.3.1 Worknit, HD, Smitty or leather gloves shall be worn when opening cans and handling sharp edged items.

2.4 Administrative

2.4.1 Operating MODE
The Main Facility AND Process Area 3 shall be in MODE 1 or MODE 2 and meet minimum staffing limits (two certified NCOs and one certified manager/Team Leader). IF area is in MODE 2, LCOs 3.1, 3.2, and 3.3 shall be met.

3. PREREQUISITES

NONE.

STABILIZATION CEMENTATION	ZO-160-060 Rev. G, Chg. 3 Page 6 of 29

4. SPECIAL TOOLS, EQUIPMENT, AND MATERIALS

Graduated Cylinder
Tape
Spatula
2 lb. Slip-lids
Scissors
Bucket
Paint Brush (to clean up spills)
Worknit HD, Smitty or Leather Gloves
Billet Cans (5½" x 7" slip-lid cans with welded seam)
Putty Knife
Crusher Feed Funnel
Crusher Catch Pan
Scupula
Hammer
Portland Cement
Screwdriver

5. PERFORMANCE DOCUMENTS

ZO-170-299, Seal Out
ZO-170-301, Seal In
ZO-200-101, Zero And Operate Mettler And Scientech Balances

5.1 Records

CHARGE PREP DATA SHEET
CALCIUM REACTION/CEMENTATION DATA SHEET
BILLED CAN DATA SHEET
OPEN UNREACTED SS&C INVENTORY SHEET
CEMENTATION LOG BOOK

6. PERFORMANCE

6.1 Preliminary Instructions

6.1.1 VERIFY Flow Reading on FI-20MB-1 north of glove box HA-20MB is greater than 20% and valve V-28311-25A is closed whenever performing Section 6.5.

6.1.2 VERIFY glovebox negative pressure relative to room pressure is between 0.5 and 2.0 in. WG to ensure contamination containment.

6.1.3 ENSURE failed or expired gloves/bags have been replaced or covered with pie plate.

6.1.4 VISUALLY inspect electrical cords for damage PRIOR to using electrical equipment in glovebox HA-20MB.

6.1.5 REPLACE equipment or complete repair of damaged cord PRIOR to equipment use.

6.2 Valve and Switch Line-up

6.2.1 ENSURE valves are positioned as follows before initial weekly start-up.

Valve	Position	Location
V-20MB-1	Close	North end of HA-20MB
V-20MB-2	Close	Middle of HA-20MB
V-20MB-3	Close	Middle of HA-20MB
V-20MB-4	Close	North end of HA-20MB
V-20MB-5	Close	North end of HA-20MB
V-20MB-6	Close	Middle of HA-20MB

6.2.2 ENSURE switches are positioned as follows before initial weekly start-up.

Switch	Position	Switch	Position
HS-20MB-1	OFF	HS-20MB-4	OFF
HS-20MB-2	OFF	HS-20MB-5	OFF
HS-20MB-3	OFF	HS-20MB-6	OFF

6.2.3 ENSURE valves are positioned as follows after weekly shutdown.

Valve	Position	Location
V-20MB-1	Close	North end of HA-20MB
V-20MB-2	Close	Middle of HA-20MB
V-20MB-3	Close	Middle of HA-20MB
V-20MB-4	Close	North end of HA-20MB
V-20MB-5	Close	North end of HA-20MB
V-20MB-6	Close	Middle of HA-20MB

6.2.4 ENSURE switches are positioned as follows after weekly shutdown.

Switch	Position	Switch	Position
HS-20MB-1	OFF	HS-20MB-4	OFF
HS-20MB-2	OFF	HS-20MB-5	OFF
HS-20MB-3	OFF	HS-20MB-6	OFF

6.3 Water Make-up

6.3.1 IF make-up water tank is at OR below low level, fill as follows:

a. PLACE transfer bucket under sanitary water line by valve V-2940-23C.

b. OPEN valve V-2940-23C to fill bucket, THEN CLOSE valve V-2940-23C.

c. TRANSFER water from bucket into make-up water tank.

d. REPEAT Step 6.3.1 as necessary until water is between low level and high level.

6.3.2 IF Chillwater Tank is at OR below low level, fill as follows:

a. ENSURE level of make-up water tank is above low level.

b. OPEN valve V-20MB-1.

c. OPEN valve V-20MB-2.

d. WHEN Chillwater Tank is between low level and high level, CLOSE valves V-20MB-2 and V-20MB-1.

e. REPEAT Step 6.3.2 as necessary.

6.4 Chiller Operation

NOTE

Chiller operation is necessary to maintain water in Chillwater Tank at 2-10°C to allow maximum SS&C throughput per batch. This task may be performed when necessary.

When power to chiller is ON, pump will be audible and light illuminates on switch.

6.4.1 WHEN chiller is required, perform the following:

a. OPEN valves V-20MB-4 and V-20MB-5.

b. START chiller with power switch DS-20MB-1.

6.4.2 WHEN chiller is not required, perform the following:

a. STOP with power switch DS-20MB-1.

b. CLOSE valves V-20MB-4 and V-20MB-5.

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6.5 Prepare Solids For Calcium Reacting

6.5.1 RECORD items to be processed in CEMENTATION LOG BOOK <u>AND</u> CROSS reference items to those listed in daily Operating Instructions.

WARNING

To limit dispersible Pu to 100 grams. maximum Pu for individual containers with dry SS&C is ≤100 grams.

CRITICALITY

Amount of plutonium allowed in HA-20MB process area is not to be more than 500 grams above HA-20MB hold-up.

Amount of plutonium allowed in HA-20MB airlock is not to exceed 500 grams.

Stacking of containers is not allowed.

6.5.2 SEAL IN SS&C items per ZO-170-301.

6.5.3 RECORD Item Number and Element Weight for item to be processed on CHARGE PREP DATA SHEET.

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WARNING

Total unreacted SS&C in open containers (including material held in slip-lid cans) is limited to less than 8500 grams in HA-20MB.

6.5.4 WEIGH item AND RECORD on CHARGE PREP DATA SHEET.

6.5.5 ENSURE addition of this weight will not cause running inventory on OPEN UNREACTED SS&C INVENTORY SHEET to exceed 8500 grams of SS&C before continuing.

CAUTION

Worknit, HD, Smitty or leather gloves shall be worn when opening cans and handling sharp edged items.

6.5.6 OPEN item AND TRANSFER to 4-mesh and 8-mesh sieve trays with empty catch pan.

6.5.7 REMOVE foreign material AND PLACE into waste container.

NOTE

Multiple passes may be required to crush material. Material that appears to be larger than ¼ in. shall be slowly dropped (1-2 pieces at a time) into crusher to keep from plugging. Material larger than ¼ in. may be placed in jaw crusher pan and gently struck with hammer to help identify calcium pieces so they may be individually fed into jaw crusher. Flattening of calcium pieces with hammer in jaw crusher pan is permitted for large calcium pieces prior to dropping into jaw crusher.

Crusher throat shall not be completely filled with material.

Crusher hopper shall be in place when feeding material.

6.5.8 CRUSH feed material greater than 8-mesh.

a. PLACE jaw crusher pan at outlet of crusher.

b. START crusher with switch HS-20MB-2.

c. FEED material into crusher slowly.

d. IF crusher becomes jammed, STOP crusher with switch HS-20MB-2.

   1. REMOVE debris as necessary to unjam crusher.

e. WHEN crusher pan is full, STOP crusher with switch HS-20MB-2.

f. EMPTY crusher pan into catch pan with 8-mesh sieve.

g. REPEAT Step 6.5.8 with remainder of material.

h. MATERIAL larger than 8-mesh shall be recycled through crusher per Step 6.5.8.

   1. AFTER 2 passes through crusher, Team Leader may approve addition of > 8-mesh material to slip-lid can.

6.5.9 PLACE up to 2000 grams of material into a covered slip-lid can as follows:

a. RECORD Slip-lid Can Number on CHARGE PREP DATA SHEET.

b. WEIGH Empty Slip-lid Can with Lid AND RECORD on CHARGE PREP DATA SHEET.

NOTE

Final weight of SS&C in slip-lid can shall not exceed 2000 grams.

c. TRANSFER material from catch pan to slip-lid can AND REPLACE lid.

d. WEIGH Covered Slip-lid Can with Material AND RECORD on CHARGE PREP DATA SHEET.

e. CALCULATE Weight of Material in Slip-lid Can AND RECORD on CHARGE PREP DATA SHEET.

f. ADD slip-lid item to OPEN UNREACTED SS&C INVENTORY SHEET.

g. REPEAT Step 6.5.9 until all material is removed from catch pan.

6.5.10 CALCULATE Slip-lid Can Element Weight for each slip-lid can AND RECORD on CHARGE PREP DATA SHEET.

6.5.11 SIGN AND DATE CHARGE PREP DATA SHEET.

6.5.12 REPEAT Steps 6.5.3 through 6.5.11 as needed.

6.6 React Calcium

6.6.1 ASSIGN next consecutive Reaction Batch Number AND RECORD on CALCIUM REACTION/CEMENTATION DATA SHEET.

6.6.2 IF processing new slip-lid can.
THEN RECORD Slip-lid Can Number, Slip-lid Can Element Weight, and Weight of Material in Slip-lid Can from CHARGE PREP DATA SHEET on CALCIUM REACTION/CEMENTATION DATA SHEET
OR
IF processing a recycled slip-lid can,
THEN RECORD Slip-lid Can Number, Unreacted Material Element Weight as Slip-lid Can Element Weight, and Unreacted Material Weight as Weight of Material in Slip-lid from previous CALCIUM REACTION/CEMENTATION DATA SHEET on current CALCIUM REACTION/ CEMENTATION DATA SHEET.

6.6.3 WEIGH Empty Mixing Bowl AND RECORD on CALCIUM REACTION/ CEMENTATION DATA SHEET.

6.6.4 PLACE mixing bowl onto reactor mixer.

6.6.5 FILL mixing bowl with chilled water from Chillwater Tank as follows:

a. OPEN valve V-20MB-6.

b. FILL graduated cylinder by temporarily opening valve V-20MB-3 .

c. EMPTY into mixing bowl.

d. REPEAT 6.6.5.b. and 6.6.5.c. until 1400-1500 ml of water is added to mixing bowl.

e. CLOSE valves V-20MB-3 and V-20MB-6.

NOTE

To reduce need to remove unreacted material from hopper, partial transfers from a slip-lid may be utilized.

CRITICALITY

No more than 180 grams of plutonium in any one liquid bearing container.

6.6.6 TRANSFER material into auger hopper from slip-lid can.

6.6.7 POSITION auger over mixing bowl.

6.6.8 ENSURE EMERGENCY STOP button is enabled.

6.6.9 ENSURE reactor mixer speed control lever is in speed (1) setting.

6.6.10 POSITION ON-OFF switch on side of reactor mixer to ON.

6.6.11 START reactor mixer with switch HS-20MB-4.

6.6.12 SET auger speed between 5 and 6 on speed control knob.

6.6.13 START auger with switch HS-20MB-1.

6.6.14 PERIODICALLY monitor (every 10-15 minutes) mixing bowl temperature as displayed on MIXER #1 HIGH TEMPERATURE alarm switch and MIXER #1 HIGH HIGH TEMPERATURE alarm switch during addition of material.

a. <u>IF</u> mixing bowl temperature is ≥ 80°C, <u>THEN</u> RESPOND per Step 6.11.1.

6.6.15 ADJUST auger speed between 0 and 10 on speed control knob as necessary to control reaction, temperature, and foaming.

6.6.16 IF excessive foaming occurs, adjust feed rate or STOP addition of material from auger with switch HS-20MB-1 temporarily until foaming subsides,
THEN RESTART auger with switch HS-20MB-1 OR CONTINUE with Step 6.6.17.

6.6.17 IF excessive thickening of reaction bowl material from heat and evaporation occurs,
THEN ADD approximately 100-200 ml of water from chillwater tank to reaction bowl as follows:

a. PLACE tubing from Chillwater Tank into graduated cylinder.

b. OPEN valves V-20MB-6 and V-20MB-3 until desired amount of water is in graduated cylinder,
THEN CLOSE valves V-20MB-3 and V-20MB-6.

c. ADD water from graduated cylinder to mixing bowl AND RECORD amount in Comment section of CALCIUM REACTION/CEMENTATION DATA SHEET.

d. REPEAT Step 6.6.17 as necessary.

6.6.18 WHEN auger is empty, more material may be added into auger hopper by REPEATING Steps 6.6.2 and 6.6.6 until up to 2000 grams have been added to reaction batch,
THEN STOP auger with switch HS-20MB-1.

6.6.19 ALLOW material to continue mixing for approximately 20 minutes or until reaction is complete, (temperature STOPS increasing and additional foaming ceases),
THEN STOP reactor mixer with switch HS-20MB-4.

6.6.20 IF required, TRANSFER any material remaining in auger into original slip-lid can.

6.6.21 RECORD Unreacted Material Weight on CALCIUM REACTION/ CEMENTATION DATA SHEET.

6.6.22 CALCULATE Unreacted Material Element Weight AND RECORD on CALCIUM REACTION/CEMENTATION DATA SHEET.

6.6.23 RECYCLE unreacted material through process per Section 6.6.

6.6.24 CALCULATE Material Reacted Weight AND RECORD on CALCIUM REACTION/CEMENTATION DATA SHEET.

6.6.25 CALCULATE Element Weight in Batch from slip-lid can AND RECORD on CALCIUM REACTION/CEMENTATION DATA SHEET.

6.6.26 CALCULATE Totals AND RECORD on CALCIUM REACTION/CEMENTATION DATA SHEET.

6.6.27 REMOVE item material weight from OPEN UNREACTED SS&C INVENTORY SHEET.

6.7 Cement Reacted Solids

NOTE

To reduce losses when adding cement into slurry, make multiple additions to achieve required cement quantity.

CRITICALITY

No more than 180 grams of plutonium in any one liquid bearing container.

6.7.1 ADD approximately 1500 grams of dry cement to mixing bowl.

6.7.2 IF mixer fails or bowl is too full, cement may be manually mixed.

6.7.3 WHEN mixing is complete, STOP cement mixer.

6.7.4 IF needed, add additional cement as required to obtain desire mixture as follows:

a. ADD dry cement to mixing bowl AND RECORD amount in Comment section of CALCIUM REACTION/CEMENTATION DATA SHEET.

b. IF mixer fails or bowl is to full, cement may be manually mixed.

c. WHEN mixing is complete, STOP cement mixer.

d. REPEAT Step 6.7.4 as necessary.

6.7.5 IF material is dry, add water to mixture as follows:

a. PLACE tubing from Chillwater Tank into graduated cylinder.

b. OPEN valves V-20MB-6 and V-20MB-3 until desired amount of water is in graduated cylinder.
THEN CLOSE valves V-20MB-3 and V-20MB-6.

c. ADD water from graduated cylinder to mixing bowl AND RECORD amount in Comment section of CALCIUM REACTION/CEMENTATION DATA SHEET.

d. IF mixer fails or bowl is too full, cement may be manually mixed.

e. WHEN mixing is complete, STOP cement mixer.

f. REPEAT Step 6.7.5 as necessary.

6.7.6 POSITION ON-OFF switch on side of mixer to OFF.

6.7.7 REMOVE mixing bowl from mixer.

6.7.8 REMOVE excess material from B Flat Beater AND ADD to mixing bowl.

6.7.9 WEIGH mixing bowl AND RECORD as Final Cement Mixing Bowl Weight on CALCIUM REACTION/CEMENTATION DATA SHEET.

6.7.10 CALCULATE Percent Pu in Cement AND RECORD on CALCIUM REACTION/CEMENTATION DATA SHEET.

6.7.11 IF Percent Pu in Cement is > 2%,
THEN CONTACT Team Leader and Technical Support before continuing.

6.7.12 SIGN AND DATE CALCIUM REACTION/CEMENTATION DATA SHEET.

6.8 Billet Can Preparation

NOTE

Billet cans may be used to seal in required cement for this process.

6.8.1 LABEL billet can(s) with ID Number assigned by Special Nuclear Material (SNM) Specialist or Team Leader.

6.8.2 RECORD Billet Can Number on BILLET CAN DATA SHEET.

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NOTE

Weight may be obtained after seal-in.

6.8.3 WEIGH empty Billet Can.

- RECORD as first Billet Can Weight on BILLET CAN DATA SHEET.
- RECORD as TARE WEIGHT on can.
- SEAL IN billet can per ZO-170-301.

6.9 Fill Billet Cans

6.9.1 RECORD Reaction Batch Number and Percent Pu in Cement from CALCIUM REACTION/CEMENTATION DATA SHEET on BILLET CAN DATA SHEET.

6.9.2 TRANSFER cement from mixing bowl until billet can(s) is within 3/4 in. of top or mixing bowl is empty.

6.9.3 WEIGH Billet Can After Addition AND RECORD on BILLET CAN DATA SHEET.

6.9.4 REPEAT Steps 6.9.1 through 6.9.3 to fill billet cans and empty Mixing Bowls completely.

a. SCRAPE out mixing bowl using spatula.

6.9.5 CALCULATE Weight of Cement Added to Billet Can AND RECORD on BILLET CAN DATA SHEET.

6.9.6 CALCULATE Element Weight Added to Billet Can AND RECORD on BILLET CAN DATA SHEET.

CRITICALITY

Stacking of containers is not allowed.

6.9.7 REPLACE lid on billet cans, THEN ALLOW cement in container to cure for 24 hours.

a. ENTER on BILLET CAN DATA SHEET TIME and DATE billet is filled.

6.9.8 INSPECT cement for free liquids.

a. FREE standing liquid shall be recycled into a subsequent reaction batch.

b. IF water was removed. ALLOW contents of container to cure as necessary.

NOTE

Scales shall be set up within 24 hours for accountability purposes.

6.9.9 WEIGH billet can per ZO-200-101 AND RECORD Final Billet Can Weight on BILLET CAN DATA SHEET.

NOTE

Contents of billet can shall have no free liquids before placing inside waste drum.

Cemented SS&C to be handled as mixed waste.

6.9.10 SEAL OUT billet cans from glovebox per ZO-170-299 into a vented PVC bag.

6.9.11 SIGN AND DATE BILLET CAN DATA SHEET.

6.10 Respond to Material Spills

6.10.1 IF container holding unprocessed material is spilled, SWEEP up spilled material AND REPLACE in container.

a. REWEIGH container and make changes to CHARGE PREP DATA SHEET as necessary.

6.10.2 IF abnormal solution spillage occurs, SHUTDOWN process per Step 6.11.3 (EMERGENCY RESPONSE) AND CLEAN UP spill.

6.10.3 IF container holding cemented SS&C is spilled, CLEAN up spilled material AND REPLACE in billet can.

a. REWEIGH container and make changes to BILLET CAN DATA SHEET as necessary.

6.11 Alarm/Emergency Responses

NOTE

The HIGH TEMPERATURE alarm is set at 80°C and is interlocked to shut down the feed auger.

6.11.1 RESPOND to MIXER #1 HIGH TEMPERATURE alarm.

a. REMOVE power to feed auger with switch HS-20MB-1.

b. WHEN vessel temperature is less than 80°C, RESET alarm by pressing #1 HIGH RESET.

c. ALLOW temperature to cool to < 60°C,
THEN GO TO Step 6.6.13.

NOTE

The HIGH-HIGH TEMPERATURE alarm is set at 90°C and is interlocked to shutdown feed auger. This provides a back-up for HIGH TEMPERATURE alarm.

6.11.2 RESPOND to MIXER #1 HIGH-HIGH TEMPERATURE alarm.

a. REMOVE power to feed auger with switch HS-20MB-1.

b. WHEN vessel temperature is less than 80°C, RESET alarm by pressing #1 HIGH HIGH RESET.

c. INITIATE investigation into failure of #1 HIGH TEMPERATURE interlock, IF interlock failed.

d. WHEN interlock investigation is resolved, RESTART process per Step 6.6.13, after temperature has cooled to less than 60°C.

6.11.3 EMERGENCY RESPONSE or other abnormal conditions occur.

a. SHUT OFF switches outside glovebox (HS-20MB-1, HS-20MB-2, HS-20MB-3, HS-20MB-4, HS-20MB-5, and HS-20MB-6).

b. SHUT OFF chiller with switch DS-20MB-1.

c. PUSH EMERGENCY STOP button.

d. RESTART system per Technical Support and Team Leader direction.

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7. **BIBLIOGRAPHY**

7.1 OSD-Z-184-00020, CH-TRU Solid Waste Disposal

7.2 OSD-Z-184-00025, Glovebox Gloves & Differential Pressure

7.3 CPS-Z-165-80634, Sand, Slag And Crucible Cementation Process, Glovebox HA-20MB

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Attachment 1 - CHARGE PREP DATA SHEET

Step		Formula		
6.5.3	Item Number			
6.5.3	Element Weight		(A) g	
6.5.4	Item Weight		(B) g	
6.5.9.a.	Slip-lid Can Number			
6.5.9.b	Empty Slip-lid Can with Lid Weight		(C) g	(D) g
6.5.9.d.	Covered Slip-lid Can with Material Weight		(E) g	(F) g
6.5.9.e.	Weight of Material in Slip-lid Can	G = E - C or H = F - D	(G) g	(H) g
6.5.10.	Slip-lid Can Element Weight	$I = \frac{G}{G + H} \times A$ or $J = \frac{H}{G + H} \times A$	(I) g	(J) g
NCO:		Date:		
Team Leader:			Date:	

** Unused boxes are ZERO when used in an equation.

Comments: ____

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Attachment 2 - CALCIUM REACTION/CEMENTATION DATA SHEET

Step		Formula	6.6.1 Reaction Batch Number:		Totals
6.6.2	Slip-lid Can Number				
6.6.2	Slip-lid Can Element Weight		(A) g	(A) g	g
6.6.2	Weight of Material in Slip-lid Can		(B) g	(B) g	Note: Slip lid can element weights must total <180 grams Pu
6.6.3	Empty Mixing Bowl Weight		(C) g		
6.6.21	Unreacted Material Weight		(D) g	(D) g	
6.6.22	Unreacted Material Element Weight	$E = \frac{D}{B} \times A$	(E) g	(E) g	
6.6.24	Material Reacted Weight	F = B - D	(F) g	(F) g	g
6.6.25	Element Weight in Batch	G = A - E	(G) g	(G) g	(H) g
6.7.9	Final Cement Mixing Bowl Weight		(I) g		
6.7.10	Percent Pu in Cement (X.XX%)	$J = \frac{H}{I - C} * 100$	(J) %		
NCO:		Date:			
Team Leader:			Date:		

** Unused boxes are ZERO when used in an equation.

Comments: ____

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____

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Attachment 3 - BILLET CAN DATA SHEET

Step		Formula	6.8.2 Billet Can Number:		
6.8.3	Billet Can Weight		(A) g	(A) g	
6.9.1	Reaction Batch Number				
6.9.1	Percent Pu in Cement (X.XX%)		(B) %	(B) %	
6.9.3	Billet Can Weight After Addition		(C) g	(C) g	Total Billet Can Element Weight
6.9.5	Weight of Cement Added to Billet Can	D = C - A	(D) g	(D) g	
6.9.6	Element Weight Added to Billet Can	$E = \frac{D \times B}{100}$	(E) g	(E) g	g
6.9.9	Final Billet Can Weight		g		
NCO:		Date:			
Team Leader:			Date:		

Comments:____

____

____

6.9.7.a. Billet can filled ____________ TIME ____________ DATE

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Attachment 4 - OPEN UNREACTED SS&C INVENTORY SHEET

Item ID	Item Material Weight In/Out IN	 OUT	Total HA-20MB OPEN SS&C Weight *

* Total running inventory of open SS&C material shall be < 8500 grams

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APPENDIX G

GENERAL DESCRIPTION OF HANFORD RESIDUE CATEGORIES: INCINERATOR ASH AND OXIDE<30WT%(PU+U)

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FLUOR DANIEL HANFORD, INC.

INTEROFFICE CORRESPONDENCE

To:	J. J. McKibben, Acting Manager Project Management	Date:	February 15, 2000
From:	T. J. Venetz, Engineer Materials Planning and Disposition	Telephone:	376-9669

cc:

R. R. Borisch	R3-57
L. T. Cunningham	R3-56
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A. L. Ramble	T5-54
RRB/LB	R3-57

Subject: INCINERATOR ASH AND LOW ASSAY PLUTONIUM OXIDE RESIDUES WHITE PAPER

The attached document contains information on incinerator ash and plutonium oxide residues that was compiled at the verbal request of Mr. R. R. Leugemors, BWXT.

If you need additional information on this matter, you may reach me at 373-9669.

rs

Attachment

A-6002-122 (08/98)

February 15, 2000 ATTACHMENT

General Description Of Hanford Residue Categories:
Incinerator Ash And Oxide <30 wt % (Pu+U)

Purpose:
The purpose of this paper is to provide general process knowledge and chemical and physical characterization information on two categories of plutonium bearing residues stored at the Plutonium Finishing Plant (PFP) that are under consideration for stabilization via a cementation process. The two residue categories are plutonium bearing incinerator ash and oxides with less than 30 wt % Special Nuclear Material (SNM) (i.e. Pu + U)

Incinerator Ash
Ash is mixture of coarse, granular, fine and very fine particulate materials from the furnaces. The ash is not homogeneous and may contain bits of tramp metal, unburned feed materials and carbon from the incomplete oxidation of some feed materials. The Hanford incinerator ash category contains about 530 items. These items consist of either individual cans of ash or large metal cans (industry-denoted as a 50 pound lard can) containing numerous individual cans of ash. Thus, the item number is not a count of the number of cans of ash. There are three broad components that comprise the incinerator ash category:

- ash which was generated at the Hanford 232-Z incinerator
- ash which was generated at Rocky Flats Plant (RFP) [site is currently called the Rocky Flats Environmental Technology Site (RFETS)]
- ash which was received from the Battelle Northwest National Laboratory (BNNL) [currently Pacific Northwest National Laboratory (PNNL)].

The majority of the Hanford incinerator ash inventory consists of about one hundred lard cans, each of which contains from 5 to 7 individual smaller cans. The incinerator ash items from RFP consist of about 410 items which are 7 inch food pack containers. The ash received from BNNL consists of about 20 of the 7 inch food pack cans of ash. The average plutonium content of incinerator ash for which there is net weight data available is 12.3 weight per cent plutonium. Only 13 items are recorded as having a Pu^{240} content greater then 7 percent.

The incinerators were used to process combustible residues that were generated by plutonium processing and recovery operations. The combustible residues were burned to reduce volume, destroy volatile constituents and recover plutonium. Large quantities of ash were leached in boiling nitric acid to recover the plutonium, and some of this ash was re-burned prior to dissolution. The items in the present inventory had not been processed when the Plutonium Finishing Plant (PFP) continuous dissolvers were shut down.

Rocky Flats Incinerator Ash
The RFP ash was produced in an oxygen-purged, hand-fed, self-sustaining incinerator maintained at about 700° C.[Trip Report, 65454-83-134, C.H. Delegard, November 15, 1983]. The incinerator system included a ball mill that was generally used to pulverize

the ash as it was generated. The ash was milled to pass through a 100-mesh screen, but may contain some of the particles that are retained on a 20-mesh sieve.

Source combustibles which produced RFP ash consisted of plastic such as polyvinyl chloride (PVC) (45 percent feed) and polyethylene/polypropylene (35 percent feed), paper (5 percent feed), liquid (5 percent feed), drybox gloves (4 percent feed), filters with carbon (3 percent feed), metal (2 percent feed), and wood (1percent feed).

The ash composition varies widely and was generally analyzed only for plutonium. The major ash components are silica (15 to 75 percent, but typically 45 percent) and carbon (5 to 40 percent, but generally about 20 percent); minor components such as aluminum oxide, calcium oxide, iron oxide, and sodium oxide can normally vary from 1 to 10 percent. [T. C. Johnson, RFP-250, Recovery of Plutonium from Incinerator Ash at Rocky Flats, 1976][C. H. Delegard, RHO-RE-SA-95P, Plutonium Dissolution from Rocky Flats Plant Incinerator Ash, June 1985[[C. H. Delegard, SD-CP-DTR-005, Laboratory Tests on Plutonium Recovery from Rocky Flats Ash Using Nitric Acid-Fluoride Leaching, 3-30-84]. Table 1 shows the laboratory analysis for typical RFP incinerator ash received at PFP. Additional analyses are reported in Table 4 and 5.

Table 1. Typical RFP Incinerator Ash Composition*

Constituent	Ash (Wt %)
Aluminum oxide	3.3
Barium Oxide	0.9
Boron Oxide	1.8
Calcium Oxide	4.0
Chromium Oxide	0.7
Copper Oxide	1.0
Iron Oxide	5.7
Lead Oxide	0.8
Magnesium Oxide	4.6
Manganese Oxide	0.1
Nickel Oxide	0.5
Phosphorus Oxide	0.0
Potassium Oxide	0.7
Plutonium Oxide	2.8
Silicon Oxide	48.5
Sodium Oxide	1.2
Tantalum Oxide	0.4
Tin Oxide	0.1
Titanium Oxide	1.4
Carbon	22.0
Total	100.5

* Data from RFP-2520

The metal ions, except for carbon, are reported as oxides. Analyses did indicate that some incinerator ash contained an average of 0.6 wt percent fluoride and 2.5 wt percent chloride [J.L. Long, "Analysis of Incinerator Ash & Heel, Internal Rocky Flats Job Report No. 1-74, DPA 950348, January 4, 1947]. The oxide is the thermodynamically stable form of most metals from an oxygen rich incineration process and is expected to be the predominant species formed as a result of incineration. However, under the incineration conditions, other species could have been formed such as chloride salts from the reaction with HCl generated from the decomposition of polyvinyl chloride (PVC), carbonates from the reaction with CO_2, and silicates and aluminates depending on the initial source of the silicon and aluminum. The more reactive alkali and alkaline metals are not characteristically found in nature as the oxide and these metals would tend to form chlorides, carbonates and silicates. Delegard specifically mentioned the presence of calcium silicate and lead ferrate in ash received from RFP. He also mentioned that incinerator ash received from RFP contained pieces of glass, bits of metal and varying amounts of incompletely burned carbonaceous materials.

The RFP incinerator ash will probably be characterized as Resource Conservation and Recovery Act (RCRA) hazardous by the derived-from rule. The hazardous constituents include F-listed wastes, chromium (D007) and lead (D008). It appears that leaded gloves must have been burned during early RFP campaigns because some "old" ash contains more than 50 wt percent lead.

All of the RFP ash presently stored at Hanford was subsequently re-burned to meet PFP vault storage requirements. Most of the items were re-burned in oxygen-rich tube furnaces in Glovebox HA-40-F, located in Room 169 of the 234-5Z building [PFD-Z-180-00005, Process Flowsheet for HA-40-F Calcination, May 25, 1984]. The procedure mandated that the "... ash shall be re-burned at 600° C for four hours with good oxygen contact. Heating rate shall be carefully controlled between 400° C to 600° C, depending on fuel value. Air shall be supplied for dilution of oxygen, as may be required, for ash with high fuel value (i.e. large amounts of carbon)." The calciners were equipped with two paddles operating up to 12 rpm to stir/agitate the ash and ensure good ash-oxygen contact. Those items that were not re-burned in the HA-40-F calciners were re-burned in the furnace in glovebox HC-21C. This re-burning further reduced the carbon content. All the RFP items met the PFP Loss on Ignition (LOI) requirements for vault storage after re-burning. The LOI tests were performed at 450° C because there was volatilization of salts when the tests were carried out at 1000° C.

As mentioned earlier, most of the resulting ash was treated to recover plutonium. Plutonium recovery was achieved by leaching ash in boiling 11<u>M</u> nitric acid containing 0.1 to 0.2 <u>M</u> fluoride ion. Ash was processed in the continuous dissolvers in the Plutonium Reclamation Facility (PRF) that was used for sand, slag & crucible (S&C) dissolution. Several hundred cans of both RFP and 232-Z ash were processed at PFP. Laboratory tests were made on the recovery of plutonium from RFP incinerator ash (M. J. Rasmussen and H. W. Crocker, Recovery of Plutonium From Incinerator Ashes, HW-72285, January 15, 1962) (C. H. Delagard, Laboratory Tests on Plutonium Recovery from Rocky Flats As Using Nitric Acid-Calcium Fluoride Leaching, SD-CP-DTR-005, March 30, 1984). There was no mention of unexpected, energetic reactions when RFP incinerator ash was contacted with boiling (about 115°C) 11M nitric acid using CaF_2 as the fluoride source.

PFP Incinerator Ash

The 232-Z incinerator was conceived as a way to reduce the volume of combustible wastes for recovery of plutonium from "various miscellaneous solid wastes" generated at both the 234-5Z Building and the 231-Z Building. The incinerator was a dual-chambered, externally heated, muffle-type incinerator fed by chopped Pu-bearing waste that entered the incinerator glovebox via a continuous wire-mesh conveyor belt. Plant operations began in January 1962 and were shut down in 1973. The system occasionally experienced operating problems due to equipment failures and various mechanical problems. Smoking, backfiring, and temperature differentials within the incinerator itself occurred as occasional problems, along with jamming of the chopper feed belt. The lack of good air flow control was a basic design flaw. [HNF-EP-0924, History and Stabilization of the PFP Complex, Hanford Site]. Typical operating conditions for the 232-Z incinerator furnace included primary combustion chamber temperature of 700°C to 800°C and about 20 minutes residence time in the furnace (full residence time range was from 6 to 60 minutes based on the belt speed capability of 2 to 20 inches per minute through a heated chamber that was 9 feet 10 inches long. Typical belt speed was 6 inches per minute).

Panesko [Internal Letter J.V. Panesko to D. G. Harlow, March 18, 1975, Information on Z Plant Incinerator] [J. V. Panesko, ARH-1981, Batch Dissolution of Incinerator Ash, February 1971] indicated that 232-Z incinerator feed was mostly PVC plastic with 25 percent rags and paper (towels and cartons). Cardboard was added to achieve a 50-50 plastic-paper mix. He also indicated 5 percent asbestos in one feed material. Only the fingertips of leaded glovebox gloves were incinerated. Process oils absorbed onto paper towels were also incinerated. All material charged to the furnace was sorted and chopped. The 232-Z incinerator process operated such that feed was sent through the chopper into a bin from which it then exited via a rubber belt with cleats, it then fell onto the vibrating chute, and then moved onto the continuous wire mesh conveyor belt and into the furnace.

The PFP Safety Analysis Report (SAR) [WHC-SD-CP-SAR-021 Revision 0, page 9C-11] indicates that the ash produced by the 232-Z incinerator routinely contained on the average 10% plutonium. The range of plutonium in ash varied from 3 to 20 % plutonium.

In a process test conducted in 1970 to determine processing advantages gained by re-burning the normal incinerator ash, [Evaluation of Process Test PRF-68-2, Re-burning of Incinerator Ash, dated July 6, 1970], it was reported that re-burning resulted in a 45 percent reduction in volume, a 36 percent reduction in the weight of the ash and a "reduction of tars and organic material in the ash." However, they also reported a 14 percent loss of plutonium which suggests that the weight and volume data is biased high. In later studies, Panesko reported "the average weight loss of the first three ashes was approximately 15.0 percent." The ash batches were described as ranging from homogeneous fines to coarse mixtures containing charcoal chunks and fibers.

The re-burning changed the color of the ash from a gray-black to a dark tan. The incinerator operating conditions for the 1970 process test were: nominal temperatures of primary inlet was 700^{0}C, primary outlet was 800^{0}C and secondary stage was 800^{0}C. The incinerator belt speed was 6 inches/minute; air flows were 5 cfm for the primary inlet, 7 cfm for the primary outlet, and 8 cfm for the secondary. It was reported during laboratory dissolution experiments "of re-burned and control ash", that dissolution of re-burned ash yielded a lighter colored and less tarry dissolver heal with smaller undissolved particles than that for regular ash. The regular ash foamed excessively during acid dissolution even after the addition of antifoam, while the re-burned ash foaming problem was easily controlled by the addition of antifoam." In a test to physically fractionate the ash [letter A. H. Case to L. A. Grande, Incinerator Ash, January 8, 1970], the ash was described as about 72.5 percent coarse and 27 percent fines. In one test, the ash was slurried in water and there was no mention of any heat generated from dissolution of any salts/oxides.

Data on the analysis of PFP generated incinerator ash is sparse compared to information on RFP incinerator ash. The result of an analysis on PFP incinerator ash can number 85 is shown in Table 2. The oxide compound is a calculated value resulting from an analysis of the element concentration.

Table 2. PFP Incinerator Ash Composition

Constituent	Ash (Wt %)
Barium Oxide	0.67
Calcium Oxide	0.17
Chromium Oxide	0.44
Chloride	0.24
Iron Oxide	10.01
Manganese Oxide	0.09
Nickel Oxide	0.10
Plutonium Oxide	17.53
Silicon Oxide	11.98
Zinc Oxide	0.12
Carbon	28.0
Total	69.35

The PFP SAR indicates that the major cations in ash include sodium, potassium, magnesium, calcium and iron, but references were not cited. The presence of chloride would suggest that some of the more reactive metals would be present as chloride salts. Analysis of incinerator slag [Letter, V. L. Schuelein to C. M. Peabody and R. E. Felt, Analysis of 232 Incinerator Slag, May 30, 1973] indicated the presence of a number of

cations. Their concentration in decreasing order (> 10,000 ppm) were silicon, lead, aluminum, calcium, magnesium, zinc, gallium, iron, and nickel.
Consequently, Hanford generated incinerator ash is not expected to contain target levels of hazardous materials.

Other General Remarks relating to Ash and Cementation of Ash
There should be insignificant generation of gases during cementation of ash. The ash material was oxidized at temperatures of around 650^{0}C or higher.

Any alkali/alkaline metals, i.e. Na, would have been oxidized to the oxide. In the case of SS&C there is a Ca metal that would be oxidized by water to form the oxide and hydrogen. There could be tramp metal, ie. Iron nuts and bolts, but they would not be oxidized by water.

There is the possibility of small particles of Pu metal in the ash which might not have been oxidized. These could react with water and liberate hydrogen. But the Pu would be widely-dispersed and in small concentration, so the rate of hydrogen generation would be slow and not lead to flammable mixture. SS&C would contain more particulate Pu metal than the ash.

We do not have any heat of reaction data for ash. Sodium oxide is reported to dissolve in water with the liberation of considerable heat. The other alkai/alkaline metal oxides do not dissolve with the liberation of much, if any, heat, i.e. BaO MgO, K_20. But the real issue is how much if any sodium oxide is there and what is its concentration. As we have stated there is no analytical data that indicates that the Na is present as the oxide. With the presence of chloride, carbonate, aluminate and silicate, the sodium oxide content would be small. If there were sodium oxide present, it would be well dispersed in the ash and entrapped in ash particles so the rate of dissolution would be slow and not generate much heat per unit of time. The heat generated from the reaction with Ca or the heat of hydration from the making of cement is probably greater that anything that could come from the dissolution of ash in water.

Cement is a mixture of calcium carbonate, silica, alumina, iron oxide, and calcium sulfate. It is not apparent that any of the components - anions or cations - of ash would cause energetic reactions with cement and water that would be greater than the normal heat evolved from the hydration and setting of cement. The ash components could retard the curing time of the cement and affect the compressive strength of the cement. Ash should be less reactive that SS&C since ash has been stabilized by burning and calcining at an elevated temperature.

Many hundreds of cans of Hanford source incinerator ash have been leached/dissolved in concentrated nitric in both batch and continous dissolvers at Hanford. Persons familiar with that work recall no remarkable heat or gas generation. We would expect less response to water or a mixture of Portland cement and water. We would expect similar behavior from lean plutonium oxide scraps that have been stabilized in a furnace with an air atmosphere. Review of Rocky Flats documentation on aqueous dissolution ash indicate that over 9,000 kilograms of ash have been processed in a continuous cascade dissolver system. No mention is made of reactivity problems; however, plugging of the offgas system with silica was cited as a major problem. Silica is formed by vapor deposition and hydrolysis of silicon tetrafluoride, which is formed by the nitric/HF acid used to dissolve the ash.

There is in the PFP history document, HNF-EP-0924, pages 12-9, reference made to a November 1968 event in which an explosion or implosion of glass vessel ash dissolver occurred. The document states that inspection of the system showed a restriction on the vent pipe. This could have been caused by over-pressurization due to vent line plugging with silca.

Plutonium Oxides/Mixed Oxides/Alloy < 30 weight percent Pu or Pu+U

There are less than 500 items in the plutonium oxides/mixed oxide/alloy <30 Wt percent Pu or Pu + U category. The items are in 35 different PFP category codes. They are typically oxide and mixed oxide residues and some low Pu content alloys, they are summarized in Table 3.

Table 3. Plutonium Oxides/Mixed Oxides/Alloy < 30 weight percent Pu or Pu+U

Sub-category	Category Codes	Percent of total
Rocky Flats Oxides	102, 900	10 %
PFP generated oxides	5,6,19,20,30,41,61,62, 63,64	64 %
Mixed oxides and alloys	51,67,70,73,74,77,78, 175,208,224,404,411, 436,439,442,451,459, 465,466,482,800,850, 950	26%

PFP Generated Oxide Residues

PFP stabilized oxide residue comprises the majority of the material. The low grade oxide residue is plutonium oxide generated from the thermal stabilization of plutonium material recovered from the process gloveboxes that resulted from process spills and powders generated during process operations. The majority of the residue came from Remote Mechanical C (RMC) line operations and from PRF operations. Although some of this material could have contained reactive and organic chemical constituents (i.e., tri-butyl phosphate degradation products), thermal stabilization was required prior to placing the material into vault storage, effectively reducing these constituents to de-minimus levels. The non plutonium constituents remaining will consist of the flowsheet process chemicals (compounds of Al, Ca, Mg, and Mn) and iron, nickel and chromium from corrosion of process equipment.

Rocky Flats Oxide Oxides
The RFP oxide residues (about 10 percent of the total) consist of plutonium oxide recovered from various pyrochemical operations and consequently contain high concentration of chlorides. However thermal stabilization of the materials would have removed all moisture, and reactive or gas generating components. These materials were stabilized to an LOI of less than 1 percent at 450 C, to meet shipping requirements.

Tests were conducted in the analytical laboratory on Rocky Flats plutonium oxides which included washing with dilute sodium hydroxide and/or acid dissolution (11 M nitric acid). [Letter, T. D. Cooper to M. J. Schliebe, Removal of Chloride from Plutonium Oxide Via Washing, May 24, 1988][Letter, C. H. Delegard and D. G. Bouse to K. S. Kalkofen, Characterization, Particle Size and Dissolution Tests of Three Rocky Flats Oxides, August 30, 1985]. There were no reported indications of any unexpected energetic reactions when the oxides were mixed with dilute base, water or nitric acid. The salts were described as consisting of pebble sized particles, fine powder, and some contained black chunks like anthracite. Some of the black chunks were identified as graphite and others appeared to be parts of fractured crucibles. Also encountered were pieces of wire and broken bits of glass and plastic. In one test the scrap was sieved through a US series 20 mesh screen to remove large chunks. Small beads of metal also collected on the screen. The beads were characterized as containing plutonium.

Mixed Oxide and Alloys
Mixed oxide and alloy residues are scrap materials which resulted from 300 Area fuel fabrication research in support of commercial, research, and test reactors. As noted in Table 3 they comprise 23 different PFP category codes, but 62 percent of the items are listed as Pu-U or Pu-EU oxide. The materials vary widely in composition. Almost all the items contain uranium compounds. Aluminum and/or zirconium is also reported to be present in some of the items, which is expected, as these elements were commonly used in reactor fuel compositions. The low grade scrap (non alloy) can be expected to contain materials generated from fuel fabrication operations and glovebox sweepings, such as grinding media, typically tungsten carbide. Organic chemicals in the form of binders and dye lubricants were used in the fuel pelletizing process, but these materials were removed, by thermal stabilization to meet either vault storage or LOI shipping requirements.

Table 4
All reported Rocky Flats ash analysis

	Reference	SD-CP-DTR-007	SD-CP-DTR-007	SD-CP-DTR-007	SD-CP-DTR-005	SD-CP-DTR-005	SD-CP-DTR-005	RFP-2520 (Johnson (anl rpt))	ANL rpt	ANL rpt	ANL rpt	JL Long, PER 1-74, DPA9503 48	JL Long, PER 1-74, DPA9503 48	JL Long, PER 1-74, DPA9503 48
Compound	Sample name	current	middle	old	current	middle	old	table I	BARF1	BARF2 1	BARF3	range low	average comp	range high
Al2O3		10.60	24.70	3.60	13.20	32.60	3.80	3.30	5.26	6.82	10.95	0.95	3.33	5.70
B2O3		4.70	3.50	3.30	3.80	3.90	2.90	1.80	0.18	0.47	0.16	0.32	1.76	3.20
BaO		1.90	1.30	2.30	1.90	1.50	2.30	0.90	1.24	1.21	0.22	-0.58	0.89	1.20
BeO									0.23	0.60	0.05			
C/combust								22.00	4.45	5.06	0.00	7.50	21.75	36.00
CaO		19.40	13.30	7.20	22.20	19.60	7.40	4.00	11.63	8.04	8.07	1.10	4.05	7.00
Ce2O3									0.02	0.02	0.06			
Cl-									1.39	2.38	0.00	0.80	2.70	6.40
Cr2O3		1.40	1.70	0.70	1.50	1.80	0.00	0.70	2.44	2.11	5.65	0.44	0.66	0.88
CuO								1.00	1.05	1.81	1.81	0.63	0.97	1.30
F-												0.30	0.60	1.80
Fe2O3		8.90	12.70	4.90	9.40	14.00	6.00	5.70	11.94	5.16	13.81	1.10	5.70	10.30
Ga2O3									0.15	0.05	0.01			
I-														
K2O								0.70	2.01	17.40	9.31	0.24	0.72	1.20
La2O3														
Li2O									0.06	0.05	0.06			
MgO		4.70	4.30	11.90	5.10	4.40	12.80	4.60	9.96	3.87	6.91	0.83	4.57	8.30
MnO								0.10	2.16	0.93	0.62	0.03	0.06	0.08
MoO3									0.42	0.03	1.45			
Na2O								1.20	2.25	1.95	6.51	0.00	1.20	2.40
Nd2O3									0.00	0.00	0.00			
NiO								0.50	2.13	1.84	2.46	0.25	0.45	0.64
NpO2														
P2O5								0.00	0.30	0.38		0.23		0.23
PbO		0.00	0.00	57.30	0.00	0.00	59.00	0.80				0.58	0.75	0.92
PoO3														
PuO2		21.20	8.30	5.50	23.20	9.50	6.50	2.80	8.69	7.04	18.90	1.80	2.80	3.80
SO3														
SiO2		27.10	27.80	20.20	23.80	24.70	18.10	48.50	23.82	23.17	10.33	14.17	48.49	74.10
SnO								0.10	0.02	0.33	0.33	0.00	0.13	0.25
Ta2O5		0.00	0.00	0.00				0.40	0.20	0.26	0.35	0.00	0.37	0.73
ThO2									0.00	0.00	0.00			
TiO2		2.70	3.10	0.80	2.70	3.20	0.00	1.40	4.64	6.02	0.97	1.00	1.35	1.70
U3O8														
WO3									0.21	0.27	0.37			
ZnO		1.20	0.80	1.30	2.60	2.20	2.60		2.77	2.70	0.60			
ZrO2									0.38	0.01	0.04			
Total		103.80	101.50	119.00	109.40	117.40	121.40	100.50	100.00	100.00	100.00	32.85	103.30	168.13

February 15, 2000

ATTACHMENT

Table 5
Composite Rocky Flats ash composition based on all available analysis

Oxide	min	nominal	max	Comments
Al2O3	0.95	3.30	32.60	low end average with spikes of high Al
B2O3	0.16	1.90	4.70	
BaO	0.22	1.29	2.30	
BeO	0.05	0.30	0.60	
C/combust	0.00	18.00	36.00	wide continuous variation
CaO	0.17	9.51	22.20	
Ce2O3	0.02	0.03	0.06	
Cl-	0.00	2.70	6.40	Uncertainty in this range
Cr2O3	0.00	1.46	5.65	may also be found in the form of tramp metals
CuO	0.63	0.97	1.81	
F-	0.30	0.90	1.80	Uncertainty in this range
Fe2O3	1.10	7.50	14.00	may also be found in the form of tramp metals
Ga2O3	0.01	0.07	0.15	
I-	0.00	0.00	0.00	no data found
K2O	0.24	0.72	17.40	local spikes
La2O3	0.00	0.00	0.00	
Li2O	0.05	0.06	0.06	
MgO	0.83	5.33	12.80	
MnO	0.03	0.51	2.16	
MoO3	0.03	0.63	1.45	
Na2O	0.00	1.80	6.51	
Nd2O3	0.00	0.00	0.00	
NiO	0.10	1.05	2.46	may also be found in the form of tramp metals
NpO2	0.00	0.00	0.00	
P2O5	0.00	0.23	0.38	
PbO	0.00	0.75	59.00	spikes from lead glove incineration
PoO3	0.00	0.00	0.00	
PuO2	1.80	7.83	23.20	
SO3	0.00	1.00	0.00	reported values not likely
SiO2	10.33	28.27	74.10	wide continuous variation
SnO	0.00	0.17	0.33	
Ta2O5	0.00	0.23	0.73	
ThO2	0.00	0.00	0.00	
TiO2	0.00	2.28	6.02	
U3O8	0.00	0.00	0.00	
WO3	0.21	0.28	0.37	
ZnO	0.12	0.80	2.77	
ZrO2	0.01	0.14	0.38	
Total	17.3601	100	338.389	

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APPENDIX H

WASTE PACKAGE DATA

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Dobbin, Kenneth D

From:	Ramble, Alan L
Sent:	Friday, November 19, 1999 3:09 PM
To:	Dobbin, Kenneth D
Cc:	Shaw, Maria E; Ramble, Alan L
Subject:	FW: G Pu in Waste Packages

Ken, some data. More to follow. Al

-----Original Message-----

From:	Baker, Eugene S (Scott)
Sent:	Wednesday, November 17, 1999 9:53 AM
To:	Baker, Eugene S (Scott); Fazzari, Dennis M; Westsik, George A
Cc:	Ramble, Alan L
Subject:	RE: G Pu in Waste Packages

Al has asked for a little more information on what I have mentioned below in my earlier message.

There are two calibration curves that everything in ITC's are counted on.

- < 25 lbs., low density, both combustible and non-combustible (#1)
- dense items or ITC's > 25 lbs. (#2)

Looking at the data below, and classifying the 100 analyses (down from 102 d ie to some confusion in classification), the information can be grouped as follows:

Pu Content	# of items counted by #1	# of items counted by #2
0-2 grams	53	15
2-10 grams	15	9
10-20 grams	1	2
20-30 grams	0	1
30-40 grams	1	1
40+ grams	0	3
Average value	2.16	9.82
High value	35.43	68.53

Based on this information, if you make the assumption that all of the items that would be considered "waste packages" are less than 25 lbs. and do not contain any dense metal items, your CSER evaluation of a waste package containing 2 grams as the "normal and base case condition" would be valid. You would also be correct in pointing out the 30 gram item identified as a contingency. I would feel a little uncomfortable in stating that item to be the " only contingency identified ....in assay data history, " however.

Scott

-----Original Message-----

From:	Baker, Eugene S (Scott)
Sent:	Monday, November 15, 1999 1:22 PM
To:	Fazzari, Dennis M; Westsik, George A
Cc:	Ramble, Alan L
Subject:	RE: G Pu in Waste Packages

I agree with the comments Dennis makes. I have also looked at the ITC results from the NaI counter for 6/1/99 to the present, and can make the following observations:

Pu content	# of items
0-2 grams	69
2-10 grams	24
10-20 grams	3
20-30 grams	1
30-40 grams	2
40+ grams	3
Total	102

Average gram Pu value, all items - 4.5 grams
Average gram value, 0 - 10 gram items (93 items) - 1.7 grams
Highest value for a single item - 68.53 grams

If you look only at items counted 9/1/99 to the present, the numbers change to:

Pu content	# of items
0-2 grams	21
2-10 grams	15
10-20 grams	1
20-30 grams	1
30-40 grams	2
40+ grams	1
Total	41

Average gram Pu value, all items - 6.0 grams
Average gram value, 0 - 10 gram items (36 items) - 2.4 grams
Highest value for a single item - 45.29 grams

Scott

-----Original Message-----
From: Fazzari, Dennis M
Sent: Monday, November 15, 1999 7:56 AM
To: Westsik, George A
Cc: Ramble, Alan L; Baker, Eugene S (Scott)
Subject: RE: G Pu in Waste Packages

There is no way I can determine what items were waste, scrap, sludge, etc... and, for that matter, what the average or maximum gram quantity might be. Operations does not identify items well and, as a result, the information you requested cannot be easily identified. Most waste items are assayed on the NaI counter - which is Scott's (Baker) responsibility.

I'm not sure where the 30 gram maximum came from. Based upon the measurement results I've reviewed, I doubt any reasonable statement can be made regarding average or maximum quantities.

Similar comments below.

Dennis

-----Original Task-----
Subject: G Pu in Waste Packages
Priority: Normal

Start date: Mon 11/15/1999
Due date: Mon 11/15/1999

Status: Not Started
% Complete: 0%

Total work: 0 hours
Actual work: 0 hours

Please look in your vast memories or backlog of papers and let Al Ramble (with a copy to me) know by COB 11/15 if the average package quantity and the upper limit quantity are reasonable. Thank you.

George

George could you confirm the 30 gram number. Mike this is the process upset for waste packages we are considering in glovebox 211.

Al Ramble

-----Original Message-----
From: Dobbin, Kenneth D
Sent: Wednesday, November 10, 1999 7:52 AM
To: Erickson, David G; Miller, Edward M; Ramble, Alan L; Richard, Robert F; Shaw, Maria E; Toffer, Hans; Wilkinson, Alan D; Wootan, David W
Cc: Dobbin, Kenneth D
Subject: Waste Package Definition

Yesterday afternoon, we agreed upon the definition of a waste package to be used for CSERs associated with plutonium stabilization. The purpose of this message is to put that definition in writing and allow meeting participants a chance to comment. Unless I hear back today, the following definition will be used in these CSERs.

Glovebox waste is generated from PFP plutonium stabilization operations. It is placed into plastic bags, transferred to Isolated Transport Containers, assayed, then placed into waste drums. This waste consists of gloves, rags, containers used to port-in items, etc. Prior to bagging, all noticable fissile material is brushed from these items ***[Fazzari, Dennis M]*** I doubt this is true. I suspect the items are bagged and removed without brushing, and no fissile item is intentionally placed in these packages. Inspection of historical assay data show that normally these packages contain only 1 or 2 grams of fissile material. ***[Fazzari, Dennis M]*** No. I don't believe there is any technical basis for this statement. The greatest quantity found was one package that contained 30 grams of plutonium. ***[Fazzari, Dennis M]*** Where did this value come from?

This CSER evaluation includes a waste package containing 2 grams as the normal and base case conditions. For this fissile loading, the package acts as a reflector and possibly adds interspersed moderation between containers, however, no more so than already modeled in the base case. The only contingency identified is the excess fissile mass condition of 30 grams that was found once in the assay data history. ***[Fazzari, Dennis M]*** ??? Errors associated with loading fissile objects into the waste package are not included because if loaded in this glovebox they would be already covered by evaluation, and if the loading error occurs in other gloveboxes and transferred to this glovebox, then two errors would be required. Waste packages are not normally brought from other gloveboxes to this one.

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APPENDIX I

FIREFIGHTING WATER DENSITY

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B & W Hanford Co.

a McDermott company

To	A. L. Ramble, Engineer PFP Facility Engineering	T5-54		
From	R. D. Pickett, Cognizant Engineer PFP Facility Systems Engineering	T4-20	File No. or Ref.:	15510-99-RDP-038
Subj	FIRE FLOODING AND SPRAY ANALYSIS FOR ROOM 638		Date:	May 17, 1999

Reference: Telephone Request for Fire Water Flooding and Spray Analysis, dated May 7, 1999.

ASSUMPTIONS

- Fire department on scene within 40 minutes (see FSAR section 9.2.2A).
- 120 psi at each sprinkler head (this is very conservative since line losses and operation of other sprinkler heads would decrease this pressure).
- Fight a fire with two hoses for a total of 400 gpm (one hose at 100 gpm and second hose at 300 gpm per information provided by the fire department). Note: these hoses are variable stream types so the pattern and flows are adjustable.
- For flooding, assume all sprinkler heads operate (this is worse than a shear of a 1 1/2" water line).
- 1 second of flow from a sprinkler head or hose will suspend the amount of water to achieve the maximum density.
- Assume 3 sprinkler heads worth of flow into the cage area.
- No leakage out of the room.
- There is 8 lb. Water in 1 gallon.
- Exclude floor space and volume of room 639 and 640.

BACKGROUND

- Area of the room floor = 130 ft2.
- 14 sprinkler heads in the room (see CVI 21097)
- Sprinklers have a 1/2" orifice with a 5.62 K-factor.
- There are 7.481 gallons per ft3.
- Occupational Classification is Ordinary Hazard (see CVI 21097).
- Caged area has two sprinkler heads.
- Ceiling height is 9' 6".
- Floor dimensions of caged area 7' x 18' 3"
- Probability of fire not being noticed and the fire department being delayed 30 minutes is discussed in section 9.2.2A of the FSAR.
- Flooding cannot occur when a fire hose is used since the doors to the room have to be open along the hose route all the way to the outside of the building. There are no hose connections inside 2736-ZB or 2736-Z.

A. L. Ramble, et. al. 15510-99-RDP-038
Page 2
May 17, 1999

CALCULATIONS

Flow per sprinkler head = $Q = K\sqrt{P} = 5.62 \bullet \sqrt{120} = 61.56$ gpm

Sprinkler flow into cage area = 3 • 61.56 = 185 gpm

Sprinkler flow into the whole room = 14 * 61.56 = 862 gpm

Volume of cage area = 7' • 18' * 9.5' = 1200 cu. ft.

CAGE DENSITY CALCULATIONS

Cage Density during fire fighting in cage area = 185 gpm from sprinklers + 400 gpm from fire hoses = 585 gpm total flow.

Water released in 1 second of sprinklers and hoses = 585 gpm * (1 min/60 sec) * 1 sec = 9.75 gal.

Water density in cage area = 9.75 gal/1200 cu. ft. = 0.0081225 gal/cu. ft.

FLOODING CALCULATIONS

Volume of water release in 40 minutes = 40 min • 862 gpm * (1 cu. ft./7.481 gal) = 4609 cu. ft.

Water level after 40 min. = 4609 cu. ft./1340 sq. ft. floor area = 3.44 ft.

CONCLUSIONS

After 40 minutes of sprinkler flow, the water level in room 638 will be 3.44 feet. The maximum density of water suspended in the cage area is 0.008-gal/cu. ft.

klm

Distribution
Fluor Daniel Northwest

K. D. Dobbin	B4-44
J. S. Lan	B4-44
J. A. Miller	B4-44
RDP File/LB	

A-6002-136 (02/98)

APPENDIX J

MAXIMUM WATER CONTENT IN SS&C - CEMENT MATRIX

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Westinghouse Hanford Company | **Internal Memo**

From: Process Engineering — 8A400-96-032
Phone: 376-9616 L5-31
Date: July 2, 1996
Subject: RESULTS OF THE PFP CEMENTATION PROCESS

To: G. A. Funston T5-55

cc: D. M. Bogen	T5-50	J. A. Hunter	L5-31
L. Dayley	T5-55	G. L. Pippy	T5-50
D. E. Gana	L6-33	W. L. Winsted	T5-55
M. W. Gibson	T5-50	WOG File/LB	

References: (1) Letter, LaPriel Dayley, WHC, to W. O. Greenhalgh, WHC, "Request Cost Estimate for Testing to Provide Data in Designing a Cementation Process," 15530-96-LD-042, dated April 18, 1996.

(2) WIPP-DOE-069, "TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant," latest Revision, Waste Isolation Division, Carlsbad, New Mexico.

(3) J. W. Phillips, "Qualification of Waste Forms to Meet the Requirements of 10 CFR-61," *Waste Management '84*, Vol. 2, dated March 11-15, 1984, pp. 183-187.

INTRODUCTION

This letter report contains a summary of the results of work requested in internal memo 15530-96-LD-042 (Reference 1). The internal memo requested the following technical support:

- Determine the maximum ratio of PFP sand, slag, and crucible (SS&C) waste to cement to obtain a product that meets WIPP/WAC requirements or optionally some other solidification agent that will meet the requirements of 10 CFR-61 (definition of a solid which is interpreted as waste form exhibiting a compression strength @ 50 psi after solidification. (Reference 3)

- Determine the set times for cement/slag waste mixtures and admixture chemicals or techniques which could be use to increase or decrease these times.

- Develop a composition range diagram.

- o Provide information to aid in the selection of mixer equipment to handle product cans roughly 5.5 inches in diameter by 6 to 8 inches high.

- o Provide mixing instructions which can be used to develop training/procedure tasks for the process operation.

WIPP-WAC

The cement solidified SS&C waste product will be a transuranic (TRU) waste because it contains residual plutonium and possibly other transuranic radionuclides. The solidified waste will have to be certified as to meeting specified criteria and then be shipped to the Waste Isolation Pilot Plant (WIPP) in New Mexico for disposal. The Waste Acceptance Criteria (WAC) for WIPP, or WIPP-WAC, as stated in, "WIPP-DOE-069," (Reference 2) that appear to be applicable to the proposed solidified SS&C waste is as follows:

- "Powder, ashes, and similar particulate waste materials are immobilized if more than 1 wt.% of the waste matrix in each package is in the form of particles below 10 microns in diameter; or if more that 15 wt.% is in the form of particles below 200 microns in diameter."

- "The TRU waste shall not be in free liquid form. Minor residual liquid remaining in well-drained inner packages shall not exceed 1 vol.%, and the total liquid in the waste package shall not exceed 1 vol.%."

The PFP plutonium SS&C waste consist of a variety of powdered or particulate materials that require immobilization according to the WIPP-WAC. If cemented, it must be done in a manner that no free liquid is left over, or generated, by the immobilization process. The WIPP-WAC does not set any standard measurement for solids, such as compression strength. However, in the future, it is expected that the United States Nuclear Regulatory Commission (NRC) will take over regulatory requirements at WIPP. They are expected to require conformance with 10 CFR-61, which is currently viewed by NRC as being at least 500 psi for cement solidified nuclear waste rather than the lower 50 psi allowed for other solidification media. Therefore, the only waste solids considered as an acceptable waste product for this report are those cement products exhibiting a compression strength of 500 psi, or greater, having no free water, and essentially having no dispersable solids. Portland cement appeared to be very compatible with the simulated PFP SS&C waste tested so no other solidification media was studied.

WATER/CEMENT/WASTE PHASE DIAGRAM

The operable water, cement, and SS&C waste parameters are generally best described or determined using a triangular (3 dimension) phase diagram. This phase diagram is listed as a compositional range diagram and is shown in Figure 1. (Attachment 5). The values for the diagram are listed in Table I (Attachment 1). The composition diagram gives the outer limit range of operation for the three components. The minimum water line represents the minimum water that can be added, and still be able to make a homogeneous, consistent, and smooth mix. This is typically thought of as that minimal amount of water required to allow the mixer to function properly and prepare a cementable mix.

The maximum water is the upper limit, where the addition of any further appreciable water will result in a dual phase product consisting of cement solids, and a lighter aqueous liquid phase, generally on top of the cement.

A third broad line is based on compression strengths, and is a boundary limit where compression strength estimates, or actual measurements on representative cement/waste products would decrease below 500 psi, based on 7-day cured specimens. Cement/concrete compression strength samples are typically cured 28 days. The samples usually exhibit compression strength values that are significantly higher (>20%) for 28 day cure samples. Use of the 7-day cure test samples will provide an extra margin of reliance in meeting the 500 psi minimum cement compression strength. The general procedure for the phase diagram and 7-day compression strength work is included in Appendix A. Compression strength values, as a function of wt.% waste, are shown in Figures 2 and 3. The compression strength as expected decreases with increasing waste content; these figures are used to predict how much waste can be added before the compression strengths values decrease below 500 psi.

<u>**CEMENT SET RATES**</u>

How long it takes for cement to set is of concern to the PFP cement process since they literally will have thousands of SS&C waste cans to process. Typically, a cement immobilized waste form is allowed to set a minimum of 24 hours after mixing, to set up and cure. After the 24 hour period, the waste solid can normally be removed. At this time it is visually checked to see that it has completely hardened, has no "free liquid", and is ready to be stored or packaged for subsequent disposal. However, if a cement set retarder material is added or is present in the waste it could take longer. In contrast, addition of a set accelerator or certain other modifications could allow the cement to set quicker allowing faster handling and processing.

The PFP Process Engineering requested cement setting data for typical type mixes, as well as some information on cement modifiers. Table 2 has this information, where the "initial set" is based on a penetrometer penetration reading of 500 psi, and the "final set" is one of 4,000 psi. As mentioned earlier, a 500 psi strength product is the value that is required to meet assumed NRC waste solidification requirements. Final sets (4,000 psi) are shown to provide an indication of a final set. However, it should be noted that this testing assumed penetration resistance values (Penetrometer readings) in psi to be equivalent to compression strength values, but they may not be, even though the same unit is used.

Table 2 (Attachment 2) provides the set times of a list of mixes at the same waste content along with their respective initial (500 psi), and final (4,000 psi) setting times. The list of set times includes set times for mixes containing some common cement modifiers.

Calcium chloride (sat. sol'n) at about 2% will hasten the overall set time, and give a good compression strength product. Fly ash, class F, will delay the initial set time, but the other retarders (glucose and Pozzolith®) did not work well with this particular mix. However, adjustment of the water content appears to be the overall best method of adjusting set time, as is indicated for the first three runs at constant waste content, but varying water content. (See Figure 4). The initial set time is approximately proportional to the water content (wt.%). The initial set time is reduced about 1.25 hr for each 1% decrease in water content. The final set time curve is parabolic, but in the minimum water area, a 1% change in water content causes about 0.8 hr. change in set time. (See Figure 4)

The above effect will, of course, change in unit dimension with changes in composition. However, the values shown should give a good indication on how to modify similar mixes for higher or lower set times. A general procedure used for determining cement set times for this work is included in Appendix A (Attachment 3).

MIXER INFORMATION

What is the best mixer or type of mixers to use for mixing a large quantity of small cement mixes in a glove-box or similar type facility? The size of the mixes, ~ 1/2 to 1 gallon, provides an excellent opportunity to use the container itself as a mixer receptacle, and merely have to add the ingredients. Adding a metal marble (steelie) into the can help facilitate the mixing process. A brief survey of the commercial market found that the most commonly used self-contained mixers for this size of mix to be paint can mixers. Use of a highly agitator mixer, as opposed to a "roller," or circular motion is thought to be better for cement solidification. Such a mixer is marketed by Red Devil, and is shown in Figure 5. Several other types of paint type mixers are available at a moderate price. Approximately 2 to 3 weeks are required to obtain one using a credit card type purchase. Price information for the Red Devil mixers are also included in Appendix B (Attachment 4).

Other options include a range of open mixers. These, of course, require frequent cleaning and some routine decontamination around the mixing area. Mixers of this type should be capable of >150 rpm, and a torque of 90 foot-lbs., or an equivalent mixing capability. Several commercial, and a number of large home-type mixers would probably work all right. Kitchen Aid and similar mixers will work for this application.

The suggested mixing technique is to lightly blend all solids first, and then add the desired liquid to provide the smoothest mix. If dusting is a problem, you can add the solids to the liquid; but do it slowly, at a controlled rate for best results.

OPTIMUM WASTE LOADINGS

In general, the higher the waste loading, the lower the disposal costs. The highest waste loadings are on the right hand side of the diagram. The minimum water mixes exhibit higher waste loadings than maximum water mixes unless the water used is also a waste material. The highest waste loading values shown in Figure 1 that meet the WIPP-WAC and NRC requirements are about 50 Wt.%. Bulk densities for the simulated waste were measured to be about 1.64 g/cc compared to 1.29 gm. for bulk cement powder. The waste loading is really equivalent to about 59 vol.%. since waste volumes not weights are the units by which waste quantities are measured and tracked. More work could be done on optomizing waste loadings to reduce waste disposal costs. A 5 to 10% increase in waste loading is very likely with additional work.

G. A. Funston
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July 2, 1996

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CONCLUSIONS

1. Minimum water composition values were fairly constant at about 24 to 25 wt.% water for the Ashgrove type I-II cement used for these tests. The minimum water mixes exhibited essentially zero (no) slump.

2. Maximum water composition values increased slightly with waste content as shown in Figure 1 from a zero waste value of 32 wt.%.

3. Compression strength limit line of 500 psi is the other limiting parameter. The compression strength limiting values were estimated from strength measurements made on minimum and maximum water samples and the graphs in Figures 2 and 3.

4. Cement mix set times were fastest for minimum water mixes, and for mixes to which sat. calcium chloride liquid has been added to accelerate the set.

5. In-can mixing, using the waste container as the mixing receptacle, is recommended for solidifying the waste. Mixer clean-up and glove-box contamination would be minimal for this type of mixer processing.

6. Waste loading data is minimal, but efficiencies approaching 60% appear possible for waste products that will meet WIPP-WAC requirements. These solid waste products shall exhibit at least a 500 psi minimum compression strength.

W. O Greenhalgh, Principal Chemist
Process Engineering

cmr

Attachments 5

8A400-96-032
ATTACHMENT 1

Table No. 1

FINAL PHASE DIAGRAM COMPOSITION AND COMPRESSION STRENGTH MEASUREMENTS

Sample	Composition Water	Composition Waste	Composition Cement	Average Comp. Strength (psi)
Max. Water				
a.	31.98	0.00	68.02	3900
b.	32.25	5.94	61.80	3190
c.	31.94	12.37	55.69	2240
d.	32.70	19.43	47.87	1990
e.	33.59	26.56	39.85	1200
f.	34.77	34.70	30.54	510
Min. Water				
g.	24.35	0.00	75.65	6620
h.	24.70	5.38	69.92	6560
i.	25.56	11.11	63.33	5450
j.	24.08	17.52	58.40	4650
k.	24.82	24.25	50.93	3810
l.	24.24	31.57	44.19	3790

Table No. 2

CEMENT/WASTE SET TIMES

Penetrometer readings have been used to estimate the following set times for the listed compositions:

	Composition (Wt%)				Set Times (hrs)	
	Water	Waste	Cement	Additive	Initial	Final
a.	33.8	26.5	39.7	0	15.9	26.6
b.	29.0	26.5	44.5	0	9.2	16.9
c.	24.0	26.5	49.5	0	3.6	12.4
d.	29.0	26.5	39.5	5 - Sucrose	No Final Set	
e.	29.0	26.5	39.5	5 - Flyash	14.5	25.2
f.	29.0	26.5	39.5	5 - Pozzolith	No Set	No Set
g.	29.0	26.5	39.5	5 - Slag Cem.	15.6	28.3
h.	29.0	26.5	43.0	1.5 - Calcium Chloride liq.	10.8	17.1
i.	29.0	26.5	39.5	5 - Calcium Chloride Liq.	3.1	17.9
j.	29.0	26.5	42.5	2 - Sucrose	44.8	89.5
k.	29.0	26.5	42.5	2 - Flyash	12.7	17.0
l.	29.0	26.5	42.5	2 - Pozzolith	365	No Set
m.	29.0	26.5	42.5	2 - Slag Cement	8.4	18.3
n.	22.0	26.5	49.5	2 - Sucrose	Data Inconclusive	
o.	22.0	26.5	49.5	2 - Pozzolith	29.7	50.9
p.	22.0	26.5	49.5	2 - Calcium Chloride Liq.	4.9	9.2

8A400-96-032
ATTACHMENT 3

Appendix A
Test Procedures

Procedure No. 1 consists of 6 pages

Procedure No. 2 consists of 3 pages

WASTE SOLIDIFICATION COMPOSITION DIAGRAM

Procedure No. 1
Wilbur Greenhalgh - April 30, 1996

INTRODUCTION:

Plutonium contaminated residues and wastes are to be disposed at the Waste Isolation Pilot Plant (WIPP) in New Mexico. The Waste Acceptance Criteria for WIPP (WIPP-WAC) require that (1). "Powders, ashes, and similar particulate waste materials are immobilized if more than 1 wt% of the waste matrix in each package is in the form of particles below 10 microns in diameter, or if more than 15 wt% is in the form of particles below 200 microns in diameter". (WIPP-DOE-069) (2). "The TRU waste shall not be in free-liquid form. Minor residual liquid remaining in well-drained inner packages shall not exceed 1 vol% and the total liquid in the waste package shall not exceed 1 vol%". (WIPP-DOE-069) These requirements mean that solidification procedures must be used that will fix any powders or dispersible materials, and any "free liquids".

Portland cement (type I-II) tested in these procedures is a hydraulic setting cement, which means it will set up even under water. This hydraulic setting property makes it easy to measure the excess water in test compositions with a slight excess of water. As the cement sets, excess liquid comes to the top (less dense than cement), and the cement forms a solid product beneath the liquid. The excess liquid is removed and measured. The maximum cement-water composition is the original mix composition minus the excess water content. The cement mix composition is corrected for the amount that was determined to be in excess. The maximum cement-water compositions for a system can be determined by varying the ratio of cement to waste residue and then determining the maximum water.

The other working boundary of cement mixes is the minimum water boundary line. This line is not as well defined as the maximum water line and is primarily a function of the mixer. It is probably best understood as the boundary where just enough water has been added to the cement or cement/residue mix that a smooth (no lumps) water slurry or pourable sludge can be made. This mixture should exhibit a nearly constant, reproducible slump. A portable slump tester will be used to follow this concrete measurement.

METHOD FOR DETERMINING THE MAXIMUM WATER COMPOSITION LINE

Apparatus:

1. Utility cement mixer, 1 gal. capacity.

2. Top loading automatic 1000 gram balance.

3. Automatic compression strength tester.

4. Portable K slump tester or its equivalent.

5. Powder blender

Supplies:

1. Portland cement type (I-II) unless otherwise specified.

2. Distilled or demineralized water.

3. Simulated or actual waste residue matrix.

4. Metal slip top tin cans, 1 pint or their equivalent.

5. Graduated glass cylinders for excess water measurement as a verification to weight measurements.

6. Test Log Book (official WHC numbered notebook)

Chemicals:

1. Magnesium oxide sand

2. Calcium fluoride powder

3. Calcium iodide powder

4. Calcium oxide powder

5. Iron filings or its equivalent

6. Silica oxide powder

Assumptions:

1. Plutonium is an actinide that exhibits many alkaline earth type properties. Calcium compounds will be used as a stand-in for the very small trace plutonium and plutonium compounds listed in the original button slag waste. Substitution of calcium compounds for the trace plutonium compounds is not expected to have any appreciable effect on the physical properties of the test cement products.

PROCEDURES

A. Prepare Simulated Crucible Slag Waste Matrix

1. Prepare one or more 1 kilogram batches of simulated crucible slag waste matrix (CSWM) by weighing in the hood the following proportions per kg of waste matrix: (Note: percentages have been adjusted for the substitution of calcium oxide for calcium metal.)

Chemical	WT%	WT. (g)
Mag. Oxide Sand	41.00	410.0
Calcium Fluoride	37.25	372.5
Iron Filings	8.32	83.2
Calcium Iodide	1.46	14.6
Silica Oxide	0.40	4.0
Calcium Oxide	11.57	115.7

2. Place all the ingredients in a powder blender and mix for at least 10 minutes and then place in a one-gallon wide mouth jar that can be sealed. Keep in a dry place.

3. Label and date the bottle and place a hazardous material communication label (NFPA sticker) that best reflects a composite of their MSDS's in regard to health, flamability, and reactivity risks.

Note: Calcium metal is the one remaining ingredient listed in the slag that is not present (8.44% or 84.4 g/kg); calcium oxide will be used instead at the same mole ratio which amounts to 11.41 wt%. The additional trace lime listed in the table above represents a trace of plutonium oxide present in the original waste matrix.

B. Determine the Maximum Water Composition Line

1. Visually check the portland cement before each use and screen out (8 mesh or finer) any lumps or large particles. Record the type and brand of cement in the test log book.

2. Prepare water rich cement mixes using the following approximate formulations and 250 grams total for each test sample required: (Note: Add dry materials first and then slowly add water).

	Water	Waste (dry)	Cement (dry)
a.	41 wt%	0 wt%	59 wt%
b.	43	5	52
c.	45	10	45
d.	48	15	37
e.	50	20	30
f.	53	25	22

3. Perform steps B-4 through B-10 for each of the above compositions.

4. Mix formulation for at least 5 minutes and then pour the mix in a preweighed pint tin can or other pint size non-leaking container.

5. Weigh the contents to determine the weight of cement mix present and record the weight value.

6. Put on the can lid and tape seal closed any air openings into the can.

7. Label the can and set it aside on a shelf to set-up for 24 hrs at ambient temperature (25 $\pm$ 5 deg. C) and record the temperature.

8. After 24 hours, remove the tape seal and collect the free liquid in a pre-weighed 10 or 25 ml graduated cylinder.

9. Measure and record both the weight and volume of the free liquid present in the can, retain all cement liquids. (haz. eval.)

10. Subtract the weight of "free liquid" (FL) from the applied formulation and calculate a "free liquid" corrected composition as shown below: (Example: assume 5 g "FL" measured for an initial 41 wt% water composition)

$$\%\text{Water (corrected)} = \frac{0.41 \times 250g - 5g}{250g - 5g} \times 100$$

$$\%\text{Water (corrected)} = 39.8\%$$

or

$$\%\text{Water (corrected)} = \frac{100[(\text{water comp.})(\text{mix wt.}) - (\text{FL})]}{\text{mix wt.} - \text{FL}}$$

10. Record all corrected maximum water contents in a log book and then plot the values on a triangular phase diagram using cement, water, and waste matrix at the apexes (points of the triangle).

11. Adjust each succeeding formulation in Step 2 by adding or subtracting water based upon the results obtained for the previous formulation. If the "free liquid" is starting to exceed 2 to 3 wt%, then reduce the quantity of water. If very little free liquid is observed then increase the water. If no free liquid was observed the maximum water line was not reached and the run must be repeated with a higher ratio of water.

C. Determine Compression Strengths for Maximum Water Samples

1. Schedule Standards Laboratory to calibrate one of the compression strength testers that meet ASTM specifications and provide written guidance as to the accuracy of the tester.

2. Repeat the preparation of the listed formulations using the corrected maximum water values. Prepare a triplicate (750 gram) size batch. Pour a third of the material into the pint can to check the maximum water correction and pour the other two portions into 2-inch cubes for compression strength samples.

3. Visually inspect for free liquid after 24 hours and record the results for the mix placed in the tin can. If appreciable water is present repeat steps B-8 through B-10.

4. Remove the two cubes (compression strength samples) after 24 hours, weigh, and seal in a plastic bag.

5. Compute a sample density by dividing the weight (g) of the 2-inch cube sample by 131.1 cc the volume of a 2-inch cube, this will give the density in g/cc.

6. Cure the compression strength samples (sealed in plastic bags) for seven days at room temperature (25 ± 5 deg. C).

7. Perform a compression strength measurement per ASTM C109-95 and record the values in lbs/sq. in. (psi).

D. Determine the Minimum Water Composition Line

1. Prepare duplicate minimum water sample mixes for each formulation listed in Step D-2 using 300 grams mix per sample.

2. Prepare the mixes by adding the dry components first and then adding the water slowly until just enough water has been added to allow the cement to be entrained in a smooth mix (no lumps). Use the approximate wt.% formulations listed below:

	Water	Waste (dry)	Cement (dry)
a.	26	0	74
b.	30	5	65
c.	33	10	57
d.	35	15	50
e.	38	20	42
f.	40	25	35

If the mix appears to exceed the minimum water appearance (too thin or wet), then add additional waste and cement in the correct ratio for that specific formulation.

3. Perform Steps D-4 through D-9 for each of the above formulations.

4. Measure the mix slump using a portable "K-slump" tester and record the slump value.

5. Place the mix into two-inch cube forms and let it set-up for 24 hours to use as compression strength samples.

6. Remove the cube forms, weigh the cubes and compute a sample density as done previously in Procedure Step C-5.

7. Place the cube forms into plastic bags, seal, and allow to cure at room temperature (25 ± 5 deg. C) for 7 days.

8. Measure and record the compression strengths per ASTM C109-95 method.

9. Plot out the minimum water composition line on the triangular diagram used just previously, also plot compression strength as a function of the waste content.

E. Determine Bulk Densities for the Cement and Waste Matrix

1. Take two preweighed graduated 100 ml cylinders. Fill one cylinder with bulk cement and other with bulk waste matrix powder. Manually vibrate and fill or adjust volume until the 100 ml mark is reached and doesn't settle with continued vibration.

2. Reweigh the graduated cylinders and compute the bulk densities by dividing the bulk cement or waste matrix weight in gram units by 100 ml(cc).

3. Record the bulk densities in the log book and use these values to compute volume percents for customer report needs.

F. Handling Test Matrix Wastes

The composition of the resultant cement test products have been submitted to Acceptance Services for designation. The test samples are non-regulated for all compositions where the percent calcium fluoride is less than 10 wt% of the total. All of the compositions listed in these procedures are less that 10 wt% and are non-regulated. A copy of the predesignation is included with the procedure.

Procedure Prepared by ~~WO Greenhalgh, Proc. Eng.~~ 5/15/96 Date
WO Greenhalgh, ~~Proc.~~ Eng.

306-E Building Manager [signature] 5/16/96
DG Panther — Date

Process Engineering Mgr. [signature] 5/16/96
JA Hunter — Date

CEMENT SOLIDIFICATION SET TIMES AND ADMIXTURES

Procedure No. 2

Wilbur Greenhalgh - May 20, 1996

INTRODUCTION:

The PFP operation is planning on solidifying some of their plutonium button slag wastes in cement to make a product that meets Waste Isolation Pilot Plant (WIPP) disposal criteria. A cement solidification composition diagram is being prepared for the cement/water/waste parameters. Cement set times for the candidate mixtures are needed for planning processing procedures. In addition, general admixture set times might be useful to either slow down or speed up set times to optomize operations or perhaps ensure mixtures receive sufficient mixing before setting occurs.

METHOD FOR MEASURING SET TIMES:

Apparatus:

1. Penetrometer - built to ASTM standards or recommendations.

2. Penetrometer Needles - Sizes 1, 1/2, 1/4, 1/10, 1/20, and 1/40 in.^{2}

3. Cement Mixer - lab size.

4. Portable K slump tester.

5. Watch or clock timer.

Supplies:

1. Portland cement type (I-II).

2. Distilled or demineralized water.

3. Simulated waste residue matrix material.

4. Cement sample containers, 3-in. min. dia. x 3-in. min. height.

Chemicals:

1. Cement Admixtures:

    1. Glucose
    2. Flyash, class F
    3. Pozzolith 122 HE
    4. Slag cement
    5. Calcium chloride liquid

PROCEDURES

1. Set up the penetrometer apparatus so it is ready for operation.

2. Set-up to prepare duplicate 700 gm samples of the following wt.% compositions:

Water	Waste (simulant)	Cement	Additive (specified)
a. 33.8	26.5	39.7	0
b. 29.0	26.5	44.5	0
c. 24.0	26.5	49.5	0
d. 29.0	26.5	39.5	5 - Sucrose
e. 29.0	26.5	39.5	5 - Flyash
f. 29.0	26.5	39.5	5 - Pozzolith
g. 29.0	26.5	39.5	5 - Slag Cement
h. 29.0	26.5	43.0	1.5 - calcium chloride liq. (2 gal./yd concrete)

3. Perform procedure steps 4 through 8 for each composition above.

4. Prepare only one duplicate set of samples at a time, add all ingredients except water and add water last of all.

5. Start the timer as soon as water is added, and place timer where it can be readily read.

6. After mixing, measure the slump using the slump tester and then pour the mix into the cement container.

7. Make penetrometer readings using 3 needles per sample at approx. 30 min., 1 hour, 2 hours, 4 hours and 24 hours per Section 9.2 of ASTM C 403-95 (procedure attached).

8. Compute and record the penetration resistance in $lbs/in.^2$.

9. Plot penetration resistance versus elapsed time on log/log paper.

WASTE MANAGEMENT:

None of the admixtures are regulated, and there will not be any liquid formed so all test sample products and residues will be non-regulated.

Procedure Prepared by	*[signature]* WO Greenhalgh, Proc. Eng.	5/20/96 Date
306-E Building Manager	*[signature]* DG Panther	5/23/96 Date
Process Engineering Mgr.	*[signature]* JA Hunter	5/21/96 Date

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Appendix B
Mixer Information

Consisting of 1 page

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Red Devil

RED DEVIL EQUIPMENT CO.

LIST PRICING
Effective January 1, 1996

ONE GALLON SHAKERS

5400 Twin One Gallon Shakers

Model No.	Description	Price
0-5400-02	6 Minute Push Button Timer	$1,191
0-5400-0M	15 Minute Mechanical Timer	$1,109
0-5400-0H	1 Hour Mechanical Timer	$1,109
0-5400-32	Heavy-Duty, 6 Minute Timer	$1,310
0-5400-M3	Heavy-Duty, 15 Minute Timer	$1,219
0-5400-H3	Heavy-Duty, 1-Hour Timer	$1,219
0-5400-X2	Explosion-Proof	$1,543
0-5400-X3	Explosion-Proof, Heavy Duty	$1,669
0-5400-E2	6 Minute Timer, 220V	$1,264
0-5400-EM	15 Minute Timer, 220V	$1,176
0-5400-EH	1 Hour Timer, 220V	$1,176
0-5400-E3	Heavy-Duty, 220V	$1,340
0-5400-Y2	Explosion-Proof, 220V	$1,683
0-5400-Y3	Explosion-Proof, Heavy-Duty, 220V	$1,790
0-5400-A1	Air-Driven	$1,129

5410 Single One Gallon Shakers

Model No.	Description	Price
0-5410-02	6 Minute Push Button Timer	$1,021
0-5410-0M	15 Minute Mechanical Timer	$ 948
0-5410-0H	1 Hour Mechanical Timer	$ 948
0-5410-32	Heavy-Duty, 6 Minute Timer	$1,123
0-5410-M3	Heavy-Duty, 15 Minute Timer	$1,044
0-5410-H3	Heavy-Duty, 1 Hour Timer	$1,044
0-5410-X2	Explosion-Proof	$1,326
0-5410-X3	Explosion-Proof, Heavy-Duty	$1,434
0-5410-E2	6 Minute Timer, 220V	$1,089
0-5410-EM	15 Minute Timer, 220V	$1,011
0-5410-EH	1 Hour Timer, 220V	$1,011
0-5410-Y2	Explosion-Proof, 220V	$1,448
0-5410-Y3	Explosion-Proof, Heavy-Duty, 220V	$1,539
0-5710-00	Air-Driven	$ 480

Bases

Model No.	Description	Price
0-5153-00	Counter Base	$ 104
0-5151-00	Pedestal Base	$ 196

5600 Auto Sperse® Shaker

Model No.	Description	Price
0-5600-01	Auto Sperse®, High-Speed	$1,051
0-5600-E1	Auto Sperse®, High-Speed, 220V	$1,156

RED DEVIL EQUIPMENT CO.
7150 Boone Avenue North
Minneapolis, MN 55428

Sales & Service (US): 800/221-1083
Sales & Service (Int'l): 612/533-2969
Fax: 612/533-0015

Auto Sperse is a trademark of Red Devil, Inc., of Union, New Jersey.

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ATTACHMENT 5

Appendix C
Figures 1 through 5

Consisting of 1 page each

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FIGURE 1: COMPOSITION DIAGRAM FOR SIMULATED PFP SLAG WASTE IMMOBILIZED IN PORTLAND CEMENT

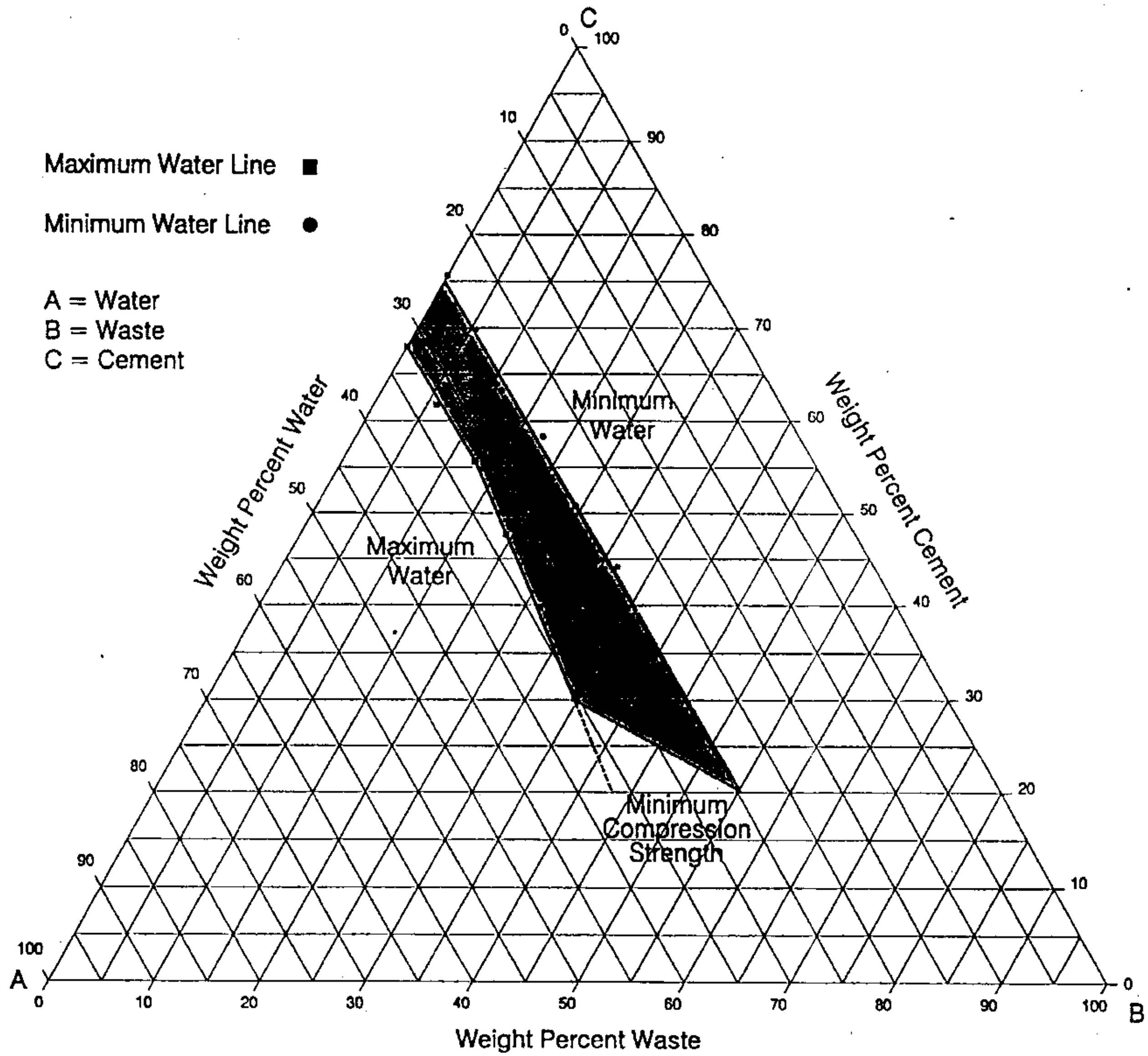

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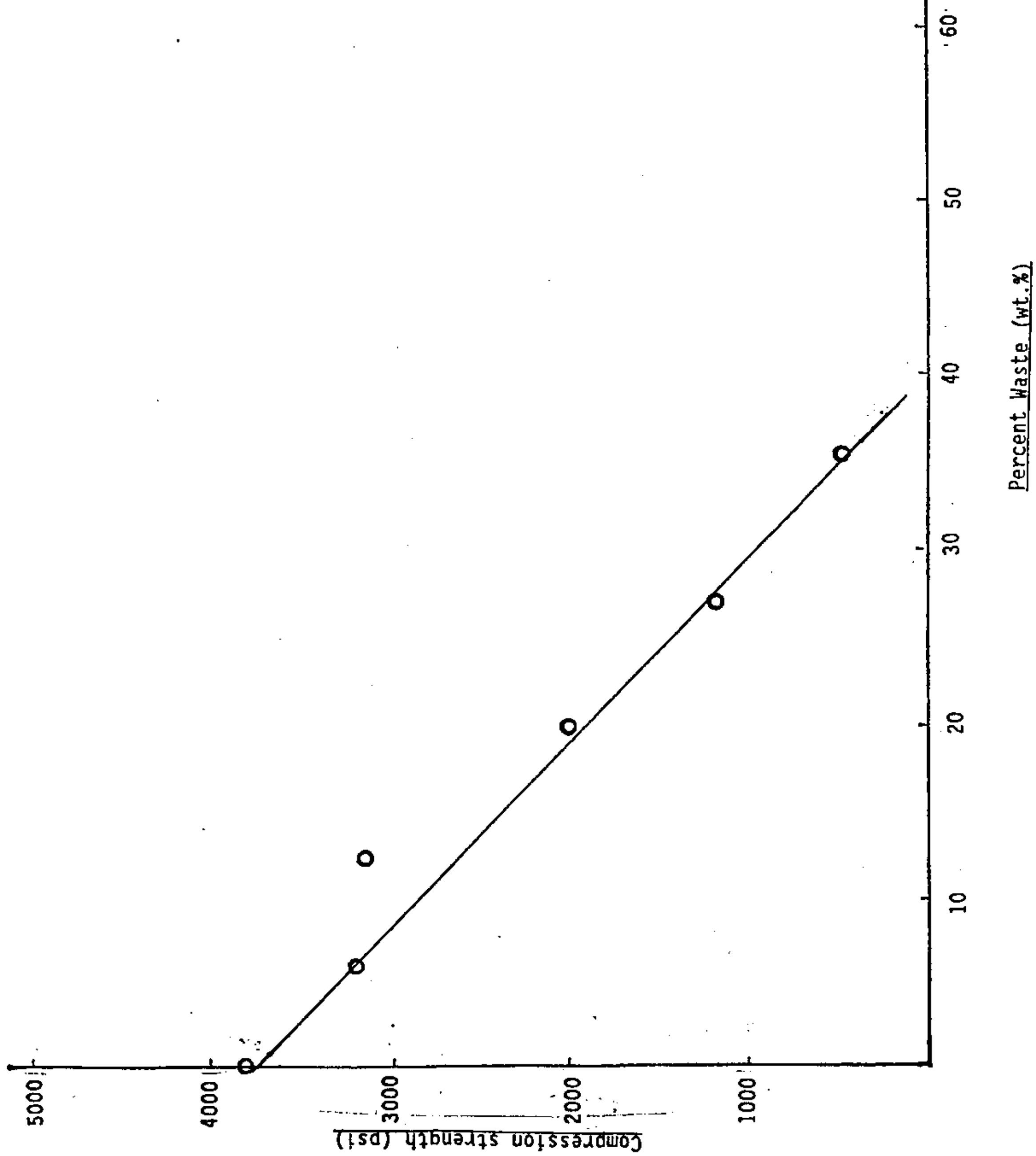
FIGURE 2: MAXIMUM WATER COMPRESSION STRENGTHS



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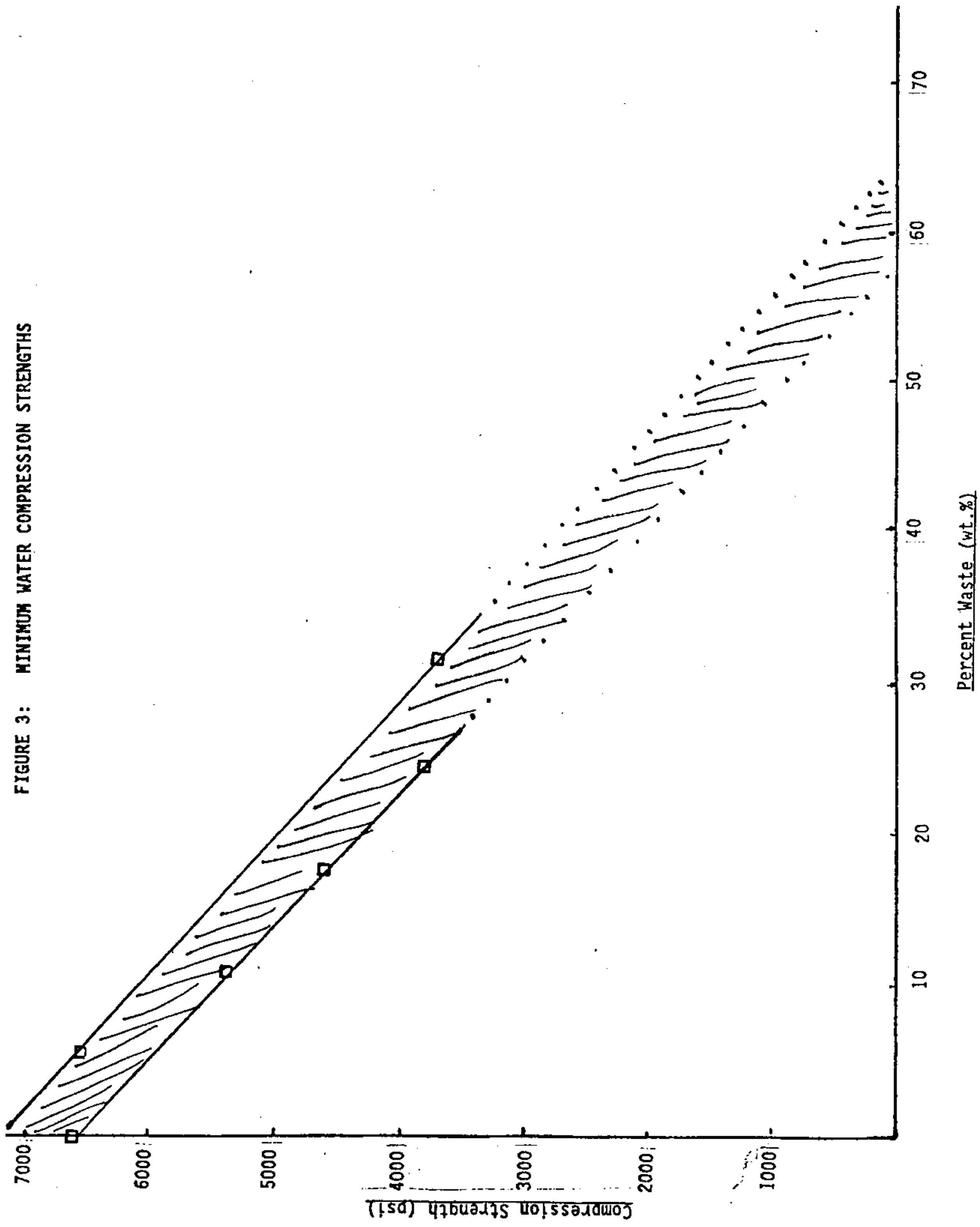

FIGURE 3: MINIMUM WATER COMPRESSION STRENGTHS

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FIGURE 4: CEMENT SET TIMES AS A FUNCTION OF WATER CONTENT

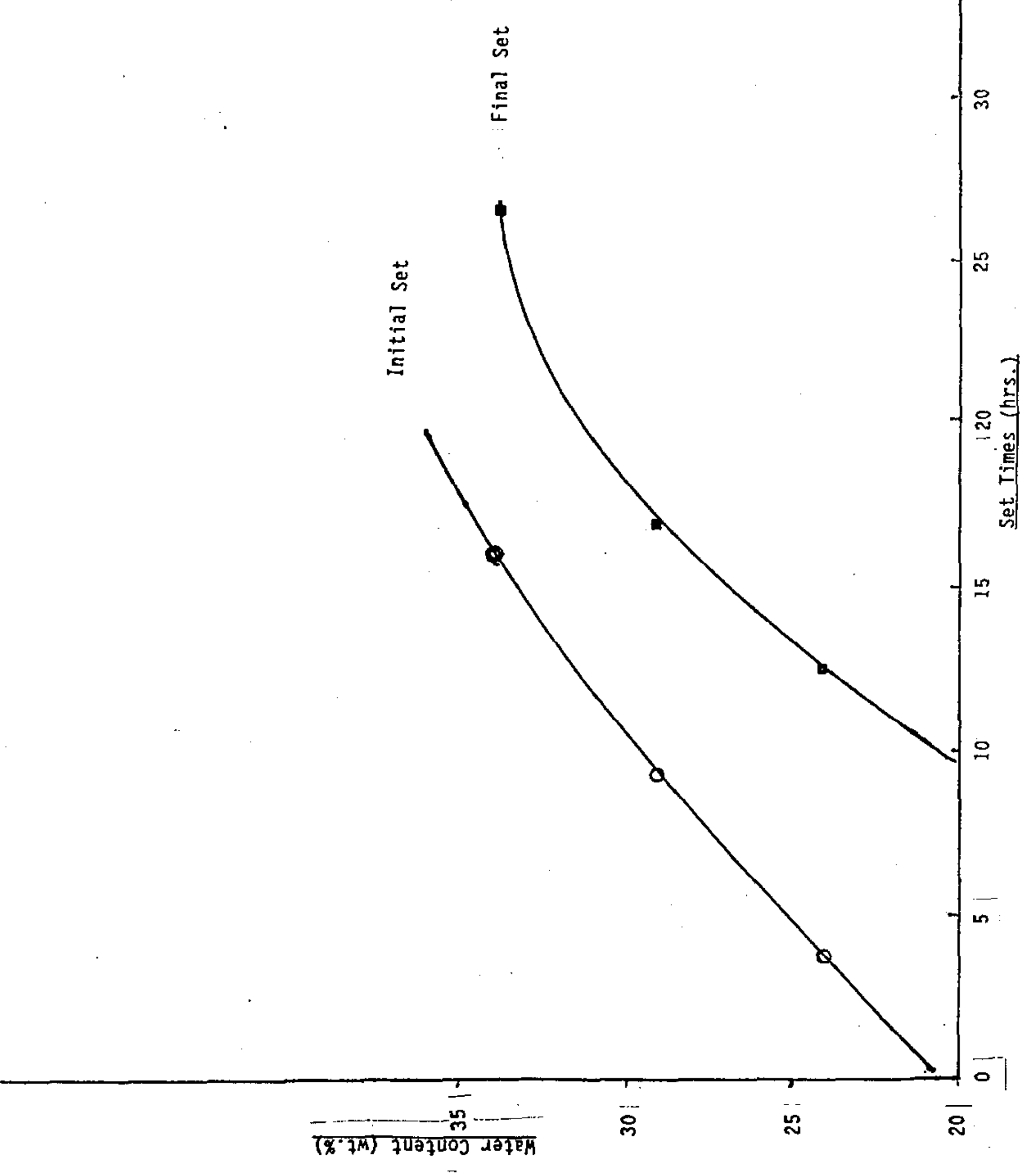

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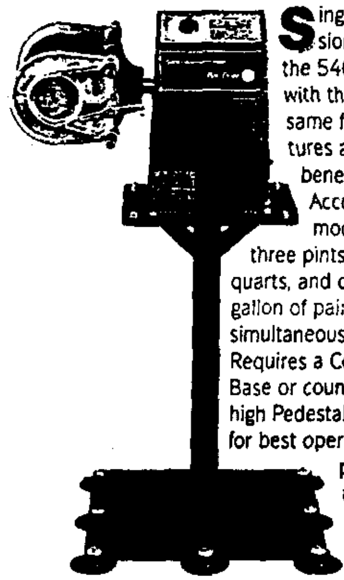
FIGURE 5: PAINT CAN MIXERS

5410 ONE GALLON SINGLE SHAKER



Single version of the 5400 with the same features and benefits. Accommodates three pints, two quarts, and one gallon of paint simultaneously. Requires a Counter Base or counter-high Pedestal Base for best operating performance.

1 Operates on 120V, 60 Hz. or 220V, 50 Hz.

2 17" L x 24" W x 17" H
(43 cm x 61 cm x 43 cm)
Shipping weight: 138 lbs. (63 kgs.)

3 UL/CSA Listed

HEAVY-DUTY OPTION
Features a ⅓ h.p. motor and heavy-duty clamp assembly. Designed for industrial or high-volume uses. Choose between a six minute or one hour timer. Heavy-Duty/Explosion-Proof Option available.

EXPLOSION-PROOF OPTION
Features an explosion-proof motor and wiring for safe use in flammable environments. Optional Explosion-Proof "On-Off" Switch. Heavy-Duty/ Explosion-Proof Option available.

AIR-DRIVEN OPTION
All the features and benefits of the 5400 Series in an air-driven shaker. Air requirement of 8 CFM at 100 psi. Explosion-Proof. Can be used in Class I, Group D Hazardous Environments.

MODEL NO.	DESCRIPTION
0-5410-02	Single Shaker, 6 Min. Timer
0-5410-0M	Single Shaker, 15 Minute Timer
0-5410-0H	Single Shaker, 1 Hour Timer
0-5410-E2	Shaker, 220V, 50 Hz.
0-5410-H3	Heavy-Duty, 1 Hour Timer
0-5410-32	6 Minute Timer
0-5410-X2	Explosion-Proof
0-5410-X3	Heavy-Duty/Explosion-Proof
5322000	Opt. explosion-Proof Switch

5151 PEDESTAL BASE

Puts your paint shaker at counter height without using valuable counter space. Rubber suction feet securely hold base to the floor reducing vibration and noise. For Red Devil 5400/5410 Series and 5710 paint shakers.

1 18" L x 20" W x 29" H
(46 cm x 51 cm x 74 cm)
Shipping Weight: 75 lbs. (34 kgs.)

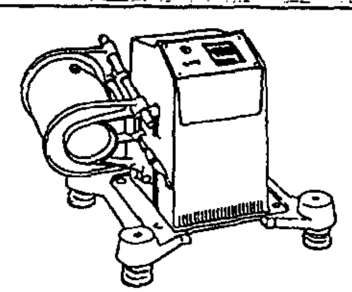
Model No.	Description
0-5151-00	Pedestal Base

5153 COUNTER BASE

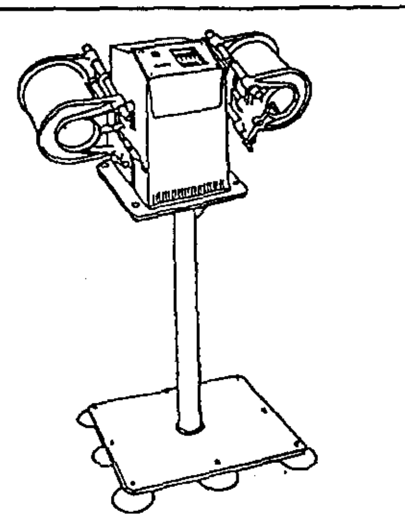
Two piece cast iron base featuring coil spring suspension for smooth, quiet, counter-top operation. For Red Devil 5400/5410 Series and 5710 paint shakers.

1 18½" L x 20¾" W x 2" H
(47 cm x 53 cm x 5 cm)
Shipping Weight: 20 lbs. (9 kgs.)

Model No.	Description
0-5153-00	Counter Base



5410-02 With 5153 Counter Base



5400-02 With 5151 Pedestal Base