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12

ENGINEERING DATA TRANSMITTAL

Page 1 of 1
1. EDT 619986

2. To: (Receiving Organization) Fluor Daniel Hanford, Inc.		3. From: (Originating Organization) B&W Hanford Company		4. Related EDT No.: N/A	
5. Proj./Prog./Dept./Div.: Plutonium Finishing Plant		6. Design Authority/Design Agent/Cog. Engr.: A. L. Ramble		7. Purchase Order No.: N/A	
8. Originator Remarks: This document is being distributed for functional review and approval.				9. Equip./Component No.: N/A	
				10. System/Bldg./Facility: 2736-ZB	
				12. Major Assm. Dwg. No.: N/A	
				13. Permit/Permit Application No.: N/A	
11. Receiver Remarks:		11A. Design Baseline Document? ☐ Yes ☒ No		14. Required Response Date: N/A	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	HNF-4823	-	0	Hazards Evaluation of Plutonium Metal Opening and Stabilization	SQ	1	1	

16. KEY		
Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)									
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature
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		Env. N/A							

18. Signature of EDT Originator <i>A. L. Ramble</i> 7/19/99 Date		19. Authorized Representative for Receiving Organization _____ Date		20. Design Authority/Cognizant Manager <i>A. L. Ramble</i> 7/19/99 Date		21. DOE APPROVAL (if required) Ctrl No. _____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	
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Hazards Evaluation of Plutonium Metal Opening and Stabilization

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U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 619986

UC:

Org Code: 403

Charge Code: 101418BB20

B&R Code: EW7002010

Total Pages: 25

Key Words: Pu metal, corrosion products, sampling, testing, packaging

Abstract: Hazards evaluation is the analysis of the significance of hazardous situations associated with an activity or process. The HE used qualitative techniques of Hazard and Operability (HazOp) analysis and What-If analysis to identify those elements of handling and thermal stabilization processing that could lead to accidents.

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Release Approval

7/19/99

Date

Release Stamp

Approved For Public Release

HNF-4823
Rev. 0

HAZARDS EVALUATION OF PLUTONIUM METAL OPENING AND STABILIZATION

Prepared by:
Fluor Daniel Northwest, Inc.

For:
B&W Hanford, Inc.

Date Published
July 1999

Approved by:
B&W Hanford, Inc.
July 1999

Prepared for the U. S. Department of Energy

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Hanford Management and Integration Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
2.0	METAL OPENING AND STABILIZATION ACTIVITY ANALYZED.....	1
2.1	Operations in Glovebox 636.....	1
2.2	Subsequent Stabilization Operations in Gloveboxes HC-21A, HC-21C, and HC-18M.....	2
3.0	HAZARD EVALUATION METHODOLOGY.....	3
4.0	HAZARDS EVALUATION PARTICIPANTS.....	5
5.0	HAZARDS EVALUATION WORKSHEET ORGANIZATION.....	8
6.0	HAZARD EVALUATION RESULTS	19

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HAZARDS EVALUATION OF PLUTONIUM METAL OPENING AND STABILIZATION

1.0 INTRODUCTION

A Hazards Evaluation (HE) was done for the opening of containers of Pu metal, conversion of the metal and corrosion products to plutonium oxide product, and sampling, testing and packaging the product. Hazards evaluation is the analysis of the significance of hazardous situations associated with an activity or process. The HE used the qualitative techniques of Hazard and Operability (HazOp) analysis and What-If analysis to identify those elements of handling and thermal stabilization processing that could lead to accidents.

2.0 METAL OPENING AND STABILIZATION ACTIVITY ANALYZED

2.1 OPERATIONS IN GLOVEBOX 636

The following is a sequential listing of the metal opening operations that will normally be done in the 636 Glovebox. These steps were identified during the HE team meetings and are the substance of the activity rather than the final procedural form and format. These are the steps that are identified in the HE worksheets with an "OM" identifier in the "Node ID" column.

1. Segregate, remove or minimize all combustibles to far end of glovebox.
2. Inspect outermost can to determine if it's a suspect (bulged, paneled, weight gained) can.
3. If suspect, punch can and wait until no further obvious reactions ongoing.
4. Open can with can opener.
5. If lid falls in can, remove lid from can with dulled screwdriver or tweezers.
6. Inspect material within can.
7. If contents are another can, go to step 2.
8. If contents are burning product, place slip-lid on top of product can. (may curtail operations until burning stops) --Seal it into a slip-lid can, bag it out, can it, and transfer it directly to Glovebox HC-21A to be thermally stabilized.
9. If contents appear to be normal product, pour contents into open container (tray, boat, can).

10. Separate corrosion products from metal:
 - a. brush whole, stable button with bristle brush
 - b. move clean stable button to a new can.
11. If contents are not a whole, stable button (per STA/Operator decision); re-can for transfer to Glovebox HC-21A.
12. When a maximum of 200 g of brushings have accumulated, can and transfer to Glovebox HC-21A.

Note: differences in operation in this GB636 & Glovebox HC-21A – 636 handles it more, no canning in Glovebox HC-21A, when opened in Glovebox HC-21A, it's poured into a boat, then conveyed to Glovebox HC-21C & thermally stabilized, and conveyed to and finally canned in GB18M.

2.2 SUBSEQUENT STABILIZATION OPERATIONS IN GLOVEBOXES HC-21A, HC-21C, AND HC-18M

The following is a sequential listing of the metal opening operations that will normally be done in the Glovebox HC-21A. These steps were identified during the HE team meetings and are the substance of the activity rather than the final procedural form and format. These are the steps that are identified in the HE worksheets with an "TS" identifier in the "Node ID" column.

1. Seal-in Pu container into Glovebox HC-21A, weigh Pu container, and furnace boat for Pu material accountability purposes.
2. Punch suspect (bulged or paneled) outer containers to relieve pressure or vacuum (typically performed in GB636).
3. Open Pu containers (includes punching and opening, if necessary, of overpack containers and inner container of Pu metal).
4. Remove materials (maybe corrosion products, metal or any combination of both) from containers and place in furnace boat.
5. Transfer furnace boat with boatcover to HC-2. Bag-out empty cans, plastic bags and tape as needed.
6. Transfer furnace boat with cover from Glovebox HC-21A to Glovebox HC-21C via conveyor or passed by hand via conveyor glovebox.
7. Remove the boatcover from the furnace boat, place boat in the furnace and operate the furnace.

8. At the end of the cool down cycle, open furnace and remove boat. After further cooling, inspect for degree of stabilization and reprocess as necessary.
9. Upon completion of stabilization and cool down, transfer furnace boat to HC-18M via HC-2 for sieve/grinding, place in can and sample.
10. Transfer can to Glovebox HC-18BS for interim storage pending sampling results.
11. If the sample passes LOI, transfer to HC-18M, bag-out and can. If the sample does not pass LOI, return material to Glovebox HC-21A for reprocessing.

In addition to the above operations, the relevant utilities associated with the plutonium metal stabilization process were examined. The specific utilities evaluated were the glovebox fire suppression system, the E-4 ventilation system that exhausts the gloveboxes, the power supply to the RMC Line equipment, and the 26-inch-Hg vacuum system that exhausts the muffle furnaces in Glovebox HC-21C.

3.0 HAZARD EVALUATION METHODOLOGY

The HE process is one that employs a systematic approach in the identification of hazards associated with a system, or process. The process is one in which the system or process is broken down into its basic elements and the hazards associated with each element are identified. Potential causes of those hazards are determined, potential consequences estimated and evaluated and possible corrective and/or preventative measures are considered. The HE was developed using a table to guide and record the results of a What-If brainstorming process. The What-If technique was combined with Hazard and Operability analysis system of using guidewords in conjunction with process parameters or procedure activities to arrive at an unintended deviation. By this method, structure was given to the otherwise unstructured What-If analysis technique. This guided What-If brainstorming was performed by individuals with detailed knowledge of the system or processes being examined, and was supported by a multi-disciplinary team familiar with the operation. A detailed discussion of the HE techniques of HazOp analysis and What-If analysis can be found in *Guidelines for Hazard Evaluation Procedures* (AIChE 1992).

The purpose and contents of each column in the HE sample table, Table B-1, are described in detail in the following paragraphs.

Column 1, Node ID: This column provides an alpha-numeric identifier for each hazard postulated in the table. The identifier is primarily used for cross-referencing within the table and as an identifier for accident sequences.

Column 2, Step #: The step or steps involved in performing each set of operations is identified in this column.

Column 3, "What-If" question: The deviation from the intended action put in the form of a "what if" question. The questions being generated using a set of deviation guide words. The deviation guides are the same as those used in a HazOp analysis.

Column 4, Consequence: Both the immediate and ultimate consequence of the activity/operational "What-If" deviation that could result are recorded in this column.

Column 5, Causes: This column identifies the causes for both the What-If and the ultimate accident sequence conclusion.

Column 6, Engineered Safety Feature(s) for "What-If" and Accident: This column identifies the engineered features (hardware items) intended or available to prevent or mitigate the consequences identified in Column 4.

Column 7, Administrative Safety Feature(s) for "What-If" and Accident: This column identifies the administrative requirements that reduce the likelihood of both the What-If event (if applicable) and the Accident event consequences identified in Column 4, or that help minimize the potential consequences of the Accident event.

Column 8, Consequence Category: This column is used to capture a code designator for the level of consequence associated with a hazardous event. The consequence ranking is the initial, qualitative estimate of the safety severity of the consequences. An alpha-numeric system has been used at the PFP to designate the severity of hazardous events. The system has the following "S" rankings characterizing safety consequences:

- S0 No effect outside the glovebox confinement systems; negligible safety concerns for the facility worker.
- S1 Potential industrial injury, low radiological or chemical exposure dose consequences to the facility worker.
- S1* Potential severe harm or potential death from industrial injury, radiological dose or chemical exposure to the facility worker.
- S2 Potential significant radiological dose consequences or chemical exposure to onsite workers located outside the facility.
- S3 Potential significant radiological dose consequences or chemical exposure to the offsite population.

Column 9, Frequency Ranking: This column shows the estimated frequency of occurrence. The frequency ranking is a first cut, qualitative estimate of the likelihood of the hazardous event. The following ranking system is used.

- F3 Events that are expected to occur one or more times during the lifetime of the facility, categorized as "anticipated" events. The frequency range associated with this category is 1E-02/yr to 0.1/yr.
- F2 Events that could occur during the lifetime of the facility, but with low probability. Such events are categorized as "unlikely" and fall in the range of 1E-04/yr to 1E-02/yr.
- F1 Events not expected to occur during the lifetime of the facility categorized as "extremely unlikely." The frequency range associated with this category is 1E-06/yr to 1E-04/yr.
- F0 Events categorized as "beyond extremely unlikely," with a frequency less than 1E-06/yr. Events in this category (such as meteor strike) are so unlikely they generally do not require special controls.

The frequency estimate, like the consequence ranking, is assigned taking no credit for active engineered features.

Column 10, Remarks: This column contains miscellaneous observations or clarifying comments for a given hazard.

4.0 HAZARDS EVALUATION PARTICIPANTS

This section contains the professional biographies of the participants of the PHA.

David M. Carson - Fluor Daniel Northwest - Specialty Engineer

Mr. Carson is currently employed in the SAR Engineering Services section of the Specialty Engineering group of Fluor Daniel Northwest. He has eight years of Nuclear Reactor Operator experience, having been a certified Operator at N Reactor, followed by nine years of Technical, Procedure, and Manual writing and editing experience from Tank Farms, Effluent Treatment, the Spent Nuclear Fuel Project, and Specialty Engineering. Mr. Carson has been trained in Process Hazard Analysis techniques, and has participated in development of the HazOp process as used in Specialty Engineering.

Craig Carro - M.H. Chew & Associates, Inc., Safety Analyst

Mr. Carro has a total of 17 years experience as a safety professional supporting DOE activities at the Rocky Flats site, Lawrence Livermore National Laboratory, and the Hanford site. For 13 years he has prepared authorization basis documents for facilities at the Hanford site including the PFP, Central Waste Complex, TRUSAF, TWRS, 242-A Evaporator and several others. Mr. Carro has a Bachelor of Science Degree in Fisheries with an aquatic ecology emphasis from the University of Washington, and a Masters Degree in Radiological Sciences with a radiation

biology emphasis from the School of Public Health and Community Medicine at the University of Washington.

Robert M. Marusich – Fluor Daniel Northwest, Inc., Engineer, Safety Analysis and Risk Assessment

Mr. Marusich has over 28 years experience in safety analysis. Mr. Marusich's experience includes both commercial reactors and DOE nuclear and non-nuclear facilities. He was also contributor and later Manager of the Probabilistic Risk Assessment (PRA) Group at Consumers Power Co. in charge of the Palisades and Big Rock Point PRA's. Mr. Marusich's area of expertise is consequence analysis. He has performed consequence analysis many of the processes performed within each of the Hanford facilities. Mr. Marusich has been performing consequence analyses for PFP for 11 years and has worked on numerous processes within PFP. Mr. Marusich has a B.S. and M.S. in Nuclear Engineering from the University of Wisconsin.

Aurora B. Rau – Fluor Daniel Northwest – Specialty Engineer

Mrs. Rau is currently employed in the SAR Engineering Services section of the Specialty Engineering group of Fluor Daniel Northwest. She has a total of 23 years of experience in the Hanford site documentation as well as a certified TRIGA reactor operator. She has eight years of experience in the documentation of Safety Analysis as well as Criticality Safety Evaluation Reports and other supporting documentation.

H. Rees Risenmay - B&W Hanford Co., Engineer, PFP Process Engineering, Solids Stabilization Cognizant Engineer

Mr. Risenmay has 16 years experience at the Hanford site. His experience has been in the Chemical Engineering Laboratory, the PUREX plant, the UO3 plant, and the PFP plant. His experience is mostly in process engineering with detailed knowledge of the processes and safety aspects for each plant. Mr. Risenmay has a Bachelor of Science Degree in Chemistry from Brigham Young University and a Bachelor of Science Degree in Engineering with chemical engineering emphasis from the University of Washington.

Errol Bonadie - B&W Hanford Company - Cognizant Engineer - Packaging & Shipping

Mr. Bonadie has worked at the Plutonium Finishing Plant since 1983. He is currently the Cognizant Engineer for Packaging and Shipping and he served as the Vault Cognizant Engineer from 1990 through 1997. Mr. Bonadie has a B.S. degree in Chemical Engineering from the Pratt Institute of New York. He also attended the New York University School of Education and the Howard University School of Engineering & Architecture.

Dennis A. Clapp - Fluor Daniel Northwest - Senior Specialty Engineer

Mr. Clapp is currently employed in the Safety Analysis and Risk Assessment section of the Specialty Engineering group of Fluor Daniel Northwest. He has been at the Hanford Site for 23 years. He has experience in nuclear power plant construction as a construction contract

administrator, field engineer, design engineer, and construction engineer. His Hanford Operations Contractor work experience includes conceptual design, Hanford Waste Vitrification Plant project design oversight, and safety analysis. His last 13 years have been in safety analysis. Mr. Clapp is certified by the Process Safety Institute as a Hazards Assessment Team Leader using the HazOp and What-If/Checklist techniques. His education is Bachelor of Science in Chemical Engineering from the University of New Mexico.

Edward Wallace - Lead Nuclear Chemical Operator - Fluor Daniel Hanford Company

Mr. Wallace has more than 16 year of experience at the Plutonium Finishing Plant. He has worked in Vault Operations for 10 years and has been a Lead Operator since 1989. Mr. Wallace is responsible for moving and/or supervising the movement of fissile material to and from process operations and storage arrays (including vaults) within the PFP complex.

Edward Kauer - Lead Nuclear Chemical Operator - Fluor Daniel Hanford Company

Mr. Kauer has more than 10 years of experience at the Plutonium Finishing Plant. He is currently working for the TSST team. He is certified in Thermal Stabilization operations, in Loadin/Loadout Plutonium nitrate operations and in General Plant operations. He has been a lead operator since 1990. He is responsible for moving and /or supervising the movement of fissile material to and from process operations and storage arrays within the PFP complex.

Thurman Cooper - B&W Hanford Company

Mr. Cooper graduated from Oregon State University with an M.S. in chemistry in 1973. Concurrent with his education, he spent 8 years on the OSU staff as a radiochemist, followed by 3 years working for Morrison Knudsen Inc. as a health physics manager and 23 years as a plutonium development chemist at the Plutonium Finishing Plant. Mr. Cooper is a member of the senior science advisory panel (also called the Critical Mass Working Group). The function of this group is to review site projects and processes and provide scientific advice to senior plant management. Mr. Cooper's professional interests include plutonium chemistry, reaction kinetics, thermodynamics, hydride chemistry, and modeling of chemical reactions. Mr. Cooper's models have played a role in safety assessments of plant processes. Examples of these assessments include:

- * Radiolytic gas generation from plutonium compounds during vault storage.
- * Radiolytic gas generation from plutonium nitrate solutions.
- * Safe handling of Pu corrosion products in air-filled gloveboxes.
- * Dust emission potential from the vertical calciner during off-normal conditions.

Robert B. Gelman - Process Engineer - Fluor Daniel Northwest, Inc.

Mr. Gelman received in BS in Chemical Engineering from Carnegie Mellon University, and his MBA from the University of Pittsburgh. He has 31 years of nuclear processing experience with the 23 of those at Hanford. He is the former facility manager for the Plutonium Finishing Plant, Hanford Waste Tank Processing Manager, Chemical Processing Quality Assurance Manager, 242-A Evaporator Restart Manager, TWRS Safety Basis Implementation Manager. He is regarded as an expert in nuclear facility management, conduct of operations, quality assurance, and program management. He is currently appointed to the ASME Nuclear Quality Assurance Subcommittee on Applications.

5.0 HAZARDS EVALUATION WORKSHEET ORGANIZATION

The HE table structure used in this analysis is provided in Table A-1. The HE table is structured to ensure a systematic and thorough review of potential hazards. The thermal stabilization of metal and metal corrosion products is broken down into logical sets of operations performed at specific locations. The operational steps covered in the analysis were identified from verbal descriptions provided by the cognizant engineers and other available information and were identified in section A.2.

Table 1. Hazards Evaluation Worksheet Form

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq. Cat	Remarks

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Table 2. Hazards Evaluation Worksheets
PFP Opening Metal Items in 636GB "What If" Hazards Evaluation Work Sheets

Hazards Evaluation Team: R.B. Gelman, E.P. Bonadie, T.D. Cooper, E.E. Wallace, E.L. Kauer, H.R. Risenmay, C.A. Carro, R.M. Marusich, D.A. Clapp, Leader, D.M. Carson Scribe
Date Hazards Evaluation Conducted: 9 June 1999

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-1a	1	What if combustibles not segregated or removed before operations begin?	Increased severity of fire due to higher combustible loading. Accident: fire initiated by sparks from opened can.	Poor housekeeping.	WI: None. A: Bayonet-equipped fire extinguishers; in-glovebox fire extinguisher with quick-disconnect (636); MgO sand; Halon (21A);.	WI: Procedural control; training. A: Training in use of fire suppression equipment and materials.	WI: S0 A: S1	WI: F3 A: F2	Credit taken for SC ventilation HEPA filters. Frequencies are given with controls in place.
OM-1b	1	What if combustibles generated during operations not segregated or removed?	Increased severity of fire due to higher combustible loading. Accident: fire initiated by sparks from opened can.	Poor housekeeping.	WI: None. A: Bayonet-equipped fire extinguishers; in-glovebox fire extinguisher with quick-disconnect (636); MgO sand; Halon (21A);.	WI: Procedural control; training. A: Training in use of fire suppression equipment and materials.	WI: S0 A: S1	WI: F3 A: F2	
OM-1c	1	What if combustibles segregated but never removed before operations begin?	Increased severity of fire due to higher combustible loading. Accident: fire initiated by sparks from opened can.	Poor housekeeping.	WI: None. A: Bayonet-equipped fire extinguishers; in-glovebox fire extinguisher with quick-disconnect (636); MgO sand; Halon (21A);.	WI: Procedural control; training. A: Training in use of fire suppression equipment and materials.	WI: S0 A: S1	WI: F2 A: F1	
OM-1d	1	What if unused gloves are not pulled out from glovebox before operations begin?	Breach of glove with subsequent spread of contamination. A: fire initiated by sparks from opened can.	Human Error	WI: none. A: gloves are self-extinguishing; Room CAMs; Halon system sends fire Alarm (21A); room fire suppression	WI: Procedural control; training. A: Training in use of fire suppression equipment and materials.	WI: S0 A: S1	WI: F3 A: F2	Check for 636 fire detection/Alarms.

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-2	2	What if we did not inspect a can?	See Remarks	See Remarks	See Remarks	See Remarks			Consequences determined by step 3.
OM-3a	3	What if we just opened a bulged suspect can without punching it first?	Release of Hydrogen from can A: Ignition of Hydrogen released from can.	See Remarks	See Remarks	See Remarks	WI: S A: S	WI: F A: F	Release and ignition of Hydrogen from a can is covered in Thermal Stabilization Addendum and in Rev. I to the PFP FSAR. Not a unique hazard to this operation.
OM-3b	3	What if we just opened a paneled suspect can without punching it first?	Increased reaction rate of contents (hydrides) A: "Sparky": (1) provides ignition source for combustibles in glovebox; (2) pressurization of glovebox; (3) provides increased particulate into glovebox.	Human error.	WI: none. A: (1) same as fire (2) ventilation system (3) glovebox containment	WI: Procedure compliance; training. A: (1) same as fire (2) none (3) none	WI: S0 A: 1)S1 2)S0 3)S0	WI: F3 A: 1)F3 2)F3 3)F3	Hydride bounds. To cause a fire, combustibles must be present. Calculations show that pressurization and particulate events are inconsequential.
OM-3c	3	What if we just opened a "weight-gain" suspect can without punching it first?	Bounded by OM-3b. A:	See Remarks	See Remarks	See Remarks	WI: S A: S	WI: F A: F	Normally, a leak of air into a can will result in formation of PuO ₂ ; however, if the leak is very, very small, reactive materials could still be present. Reactivity of materials is bounded by Pu hydride case, above.
OM-4a	4	What if typically-seen very fine dust coming from opened can is Pu hydride?	Powder will rapidly react in air -- "Sparky". A: See OM-3b.	See OM-3b.	See OM-3b.	See OM-3b.	WI: S0 A: 1)S0 2)S0 3)S0	WI: F3 A: 1)F3 2)F3 3)F3	Essentially the same as OM-3b.

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-4b	4	What if typically-seen very fine dust coming from opened can is non-reactive Pu compounds? (e.g., oxide)	Increased holdup in glovebox; higher dose rate.	See Remarks	See Remarks	See Remarks	S0	F3	Judged to be inconsequential.
OM-4c	4	What if the inmost can is turned upside-down, agitated, dropped, turned sideways, etc., before being opened?	Suspension of more particulate, which may escape and react -- "Sparky". A: See OM-3b.	See OM-3b.	See OM-3b.	See OM-3b.	WI: S0 A: 1)S0 2)S0 3)S0	WI: F3 A: 1)F3 2)F3 3)F3	Calculations show ~ 0.75 g could be released from a pressurized can; this amount will likely be less than that.
OM-5	5								Inconsequential
OM-6a	6	What if the contents are not inspected before being dumped, and the material is burning?	Larger surface area available for reaction, greater exposure to oxygen. A: Fire in glovebox, assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	Single container will not contain more than 200 g of Pu hydride, and this quantity of hydride reacting anywhere in the glovebox is not enough to pressurize glovebox. This can be proven scientifically within a can, and by ~50 years of processing experience for outside the can, in the glovebox. (See Thurman for details). This is the highest likelihood for a fire in the glovebox -- lots of glowing, burning, sparking material spread around.
OM-6b	6	What if foreign (e.g., aluminum foil) material is in the can?	WI: none A: foreign material trapping corrosion products and igniting while it is mixed with combustibles and causing a glovebox fire	WI: foreign material originally packaged with Pu metal	WI: none A: See OM-1a.	WI: none A: See OM-1a.	See OM-1a.	See OM-1a.	It is not anticipated that foreign materials will be present.
OM-7	7								Nothing to evaluate.

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-8a	8	What if we do not place a slip-lid on top of a can full of burning material?	Continues to burn; source of ignition for combustibles. A: Fire in glovebox, assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	We don't expect to see fast-burning, high-temperature buttons, as we don't have enough hydride to do that. Calculations exist to verify that.
OM-8b	8	What if an Alarm sounds and the room is evacuated with burning material still sitting exposed in the glovebox?	Continues to burn; source of ignition for combustibles. A: Fire in glovebox, assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	
OM-9a	9	What if normal-appearing product begins to burn when it's poured into tray?	Same as 8.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	Three things that could be done: 1) Let it burn. 2) Cover burning material with slip-lid can. 3) Cover it with MgO sand.
OM-9b	9	What if the material was poured on the floor of the glovebox rather than in the tray?	Same as 8.	See OM-1a.	See OM-1a.	See OM-1a.	WI: S0 A: S1	WI: F3 A: F2	This would likely pose a lower hazard because of a higher heat transfer through the floor of the glovebox.

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Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-9c	9	What if the material does not come out of the can?	WI: can't process material and requires further evaluation to get it out. A1: puncher of glove with tool during forced extraction A2: reactive piece ejected and lands on combustible material causing a glovebox fire.	Panneled can or hardened corrosion products	WI: none A1: none A2: See OM-1a.	WI: none A1: training, treatment of contaminated wound A2: See OM-1a.	WI: S0 A1: S1 A2: See OM-1a.	WI: F3 A1: F3 A2: See OM-1a.	
OM-10a	10a	What if a stable-looking button crumbles when you pick it up for brushing?	Possibility of generating dust: increased holdup in glovebox; higher dose rate.	See Remark	See Remark	See Remark	S0	F3	Amount of generated dust judged not to have a significant impact.
OM-10b	10a	What if brushing is over-vigorous, leading to large amounts of suspended powder?	Material suspended in glovebox atmosphere.	See Remark	See Remark	See Remark	S0	F0	Years of button brushing have shown that this is not a concern.
OM-11	11								Activity covered by AB.
OM-12a	12	What if the accumulation of reactive brushed material in the glovebox exceeds our experience base? (200g of brushed material from multiple containers).	Potential for pressurization of glovebox A: Loss of glovebox containment and contamination spread to room.	Lack of inventory control.	WI: none. A: CAMs and glovebox differential pressure and HEPA filtered exhaust	WI: Accountability/ Inventory control system for brushed material. A: none.	WI: S0 A: S1	WI: F2 A: F2	Propose: hotplate in 636 to heat brushed material to 350 °C to passivate the material OR send brushed material over to 21 A in single-batch amounts or single-brushing amounts.

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Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
OM-12b	12	What if the brushed reactive material appears to burn when poured into a new can?	Source of ignition for combustibles. A: Fire in glovebox, assuming contact with sufficient combustibles	Intentional action. A: See OM-1a	See OM-1a	See OM-1a	WI: S0 A: S1	WI: F3 A: F2	Reactive materials close to combustibles. You would expect to see reactions when pouring this 200 g of highly-reactive, non-passivated brushed material through the air to a new can, or sweeping it from the tray to a can.
PFP Opening Metal Items and Thermal Stabilization in GB HC-21A "What If" Hazards Evaluation Work Sheets Hazards Evaluation Team: R.B. Gelman, E.P. Bonadie, E.L. Kauer, C.A. Carro, D.A. Clapp, Leader, A.B. Rau, Scribe Date Hazards Evaluation Conducted: 15 June 1999									
TS-1	1								Hazards associated with these activities are addressed in the Thermal Stabilization Addendum to WHC-SD-CP-SAR-021.
TS-2	2								Covered in OM-3 (a, b, and c) see above.
TS-3	3								Covered in OM-4 (a, b, and c) see above
TS-4a	4	What if hydride is present and reacts	WI: material continues to react to completion; source of ignition for combustibles A: fire in glovebox assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.

Deviation Guides: (1) No, None (2) Less, Lower (3) More, Higher (4) Part of (5) As Well As (6) Reverse (7) Other Than, Sooner, Later, Where Else									
Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
TS-4b	4	What if metal is present and begins to burn?	WI: material continues to react to completion; source of ignition for combustibles A: fire in glovebox assuming contact with sufficient combustibles.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.	See OM-1a.
TS-4c	4	What if we spill it on the glovebox floor?	See OM-9b.	See OM-9b.	See OM-9b.	See OM-9b.	See OM-9b.	See OM-9b.	See OM-9b.
TS-5	5								No safety impacts.
TS-6a	6	What if corrosion products react or metal ignites on conveyor?	WI: provides a heat ignition source A: loss of glovebox containment and contamination spread to room	none	WI: none A: See OM-12a.	WI: none A: procedures and training	WI: S0 A: S1	WI: F2 A: F2	There is a very short residence time (e.g., less than a minute) on the conveyor.
TS-6b	6	What if furnace boat contents spill on conveyor?	WI: possibility of creating dust and increased holdup in glovebox A: higher dose rates to operators	Furnace boat becomes entangled with glovebox glove or operator drops furnace boat.	Furnace boat cover	Procedures and training and glovebox gloves are withdrawn and bungeed	S0	F3	
TS-6c	6	What if boat cover left off and boat inadvertently transferred to HC-18BS and reactive corrosion products disperse and ignite?	WI: exposed powder A: potential pressurization of glovebox if more than 200 grams of hydride	WI: human errors	Glovebox differential pressure, CAMs and HEPA filter exhaust	Procedures and training, 200 gram hydride restriction	S1	F1	Frequency judged to be at lower end of range (i.e., approaching 10 ⁻⁶ per year.
TS-7a	7	What if material not heated to >300 °C?	Residual hydride and potential exothermic reactions during subsequent processes	Equipment failure and failure to detect	Controller programmed to raise temperature to 1000 °C Setpoint temperature deviation alarms	Logbook entry and check chart recorders per procedure	S1	F1	This event could result in a glovebox fire. Glovebox fires have been previously identified in this Hazards Analysis with a probability of >F1.

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Node ID	Step #	"What If" question	Consequence	Cause(s) of "What If"	Engineered Safety Feature(s) for "What If" and Accident	Administrative Safety Feature(s) for "What If" and Accident	Cons Cat	Freq Cat	Remarks
TS-7b	7	What if there is no vacuum and hydrides are present?	Potentially flammable concentration of hydrogen within furnace and potential deflagration	Human error or equipment failure	Glovebox differential pressure, CAMs, HEPA filter exhaust	Procedures and training	WI:S0 A: S1	WI: F3 A: F2	

6.0 HAZARD EVALUATION RESULTS

Table 3 summarizes all of the potential accidents with significance worker consequences.

Table 3. Accidents With Potential Significant Worker Consequences (S1). (2 sheets)

ID#	Accident	Cause	Cons. Cat.	Freq. Cat.
OM-1a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-1b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-1c	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F1
OM-1d	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-2	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F3
OM-3a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-3b(1)	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F3
OM-3c	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-6a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-6b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-8a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-8b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-9a	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-9b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
OM-9c(1)	Hand puncture wound with Pu injection	Difficult extraction of solids from "paneled" - inadequate extraction tools.	S1	F3
OM-9c(2)	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2

Table 3. Accidents With Potential Significant Worker Consequences (S1). (2 sheets)

ID#	Accident	Cause	Cons. Cat.	Freq. Cat.
OM-12a	Loss of 636 or HC-21A glovebox containment	Accumulation and subsequent reaction of more than 200g of the most reactive corrosion products - reaction produces enough energy to pressurize glovebox to the point of breach of containment.	S1	F2
OM-12b	Fire in glovebox 636 or HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
TS-2	Fire in glovebox HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F3
TS-4a	Fire in glovebox HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F3
TS-4b	Fire in glovebox HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
TS-4c	Fire in glovebox HC-21A	Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F2
TS-6a	Loss of HC-21A glovebox containment	Spontaneous reaction of corrosion products while traveling conveyor - ignites and/or melts glove that may be left in box causing leak path from glovebox.	S1	F2
TS-6c	Loss of HC-21A glovebox containment	More than 200 grams of hydride being conveyed - reaction produces enough energy to pressurize glovebox to the point of breach of containment.	S1	F1
TS-7a	Fire in glovebox HC-21A	Material not heated to stabilization temperature leaving residual reactive material which may react while not controlled in subsequent processing/handling activities. Superfluous and uncontrolled combustibles ignited by corrosion product reaction sparks from opened can.	S1	F1
TS-7b	(1)Fire in glovebox HC-21A (2)Loss of glovebox containment (HC-???)	Simultaneous loss of furnace vacuum and presence of hydrides causing flammable concentrations of hydrogen with ignition.	S1	F2

[illegible]