Safety Analysis Report
for the
West Valley Melter Package

SARWVMP-01

Revision 1
April 2015
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[References for Chapters 4 though 8]

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10282 Rock Springs Road
West Valley, NY 14171

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&
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Stabilization of Residue Plutonium in L-9 Hood in Product Removal Room of PUREX With Polymeric Barrier System, WHC-SD-SQA-CSA-508, Rev. 0, Chiao, T., Westinghouse Hanford Company, Richland, Washington.

Stabilization of Residue Plutonium in L-9 Hood in Product Removal Room of PUREX With Polymeric Barrier System

T. Chiao
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

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Key Words: L-9 Hood, Plutonium, Polymeric Barrier System, Criticality Safety, Subcritical

Abstract: This report examines the application of Polymeric Barrier System to stabilize the remaining plutonium inside 1-9 Hood in PR Room, Purex for criticality safety.

Karen S. Noland 7/10/96
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CRITICALITY SAFETY EVALUATION REPORT 96-009

Title: Stabilization of Residue Plutonium in L-9 Hood in Product Removal Room of PUREX with Polymeric Barrier System

Prepared by: Tang Chiao Date: 4/24/96
Tang Chiao, Criticality Evaluation Team of Nuclear Physics and Shielding

Reviewed by: Allen L Hess Date: 4/25/96
A. L. Hess, Criticality Evaluation Team of Nuclear Physics and Shielding

Approved by: J G Greenborg Date: 4/25/96
J. Greenborg, Nuclear Physics and Shielding

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STABILIZATION OF RESIDUE PLUTONIUM IN L-9 HOOD IN PRODUCT REMOVAL ROOM OF PUREX WITH POLYMERIC BARRIER SYSTEM
Revision 0

WHC-SD-SQA-CSA-508

June 1996

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CONTENTS

LIST OF TABLES

LIST OF TERMS

ALARA	As low as reasonable achievable
CPS	Criticality prevention specification
CSER	Criticality safety evaluation report
NDA	nondestructive assay
PBS	Polymeric barrier system
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
PR	Product removal
Pu	Plutonium
PUREX	Plutonium Uranium Extraction (Facility)

1.0 INTRODUCTION

This criticality evaluation discusses the deactivation activities and final conditions of the Plutonium Uranium Extraction (PUREX) facility L-9 hood. These conditions are evaluated for potential impacts of applying a polymeric barrier system (PBS) to fix the remaining contamination in the hoods. While a great deal of the evaluation is centered on the L-9 hood activities, the objectives of this analysis is to define conditions for similar hood activities in the future. This criticality safety evaluation report (CSER) was not used to support activities in the L-9 hood. However, this CSER documents the technical basis for activities in the L-9 hood (see Appendix A).

The applicability of this evaluation to other plutonium (Pu) bearing hood and the appropriate restrictions are discussed in Section 7.0. The primary considerations required for applicability of this evaluation are the blanking of process and water lines to the hood, and the removal of Pu such that the final material is dispersed in a more or less uniform manner through out the hood.

2.0 L-9 HOOD

The deactivation activities of the L-9 hood in the product removal (PR) room of PUREX included the blanking of all solution lines to the hood and the removal of the residual material for cleanup. The residual material included dry Pu nitrate. The methods of removal of the residual material, especially for the remaining fissile material, included flush and cleanup of the hood floors, walls, and equipment to the maximum extent possible without impacting operator safety and doses.

After the cleanup, the L-9 hood was assayed using nondestructive analysis techniques to determined the amount of Pu remaining in the hood. The nondestructive assay (NDA) was performed by Pacific Northwest National Laboratory (PNNL) (see Appendix B) and the results indicate that a total of approximately 1 kg of Pu remains on floors, walls, corners, and pockets of the L-9 hood.

The remaining Pu is a radiation source and a potential criticality safety concern, because the quantity of remaining Pu exceeds the minimum critical mass. However, additional flush and cleanup of Pu residuals is difficult and would cause significantly high exposures to the cleanup crews. In order to meet the as low as reasonable achievable (ALARA) principle for radiation exposure protection and to eliminate the criticality safety concerns, the PUREX team has stabilized the remaining Pu in the L-9 hood by applying a PBS to the inside walls and floor of the hood fixing the contamination.

The L-9 hood is located in the product removal (PR) room inside the PUREX facility. The floor dimensions of the hood are approximately 7.4 m x 0.53 m, but the inside of the glovebox is not partitioned. The side and the back walls of the glovebox are made of concrete for shielding purposes. The following drawings provides general information about the PR room and the L-9 hood:

- H-2-53309 — General arrangement of the PR room
- H-2-66145 — L-9 sample hood details.

The hood contains the L-9 tank consisting of three interconnected, 12.7 cm diameter steel columns as a Pu product sampler, and related pipings. A criticality drain was installed in the floor of this hood to prevent the buildup of liquid inside the hood.

3.0 QUANTITY OF PLUTONIUM IN L-9 HOOD

The NDA technique was used to identify the location and to evaluate the quantities of the remaining Pu in the L-9 hood. For assay purposes, the hood was divided into four segments along its length. PNNL performed the NDA. The details of the NDA results are presented in Appendix B. A summary of the NDA estimated quantity of Pu is listed in Table 2-1.

Table 2-1. Summary of Hood L-9 Plutonium Holdup Distribution.

Location	Estimated quantity of plutonium (planar) (g)	Estimated quantity of plutonium (linear) (g)	Estimated quantity of plutonium (point) (g)	Total estimated quantity of plutonium (g)
L-9: Section 1	100	240	80	420
L-9: Section 2	100	250	140	490
L-9: Section 3	40	50	80	170
L-9: Section 4	10	50	0	60
Total	250	590	300	1,140

The planar source is assumed to be a thin layer coating the face and back wall of the hood. The linear source is assumed to be concentrations on the floor, corners, and on tubing. The point source is assumed to be pockets or hot spots.

The following quoted information is taken from Appendix B:

> "The total estimated quantity of plutonium is assumed to be spread throughout the hood, with larger quantities on or near the floor as may well be expected. The numbers in the table include the 126 g of plutonium removed on 4-17-4-18\96; therefore, the estimated plutonium remaining in the box currently is ≈1 kg. In addition, the gamma spectrometer results confirm the remaining plutonium is in the lower reaches of the glovebox, strongly support the column of point source values, and indicates no particular heavy buildup of material .."

4.0 POLYMERIC BARRIER SYSTEM AND THE APPLICATION OF PBS

According to the PUREX team, the Pu residue will be stabilized by applying a PBS to the inside hood surfaces. The PBS is a water soluble material, that is diluted with water when added to the inside surface of the hood, and will fix contamination. The concentrated PBS purchased from the vendor has a specific gravity between 1 and 1.2 and is 38 wt% water. This PBS is further diluted by the painters before application. The water will evaporate and leave the solid PBS (68 wt% of the purchased product prior to dilution) which has a hydrogen density of 8.7 wt% (water is 11 wt%).

The paint is to be applied to the hood using a low volume-high pressure spray pump and wand which has a very small diameter nozzle tip. The pump and PBS supply remain external to the hood at all times. No air or other motive fluid is used or needed. This method of application was selected because it minimizes resuspension of dry Pu powder, thus allowing the PBS to affix Pu powders to the surfaces. This technique cannot be used as a tool to transport Pu within a hood.

The PBS is to be applied as a single coating of about the same thickness as other paints. All surface areas and equipment within the hood will be stabilized. When finished, the painting nozzle is removed from the hood and metal covers are placed on all the ports (see Appendix C).

The amount of the mixture of PBS and water needed for the entire hood, walls, floor, equipment surfaces, etc., is estimated to be less than 19 L. Once the mixture is dried, the PBS is non-strippable.

5.0 CRITICALITY SAFETY EVALUATION

According to the NDA results given in Section 3.0, the description of PBS, and the procedures for applying PBS as stated in Section 4.0, the following data are established:

- There is no heavy buildup of Pu in any local spot (less than 140 g [0.31 lb])
- The surface Pu contamination most probably covers more than 1.0 m^2. Then, the maximum area Pu concentration will not exceed 2,160 g/m^2 (200 g/ft^2)
- The contamination remaining in the hood will not be moved in the process of PBS applications. The distribution of the remaining Pu will not be disturbed
- The estimated thickness of the "paint" (the mixture of PBS and water) will be less than 0.5 cm if it is assumed (conservatively) that the entire "wet paint" is applied to the floor.

According to III.A7 (100)-3 of Criticality Handbook Volume II (Carter, 1968), the minimum areal criticality concentration for ^{239}Pu is 2,160 g/m^2 (200 g/ft^2). The critical solution depth for this Pu concentration must be more than 17.78 cm under full water reflection.

The "wet paint" material can be conservatively considered like water as a neutron moderator. The Pu concentration on the hood floor and on the wall is likely below the minimum area critical concentration and the maximum thickness of the "paint" is less than 0.5 cm even if assuming the entire "paint" is applied to the floor. In addition, the process of applying the "paint" is not going to move the current Pu distribution. Therefore, stabilizing the Pu residue inside the L-9 hood with the PBS is critical safe under normal conditions.

6.0 CONCLUSIONS AND RECOMMENDATIONS

A criticality accident may be possible if the following conditions exists.

- The criticality drain is plugged.
- External water (liquid) pours into the hood and the depth of inflow water (liquid) exceeds 17.78 cm.
- The residual Pu is re-distributed so that a local area Pu concentration exceeds 2,160 g/m^2 (200 g/ft^2).

Hood L-9 will be sealed and all piping connected outside will be plugged. It is not credible to expect liquid ingress into this hood. Also, it is not credible to expect all residual Pu would be concentrated into a local region so that a high area Pu concentration (2,160 g/m^2 [200 g/ft^2]) is attained. The accident scenario requires two independent failures (plugged criticality drain and liquid inflow) which meets the double contingency requirement for criticality prevention.

According to the manufacture of PBS, the "paint" should stay in place at least 20 years when it is dry. However, if the paint flakes off and falls on the floor, the hood will remain sub-critical because the thickness of the accumulated peered off "paint" is unlikely to exceed 17.78 cm.

However, in order to ensure that the L-9 hood remains sub-critical, the following requirements shall be implemented:

- The amount of the mixture of PBS and water applied on the entire hood; walls, floor, equipment surfaces, etc., shall not be more than 19 L
- No container larger than 1.0 L is allowed in the hood
- The criticality drain shall be maintained operational
- A "permanent" posting shall be installed on hood L-9 to list the quantity of residual Pu inside the hood and note the application of PBS for stabilization of the residue.

7.0 APPLICATION OF POLYMERIC BARRIER SYSTEM ON OTHER SIMILAR HOODS

Application of PBS or other non-strippable "paint" material on similar hoods to fix the residual Pu contamination in PUREX and Plutonium Finishing Plant (PFP) can be supported by this CSER if the following conditions and requirements are satisfied.

- The hood shall be cleaned with reasonable and customary methods so that no visible Pu contamination remains.
- All solution lines to the hood shall be blocked off.
- The "paint" shall be non-strippable when it is dried.
- There is no heavy buildup of Pu in any local spot (less than 140 g).
- The maximum areal Pu concentration shall not exceed 972 g/m^2 (108 g/ft^2).
- The contamination remaining in the hood shall not be moved in the process of PBS (or other "wet paint") applications. The distribution of the remaining Pu shall not be disturbed.

- The estimated thickness of the "paint" (the mixture of PBS and water) shall be less than 0.5 cm if the entire "wet paint" is applied to the floor.
- No container larger than 1.0 L is allowed in the hood.
- The criticality drain shall be maintained operational.
- A "permanent" posting shall be installed on the hood to list the quantity of residual Pu inside the hood and note the application of the PBS for stabilization of the residue.

8.0 REVIEWER'S COMMENTS

It was established in Addendum 1 to CSAR 86-011 (Frair, 1995) that shutdown hood cleanup rules for criticality safety developed for PFP hoods were also appropriate to the PUREX hoods. The analyses and arguments reported above provide an extension of the previous evaluations to more adequately address the stabilization of fissile residues using fixing paints. The criticality prevention specifications (CPSs) to be developed for cleanup/ stabilization for the PUREX hoods should include only the appropriate items from the PFP CPS (#Z-165-80012), as supported by CSER 86-011, and the new rules on painting.

9.0 REFERENCE

Carter, R. D., G. R. Kiel, and K. R. Ridgeway, 1968, *Criticality Handbook*, ARH-600, Vol. II, Atlantic Richfield Hanford Company, Richland, Washington.

Frair, D. E., 1995, *Addendum 1 to CSAR 86-011: Glove Box Clean Up in PUREX*, Rockwell Hanford Operations, Richland, Washington.

APPENDIX A

INTERNAL MEMO FROM TANG CHAIO AND A. L. HESS

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Post-it™ Fax Note 7671	Date 4/22	# of pages ▶ 1
To Ed Dodd III	From Denelle Friar	
Co./Dept.	Co.	
Phone #	Phone # 372-2891	
Fax # 783-5067	Fax #	

Date: April 22, 1996

To: File

From: Tang Chiao and Al Hess T.C. AH

Subject: Applicability of Addendum 1 to CSER 86-011 to Painting the PR Room Glovebox in PUREX

The subject request was received from Ed Dodd III, PUREX CSR. The glovebox is believed to contain as much as 1200 grams Pu distributed throughout the glovebox. It is impractical to remove any more of the contamination.

Because the amount of Pu exceeded a minimum critical mass, the CSR wanted to verify that Addendum 1 to CSER 86-011 was applicable.

The proposed cleanup operation includes painting the interior of the glovebox with a non-strippable paint that would be thinned with water, as needed. The amount of paint and water was estimated to be about 5 gallons, a quantity that if spilled would only be a layer 1/4 inch deep on the glovebox floor.

Reasonable efforts will be taken to apply the paint to minimize the redistribution of the Pu, as by excessive flow or subsidence of the applied paint.

The discussions of glovebox flooding indicated that the fire sprinklers are still active in the room, that the glovebox fire sprinklers are a limited volume (about 12 gallons), manually-operated system, and that process water sources to the glovebox itself have been blanked off. The fire sprinkler system will be shut off as well, along with the electrical power when the clean up is complete. Meanwhile, the existing glovebox criticality drain will be left open as an aid in maintaining glovebox ventilation. The room is still posted fire category C. We concluded that flooding the glovebox was an unlikely event, and that flooding with a plugged glovebox criticality drain meets the double contingency requirements referenced in the Addendum. PUREX conduct of operations provides assurance that operators will remove paint cans, rags, and other debris (resulting from the painting efforts) from the glovebox when the painting is finished. The intent is to remove materials that might block the criticality drain.

We concluded that, despite the larger than usual inventory in this glovebox, the subject addendum encompasses the work scope described.

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APPENDIX B

PACIFIC NORTHWEST NATIONAL LABORATORY NONDESTRUCTIVE ASSAY RESULTS FOR L-9 HOOD

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Battelle
Pacific Northwest Laboratories
Battelle Boulevard
P.O. Box 999
Richland, Washington 99352
Telephone (509) 376-0405

April 18, 1996

Andrew G. Westra
Westinghouse Hanford Company
P. O. Box 1970
Mail Stop S6-21
Richland, WA 99352

Dear Mr. Westra:

PNNL NON-DESTRUCTIVE ASSAY RESULTS

This report summarizes data collected March 30, 1996, April 3, 1996, and April 11-17, 1996, using the PNNL NDA Systems on the L9 Glovebox in the Product Removal (PR) Room of the PUREX Building, 200 East Area. The PNNL NDA Systems employ high-resolution (HPGe) gamma-ray spectrometers and/or total-neutron slab detectors to characterize radioactive emissions using non-destructive assay (NDA) techniques.

The counts were performed to assess the upper-limit quantity of plutonium expected within the L9 Glovebox and to assess its relative distribution. We were informed that the glovebox had never processed fluorides. Our gamma-ray data confirmed this information. We were also told to assume that the majority of the plutonium would be on or near the floor of the glovebox. Again, data collected using a collimated gamma-ray detector confirmed this assumption.

<u>Alpha-Particle Activity Measured via Passive Neutron Counting</u>

The passive thermal-neutron counter is a slab-type detector that employs 10 $^{10}BF_3$ tubes surrounded by 2.54-cm-thick high-density polyethylene. The 5-cm-diameter $^{10}BF_3$ tubes have an active length of roughly 180 cm and a fill pressure of 12 kPa. The boron is enriched to 95% ^{10}B.

Alpha-particle activity in the glovebox results in neutron emissions via (α,n) reactions, predominantly with oxygen and other light elements of the matrix. Neutron emissions are also generated by spontaneous fission, typically of even-numbered transuranic isotopes, such as ^{240}Pu. We were told to assume weapons-grade (6% ^{240}Pu) plutonium nitrate in the PR Room L9 Glovebox.

The neutron counts were taken at the face of the glovebox and again at a distance of approximately 27 cm at 4 separate positions along the 20-foot length of the glovebox; background counts were taken on a platform just inside the door to the

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PR Room. Figure 1 shows the layout of the PR Room with the counting positions marked as "Section 1", "Section 2", "Section 3", and "Section 4." Sections 1 and 2 were visibly more contaminated than Sections 3 and 4, with Section 4 visibly being the least affected by previous campaigns.

The narrow false-floor adjacent to the face of the L9 Glovebox made positioning of the detectors difficult and limited the distance that the detectors could be moved back from the glovebox face. The narrow construction and the concrete walls resulted in a "neutron cave" in which emitted neutrons bounce between walls until thermalized and absorbed: a given neutron typically has several chances to be counted by a detector, which increases the apparent efficiency of the neutron detector; a point source does not appear to strictly follow the $1/R^2$-law but some smaller fraction of 2; a line source does not appear to strictly follow the 1/R-law but some smaller fraction of 1. These anomalies complicate the interpretation of observed data.

Table 1 summarizes count rates obtained along the L9 Glovebox on 3 separate occassions. The count on 03/28/96 established a baseline for the L9 Glovebox neutron count. A total of 425 g of plutonium were removed prior to the count on 04/03/96. A total of 228 g of plutonium were removed prior to the count on 04/11/96.

Table 1. Summary of Counts Taken Along the L9 Glovebox in the PR Room of PUREX.

Location	Distance to Face (cm)	Count Rate [03/28/96] (c/60s)	Count Rate [04/03/96] (c/60s)	Count Rate [04/11/96] (c/60s)
Outer Area	--	3749 ± 87	--	--
L9: Section 1	0	253910 ± 151	168130 ± 346	110616 ± 462
L9: Section 1	27	220903 ± 222	150402 ± 571	100955 ± 170
L9: Section 2	0	146020 ± 504	126598 ± 333	113487 ± 66
L9: Section 2	27	137034 ± 100	117744 ± 121	105251 ± 345
L9: Section 3	0	59333 ± 261	51214 ± 127	58203 ± 21
L9: Section 3	27	58064 ± 54	53126 ± 205	57738 ± 94
L9: Section 4	0	27225 ± 229	22670 ± 285	23635 ± 109
L9: Section 4	27	28449 ± 95	24018 ± 499	24349 ± 174

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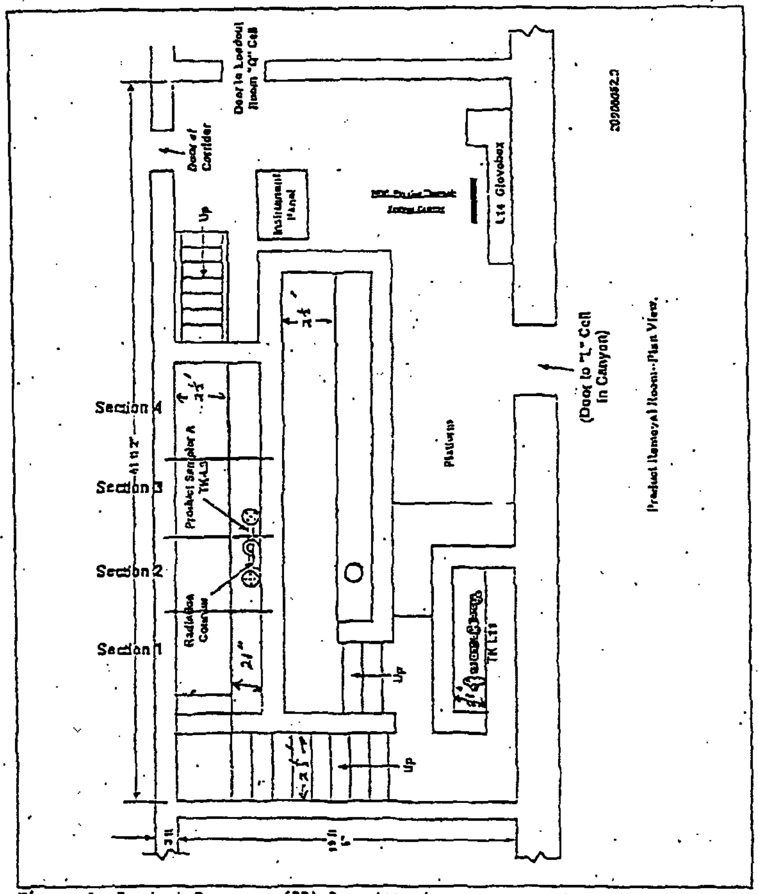

Figure 1 Product Recovery (PR) Room Layout.

Activity Measured via Gamma-Ray Spectrometry

Several sets of data were acquired using a high-purity germanium (HPGe) gamma-ray spectrometer. A collimator was designed to fit an ORTEC hand-held system. The collimator system consisted of a 1-cm-thick sleeve of lead that fit over the snout of the detector and shielded the germanium crystal from low-energy gamma rays entering from oblique angles. Lead inserts with square holes were used to provide various aspect ratios. The spectrometer with this collimator system was calibrated with a 100-gram weapons grade PuO_2 standard that simulated a point source.

Gamma-ray results were used to identify radiological activity within the L9 Glovebox, to locate hot spots, and to establish concentration levels. The gamma-ray system confirmed that fluorine was not present in the L9 Glovebox at a level that would detrimentally inflate the neutron count rate via the $^{19}F(\alpha,n)^{22}Na$ reaction; the presence of fluorine is manifest in the gamma-ray spectrum as 511-keV and 1275-keV gamma rays that are not as well resolved as adjacent peaks due to prompt capture/decay effects. The gamma-ray spectrometer also indicated the presence of ^{137}Cs in the L9 Glovebox with a higher ratio at Section 4 (relative to the plutonium) than in the other sections. The presence of ^{228}Th was also observed, presumably arising from ^{232}U (since no activity from ^{228}Ac was observed that would indicate ^{232}Th as the parent of the ^{228}Th).

Results and Conclusions

The neutron data were heavily used to estimate the quantity of plutonium present in the L9 Glovebox. The known response of the neutron counter to neutron sources at different positions allows corrections to be made for the cross-talk expected when counting adjacent sections. The gamma-ray data were used to aid the model used to correlate expected readings with actual measurements. Some allowance was made for the "neutron cave" effect and the apparent increased efficiency of the neutron counter.

The source term was apportioned in each section to a planar, a linear, and a point source. The planar source is allowed to be on both walls and does not vary with distance from the detector. The planar and linear sources are assumed to be close to the far wall of the glovebox.

The results of using this model and a similar, independent model are provided in Table 2. The Planar source is assumed to be a thin layer coating the face and back wall of the glovebox. The Linear source is assumed to be concentrations on the floor, along corners, and along any tubing. The Point source is assumed to be any pockets or hot spots.

The change in count rate for each section after known quantities of plutonium were removed proved invaluable in estimating the quantity remaining. The

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approximate location of the removed quantities also contributed to estimating total amounts.

The total estimated quantity of plutonium is assumed to be spread throughout the glovebox, with larger quantities on or near the floor as may well be expected. The numbers in the table include the 126 g of plutonium removed on 4/17-18/96; therefore, the estimated plutonium remaining in the box currently is ≈1 kg. Additional data taken with the neutron counter after the 126 g quantity had been bagged up, but before it was removed from the hood, completely support the table data. Additionally, data taken with the gamma-ray spectrometer, especially looking at the floor through a hole in the side of the lead sleeve, further confirms these estimated quantities, further confirms that the preponderance of the remaining plutonium in is the lower reaches of the *glove box, stongly* supports the column of point source values, and indicates no particular heavy buildup of material that might constitute a criticality concern.

Table 2. Estimated Quantity of Plutonium: L9 Glovebox of the PR Room in PUREX.

Location	Estimated Quantity of Plutonium [Planar] (g)	Estimated Quantity of Plutonium [Linear] (g)	Estimated Quantity of Plutonium [Point] (g)	Total Estimated Quantity of Plutonium (g)
L9: Section 1	100	240	80	420
L9: Section 2	100	250	140	490
L9: Section 3	40	50	80	170
L9: Section 4	10	50	0	60
Total	250	590	300	1140

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Any questions may be directed to me at Mail Stop P8-08, by cc:Mail, by FAX at 376-2329, or by phone at 376-0405.

Sincerely,

Dr. Richard J. Arthur
Sr. Research Scientist

TRU Results Review and Concurrence:

Dr. Ronald L. Brodzinski
Staff Scientist

Enclosures
Attachments

cc w/attachments:
DE Robertson, P8-01
MD Winterrose, P8-01
File /LB

APPENDIX C

COMMUNICATION WITH MARK EHGUSEN VIA CCMAIL

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COMMUNICATION WITH MARK EHGHUSEN VIA CCMAIL

Per our discussion I will try to fill you in on the stabilization procedure used for the PR Room and N Cell gloveboxes. All the gloveboxes are first NDA'd to determine Pu content. (As yet only the L9 glovebox contained greater than 150 grams of Pu.)

The glovebox is stabilized by removal of all gloves and application of a Polymeric Barrier System (PBS) to the inside surfaces. The PBS is a water soluble material which is diluted with water which when added to the inside surface of the glovebox, will fix contamination. The concentrated PBS purchased from the vedor has a specific gravity between 1 and 1.2 and is 38 % weight per cent water. This PBS is further diluted by the painters prior to application. The water will evaporate to leave the solid PBS (68 weigher per cent of the purchased product prior to dilution) which has a hydrogen density of 8.7 weight percent (water is 11 %).

The paint is applied to the glovebox using a LOW VOLUME-HIGH PRESSURE SPRAY PUMP AND WAND WHICH HAS A VERY SMALL DIAMETER NOZZLE TIP. The pump and PBS supply remain external to the glovebox at all times. No air or other motive fluid is used or needed. This method of application was selected because it MINIMIZES RESUSPENSION OF DRY PU POWDER THUS ALLOWING THE PBS TO AFFIX PU POWDERS TO THE SURFACES. (This application technique cannot be used as a tool to transport the Pu within a glovebox.)

The PBS is applied in as a single layer about the same thickness as other paints. All surface areas and equipment within the glovebox will be stabilized. The painting nozzle is removed from the glovebox and metal covers are placed on all the ports.

The criticality drain will remain open to the canyon to provide contamination control thru differential pressures.

I hope this assists in evaluating the glovebox stabilization process. If you have further questions, call me at 3-3837 or Ed Dodd at 3-1293.

Mark

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DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Nuclear Physics and Shielding	Date 04/24/96
Project Title/Work Order Stabilization of Residue Plutonium in L-9 Hood in Product Removal Room of PUREX with Polymeric Barrier System		EDT No. 603242 ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
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Hood L-9 will be sealed and all piping connected outside will be plugged. It is not credible to expect liquid ingress into this hood. Also, it is not credible to expect all residual Pu would be concentrated into a local region so that a high area Pu concentration (2,160 g/m^2 [200 g/ft^2]) is attained. The accident scenario requires two independent failures (plugged criticality drain and liquid inflow) which meets the double contingency requirement for criticality prevention.

According to the manufacture of PBS, the "paint" should stay in place at least 20 years when it is dry. However, if the paint flakes off and falls on the floor, the hood will remain sub-critical because the thickness of the accumulated peered off "paint" is unlikely to exceed 17.78 cm.

However, in order to ensure that the L-9 hood remains sub-critical, the following requirements shall be implemented:

- The amount of the mixture of PBS and water applied on the entire hood; walls, floor, equipment surfaces, etc., shall not be more than 19 L.
- No container larger than 1.0 L is allowed in the hood
- The criticality drain shall be maintained operational
- A "permanent" posting shall be installed on hood L-9 to list the quantity of residual Pu inside the hood and note the application of PBS for stabilization of the residue.

7.0 APPLICATION OF POLYMERIC BARRIER SYSTEM ON OTHER SIMILAR HOODS

Application of PBS or other non-strippable "paint" material on similar hoods to fix the residual Pu contamination in PUREX and Plutonium Finishing Plant (PFP) can be supported by this CSER if the following conditions and requirements are satisfied.

- The hood shall be cleaned with reasonable and customary methods so that no visible Pu contamination remains.
- All solution lines to the hood shall be blocked off.
- The "paint" shall be non-strippable when it is dried.
- There is no heavy buildup of Pu in any local spot (less than 140 g).
- The maximum areal Pu concentration shall not exceed 972 g/m^2 (108 g/ft^2).
- The contamination remaining in the hood shall not be moved in the process of PBS (or other "wet paint") applications. The distribution of the remaining Pu shall not be disturbed.

Material Safety Data Sheet **Bartlett Inc.**

IDENTITY *(As Used on Label and List)*	**Polymeric Barrier System (PBS)**

Section I

Manufacturer's Name: **Bartlett Services, Inc.**	Emergency Telephone Number: **1-800-225-0385** Bartlett Safety Manager: **1-508-591-1295**
Address *(Number, Street, City, State, and ZIP Code)*	Telephone Number for Information : **1-800-225-0385**
60 Industrial Park Road **Plymouth, MA 02360**	Date Prepared: **October 17, 2007** Date Reviewed and Updated: **August 19, 2011**
	Signature of Preparer *(optional)*

Section II - Hazard Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	CAS NUMBER	OSHA PEL (8-hr TWA)	ACGIH TLV (8-hr TWA)	NIOSH REL (<10 hr TWA)	Percent Concentration by weight
Acrylate Based Polymer Comprised of the following:	None	Not Established			<62%
Butyl acrylate *(Acrylic acid, butyl ester; Butyl 2-propenoate; n-Butyl Acrylate)*	141-32-2	Not Established Proposed 1989 10 ppm ($52\ mg/m^3$)	2 ppm ($10\ mg/m^3$)	10 ppm ($52\ mg/m^3$)	<0.1%
Methyl methacrylate *(Methacrylate monomer; Methyl ester of methacrylic acid; Methyl-2-methyl-2-propenoate)*	80-62-6	100 ppm ($410\ mg/m^3$)	50 ppm ($205\ mg/m^3$) STEL 100 ppm	100 ppm ($410\ mg/m^3$)	<0.1%
Styrene *(Phenylethylene; Vinylbenzene; Cinnamene; Styrene monomer)*	100-42-5	100 ppm ($426\ mg/m^3$) CEILING 200 ppm exception: exposures may exceed 200 ppm, but not more than 600 ppm (peak), for a single time period up to 5 minutes for any 3 hours	20 ppm ($85\ mg/m^3$) STEL 40 ppm	50 ppm ($213\ mg/m^3$) STEL 100 ppm	<0.1%
Ammonia *(Anhydrous ammonia)*	7664-41-7	50 ppm ($35\ mg/m^3$)	25 ppm, ($17\ mg/m^3$) STEL 35 ppm	25 ppm ($17\ mg/m^3$) STEL 35 ppm	<0.04%
Water	7732-18-5	Not Established			38%

Titanium dioxide *(Anatase; Brookite; Rutile; Titanium oxide; Titanium peroxide)*	13463-67-7	15 mg/m^3	10 mg/m^3	Not Issued	<2%
Polyacrylic acid	9003-01-4	Not Established			0.15%
Triethylamine *(N,N-diethylethanamine, TEN, di(ethylamino)ethane, diethylaminoethane, ethanamine)*	121-44-8	25 ppm (103 mg/m^3)	1 ppm (4.1 mg/m^3) (Skin Notation) STEL 3 ppm	10 ppm (41 mg/m^3) STEL 15 ppm	0.1%
Propylene glycol n-butyl ether *(1-Butoxy-2-propanol, n-Butoxypropanol)*	005131-66-8	Not Established			0.1%

Section III - Physical/Chemical Characteristics

pH	**4.5 - 7.5**	Specific Gravity (H_2O = 1)	**1.0 to 1.2**
Evaporation Rate (Butyl Acetate = 1)	**<1 (slower than water)**	Melting Point	**0°C (32°F)**
Vapor Pressure (mm Hg.)	**17.5 @ 20C (68°F)**	Boiling Point	**100°C (212°F)**
Vapor Density (AIR = 1)	**<1 (lighter than water)**	Freezing Point	**0°C (32°F)**
Solubility in Water	**Liquid form product is soluble in water**		
Appearance and Odor:	**Milky white or red or blue colored fluid, or other custom colors. Odor: Characteristic**		

Section IV - Fire and Explosion Hazard Data

Flash Point (Method Used)	**Not Applicable**	
Flammable Limits	LEL: **N/A (Liquid)**	UEL: **N/A (Liquid)**
Extinguishing Media	**Dried product will burn. Use alcohol type or all-purpose foam for large fires. Use CO_2 or dry chemical media for small fires.**	
Special Fire Fighting Procedures	**Use Self Contained breathing apparatus when fighting fires in enclosed areas.**	
Unusual Fire and Explosion Hazards	**Liquid form product will not burn but may spatter if temperature exceeds boiling point of water. Dried solids can burn, giving off oxides of carbon and other potentially dangerous combustion by-products.**	

Section V - Reactivity Data

Stability	**Stable in Liquid Form** **Stable in Solid Form**	Conditions to Avoid	**Can coagulate if frozen**
Incompatibility *(Materials to Avoid)*	**Addition of chemicals, such as acids or multivalent metal salts, may cause coagulation.**		
Hazardous Decomposition or Byproducts	**Depends on temperature, and the presence of other materials**		
Hazardous Polymerization	**Will not occur**	Conditions to Avoid	**No know "conditions to avoid"**

Section VI - Health Hazard Data

Route(s) of Entry:	
Inhalation:	**Trace component and residual monomer vapors may be irritating to eyes, skin, mucous membranes, respiratory tract, and may produce symptoms of headache and nausea in poorly ventilated areas.**
Skin:	**Prolonged contact may cause transient reddening of the skin.**
Ingestion:	**No evidence of adverse effects from available information.**
Eye:	**Direct contact may cause eye irritation.**
Emergency and First Aid Procedures:	
Inhalation:	**No emergency care anticipated. Remove to fresh air. Give artificial respiration if not breathing. Oxygen may be given by qualified personnel if necessary. Call a physician.**
Skin:	**Wash skin with soap and water until water is not cloudy. If clothing is soaked, remove and wash separately before reuse. Seek medical assistance if skin irritation develops.**
Ingestion:	**If swallowed, seek medical attention. Do not induce vomiting unless directed to do so by medical personnel**
Eye:	**Immediately flush eyes with tepid water and continue washing for at least 15 minutes. Remove contact lenses, if worn. Obtain medical attention if eye irritation develops.**

Carcinogenicity:	**PBS does not contain any materials identified by OSHA, ACGIH, NTP, or IARC as a potential carcinogen.**
Health Hazards *(Acute and Chronic)*	**No evidence of adverse effects from available information. Toxicology studies of similar material have shown the material to be of very low acute toxicity. There is no specific antidote. Treatment of overexposure should be directed at the control of symptoms and the clinical condition.**
Signs and Symptoms of Exposure	**May produce symptoms of headache and nausea in poorly ventilated areas and may cause transient reddening of the skin.**
Medical Conditions Generally Aggravated by Exposure	**A knowledge of available toxicology information and of the physical and chemical properties of the material suggests that overexposure is unlikely to aggravate existing medical conditions.**

Section VII - Precautions for Safe Handling and Use

Steps to Be Taken in Case Material is Released or Spilled	**Restrict area to only those personnel needed. Major spills should be collected for disposal. Minor spills may be flushed to sewer if permitted by state, federal and local regulations.**
Waste Disposal Method	**Incinerate or bury in suitable landfill where permitted by appropriate government regulations.**
Precautions to Be taken in Handling and Storing	**Handling: Avoid prolonged or repeat contact with skin. Storage: Store between 4.4°C (40°F) and 43.3°C (110°F)**

Section VIII - Control Measures

Respiratory Protection *(Specify Type)*	**In most conditions no respiratory protection should be needed; however, if discomfort is experienced, use an approved air-purifying respirator. Recommended: Organic vapor with a particulate pre-filter.**
Ventilation	
Local Exhaust	**Use local exhaust if needed to control mist or vapor.**
Mechanical *(General)*	**General ventilation is expected to be satisfactory in most conditions.**
Special	**Good industrial hygiene practices recommend that engineering controls be used to control environmental airborne concentrations at or below applicable permissible exposure limits. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations that require entry into enclosed or confined spaces. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration or by the National Institute for Occupational Safety and Health. Respirator selection is the responsibility of the user and should be made only by an individual who is competent in evaluating potential worker airborne exposure that may occur during application or removal.**

Eye Protection	**When handling any liquid wear tight fitting chemical goggles or a face shield. An emergency eyewash facility, which provides at least 15 minutes of tepid water for flushing, should be immediately available.**
Protective Gloves	**Use gloves impervious to water and soap. Examples of preferred glove barrier material: Chlorinated polyethylene, Polyethylene, latex, neoprene, viton. Avoid gloves made of Polyvinyl alcohol (PVA)**

Section IX - Special Precautions

Precautions to be taken in Handling and Storing
1. **Avoid breathing vapors in top of shipping container.** 2. **Keep container closed.** 3. **Use with adequate ventilation.** 4. **Avoid contact with skin and clothing.** 5. **Wash thoroughly after handling.** 6. **Store above 4 °C (40 °F). Do not freeze.**

Other Precautions
THIS PRODUCT IS INTENDED FOR INDUSTRAL USE ONLY! The opinions expressed herein are those of qualified experts within Bartlett Services, Inc. We believe the information contained herein is current as of the date of this Material Safety Data Sheet. Since the use of this information and these opinions and the conditions of use of the product are not within the control of Bartlett Services, Inc., it is the user's obligation to determine the conditions of safe use of the product.

Reviewed by Salvatore R. DiNardi, Ph.D., CIH

Revision date 13 November 2007

Reviewed by David A. Montt, MS, MSChE, CHP

Revision date 19 August 2011

WVMP SAR Reference 4-5

Decontamination Using Remote-Deployed Nitrocision Technology, Chilson L. and L. B. Winkler, WM2011 Conference, February 27 – March 3, 2011, Phoenix, Arizona.

Decontamination Using Remote-Deployed Nitrocision® Technology – 11221

Lettie Chilson* and L. B. Winkler*
*West Valley Environmental Services LLC

ABSTRACT

The Main Plant Process Building (MPPB), used during commercial spent nuclear fuel reprocessing between 1966 and 1972, is comprised of approximately 55 rooms (cells) with concrete walls varying in depths up to 1.5 meters (five feet). Two of the cells in the MPPB – the Process Mechanical Cell (PMC) and the General Purpose Cell (GPC) – were extensively contaminated with spent fuel during reprocessing operations with radiation dose levels measuring from 1-105 R/hour at the beginning of the Interim End State contract.

Due to the high levels of radiation in the cells, WVES would have to perform cell decontamination using remotely-deployed technology to protect its workers. Nitrocision® technology was selected for its historical performance in decontaminating surfaces, but the remote application was new technology and would require the combined engineering talents of both WVES and Nitrocision® to develop and operate the system effectively in-cell.

The system, provided by Nitrocision LLC, possesses several advantages including removal efficiency, waste minimization and versatility over other traditional decontamination methods including water, carbon dioxide and decontamination gels. WVES and Nitrocision have partnered to develop the remote application methods, evaluate performance and enhance system availability, develop lessons learned, test and deploy prototype equipment, and apply the technology to high-hazard, remotely-conducted decontamination work. This effort may lead to other remote applications at DOE cleanup sites, as well as nonradioactive industrial applications.

HISTORY

The West Valley Demonstration Project (WVDP) located in West Valley, New York, is a high-level waste (HLW) solidification and radiological cleanup project. The MPPB in West Valley was the location of the only commercially-operated spent nuclear fuel (SNF) reprocessing facility to have operated in the United States (1966-1972).

The primary mission of the WVDP is to complete actions articulated in the West Valley Demonstration Project Act (WVDP Act, Public Law 96-368). These actions include HLW solidification and transport; decontamination and decommissioning of facilities, materials, and hardware used to complete the HLW solidification; and disposal of low-level waste (LLW) and transuranic (TRU) wastes generated from the HLW solidification process. Activities related to HLW solidification were completed in September 2002; facility decontamination and waste processing activities are ongoing. Recently, these activities have focused on decontaminating highly radioactive and highly contaminated process cells in the MPPB where SNF reprocessing operations were conducted.

Constructed more than 40 years ago, the MPPB housed a system to prepare SNF assemblies for chemical processing to recover uranium (U) and plutonium (Pu) from SNF rods. Dismantlement of component and initial surface decontamination of two heavily-shielded, highly-contaminated Head End Cells (HECs) where SNF was mechanically prepared during commercial operations - the PMC and the GPC – were completed in 2004. That initial cleanup effort was concluded with the application of a fixative, Polymeric Barrier System (PBS), to the cell walls and floors to seal remaining contamination.

The U.S. Department of Energy (DOE) is currently preparing the MPPB for demolition under the Record of Decision issued in 2010. West Valley Environmental Services (WVES) has been contracted to further decontaminate the Head End Cells. WVES has evaluated several technologies and selected the remote application of high-pressure liquid nitrogen.

BACKGROUND

The GPC and PMC were coated with PBS fixative in 2004 to lock down remaining contamination after the removal of significant processing debris and cell waste. This resulted in significant improvement in airborne radiological conditions; however dose rates in the cell remained too high to permit human access. A survey performed in December 2009, before beginning further decontamination of the PMC, showed gamma dose rates in the range of 0.7 R/hr to 37 R/hr at a distance of three feet from the floor. GPC values (obtained in October 2010) are slightly higher with a range of 0.51 R/hr to 105 R/hr at the same three foot distance. As a result of the measured dose rates, further decontamination of the cells would require remote deployment of any selected cleaning technology.

Radiological contamination in the Head End Cells is a result of processing spent nuclear fuel and is primarily beta-gamma emitters with an alpha component. At deployment, the PBS, a very hydropholitic material, was applied with the viscosity of a thick paint and, even when cured, retains a very flexible, rubbery consistency. The material coats the walls and floors of the cells in varying thicknesses based on volume applied and the effect of a varying floor slope – experienced in both cells. Both cells also have complicated surfaces from a decontamination perspective, penetrating pipe, structures with rails and deep wells, and limited ability to access wall surfaces above the physical range of in-cell equipment.

As a result of the contamination and radiation levels associated with the Head End Cells, all equipment installation interfaces had to be done through prepared ports with hands-on work performed by robotic arms mounted to the inside cell walls or by an in-cell bridge crane equipped with a chain hoist and bridge mounted remotely operated arm (PaR arm). When selecting a decontamination technology, top priority was assigned to maintaining worker dose As Low As Reasonably Achievable (ALARA) and the capability of the technology to be applied remotely.

DECONTAMINATION TECHNOLOGIES EVALUATED

WVES evaluated several decontamination technologies – steam, carbon dioxide, sand/grit blasting, and liquid nitrogen for remote application in the HECs – before selecting Nitrocision® technology. Each of the other technologies had significant deployment disadvantages such as:

- Potential facility ventilation filtration integrity compromise;
- Questionable effectiveness;
- Inability to troubleshoot or verify performance at a distance;
- Significant secondary waste stream production and associated handling and disposal costs.

Cost-benefit analysis drove the selection of Nitrocision® technology to remove the PBS from the cell walls.

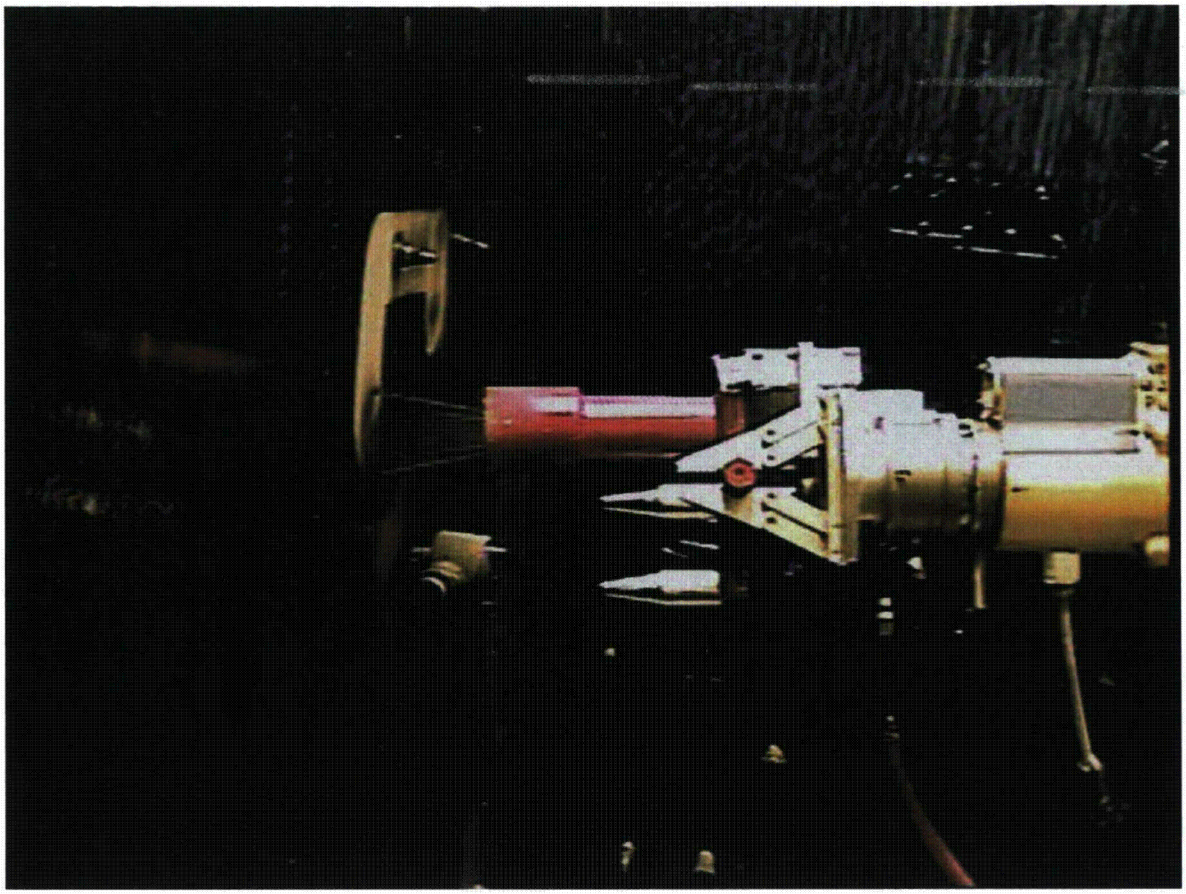
NITROCISION TECHNOLOGY

Nitrocision® employs liquid nitrogen at variable temperature and pressure to provide an aggressive, yet safe, cleaning application. The system is designed to support operating temperatures down to -160 degrees Celsius (-260 degrees Fahrenheit) and up to 4,200 kg/cm (60,000 psi) where the liquid nitrogen quickly converts to a gas.

Nitrocision® decontamination is accomplished by moving liquid nitrogen from a supply source through vacuum jacketed piping to maintain the temperature of the liquid and avoid direct conversion to gas

before it is pressurized and cooled. The liquid is then introduced into the Nitrojet 6000 skid where it passes through a series of intensifiers and is pressurized up to 4,200 kg/cm (60,000 psi) where it is pushed from the skid through high pressure tubing to a chiller. The chiller is where the temperature of the liquid nitrogen is brought back down to approximately -160 degrees Celsius (-260 degrees Fahrenheit) and it is pushed through a flexible "whip tube" to the working tool (Fig. 1). The tools in use in the HEC include a 5 centimeter or 10 centimeter (two-inch or four-inch) head and can rotate or be used stationary depending on the application. The liquid nitrogen exits the tool through orifices sized in the thousandths of inches to direct the flow to the surface being cleaned. Air is used to rotate the working end of the tool and a nitrogen purge gas is used to keep the rotational bearings dry.

Fig. 1. Nitrocision® technology was deployed remotely in the Process Mechanical Cell (PMC).



In the conversion from a liquid to a gas, the gas expands nearly 700 times. Because the nitrogen dissipates into the environment almost immediately, all secondary waste streams are eliminated; all that remains for disposal is the material that was removed. Additionally, the almost immediate dissipation of the nitrogen gas by-product results in no impact to facility filtration systems. Nitrocision® does offer a grit entrainment system that can be added to the nitrogen stream at the tool end for cutting and scabbling applications. This provided WVES with additional options once the decontamination began if nitrogen alone was ineffective at removing thicker sections of PBS.

Remote deployment of the working tool and facility ventilation configurations caused the usage of nitrogen to be less of a safety concern than initially thought. Nitrocision® technology can be integrated with a vacuum capture system (Fig. 2) allowing for the simultaneous removal and collection of the PBS removed from the walls; thereby further limiting the impact to facility ventilation. Another advantage of using liquid nitrogen is that it freezes the PBS material as it is removed making it much easier to vacuum and collect. At performance testing it was found that when super-cooled by the liquid nitrogen, the fixative does not get sticky or liquefy. Instead it becomes brittle at removal and over time achieves the consistency of Play Doh®. Further benefits of using

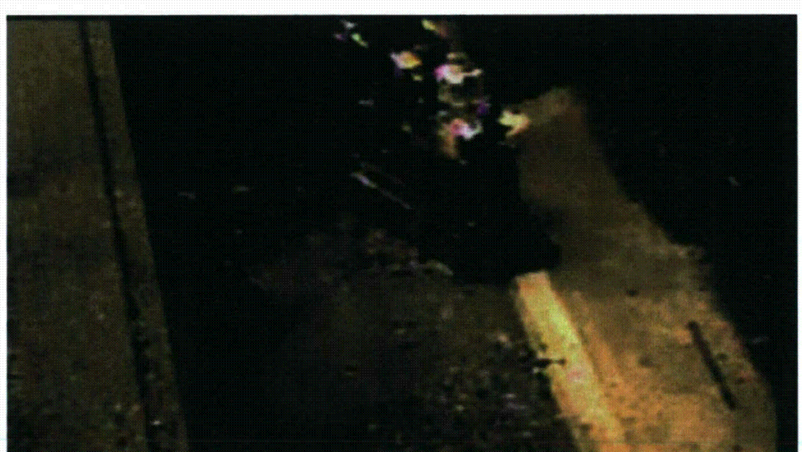


Fig. 2. Nitrocision® technology is being used to vacuum the debris that was removed from the walls of the Process Mechanical Cell.

Nitrocision® are that nitrogen is a comparatively inexpensive decontamination cleaning agent, non-hazardous, and a readily renewable resource.

SYSTEM INSTALLATION AND TESTING

Installation

Once the technology was selected, WVES Engineering worked with Nitrocision LLC personnel to further hone design work they had done on the remote tooling and guide selection of in-cell equipment to meet size constraints for moving equipment (e.g., vacuum system) through hatches among the HECs. Because the technology was being installed in an existing facility, there was significant retro-fitting and piping design work that had to be adapted to as-built components. Additionally, any area over seven feet in the MPPB is radiologically contaminated so care had to be exercised when installing piping in the overheads to avoid spreading contamination to the facility surfaces below.

Significant infrastructure upgrades and maintenance had to be performed specifically addressing functionality of the in-cell robotic arms, PaR bridge and hoist for both of the cells and associated aisles. This equipment was idle since the last decontamination effort in the HECs. Maintenance on that equipment is time-consuming and physically challenging due to high contamination levels and dose rates.

The layout of the MPPB was designed for SNF reprocessing, not facility decontamination. Mobility within the MPPB and access to areas that required retrofitting, equipment installation and/or maintenance was labor-intensive. The Nitrojet 6000 skid (the skid, Fig. 3) had to be located in an area large enough to support it and a hydraulic oil containment system (should there be a leak from the hydraulically powered intensifier supply) with adequate room to perform routine and emergent maintenance. A tool room was established and equipped with specialized equipment and tooling fabricated for sealed change outs both on the skid and the in-cell working tool. Electricians established additional power supplies from the HEC motor control center to support the power needs of the skid and vacuum system. Instrument and Controls staff installed the control panels, oxygen deficient monitors and various other communication lines needed to run and monitor the system.

Fig. 3. Nitrocision® 6000 skid.

Nitrocision® LLC, together with WVES and Cryotech International, designed the run of vacuum-jacketed piping that would convey the liquid nitrogen from the 49,000 liter (13,000 gallon) supply tank (outside of the MPPB) to the Nitrojet 6000 skid and chiller inside the MPPB. Additionally, the system relies on a clean, regulated 7.0 kg/cm (100 psi) of air to turn rotating motors on the in-cell working tool. The system was originally connected to the Plant air supply that later turned out to be problematic from both a supply and quality perspective. The existing MPPB air supply was moist and not clean, and fluctuated in its delivery volume based on demand in the rest of the building. Supply air issues caused operational down time that was not initially recognized by the team as being air supply related.

Testing

The system was performance tested at Nitrocision's facility and demonstrated that the equipment could decontaminate stainless steel coated with PBS at a rate of 1.2 linear meters (4 linear feet) per minute with at least 80 percent removal efficiency. Removal capabilities were also demonstrated on carbon steel and concrete with the same success rate. The vacuum system captured approximately 90 percent of the material removed from the surface at that rate of cleaning. System availability at performance testing was 100 percent with some slight delays getting started.

SYSTEM OPERATION AND AVAILABILITY IMPROVEMENTS

Since declared operational, the system's performance has varied from 18 percent in May 2010 to 67 percent in June, peaking in August 2010 at 80 percent. Figure 4 illustrates the failure type by frequency.

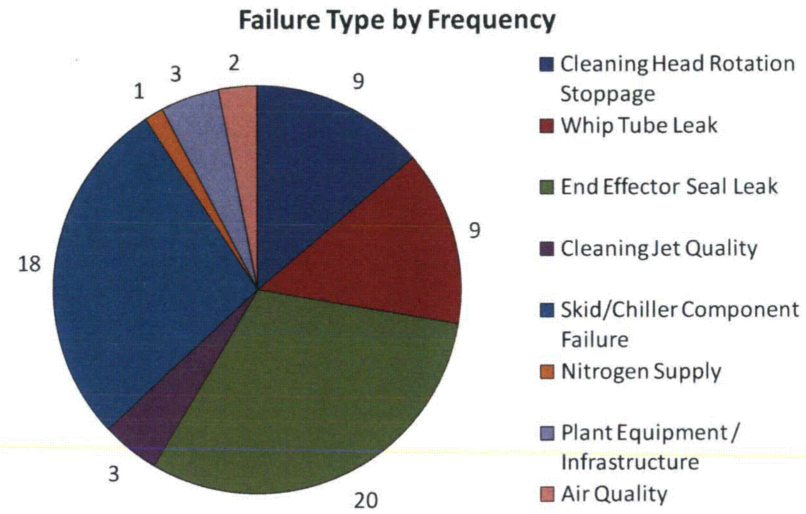


Fig. 4. Failure Type by Frequency.

The Team analyzed the initial operational challenges and grouped them into three general categories including in-cell components, ex-cell components, and plant equipment/infrastructure. In-cell failures were related to loss of rotation of the cleaning head, connection failures between whip tubes and between the tool and the tube, seal leaks on the end effectors (tool), plugged end effector jets. Ex-cell equipment challenges affecting operability of the equipment included chiller and skid operational issues, nitrogen tank and piping related supply inadequacies. The plant infrastructure and major in-cell equipment failures brought about operational down time as well. Equipment challenges related to the successful utilization of Nitrocision decontamination technology are described below.

Cleaning Head Rotation Stoppage and Air Quality: Loss of rotation of the decontamination head had been a result of plant air supply issues (inadequacy of volume/cleanliness of supply). Loss of rotation had resulted in approximately 12 percent of unplanned equipment shutdowns. When rotation is lost at the decontamination head, cleaning effectiveness is impacted immediately and typically results in the decontamination head freezing up. Rotational failure causes cleaning to stop immediately and results in tool swap out and lost time due to the need for remote tool change out. Initially, air supply quality was addressed by the installation of a desiccant drying system and an automatic blow down on the air supply, plumbing from another facility at the site, and removing excess hose and quick connections from the line to improve delivery quality and pressure, however; the ultimate solution became renting an air compressor that could provide high quality, dry, consistent air supply with a capability slightly beyond what is needed to compensate for line loss over distance. At the same time the team continues to monitor rotation issues and has procured a higher torque motor that can be tested and put into service on the tooling should this become necessary.

Whip Tube Leak: Whip tube connections between the sections of whip tube have come apart resulting in down time to reconnect remotely. Challenges at the whip tube connection had resulted in approximately 12 percent of unplanned equipment shutdowns. The connection between the whip tube and the end effector is coned and threaded 1.43 centimeter (0.5625 inch) high-pressure tubing that is susceptible to shouldering. Connection quality degrades over time with the frequent end effector change out and

maintenance that is required to keep the tool viable. Down time is associated with tightening the whip tube connection at the end effector which can be exacerbated by the in-cell location of decontamination. Utilizing the remote equipment to bring the tool to the maintenance station is time consuming in itself and then there is the time to tighten the connection and test. A loose connection between whip tubes can result in a greater amount of down time because of the need to bring the connection to a work surface in cell and then perform the tightening. Because of the rigidity of the tube this can be very time consuming. Replacement of whip tube sections as the connection end becomes un-sealable has resulted in the replacement of whip tube sections. Operators have been trained on the correct procedure and sensitized to the importance of not over-tightening the connection. A new style torque wrench was modified for remote operations and installed in cell for this application to ensure over-tightening does not occur. Initial performance testing identified the whip tube to whip tube connection as a possible challenge as the fitting tends to come unscrewed as the tube is moved around during decontamination. Recognizing this problem, Nitrocision LLC worked with an outside vendor to produce 12 meter (40 feet) tube lengths rather than the 6 meter (20 feet) lengths they were working with to minimize the number of connections. Nitrocision LLC worked with an outside vendor to design/develop/test a new quick disconnect style connector for the end effector/whip tube location. This style connector has alleviated the problems associated with hard plumbed connections and has greatly reduced end effector change out time. Additionally, anti-vibration tubing connectors have been functionally tested and adopted to successfully address the whip tube to whip tube connection challenges.

End Effector Seal Leak: Seal leaks at the end effector result in a visible cloud of nitrogen escaping before the true working end of the tool. Small leaks can be tolerated and do not impact decontamination efficiency but during operations the leak worsens and at some point takes up too much of the nitrogen being supplied to the cleaning head and decontamination effectiveness is impacted. At that point the tool is changed out. Rotary seal life expectation is currently 6 – 8 hours. Leaking end effector seals have resulted in approximately 25 percent of unplanned equipment shutdowns. Tooling repair is both time and labor intensive because of the remote nature of the work, however; the time involved has been decreased Significantly as a result of installing the quick disconnects on the tool and whip tube discussed above. Because of the nature of the seal, high pressure and extreme cold temperature, seal leaks are an understandable challenge, however; steps have been taken to alleviate the problem and to some extent lengthen the life of the seals. Cyclical cooling and warming of the seals tends to accelerate in seal failure. As a result the project has been staffed so that breaks and lunches are taken on a rotational basis and the equipment is not shut down. The original operations plan for the project included tool maintenance to be performed, in its entirety, remotely using manipulators and the PaR. As a result of in-cell environmental issues (cleanliness) and significant down time experienced during tooling maintenance, tooling maintenance is now performed hands-on rather than remotely and is a scheduled manned-entry into an ancillary cell on a weekly basis. Increasing the number of tools in the work area has allowed for ready tool change out and continued cleaning operations.

Cleaning Jet Quality: Plugged nozzles on the end effector can happen as the tooling is used for decontamination. It is not uncommon for one of four jets to plug while the others function well and decontamination efficiency is maintained. However, there is a point where either another jet plugs or material is clearly not being removed from the wall that the tooling is non-viable and must be changed out. Both the plugged jet and potential loss of cleaning efficiency are visible to the operator running the cleaning head. Plugged end effector jets have resulted in approximately 4 percent of unplanned equipment shutdowns. When the jet nozzles at the end of the cleaning head plug, cleaning stops, resulting in lost time due to remote tool change out. Tool disassembly location for change out has been changed to leave reduced chances of possible contamination of jets. When performing tool maintenance all orifices are replaced, not just the plugged one. Tool decontamination prior to teardown has been adopted to minimize the potential for loose particles to become trapped in the internals of the tool. This is performed with low-pressure nitrogen or air. Tooling maintenance entries are scheduled weekly and are performed using a Maintenance Mechanic and an operator so that both aspects of the maintenance activity are addressed: operability and tracking wear.

Skid and Chiller Operational Issues: Skid and chiller operational issues combined have resulted in approximately 23 percent of unplanned equipment shutdowns. The bypass valves on the chiller both have failed resulting in shut down of operations. Three different failure types have been associated with the skid and chiller unit; a failure of the chiller valve result in an inability to divert or shut off the supply to the end effector or the bypass nozzle in a timely manner. The failure of the bypass valve on the chiller results in decreased cycling of the intensifiers on the skid and a subsequent rupture disk failure and skid shut down. Intensifier check valve assembly failures and static and dynamic seal failures result in poor system performance at the skid. WVES worked with Nitrocision to troubleshoot and repair the system, the vendor was called in to assist directly with this effort. Both valves were custom made during system construction by a secondary vendor to Nitrocision. The divert valve has since been replaced with a new custom valve and the bypass valve was replaced with an off the shelf model that performs the same function as the one that failed. Replacement of the valves has led to zero failures at that location on the equipment. Nitrocision's troubleshooting resulted in the recognition of the temperature-induced shrinking of the bushing (brass) resulting in the valve stem inability to shift/operate properly when brought down to operating temperature. The issue was diagnosed as material incompatibility (brass and stainless steel) due to different thermal expansion rates in the valves. As a result, updated versions of the equipment are outfitted with the new valves identified through the WVES problems. Mechanics continue to develop new techniques for seal replacements. System performance monitoring is the job assignment of an operator to catch issues before they become significant. It is critical to have the maintenance mechanic trained to a high level so they can troubleshoot and repair skid components when operational issues arise. Maintenance activities are scheduled to continue to avoid run to failure conditions.

Nitrogen Supply: To this point, issues with the nitrogen supply system have contributed 1% of unplanned equipment shutdowns. Failure of the nitrogen supply system has only impacted operations once, resulting in the inability to run the system, the cause was a failed solenoid on the main supply valve between the bulk tank and the skid. Troubleshooting of the failed solenoid resulted in the engineering determination that it was a non-predictable failure. Because the failure was unpredictable and the purchase of a spare solenoid was feasible the team decided to have a spare solenoid on the shelf in the event of another failure of this type. The voltage of the solenoid was not common to any similar valve on site so there is no common stock to draw from.

Plant Equipment/Infrastructure and Air Quality: Eight percent of the downtime has been attributed to plant equipment, infrastructure and air quality issues. Significant infrastructure upgrades and maintenance had to be performed specifically addressing functionality of the in-cell robotic arms, PaR bridge and hoist for both of the cells and associated aisles because this equipment was idle since 2004. Fabrication of tooling to perform sealed change outs and maintenance as well as adequate room to perform maintenance activities around the Nitrojet 6000 skid unit were critical factors in minimizing system downtime. The system relies on a clean, regulated 7.0 kg/cm (100 psi) of air to turn rotating motors on the in-cell working tool. The system was originally connected to the Plant air supply that later turned out to be problematic from both a supply and quality perspective. The existing MPPB air supply was moist and not clean, and fluctuated in its delivery volume based on demand in the rest of the building. Supply air issues caused operational down time that was not initially recognized by the team as being air supply related. WVES brought on-line a generator to produce sufficient, high quality air for this project.

LESSONS LEARNED FROM CELL WALL DECONTAMINATION OPERATIONS

Cell wall decontamination in the PMC offered learning opportunities for the team that were implemented in the decontamination of the GPC. Specifically, high pressure liquid nitrogen exiting the end effector must be kept away from cell penetrations. Enhanced radiological monitoring for the spread of contamination was performed after finding that radioactive contamination was pushed through cell penetrations to the operating aisle. An initial effort was made to seal cell penetrations however, some existed but were not obvious/identified on drawings and when the decon tool is passed over them, even those that were sealed had the potential to leak as a result of the high pressures involved. Subsequently,

decontamination of the aisle wall shared with the cell was performed in respiratory protection with accompanying contamination monitoring to continuously look for changed conditions and protect the operator.

The team had decided to move away from remote rebuild of equipment early in the process of PMC decon because of the dirty in-cell environment introducing particulate contaminates into the very small internals of the tools and causing subsequent failures requiring more maintenance. As a result, tool maintenance has been performed hands-on. Initially, hands-on work did not pose a problem from a contamination or radiation stand point on the tooling, however; as the project progressed, radiological hazards moved to the forefront and additional controls had to be put in place. The team was using low pressure (less destructive) to decontaminate/blow off the tools before transferring them to the hands-on work area. Eventually, tooling dose rates reached 120 Rad /hr (contact) with associated removable contamination levels 5.6 E6 dpm/100 cm^2 alpha and 2.8 E8 dpm/100 cm^2 beta/gamma. Utilization of high pressure liquid nitrogen decontamination on that tooling resulted in a 90 percent drop in levels and the ability for site workers to continue hands-on maintenance with the higher quality result. As a result of the success in cleaning the end effectors, the project team is working on developing ways to protect critical areas of the PaR and have performed initial decon to reduced levels on that equipment as well.

Remote Tooling

The first generation tooling and first-time deployment of this equipment in a fully-remote application has challenged WVES mechanics to use their ingenuity and on-site facilities to make modifications to tooling designed by Nitrocision LLC as well as design new tooling to meet operational challenges that were unforeseen in the development phase. Specific tooling challenges have included:

- The interface location between the robotic arm or PaR grip and the end effector tooling;
- Special "hand tools" to use with the robotic arm and PaR to perform remote disassembly of equipment (e.g., performing a modification of the torque wrench to make it more remote-able); and
- Fabrication of tooling extensions that allow for the stable passage of whip tube, utility lines, and vacuum hose and the associated end effector into difficult-to-access areas such as an in-cell passageway approximately 2.3 meters (7.5 feet deep) by 0.6 meters (2 feet) wide.

Additionally, WVES mechanics have designed and fabricated camera mounts to allow for visibility of the working surface and a table to perform in-cell tool maintenance for each cell that is used for disconnection of one tool and the replacement of another on the whip tube. The ability to design and build modifications to the tooling on site has resulted in less down time.

CHALLENGES AND SOLUTIONS

Though the system has had its share of operational issues which have been primarily with the end effectors, the system has had remarkable results cleaning the PBS coating off the walls and floor. Except for a few hard-to-reach areas, the walls of the three-story PMC have been cleaned using the Nitrocision tooling and efforts are now focused on cleaning and vacuuming the floor. As of November 2010 approximately 87 percent of the wall surfaces and 10 percent of the floor have had the PBS material removed and collected in TRU waste drums. GPC wall decontamination has begun with approximately 30 percent of the cell being complete to this point. Approximately 30 square meters (100 square feet) can be decontaminated in a ten-hour shift, achievable surface area varies with characteristics of the terrain. Penetrations and irregular surfaces add time as does the surrounding area because the whip tube and utility line bundle have to be watched at all times for snagging. Final cell radiation surveys will be conducted once decontamination of the cell floors is complete and containerized waste is removed from the cell. Additional decontamination efficiency data will be gained by performing identified "hot spot" decontamination and subsequent re-survey after the initial decontamination pass is complete.

As a result of the effectiveness of the technology to date WVES has opted to deploy the technology in other facilities. As a result, Nitrocision LLC has developed software and skid upgrades to allow one skid to facilitate decontamination operations in two different cells in adjoining facilities at the same time while maintaining cleaning efficiency.

PARTNERING

The combination of WVES' expertise on the conditions of the PMC and GPC and Nitrocision's technology, and the synergy gained by putting the two areas of expertise, has been a winning strategy.

Internal partnering among WVES operational, engineering and radiological disciplines further contributed to the success-to-date of the decontamination of the PMC and GPC using Nitrocision technology. Finding site-specific means of deploying the technology, using outside-the-box thinking to enhance system performance, and evaluation of lessons learned for future applications will be the legacy of this strong technical partnership.

CONCLUSION

The partnership between WVES and Nitrocision led to the evolution of an already-established technology into an enhanced technology with remote radioactive decontamination applications that can be used, not only in other areas of the WVDP, but in the larger DOE cleanup complex and in other industrial settings where remote applications are necessary or desired.

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www.nitrocison.com

WVMP SAR Reference 4-6

Impact Testing of Vitreous Simulated High-Level Waste in Canisters, IBNWL-1903 UC-70, Pacific Northwest National Laboratory, Richland Washington, May 1975.

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Impact Testing of Vitreous Simulated High-Level Waste in Canisters

May 1975

Prepared for the U.S. Energy
Research and Development Administration
under Contract AT(45-1):1830

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Battelle
Pacific Northwest Laboratories

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On January 19, 1975, research and development programs of the U.S. Atomic Energy Commission (AEC) became part of the newly formed Energy Research and Development Administration (ERDA). In this report, since it refers to work done in 1974, most references are to AEC programs.

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IMPACT TESTING OF VITREOUS SIMULATED HIGH-LEVEL WASTE IN CANISTERS

by T. H. Smith and W. A. Ross

May 1975

Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

ACKNOWLEDGMENTS

Significant contributions by the following people to the test program and/or this report are gratefully acknowledged: S. L. Sutter removed the particles from the canisters, sieved the particles, and contributed to Sections 8.0 and 9.0. L. C. Schwendiman and M. O. Cloninger contributed to Section 11.0.

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1.0 SUMMARY

This work was performed in support of a risk analysis of a conceptual management system for high-level nuclear waste. Three basic driving forces are generally associated with accidental release of radioisotopes: mechanical and thermal forces and dissolution processes. These forces could not only breach the containment barriers, but also modify the form of the waste. For example, mechanical forces acting on a canister of solidified (e.g., vitrified) waste could not only fail the canister, but also break the glass into smaller, potentially respirable particles. The increased glass surface area would also hasten dissolution and volatilization if driving forces for these were present.

Because no data for impact breakup characteristics of encapsulated waste glass were located, this test program was begun. The objectives, in order of priority, were to estimate 1) the quantity of respirable glass fines produced; 2) the increase in glass surface area; 3) the impact resistance of the filled canisters. Even if all test canisters were to remain intact, the first two items are needed because it cannot be guaranteed that every production canister will be fabricated soundly and maintained properly.

Two series of tests were conducted using nonradioactive waste glass type 72-68 (simulated waste composition PW-4b-2) in cylindrical 304L stainless steel canisters. Six specimens of a 1/2 scale model of a 10-ft canister were impacted at room temperature and at velocities up to 10 CFR 71 requirements of 44 fps. Twenty-two smaller specimens were tested at room temperature and at elevated temperature (425°C), at velocities up to that of high-speed train impact (80 mph or 117 fps). Both series included specimens which were essentially glassy and those which had been partially devitrified by thermal treatment.

The canisters breached only at the two highest velocities (66 and 117 fps). The breaches were all very small cracks. Pre- and post-test weight checks indicated that very little, if any, glass escaped through the cracks.

The resulting fines were removed and sieved. Particle size distribution curves were plotted. The inventory fraction smaller than 10 μ typically ranged from 10^{-8} for control specimens to 10^{-4} for 80 mph impact. This compares with approximately 10^{-2} for nonimpacted calcined waste (and probably for impacted calcine also).

Geometric calculations were made of the surface area created. The surface area typically increased by only a few percent of the initial surface area for control specimens, but by a factor of 40 for 80 mph impact.

Within the scatter of the limited data obtained, no consistent difference was observed between the essentially glassy and the partially devitrified specimens nor between small and large canisters when the results were compared on a fractional breakup basis. Testing of specimens which are more severely devitrified might lead to observable differences between glassy and devitrified waste. Testing at elevated temperature increased the quantity of large particles produced, but no significant effect was observed on the quantity of particles smaller than about 20 to 50 μ.

2.0 INTRODUCTION

MANAGEMENT OF HIGH-LEVEL NUCLEAR WASTE

High-level waste originates in aqueous form as a result of solvent extraction in the reprocessing of spent nuclear fuel. Current regulations call for solidification of commercial waste within 5 years of its generation and shipment to a Federal repository within a total of 10 years. The product may be stored for up to 100 years in a Retrievable Surface Storage Facility (RSSF) before permanent disposal. One possible scheme for waste solidification and fixation by reprocessors involves producing a calcine followed by fixation in a glass/ceramic form.

Decisions regarding management of high-level waste depend heavily upon product comparisons of candidate waste forms. An ultimate framework for such comparisons is that of system safety studies.

WASTE FIXATION PROGRAM

Battelle Pacific Northwest Laboratories is conducting the Waste Fixation Program (WFP) for the Energy Research and Development Administration (ERDA). Primary objectives are development of improved product forms and demonstration of practical production on an engineering scale. The program is expected to provide technological bases for early adoption and implementation, by industry or a Federal facility, of techniques to convert high-level waste to solid forms of superior performance and stability.

Silicate glasses presently appear the most promising in terms of low dispersibility, ease of processing, and insensitivity to changes in waste composition. However, other product forms are also being investigated. Of particular interest are comparisons between these forms and calcined waste.

SAFETY AND SYSTEMS EVALUATION TASK OF THE WASTE FIXATION PROGRAM

The purpose of the safety and systems evaluation task is to define and evaluate parameters of waste management systems as related to

containment and risk. The results of the task will guide R&D efforts, formulation of waste product criteria, and comparisons of alternative waste management schemes.

The chief thrust of the task is to perform a risk analysis of a conceptual management scheme for high-level waste. A representative management scheme (Figure 1) involves storage of liquid waste followed by solidification, encapsulation, and canister storage, all at the reprocessing plant. The waste is then shipped to a RSSF for interim storage. This is followed by shipping to and emplacement in ultimate disposal facilities. As a first attempt, the total annual risk of system processes 1 through 9 for the year 2000 is being estimated.

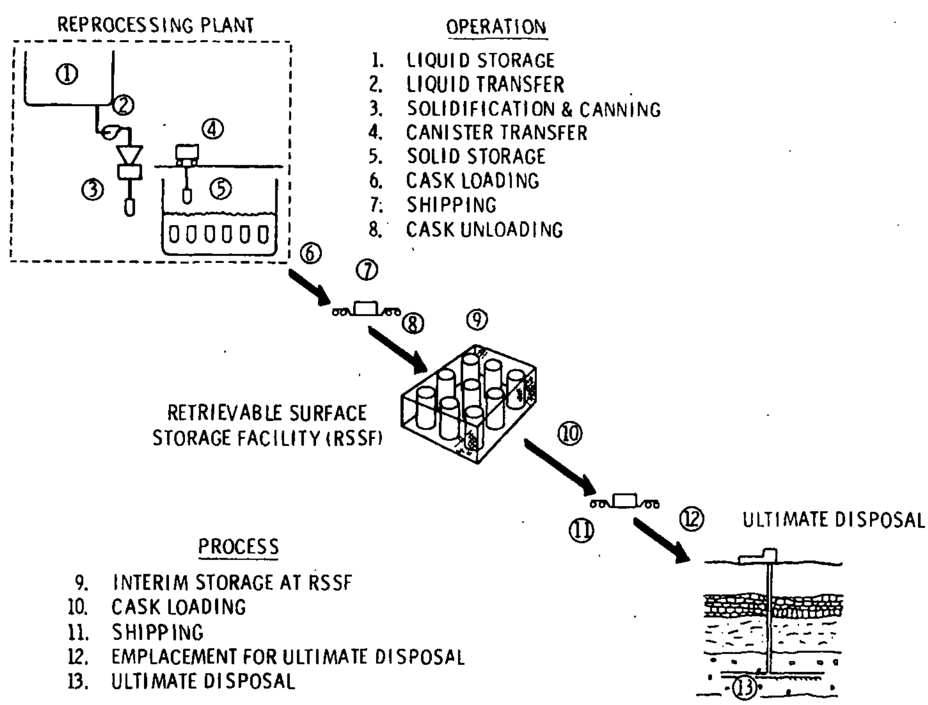


FIGURE 1. Representative Year-2000 Waste Management System

NEED FOR IMPACT DATA

In the risk analysis methodology, potential failure sequences are analyzed by relating release probability to release consequences. This relationship is expressed mathematically as the product of the expected frequency of release and the radiological consequences. The relationships among the various informational inputs are shown schematically in Figure 2.

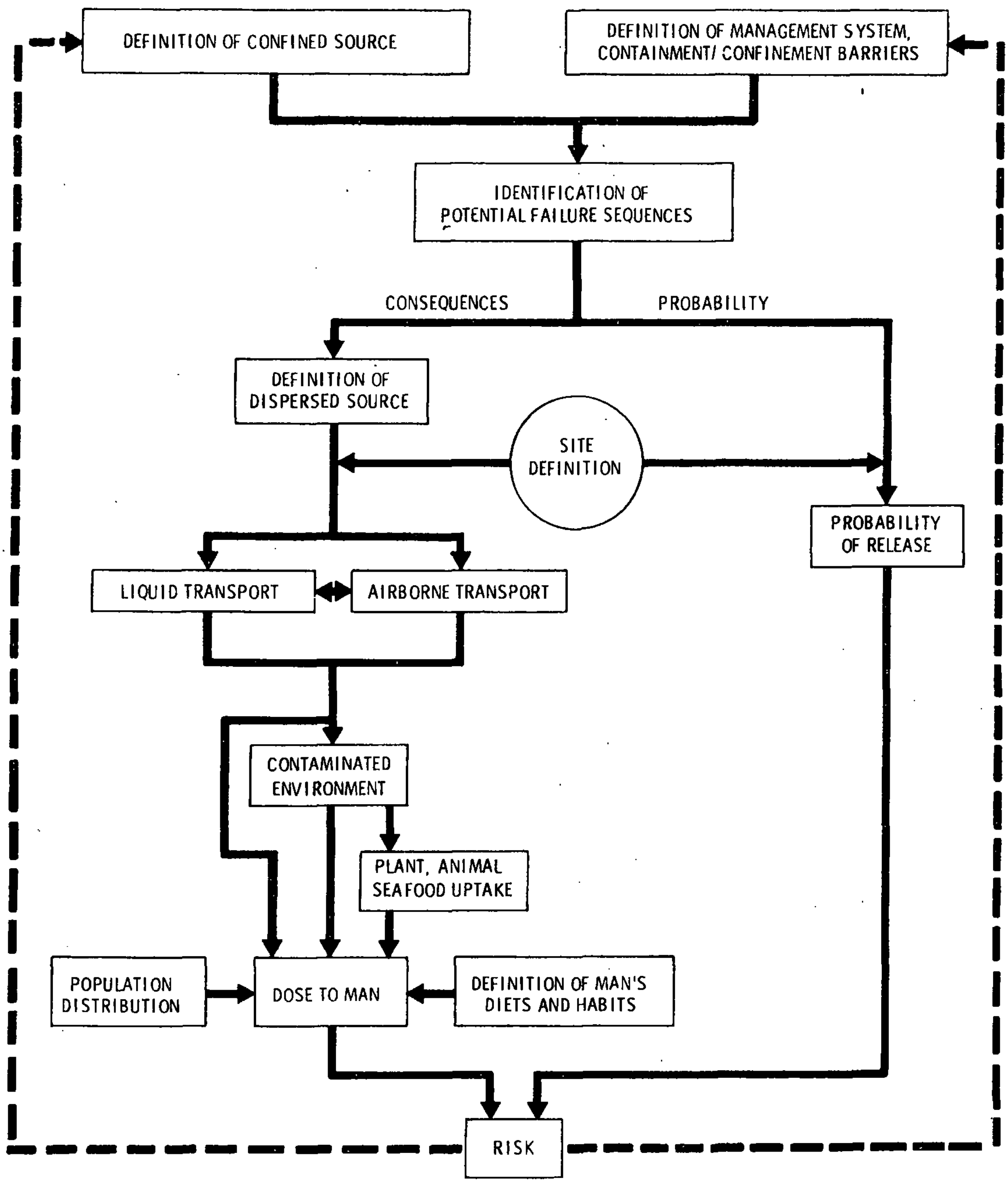


FIGURE 2. Risk Analysis Methodology

A key step in ascertaining release consequences is estimation of the quantity and characteristics of material released by a postulated failure sequence. This step, designated "Definition of Dispersed Source" in Figure 2, provides input to models describing radionuclide transport from one environmental component to another. Depending on the type of failure event, physical properties of the waste can be drastically altered during the release. For example, exposure of monolithic solids to high temperature can result in release of semivolatile constituents as submicron particles. Obviously, such transformations affect transport of radionuclides through the environment.

Three basic physical properties are prominent in dispersed source descriptions: volatility, leachability, and frangibility. These are pertinent to release sequences involving the following respective events: fires, contact with groundwater or surface water, and mechanical forces such as those in impact.

Studies of the leachability and volatility of waste solids had been conducted[1-4] before the risk analysis was under way. However, only preliminary percussion tests had been conducted[5] on phosphate ceramics and glasses in the predecessor to the WFP. The need was evident for definitive information on impact behavior of solid waste forms in terms of the size distribution of particles produced and the increase in surface area.

This need was the basis of the impact tests described here. The data have been related to potential failure modes involving impact events such as could be encountered in transportation, handling and storage. Knowledge of the quantity of extremely small particles ($\lesssim 10\ \mu$) produced is important for studies of airborne transport. Knowledge of the glass surface area produced is important, along with leachability, for analysis of release to groundwater or surface water.

3.0 REVIEW OF PREVIOUS WORK

Although the literature on impact is voluminous, publications closely related to this problem are scarce. Previous work which may aid in understanding impact of glass in metal canisters is briefly reviewed here.

CANISTER IMPACT BEHAVIOR

Although shell response has been studied at least since 1828, most studies have assumed linearly elastic systems, which are not representative of severe impact. Aerospace nuclear safety programs of the 1960s and early 1970s have provided data and the first useful simplified theories for plastic deformation and failure of shells in impact.[6] Much of that work built upon efforts of Stoneking et al.,[7,8,9] who tested hollow and partially-filled spheres and cylinders and formulated theories describing the impact behavior. Most studies since Stoneking's have concerned small hollow spheres.

Haskell[6] produced a simple failure criterion based on correlations of the Stoneking data. Morris used dimensional analysis along with the Stoneking data and more recent data to correlate deformation[10] and failure[11] of hollow spheres. Bodenschatz[12] correlated end-on failure velocities of filled cylinders and found only weak dependence of failure velocity on the L/D ratio of the cylinder, as long as $L/D \geq 2$. This result is more obvious from Haskell's tabulation of the Stoneking data, presented in Figure 3. Use of shortened cylinders, required in a portion of the present program, is therefore expected to have a small effect on cylinder deformation and failure. However, the effect on fines produced could not be predicted and is discussed in Section 10.0.

Impact tests of radioisotopic fuels and capsules were summarized by Dalby.[13] The above-mentioned theories were reviewed by Barsell[14] for spherical capsules, compared with new data, and modified for improved predictive capability. Barsell[15] also analyzed fueled spherical capsules

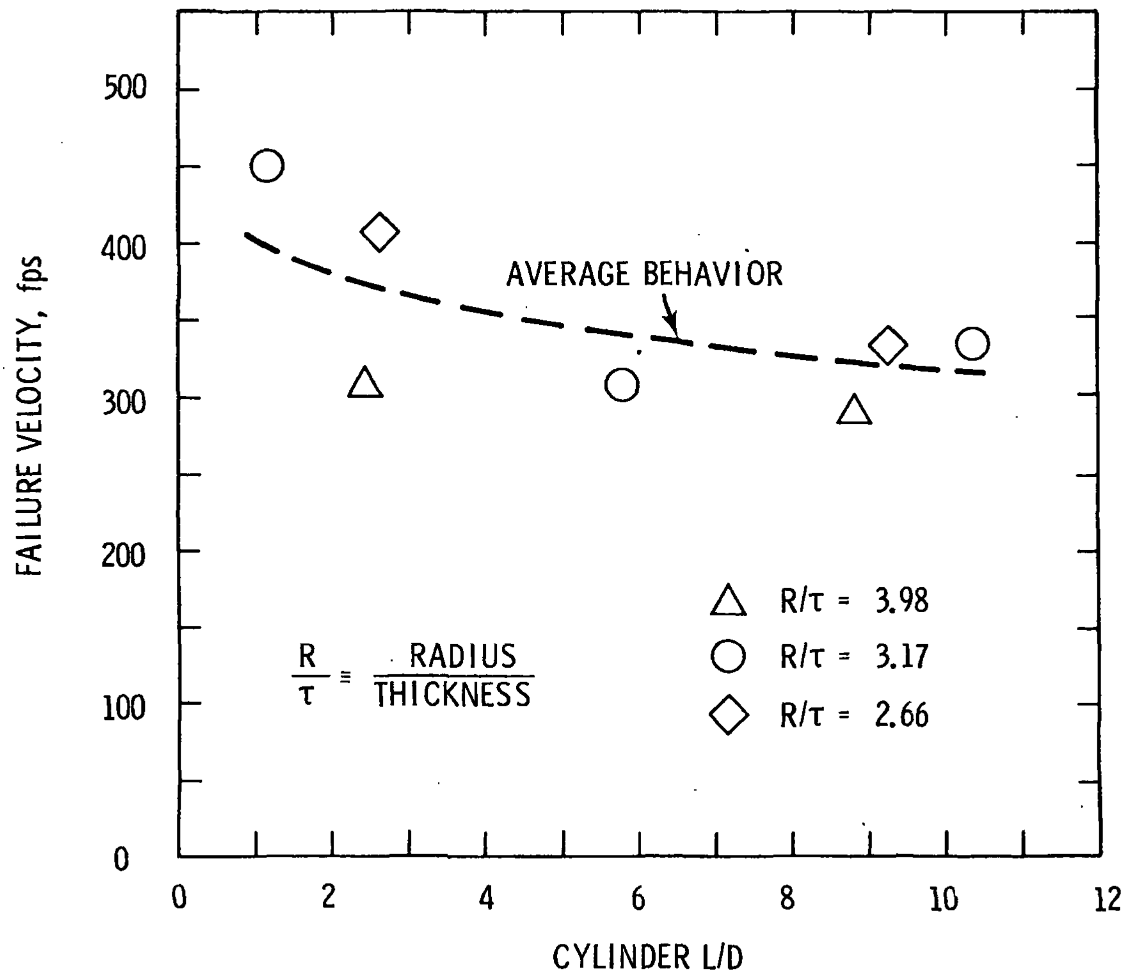


FIGURE 3. Dependence of Failure Velocity of Filled Cylinders on Length/Diameter Ratio (Adapted from Reference 6)

using a time-integrated energy approach. Adaptation of Barsell's method to cylindrical capsules seems the most promising theoretical approach for prediction of canister behavior.

Considerable testing and analysis of shipping casks have been performed at Oak Ridge National Laboratory (e.g., Ref. 16).

High strain-rate mechanical properties of Type 304 Stainless Steel, similar to that used in the present tests, have been published by Steichen and Paxton.[17]

DATA FOR POST-IMPACT PARTICLE SIZE DISTRIBUTION

Capsules containing $^{238}PuO_2$ fuel as pressed oxide, PuO_2-Mo cermet and microspheres were impacted under aerospace nuclear safety programs.[18-21]

Particle size distributions resulting from these tests were reviewed in Reference 22 as part of the present impact program. The distributions of References 18-20 were matched poorly by log-normal and Rosin-Rammler distributions. Plots of size fraction versus velocity for Reference 19 and 20 data showed considerable scatter. Less scatter and a better log-normal fit in the 10 to 100 μ range were found for the data of Reference 21.

Preliminary percussion fines data were obtained in the Waste Solidification Program.[5] A weight was dropped on bare samples of radioactive waste or stand-ins of these forms: phosphate ceramic, phosphate glass, borosilicate glass. Particles were screened only down to the fraction <0.02 in.

A large body of literature (e.g., Ref. 23) concerns particle size distributions resulting from crushing and grinding. Many publications (e.g., Ref. 24) deal with fractures produced in bare glass by impact. However, none of these study areas directly applies to the requirements of this program.

SCALING LAWS

Scaling laws for impacted canisters have been formulated by Duffey[25] and by Tsai.[26]

4.0 TEST PROGRAM RATIONALE

OBJECTIVES

The objectives of the program, in order of priority, were to estimate, on a preliminary basis, 1) the quantity of respirable fines produced from the borosilicate waste glass; 2) the increase in glass surface area; and 3) the impact resistance of the filled canisters. Supporting objectives included the following: determine the effects of several parameters upon the results; by means of correlations, facilitate prediction of results for impact environments not tested; facilitate comparisons of the impact behavior of borosilicate glass with that of calcine. All of these objectives were to be addressed within the context of accident environments identified in the WFP risk analysis.

APPROACH

The need for timely input to the WFP risk analysis constrained the program to use locally available equipment. More elaborate impact facilities are available at ORNL and Sandia.[27,13] Two facilities in the Hanford area were utilized. The Donald W. Douglas Laboratories (DWDL) operates a rotating-arm impact facility capable of impact at high velocities and temperatures but limited in the specimen size it can accommodate. Operation of a large mobile crane is provided by the Atlantic Richfield Hanford Company (ARHCO), and large reinforced concrete slabs suitable for drop tests are located nearby. This equipment can accommodate rather large specimens but is not capable of testing at high velocities nor controlled elevated temperatures.

The approach combined the capabilities of both facilities so as to provide maximum information. The tests consisted of two series of simulated accident environments. The main series used the crane and concrete pad for testing of a limited number (6 including controls) of half-scale specimens. To supplement this series, a series of 22 (including controls) shortened one-sixth scale specimens was tested at the DWDL facility. The smaller

size permitted more test runs because of reduced costs of fabrication and of fines analysis. The DWDL facility's flexibility allowed ranges of parameter variations, such as impact velocity and temperature, not available at tower drop facilities. Results of the two series were to be correlated for estimates of impact behavior under a wide range of conditions.

It was recognized from the outset that 1) the difficulties and cost of precisely modeling impact conditions with a large number of full-size specimens were prohibitive; 2) compromises necessary to complete the program at reasonable cost would affect the results to some extent; 3) the program was essentially a pioneering effort in testing impact behavior of vitreous waste forms. Therefore the results were expected to provide order-of-magnitude estimates at best. Comparisons between values were expected to be more reliable than absolute results.

SELECTION OF TEST CONDITIONS

The basic considerations are what to test and under what conditions. Though such decisions are somewhat arbitrary, justification is given here for the decisions made.

The waste form (nonradioactive simulant) chosen was borosilicate glass, the prime WFP candidate. Two structural variations were studied: one glassy and the other purposely devitrified by time-temperature exposure. The latter was included because of possible post-fabrication devitrification in the waste management system of Figure 1. No variations in waste composition, other than local effects within a batch, were included.

A major decision concerned containment of the glass during the tests. Possible configurations were 1) bare glass, tested briefly in an earlier program; 2) glass formed inside the canisters anticipated for primary containment and use in handling and water basin storage; 3) glass/canisters placed inside heavy shipping casks or RSSF storage casks. Test conditions were chosen to correspond to accident sequences identified in fault tree analyses of the WFP safety task. Because bare nonmolten glass is not intended to exist in the waste management system, configuration 1 was eliminated. Transportation accidents (Steps 7 and 11, Figure 1) could

involve configuration 3, as could RSSF storage (Step 9). Accidents involving configuration 2 could occur in Steps 3, 4, 5, 6, 8, 10 and 12. Because this containment configuration is relevant for the greatest portion of the management system and because of reduced cost and complexity, the impact tests used simulated glass/canister systems (configuration 2). Detailed descriptions of the impact specimens are given in Section 5. It should be stressed that the impact behavior of the containment was not of prime interest except insofar as it influenced fracture of the waste simulant.

The impact velocities (25, 44, 66, and 117 fps) were selected to represent potential accident conditions (Table 1). The small specimens were tested at all four velocities, while the large specimens were tested only at 25 and 44 fps.

TABLE 1. Impact Test Velocities

Velocity fps	mph	Equivalent Drop Height, ft	Small Specimens	Large Specimens
25	17	10	X	X
44	30	30	X	X
66	45	>68	X	
117	80	>213	X	

NOTE: A large specimen was dropped onto a penetrator from a height of 40 in. (15 fps).

The two lower velocities correspond to free drop distances of 10 and 30 ft, respectively. If a drop occurred within the facilities under consideration, a 10-ft distance would not be unusual, whereas a 30-ft distance would be near the upper limit. The 30-ft drop also matches the transportation packaging requirement of 10 CFR 71, Appendices B and D. The test targets were essentially unyielding, although no attempt was made to minimize yielding effects.

The 66 and 117 fps values (45 and 80 mph) represent velocities associated with severe train accidents. Approximately 90% and 99+%,

respectively, of freight train accidents occur at velocities lower than these.[28] Only lower limit drop distances can be attached to the higher velocities because aerodynamic drag, a function of canister orientation, becomes significant.

There are two cautions in relating the higher velocity tests to railroad accidents. First, the canisters tested were not inside simulated shipping casks. Second, objects on board a train would generally experience much lower impact velocities than that of the train, because of cushioning provided by deformation of the cars and mountings. However, results of the present tests may be useful for limiting analyses. When data become available relating vehicle velocity to the effective impact velocity of cargo, the present results may furnish crude estimates of expected behavior.

The impact orientation selected was edge-on. This orientation was hypothesized to be the most severe. It could also be the most probable orientation. An accidentally released canister would generally experience some rotation-producing moment, either at release or during descent. One small specimen was tested end-on to check the effects of orientation.

Details of the test conditions are discussed in Section 6. This includes canister orientations, impact temperatures, glass forms, target descriptions, and uncertainties in test parameters.

5.0 SPECIMEN DESCRIPTION

GLASS DESCRIPTION

The precise composition of high-level waste will depend on the reprocessing scheme as well as on the type of spent fuel and its reactor exposure. In addition, many glass compositions could result from a given waste composition.

The glass used for the impact tests was made to simulate the 72-68 glass composition[29] proposed for high-level waste fixation studies. It was prepared from 75 wt% frit (glass formers) and 25 wt% calcine (particulate simulated high-level waste) prepared in a continuous spray calciner.[30] The simulated waste composition, designated PW-4b-2, of the calcine is shown in Table 2. Substitutions made for reasons of cost and availability include Fe for Ru, Mo for Tc, K for Rb and Cs, Co for Rh, and Ni for Pd. A natural rare earth mix containing Y and Ce is used in place of the actual Y and rare earth distribution. Actinides are not included nor substituted.

The premelted and presized frit was added to the melter as particles sized between 6-mesh and 20-mesh. The composition of the frit, identified as 73-1, is given in Table 2.

The final glass composition is also listed in Table 2. The frit and calcine are fed semicontinuously into an Inconel 690 melter[30] which forms batches of 35-40 lb of glass. The melts are formed at 1150°C and are of low viscosity (∿10 poise). The melting temperature is not sufficient to bring all materials into the glass solution. Thus the "glassy" specimens were not 100% glassy. Residue crystals of CeO_2, Zircon, and a spinel composed of Fe, Cr, Ni, and Zn have been identified in similar melts.[1]

The glass has a strain point of 475°C, annealing point of 502°C, and average thermal expansion coefficients of 7.9 x 10^{-6}/°C between room temperature and 330°C and 10.0 x 10^{-6}/°C between 330°C and 500°C.

TABLE 2. Chemical Compositions of Simulated Calcine, Frit and Glass

Oxide	Wt% in PW-4b-2 Calcine	Wt% in 73-1 Frit Glass Formers	Wt% in 72-68 Glass
Fe_2O_3	9.50		2.38
Cr_2O_3	1.00		0.25
Ni O	3.01		0.75
P_2O_5	1.96		0.49
MoO_3	18.44		4.61
SrO	3.05	2.0	2.26
BaO	4.52	2.0	2.63
K_2O	3.30	5.5	4.95
RE_2O_3(a)	37.65		9.41
ZrO_2	14.39		3.60
CoO	0.81		0.20
TeO_2	2.09		0.52
Cd O	0.28		0.07
SiO_2		37.0	27.75
B_2O_3		15.1	11.33
Na_2O		5.5	4.13
ZnO		28.9	21.68
CaO		2.0	1.50
MgO		2.0	1.50

a. A natural rare earth mix containing CeO_2 + Y_2O_3

CANISTER DESCRIPTION

1. Small Specimens

The canisters, shortened 1/6-scale models, were made from 304L stainless steel tubing machined to 0.040-in. wall thickness. The tubes were approximately 1.96 in. OD, with flat end caps of 0.0375 in. 304L stainless steel welded to form a closed cylinder approximately 4.04 in. long. Exact dimensions of each specimen before and after testing are given in Section 7.0.

Welds were checked by dye penetrant. Specimen weight, including glass, ranged from 540 to 610 g (1.2 to 1.35 lb). Exact weights are given in Section 10.0. Figure 4 illustrates typical pretest dimensions. The depth of glass fill, discussed in the next subsection, is also shown.

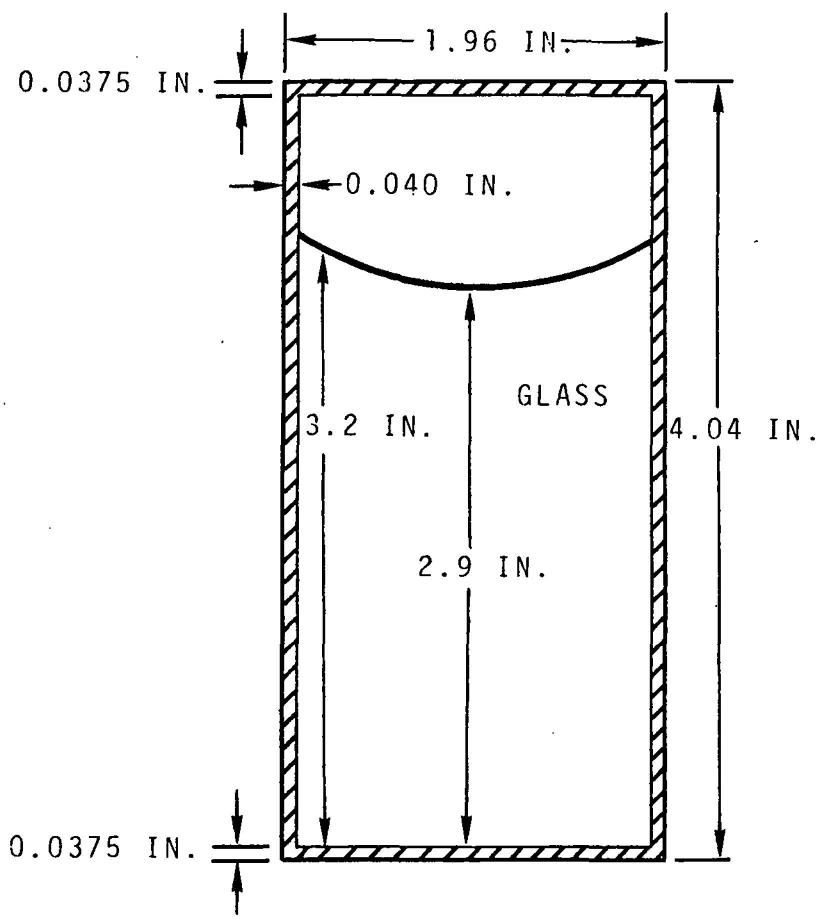


FIGURE 4. Typical Pre-Impact Dimensions of Small Specimens

2. Large Specimens

These cylindrical specimens, 1/2-scale models, were fabricated from 6-in. schedule 10 (6.625-in. OD, 0.134-in. wall) 304L stainless steel pipe. The pipe had been formed by rolling and had a continuous longitudinal weld. End plates were 0.134-in. 304L stainless, attached by V-type full-penetration welds. Outside length of the cylinders was approximately 62.2 in. Figure 5 illustrates typical pretest dimensions of the large specimens. Dimensional changes accompanying testing are given in Section 7. The depth of glass fill, discussed in the next subsection, is included. Specimen weight, including glass, ranged from 234 to 246 lb. Exact weights are given in Section 10.0.

Lifting eyes which protruded 1-1/2 in. from the outside wall were welded 2 in. below the top of the canisters. All welds were dye checked for cracks or pin holes.

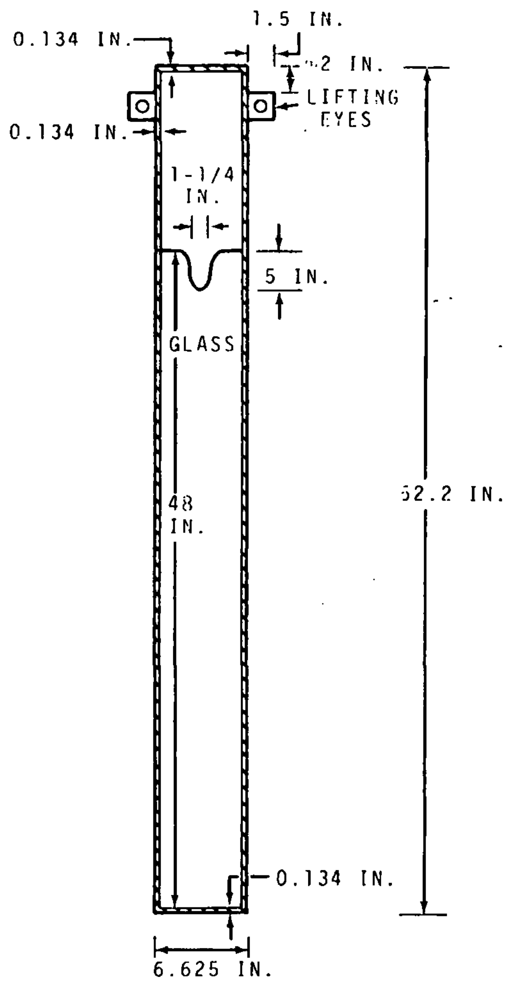


FIGURE 5. Typical Pre-Impact Dimensions of Large Specimens

3. Comparison of Test Canisters with Full-Size Canisters

The test canisters are simplified models of the primary containment canisters anticipated for the handling, shipping, and storing of high-level waste. There is presently no official canister design. Diameters from 6 to 24 in. and lengths from 2 to 15 ft are under consideration in RSSF studies. A reference design[31] for calcined waste is shown in Figure 6. The canister is 10 ft long and 12.75 in. OD with a 0.375-in. wall of 300 series stainless steel. The canister contains 6.28 ft^3 of waste, implying a fill depth of 8 ft. Filled weight would be on the order of 1700 lb. The canister has a neck section, which serves as a fill port, and a connector pin for lifting.

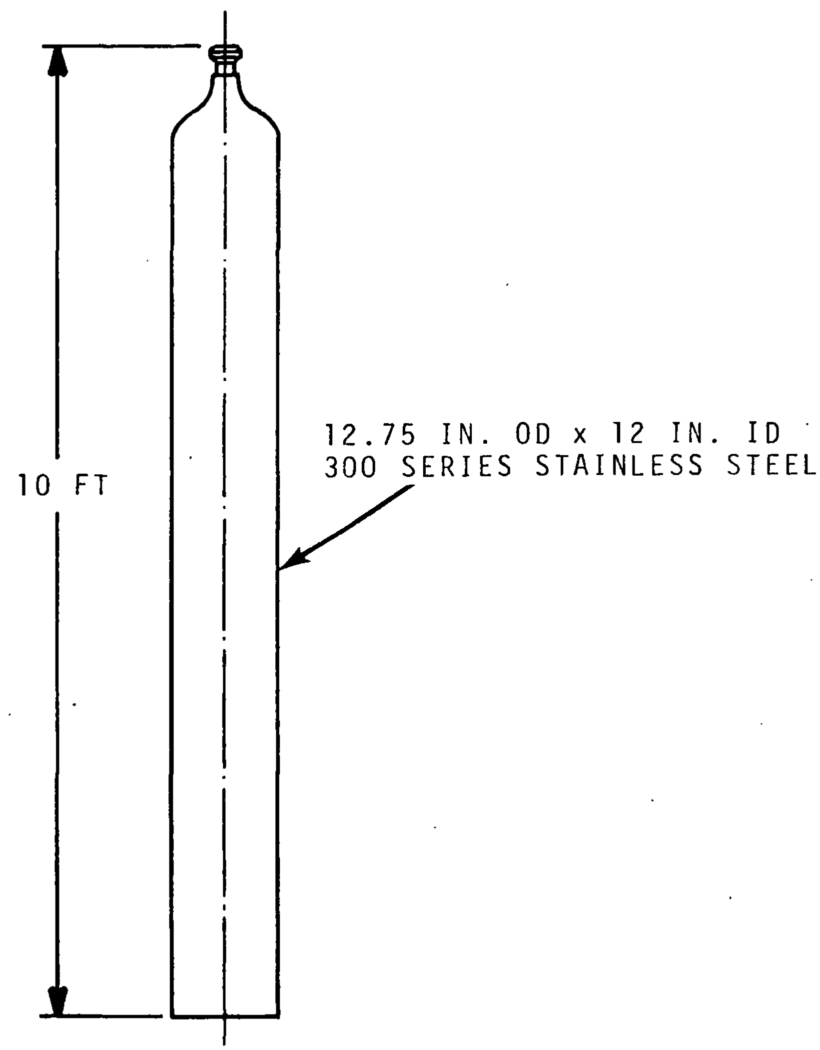


FIGURE 6. Reference Canister for Calcined Waste (Ref. 31)

The design of canisters containing glass is not established. The neck portion may be unchanged, larger, or even nonexistent. No attempt was made to model the neck portion in designing the test canisters. For any impact orientation except the unlikely impact on the upper end, this effect is expected to be negligible.

The dimensions and dimension ratios of the two test canister designs are compared with those of the full-size reference canister in Table 3. A few comments are in order regarding differences in the dimension ratios. To control costs, the test specimens were generally made from standard-dimension pipe tubing and plate. The ratio of head thickness to wall thickness is a close match. The ratio of radius to wall thickness for the test specimens reflects the 0.250-in. wall thickness of an earlier reference canister at the time of design of the specimens. The ratio of length to diameter for the large specimens closely matches that of the reference. The small specimens were shortened considerably to allow use of the DWDL rotating-arm facility, which has a specimen length limit of about 4 in. If the small specimens had been scaled precisely from the earlier reference, the wall thickness would have been 8 mils, which of course is unreasonable for fabrication. Therefore, the diameter and wall thickness were kept in the proper ratio, but the L/D ratio was reduced. For non-side-on impact, the effect of the L/D value on canister behavior is small for $L/D \gtrsim 2$. The effect on fines production was not known at the time of design. Unfortunately, the required use of shortened small specimens resulted in the simultaneous variation of two parameters--size and L/D ratio. Thus, it is difficult to separate these two effects in the results of the tests.

CANISTER FILLING AND HEAT-TREATING PROCEDURES

1. Small Specimens

The small specimens were divided into two lots for filling with glass, each lot being filled from one melter batch. The canisters were held under the melter and filled to 80 to 85% of the internal volume. However, the glass contracted about 6 vol% during cooling, reducing the effective fill depth to 75 to 80%. The upper surface became concave because of shrinkage.

TABLE 3. Comparison of Test Canisters with Full-Size Reference Canister

	Small Canister	Large Canister	Full-Size Reference Canister
Average[(a)] radius, R_a, in.	0.96	3.245	6.1875
Wall thickness, t_w, in.	0.040	0.134	0.375
Head thickness, t_h, in.	0.0375	0.134	0.375
Average[(a)] length, L_a, in.	4.00	62.1	119.6
R_a/t_w	24.0	24.2	16.5
t_h/t_w	0.94	1.0	1.0
$L_a/(2R_a) = L_a/D_a$	2.1	9.6	9.7

a. Average of inside and outside dimensions

The heat capacity and low thermal conductivity of the glass allowed several minutes for handling between filling and cooling of the outside surface to the annealing point. During this period, the samples were put into a furnace at 530°C and allowed to stabilize at that temperature. The furnace was then cooled by hourly adjustments of a set point controller. The cooling rate was 5°C/hr to 490°C, then 8°C/hr to 436°C, and finally 44°C/hr to room temperature. The above cycle was calculated from equations[(32)] for production of an annealed sample of glass.

2. Large Specimens

The large specimens, being 3-1/2 times the diameter and 15 times the length of the smaller specimens, required about 180 times as much glass per specimen. This involved six batches of glass per canister. Each 35 to 40 lb batch filled about 8 in. of the canister. To prevent thermal shock to the glass as each batch was added, the canisters were held in a 565°C furnace during filling. Four canisters were held in the furnace at one time to

duplicate cooling rates and allow higher production rates. The glass in the first canister filled, therefore, had a residence time of about 3 days at 565°C while subsequent canisters were being filled. When the four canisters were filled to the desired 4-ft depth, the furnace was cooled at 5°C/hr to 530°C and the temperature then maintained for 3 hr to allow the glass to approach equilibrium.

The annealing was started at 0.5°C/hr with temperature adjustments of 4°C every 8 hr until the temperature reached 490°C. The 4°C adjustments were then made every 4 hr until the furnace temperature was 440°C, after which 5°C adjustments were made hourly until the samples reached room temperature. The complete cooling required 9 days.

The cooled castings appear monolithic. However, acoustic monitors coupled to the canisters indicated that some cracking may have occurred during cooldown below 440°C. This may represent metal-glass interactions due to differential thermal expansion. The glass contracted significantly during cooling, leaving a void in the top surface about 1-1/4 in. in diam and 5 in. deep.

IMPOSED DEVITRIFICATION

1. Background

The metastable glassy or vitreous state exists only because its high viscosity retards the diffusion of ionic species necessary for crystal nucleation and growth. At elevated temperatures, generally above 500°C., the lowered viscosity permits crystallization, or devitrification, to begin.

This process is complex in relatively simple glasses and even more so in the waste glass system. It depends on composition and on time-temperature history. A number of crystalline species can form, each of which leads to a change in composition of the residual glass phase.

Since canisters of waste glass will be self-heating, centerline temperatures during handling, shipping, and storage may reach 700°C., sufficient for some devitrification to occur. Centerline temperatures may be constrained to lower levels by finning or other means.

Although the waste glass is relatively resistant to devitrification, purposely devitrified samples were included in this study to assess the effect on impact behavior. Effects of devitrification on other glass properties, such as leach rate, are under study separately.

The thermal histories of the devitrified specimens are described in the following sections. Basically, the time-at-temperature was 3 to 4 days at 700°C. It should be stressed that although the devitrification was probably sufficient to approach a steady state at that temperature, it was not 100% complete. X-ray diffraction analysis of a glass sample held at 700°C for 24 hr indicated that the primary crystals present were $SrMoO_4$ and a CeO_2-ZrO_2 solid solution. Minor phases may also be present but were not detected.

Structural changes resulting from devitrification are expected to be more significant than those resulting, either directly or indirectly, from radiation. The major damage is expected to occur from alpha decay of the actinides.[29] One form of this damage may be from helium buildup within the glass, which has been postulated to result in significant stress levels over long time periods.[30] Experiments are under way involving simulated waste glass doped with ^{244}Cm to accelerate possible effects of alpha damage.

2. Treatment of Small Specimens

The first lot of samples was subjected to a devitrification process after filling and cooling. The process involved a 25°C/hr heating rate to 700°C, with 72 hr at temperature for crystal growth. The specimens were cooled to 530°C at 25°C/hr then annealed in the previously described cycle. To limit oxidation of the stainless steel, the specimens were covered with an atmosphere of flowing argon while the temperature was above 500°C. To prevent glass vaporization, the canisters were welded before devitrification. During welding of the upper end cap, the samples were held in water to avoid thermal shock of the glass.

A group of the small specimens immediately prior to impact testing is shown in Figure 7.

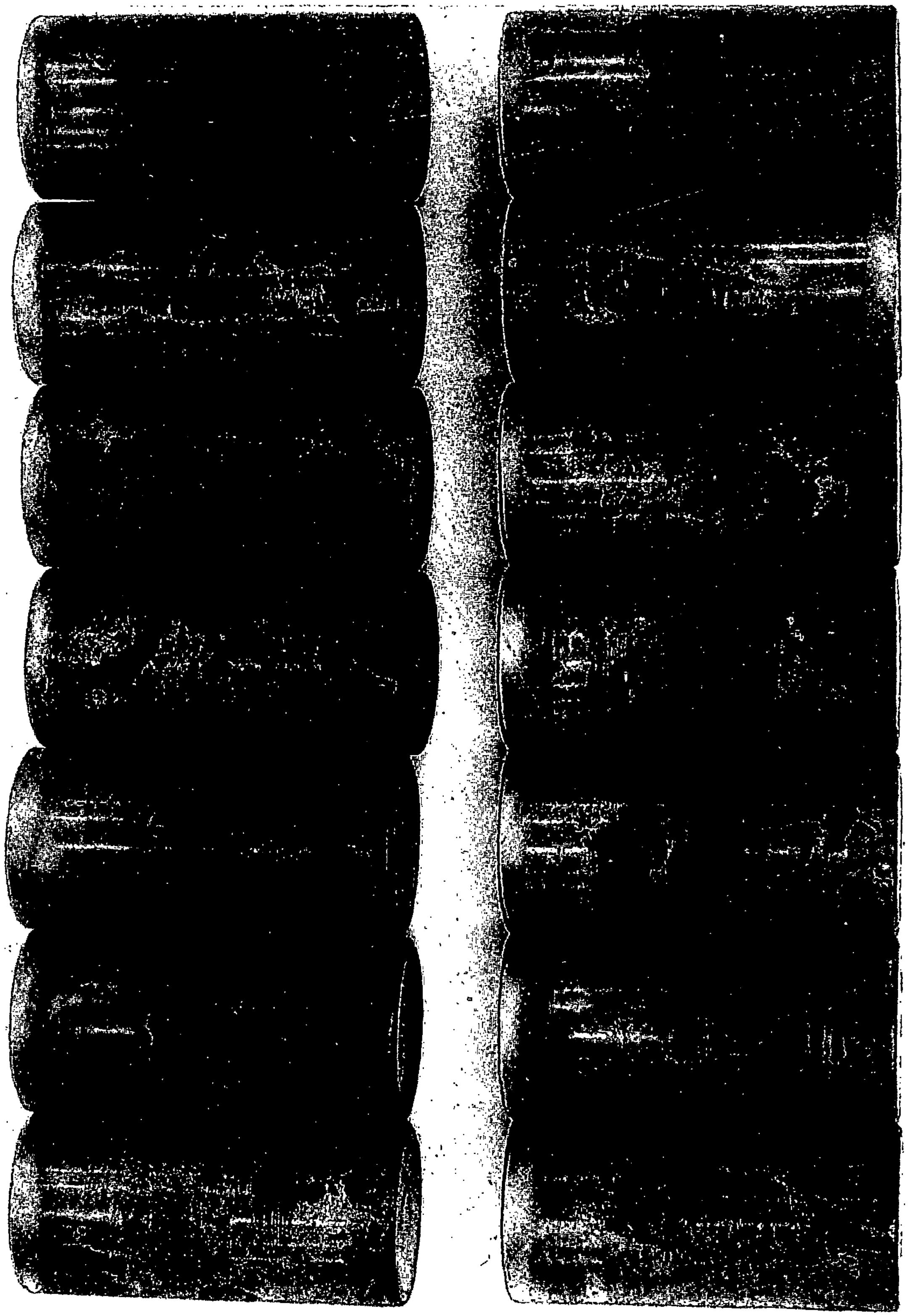


FIGURE 7. Small Canisters Before Impact Testing

3. Treatment of Large Specimens

Two additional large canisters were filled similarly to those described above. After filling, however, the furnace temperature was increased to 700°C and held for 88 hr to initiate devitrification. The canisters were cooled at 25°C/hr to 565°C, then 10°C/hr to 530°C. Slow annealing was started with 5°C adjustments twice daily to 490°C. The 5°C adjustments were made three times daily down to 440°C. Then 5°C adjustments were made hourly nine times a day until the canisters reached room temperature. The total cooling cycle for these canisters covered 3 weeks.

After cooling, the canisters to be impacted were welded closed with the upper section kept wet to avoid thermal shock to the glass.

COMPARISON OF GLASS PROCESSING OF SPECIMENS WITH PROPOSED LARGE-SCALE PROCESSING

The currently proposed process for large-scale glassification of calcined waste is in-can melting with a maximum temperature of about 1000°C. (The melt temperature for this impact program glass was 1150°C.) This lower processing temperature would increase the amount of crystalline material not soluble in the glass phase. The effect on the glass properties is not completely characterized, but the behavior probably lies between the present glassy and devitrified samples.

A second difference which could have more effect is the faster cooling rates being considered for full-scale canisters. These cooling rates would lead to some fracturing of the glass by thermal stress. The impact behavior of such material is expected to be inferior to that of the fully annealed samples used in these impact tests.

6.0 TESTING PROCEDURES AND CONDITIONS

LARGE SPECIMENS

Six large specimens were fabricated and subjected to the heat treatments described in Section 5.0. Two of these serving as controls were subjected to the same handling sequence except for impact and the transportation to and from the impact site.

The four test specimens were impacted at ambient temperature by dropping from a large mobile crane. A special harness and release system minimized changes in orientation caused by the release process. Visual observation and detailed analysis of high-speed films revealed no significant effect of release on the impact angle. A lightweight rope, marked at the 10- and 30-ft points, was taped to the bottom of the canister to gage the drop height. Drop height uncertainty is estimated to be $\sim$1%.

The canisters were dropped onto a reinforced concrete block atop and part of a large, 6-in. thick pad. The block dimensions are about 7 ft by 5 ft by 18 in. in thickness. The weight of the block alone is approximately 35 times that of a large canister. No visible damage to the block resulted from the testing.

Two canisters were dropped 10 ft and one dropped 30 ft, each onto the bottom edge, with the center of gravity directly above the impact point. A 40-in. side-on drop (canister horizontal) onto a 3-in. diam steel penetrator was also conducted. This was a 1/2-scale simulation of a full-size canister undergoing the puncture test of 10 CFR 71 Appendix B.

Impact conditions are summarized in Table 4. After impact the canisters were dye checked, photographed, and characterized dimensionally.

SMALL SPECIMENS

Twenty-four small specimens were fabricated and subjected to the heat treatments described in Section 5.0. Three of these specimens serving as controls were subjected to the same fabrication, handling, and transportation sequence as the test specimens. Two specimens were incorrectly impact tested due to failure of the injection device.

TABLE 4. Test Conditions for Large Canisters

Canister Number	Glass Condition	Drop Height	Impact Velocity	Impact Orientation
1	G	C O	N T R	O L
2	G	30 ft	44 fps	bottom edge
3	G	40 in.	15 fps	side-on[a]
4	G	10 ft	25 fps	bottom edge
5	DV	C O	N T R	O L
6	DV	10 ft	25 fps	bottom edge

a. Onto 3-in. diam steel penetrator
G ≡ Glassy
DV ≡ Devitrified

Early in the program two of the controls were taken through the same pre-impact heatup and post-impact cooldown as the test specimens, but without impact. This was done because of the possibility of thermal stresses inducing sufficient glass breakage to obscure results from the impact. Such concern proved to be unwarranted.

The DWDL impact facility[21] has a 75-lb granite block mounted on a counterbalanced rotating arm. Specimens up to about 3 lb can be tested The specimen is held at precisely controlled temperatures (up to 1500°F) in an argon-purged furnace above the plane of rotation. The impact angle is precisely controlled by mounting the specimen in a thin quartz holder attached to an injection mechanism. The specimen is injected into the path of the rotating block between revolutions by means of a pneumatic cylinder timed by the position of the rotating arm shaft. Impact velocity is known to within 1 fps. The specimen rebounds from the granite block and is caught in a ceramic fiber receiver to dissipate the kinetic energy without secondary damage to the specimen. (Tests of the large specimens involved repeated secondary impact from multiple bounces. This is the more realistic accident situation and is a small point of difference between test procedures for small and large specimens.)

The arm, furnace, and receiver are in a reinforced concrete pit below ground level. The test area is covered with plywood to preclude release of debris. Motor control, injection actuation and furnace operation are accomplished remotely with recording capability for temperatures and velocity. High-speed photographic coverage is available, but was not included in the current test series.

The nineteen noncontrol specimens were impacted according to the conditions in Table 5.[33] Approximately half were tested at room temperature and the other half at 800°F (425°C) in order to study effects of temperature on glass behavior. The 800°F value is the approximate bulk temperature of the waste in full-size 10-ft canisters in typical shipping, handling, and storage configurations. (The centerline temperature is 1000 to 1100°F; peripheral temperature, 400°F.) Heatup prior to testing was performed slowly (∿1°F/min) to minimize thermal stresses. The calculated temperature change during the period between removal from the furnace and impact is negligible.

Impact velocities were 25, 44, 66, and 117 fps. All specimens were impacted edge-on (through the center of gravity, an angle of about 23°), except for one end-on specimen to check for orientation effects.

The test matrix (Table 5) was designed to measure the reproducibility of the test results: specimens 24, 23, and 4 were tested under ostensibly identical conditions. The matrix also provides simple checks on the effects of variables. Pairs of glassy and devitrified specimens are evident throughout, as are pairs of room temperature and elevated temperature tests.

Specimens were weighed, measured, photographed and leak-checked after impact.

TABLE 5. Test Conditions for Small Canisters[33]

Specimen	Waste	Velocity,[a] fps	Orientation	Temperature, °F[b]
1	G	No Impact	-	802
24	G	117	Edge-on	800
23	G	117	Edge-on	800
4	G	117	Edge-on	800
5	DV	117	Edge-on	796
6	G	117	End-on	802
7	G	66	Edge-on	802
8	DV	66	Edge-on	798
9	G	44	Edge-on	800
10	DV	44	Edge-on	798
11	G	25	Edge-on	800
12	DV	25	Edge-on	796
13	DV	No Impact	-	798
14	G	114	Edge-on	RT
15	DV	117	Edge-on	RT
16	G	66	Edge-on	RT
17	DV	66	Edge-on	RT
18	G	44	Edge-on	RT
19	DV	44	Edge-on	RT
20	G	25	Edge-on	RT
21	DV	25	Edge-on	RT
22	G	No Impact	-	RT

G ≡ Glassy DV ≡ Devitrified RT ≡ Room Temperature

a. Velocity of the impact block was checked with a stop watch at low speed and a strobe light at higher speeds. Indicated velocities above were approximately 1% higher than actual test velocities. This difference was neglected.

b. Temperatures were controlled by a Research Incorporated Data-Trak Programmer set up to heat the specimen from room temperature to approximately 800°F in a smooth ramp over a 10-hr period. Temperatures were sensed by a thermocouple in contact with the specimen until the specimen was ejected from the furnace. Maximum temperatures prior to injection ranged between 796° and 812°F.

7.0 IMPACT EFFECTS ON THE CANISTERS

Because this report is organized by procedural steps, this section reviews the effects of impact on the canisters (deformation and breach of containment), effects of secondary interest in this study. The subject of primary interest, impact effects on the glass within the canisters (particle size distribution and surface area increase), is covered in Section 10.0.

SMALL CANISTERS

1. Deformation

As shown in Figures 8-13, impact at 25 or 44 fps produced little deformation. Impact at 66 or 117 fps resulted in greater deformation, but the effects were still localized.

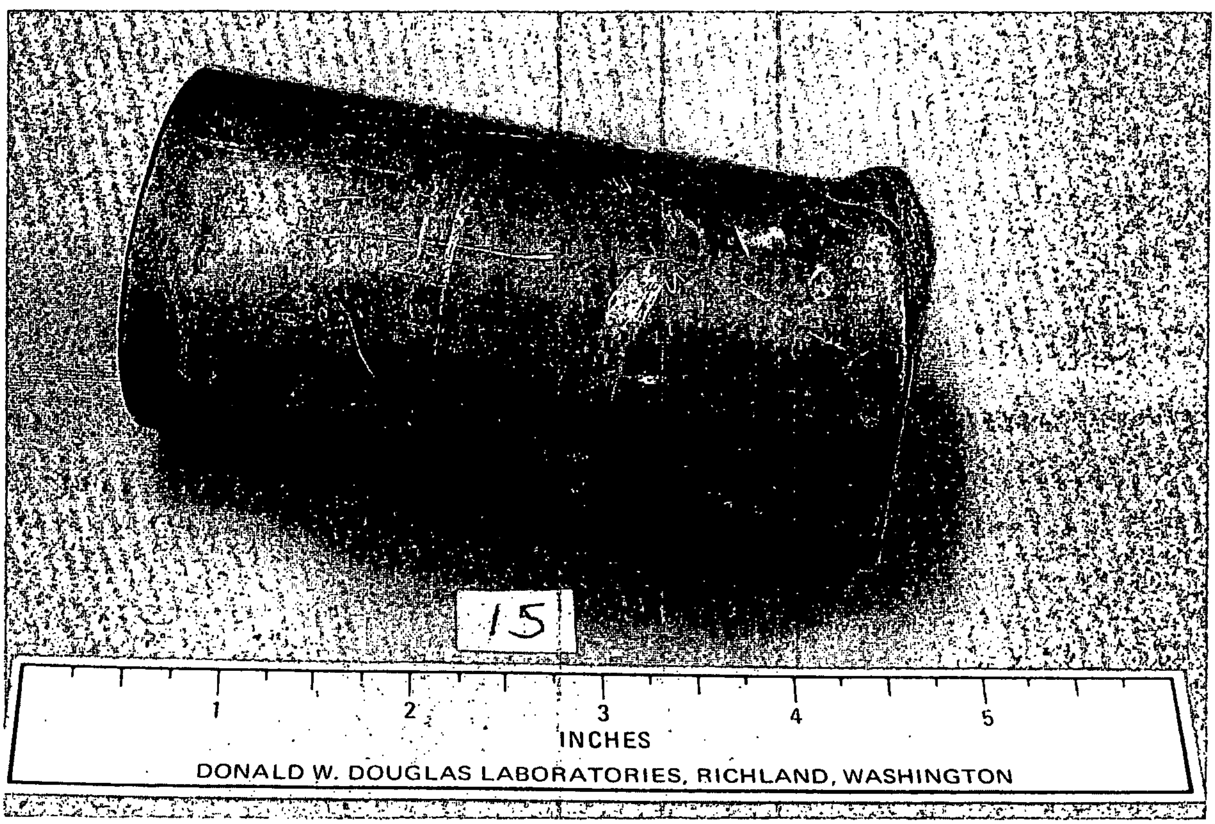


FIGURE 8. Specimen 15 After Edge-On Impact at 117 fps

FIGURE 9. Specimens 23 and 14 After Edge-On Impact at 117 and 114 fps, Respectively

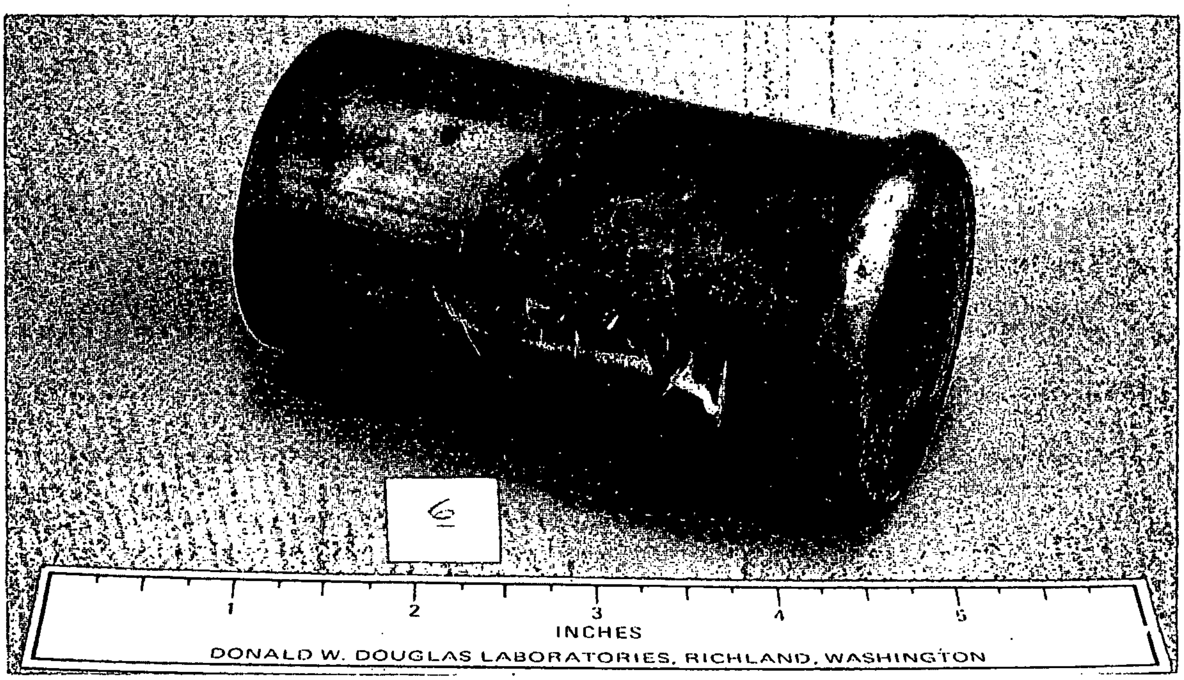


FIGURE 10. Specimen 6 After End-On Impact at 117 fps

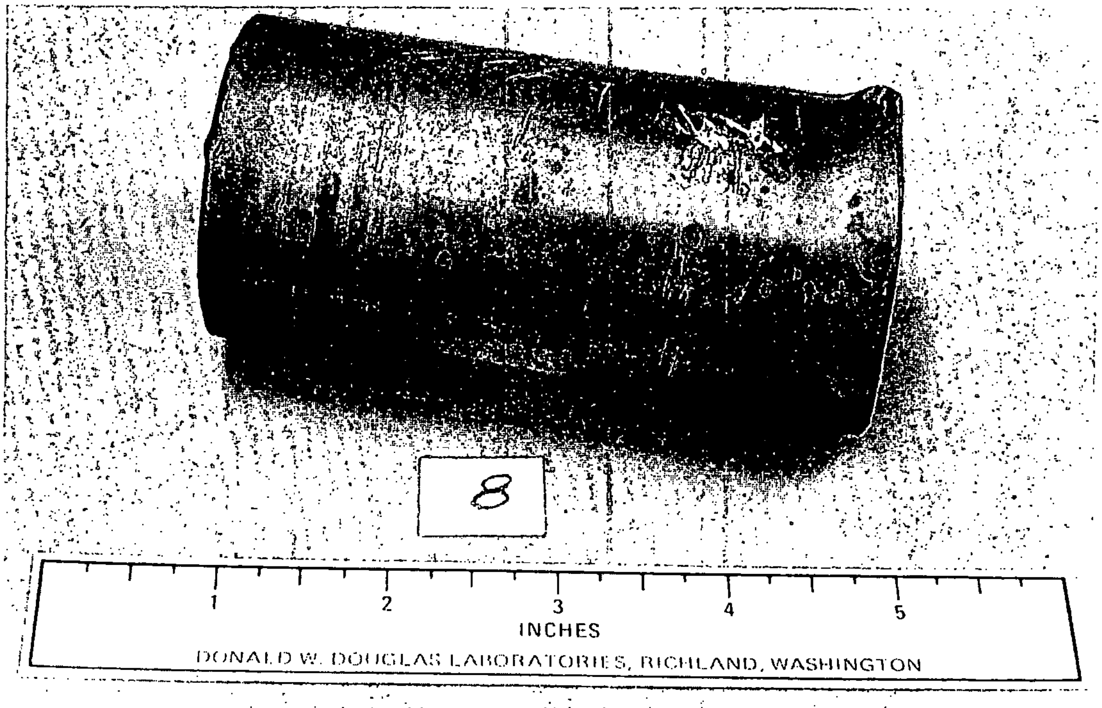


FIGURE 11. Specimen 8 After Edge-On Impact at 66 fps

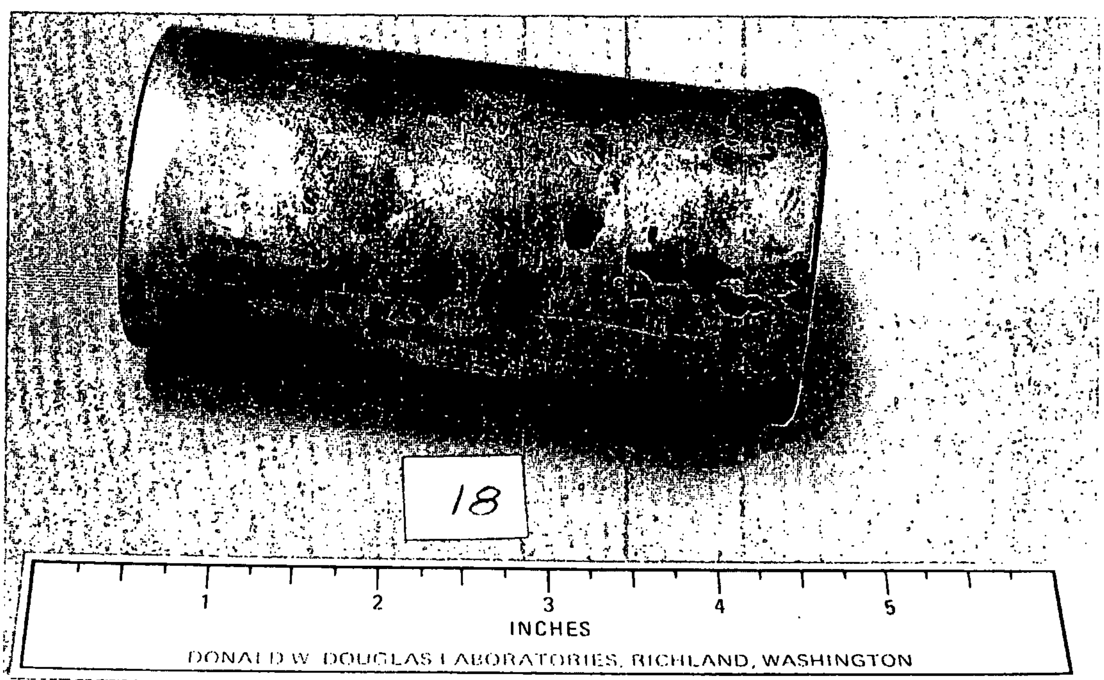
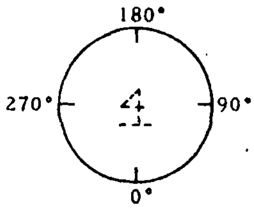


FIGURE 12. Specimen 18 After Edge-On Impact at 44 fps

FIGURE 13. Specimen 21 After Edge-On Impact at 25 fps

Pre- and post-impact measurements are presented in Table 6 (Ref. 33). Three problems make exact comparisons between canisters impossible: 1) Because the edge-on impact was not at the same circumferential point (with reference to the 360° coordinate system in Table 6) for every canister, it was difficult to determine the maximum decrease in length, ΔL_{max} for a given canister. 2) Measurement reference markings were obliterated by impact, especially at the higher velocities. The missing length measurements are generally those which would have shown the greatest ΔL values. 3) The postimpact end bulge of the specimens made it difficult to define a minimum canister length. However, representative ΔL_{max} values derived from posttest photographs are 0.4 in. for 117 fps, 0.2 in. for 66 fps, 0.1 in. for 44 fps, and 0.05 in. for 25 fps.

TABLE 6. Pre- and Post-Impact Measurements of Small Canisters(33)



Diameters taken 1/4 in. from each end (from 0° to 180°) and at mid-length (from 0° to 180° and from 90° to 270°).

Upper end is where void space remains.

Minor differences in lengths are not significant because measurements were made over weld beads and vary somewhat with small changes of postion of the vernier calipers.

Specimen		Length (in.)				Diameter (in.)				Weight (gm)
		0°	90°	180°	270°	Upper 0°-180°	Lower 0°-180°	Midpoint 0°-180°	Midpoint 90°-270°	
1	Pre-	4.037	4.037	4.042	4.037	1.956	1.960	1.959	1.960	593.5
	Post-	No Measurements				No Measurements				593.5
	Δ									0
24	Pre-	4.037	4.038	4.036	4.028	1.961	1.960	1.959	1.961	602.9
	Post	4.036	4.000	-(2)	4.022	1.961	2.184	1.996	1.975	602.9
	Δ	-0.001	-0.038	-	-0.006	0	0.224	0.037	0.014	0
23	Pre-	4.038	4.036	4.045	4.046	1.962	1.965	1.962	1.964	589.9
	Post-	-	4.025	4.041	-	1.963	2.042	1.976	1.976	589.9
	Δ	-	-0.011	-0.004	-	0.001	0.077	0.014	0.012	0
4	Pre-	4.041	4.042	4.040	4.040	1.951	1.960	1.957	1.959	603.4
	Post-	4.041	-	-	4.042	1.951	2.068	1.976	1.980	603.4
	Δ	0	-	-	0.002	0	0.108	0.109	0.021	0
5	Pre-	4.052	4.048	4.049	4.041	1.956	1.961	1.947	1.956	591.4
	Post-	4.052	4.045	-	-	1.959	2.047	1.960	1.969	591.4
	Δ	0	-0.003	-	-	0.003	0.086	0.013	0.013	0
6	Pre-	4.049	4.046	4.031	4.031	1.959	1.963	1.963	1.961	595.9
	Post-	3.914	3.926	3.918	3.906	1.960	2.105	1.976	1.964	595.9
	Δ	-0.135	-0.120	-0.113	-0.125	0.001	0.142	0.013	0.003	0
7	Pre-	4.040	4.037	4.043	4.046	1.950	1.959	1.957	1.955	594.9
	Post-	-	4.032	4.045	4.045	1.949	2.025	1.966	1.960	594.9
	Δ	-	-0.005	0.002	-0.001	-0.001	0.066	0.009	0.005	0
8	Pre-	4.055	4.060	4.052	4.044	1.952	1.961	1.961	1.948	584.1
	Post-	4.051	-	4.051	4.043	1.953	1.961	1.961	1.945	584.1
	Δ	-0.004	-	-0.001	-0.001	0.001	0	0	-0.003	0
9	Pre-	4.037	4.035	4.026	4.040	1.960	1.962	1.962	1.963	609.5
	Post-	-	4.039	4.027	4.040	1.959	2.006	1.965	1.966	609.5
	Δ	-	0.004	0.001	0	-0.001	0.044	0.003	0.003	0
10	Pre-	4.042	4.045	4.037	4.042	1.955	1.955	1.951	1.955	578.2
	Post-	4.043	4.044	-	4.042	1.956	2.001	1.952	1.955	578.2
	Δ	0.001	-0.001	-	0	0.001	0.046	0.001	0	0

TABLE 6. (contd)

Specimen		Length (in.)				Diameter (in.)				Weight (gm)
		0°	90°	180°	270°	Upper 0°-180°	Lower 0°-180°	Midpoint 0°-180°	Midpoint 90°-270°	
11	Pre-	4.039	4.035	4.034	4.031	1.954	1.958	1.958	1.955	589.7
	Post-	4.038	4.036	4.024	4.033	1.953	1.986	1.959	1.966	589.7
	Δ	-0.001	0.001	-0.010	0.002	-0.001	0.028	0.001	0.011	0
12	Pre-	4.046	4.044	4.050	4.047	1.957	1.966	1.962	1.957	582.9
	Post-	4.048	4.046	4.048	4.042	1.956	1.968	1.964	1.958	582.9
	Δ	0.002	0.002	-0.002	-0.005	-0.001	0.002	0.002	0.001	0
13	Pre-	4.031	4.032	4.040	4.040	1.952	1.963	1.960	1.960	543.5
	Post-	4.031	4.031	4.038	4.042	1.952	1.963	1.960	1.961	543.5
	Δ	0	-0.001	-0.002	0.002	0	0	0	0.001	0
14	Pre-	4.041	4.035	4.037	4.045	1.959	1.960	1.960	1.961	615.0
	Post-	4.045	4.036	4.037	-	1.959	1.960	1.961	1.960	615.0
	Δ	0.004	0.001	0	-	0	0	0.001	-0.001	0
15	Pre-	4.050	4.048	4.053	4.052	1.951	1.965	1.962	1.965	589.9
	Post-	-	4.049	4.050	4.052	1.951	2.040	1.962	1.964	589.9
	Δ	-	-0.001	-0.003	0	0	0.075	0	-0.001	0
16	Pre-	4.042	4.039	4.036	4.041	1.954	1.958	1.957	1.959	598.2
	Post-	4.042	4.041	4.035	-	1.953	1.959	1.956	1.959	598.2
	Δ	0	0.002	-0.001	-	-0.001	0.001	-0.001	0	0
17	Pre-	4.063	4.050	4.047	4.060	1.950	1.961	1.955	1.958	580.0
	Post-	-	4.050	4.047	4.060	1.951	1.990	1.956	1.956	580.0
	Δ	-	0	0	0	0.001	0.029	0.001	-0.002	0
18	Pre-	4.028	4.022	4.033	4.037	1.957	1.964	1.960	1.959	613.7
	Post-	4.027	-	4.033	4.035	1.957	1.963	1.960	1.960	613.7
	Δ	-0.001	-	0	-0.002	0	-0.001	0	0.001	0
19	Pre-	4.050	4.046	4.042	4.046	1.958	1.966	1.964	1.966	571.0
	Post-	4.050	4.045	4.048	4.048	1.958	1.976	1.966	1.966	571.0
	Δ	0	-0.001	0.006	0.002	0	0.010	0.002	0	0
20	Pre-	4.040	4.043	4.046	4.045	1.947	1.956	1.952	1.948	605.2
	Post-	4.039	4.042	4.046	4.043	1.948	1.956	1.951	1.948	605.2
	Δ	-0.001	-0.001	0	-0.002	0.001	0	0.001	0	0
21	Pre-	4.046	4.055	4.057	4.060	1.953	1.965	1.957	1.951	598.1
	Post-	4.044	4.053	4.055	4.061	1.953	1.974	1.953	1.952	598.1
	Δ	-0.002	-0.002	-0.002	0.001	0	0.009	-0.004	0.001	0
22		No Measurements				No Measurements				

Hyphens indicate that posttest length measurements were omitted because impact deformation destroyed the measurement reference point.

Comparisons of canister ductility with glassy versus devitrified waste are inconclusive based on ΔL_{max} values. The same is true for comparisons of test results for room temperature and elevated temperature.

Of interest are the similar ΔL values at all measurement points for end-on impact (Specimen 6). This similarity indicates a nearly perfect end-on orientation at impact.

Upper-end diameter changes were less than the measurement uncertainty. Except for canister 4, mid-length diameter changes were very small. Lower diameter changes are uncertain because of the rotational orientation of the canister at impact. Estimated maximum diameter increases are 0.3, 0.1, 0.06, and 0.04 in. for impact velocities of 117, 66, 44, and 25 fps, respectively.

2. Canister Integrity

Posttest canister integrity was evaluated by visual observation and dye penetrant checks. The former technique can detect holes of dimensions greater than about 8 mils. The latter technique is good down to about 0.04 mils. A smaller breach could not release significant quantities of a low-leachability glass within a reasonable time.

No breaches were detected after impact at 25 or 44 fps. Impact surfaces of higher velocity canisters were obscured by debris (fragments of granite and paint from the impact block) ground into the point of impact. It was very difficult to distinguish between adherent debris and cracks in the canisters. But after most of the debris was removed, the breaches listed in Table 7 were apparent.

There seems to be no correlation of breach frequency with waste form or impact temperature. The only observed correlation is with velocity: no canisters breached at 25 or 44 fps, half breached at 66 fps, and nearly all breached at 117 fps.

Specimen 6, the end-on unit, was damaged much less than its edge-on counterparts. This result supports the hypothesis that the edge-on impact orientation is the most severe, at least for the canister.

TABLE 7. Breaches in Small Canisters

Specimen	Impact Velocity, fps	Impact Temperature, °F	Waste Form	Equivalent Total[a] Crack Dimensions, in.
7	66	802	G	0.01 x 0.3
17	66	RT	DV	0.01 x 0.2
4	117	800	G	0.05 x 0.7
5	117	796	DV	0.1 x 0.8
14	114	RT	G	0.01 x 0.5
23	117	800	G	0.03 x 0.6
24	117	800	G	0.1 x 0.5

RT ≡ Room temperature
G ≡ Glassy
DV ≡ Devitrified

a. In a few instances, there was more than one crack.

Pre- and post-test weights were recorded to estimate the quantity, if any, of glass lost during impact. In no case was there any measurable weight change. The weights were uncertain to about ±0.1 g and were further obscured by the adherent debris. Although a small amount of glass could have exited during impact, the consistent lack of any measurable weight change indicates that this quantity must have been extremely small.

LARGE CANISTERS

1. High-Speed Photographic Coverage

Impact of the large canisters was recorded by a Fastex high-speed (∿4000 frames per second) 16 mm camera. Ektachrome E.F. Daylight film was used. Figure 14 and 15 show every tenth frame near the time of impact for two canisters. The film coverage provided a record of the sequence of primary and secondary impacts for each canister. It facilitated measurement of actual impact angle (as opposed to drop angle) to within 1 to 2° and actual impact velocity (as a check on drop height) to within 5 to 10%. It also facilitated estimation of the impact duration.

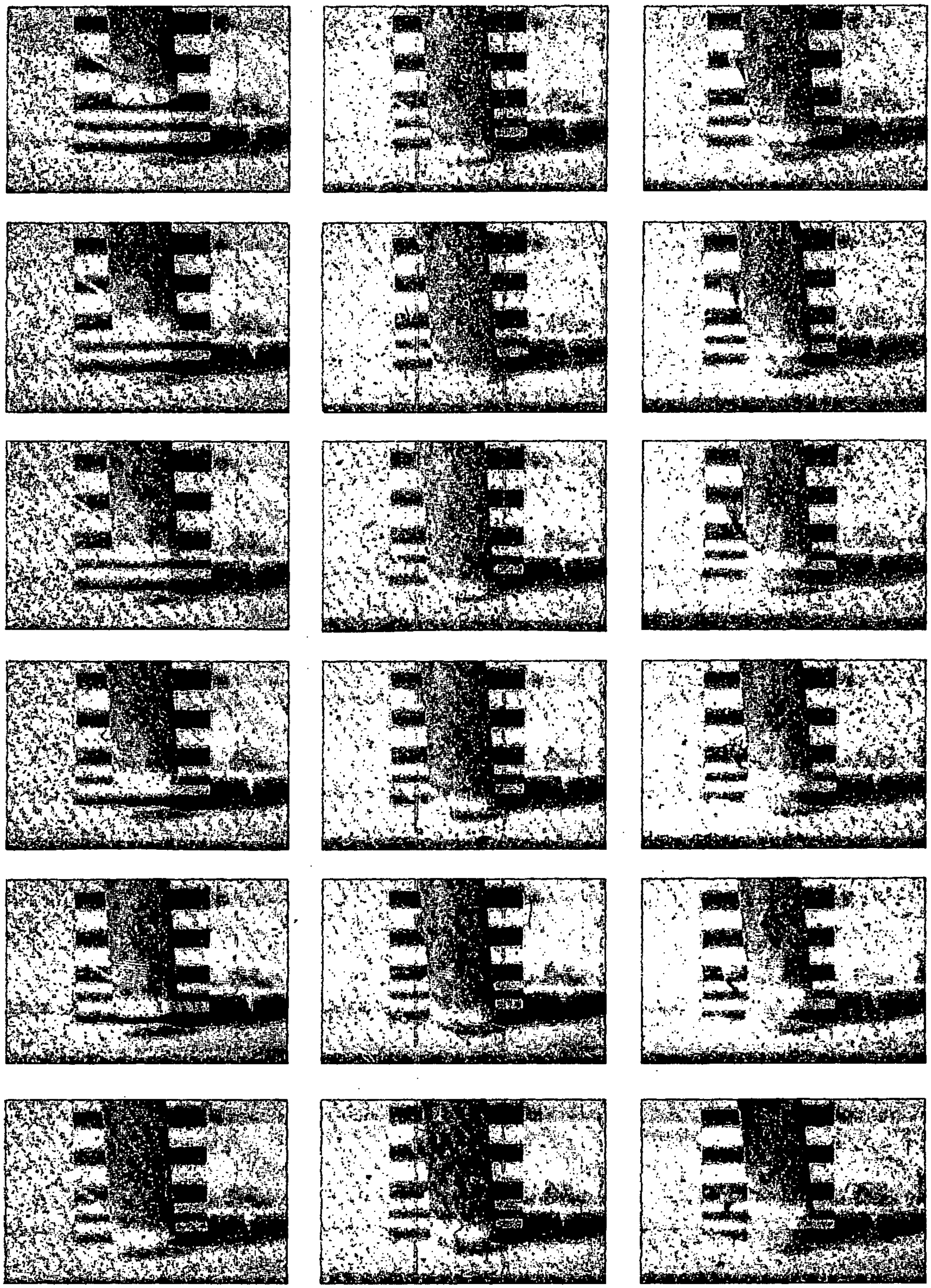


FIGURE 14. High-Speed Photographic Coverage of 30-ft Drop Impact. Every tenth frame is shown. Camera speed is 4680 frames/second.

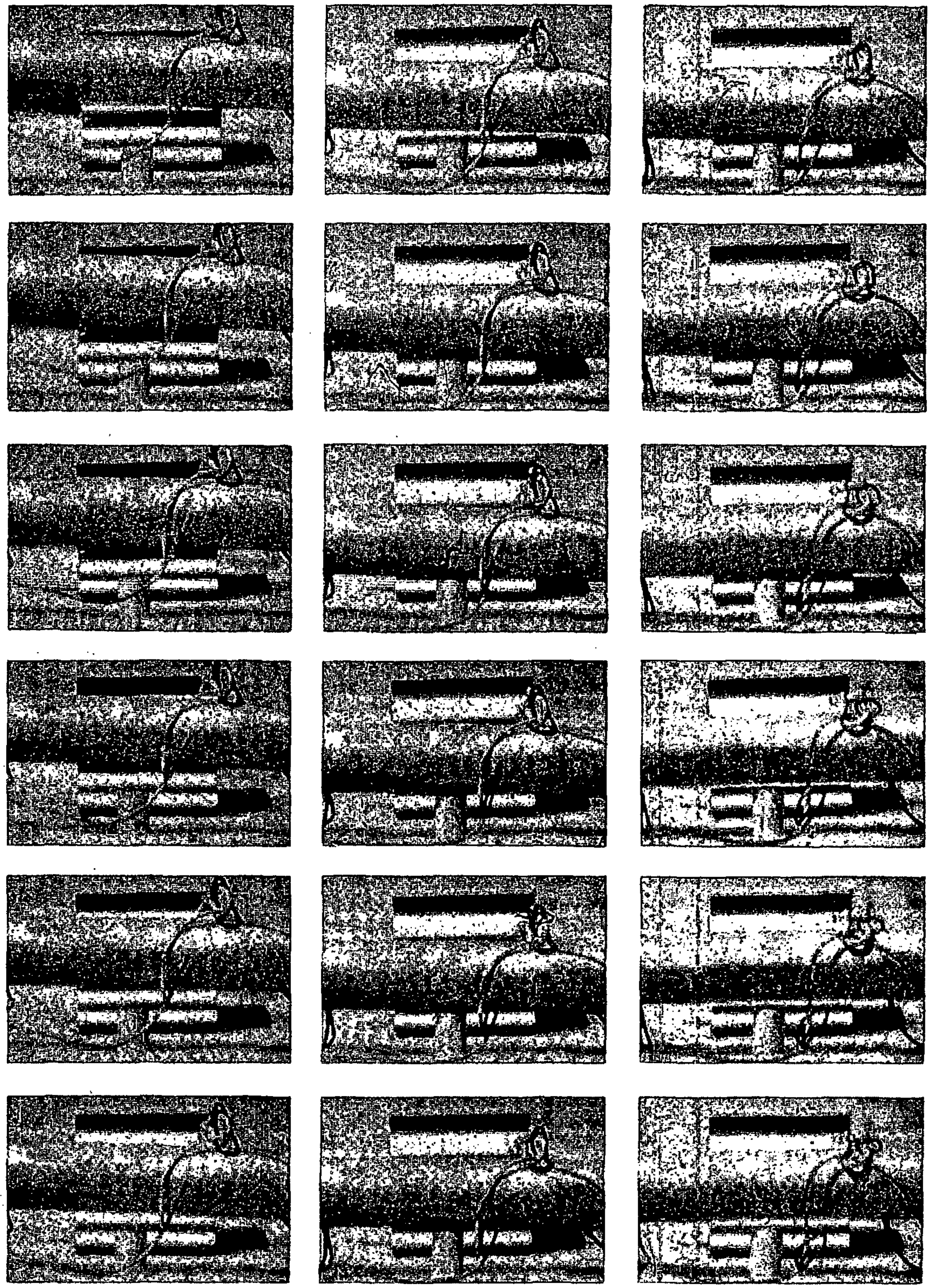


FIGURE 15. High-Speed Photographic Coverage of Side-On Penetration Test. Every tenth frame is shown. Camera speed is 3480 frames/second.

The impact velocity of canister 2 was seen to be about 44 fps, matching the intended value. Impact angle was 4 to 5°. (The intended angle, with the center of gravity above impact point is 5°, for a canister with no lifting eye. Adding the lifting eye increases the equilibrium angle of suspension to about 6°. Thus there was little apparent tendency of the canister to change orientation during release and descent.) The duration of impact was 1 to 2 1/2 msec. Shadows and parallax effects precluded a more accurate measurement. Rebound velocity was approximately 15 fps, giving a coefficient of restitution of about 0.3. The canister bounced about 5 ft high while canting over. The second impact was on the top edge of the canister and on the lifting eye.

The impact velocity of canister 4 was estimated at 24 fps, just below the intended 25 fps. Impact angle was 7 to 8° and impact duration was 2 to 4 1/2 msec. Rebound velocity was about 6 fps, for a coefficient of restitution of 0.2 to 0.3. The rebound height was about 9 in. The second impact was on the bottom but at a greatly changed angle. The third impact was on the top and the fourth on the bottom. Numerous small seesaw bounces followed.

The impact velocity of canister 6 was not checked. The impact angle was 6 to 7° and the duration was 2 to 3 msec. Rebound velocity was about 10 fps and rebound height was 24 to 30 in. The sequence of secondary impacts was the same as that of canister 4, which was dropped from the same height.

Canister 3 impacted the penetrator at an angle of 3°, compared with the intended 0°. Impact duration was 10 to 15 msec. Symmetric elastic bending of the canister about the point of impact was readily observable on the film. The canister bounced almost directly upward about 5 in. Succeeding contacts with the penetrator were at increasingly greater angles.

2. Deformation

Close visual observation was required to detect impact areas of most large canisters. The point of greatest deformation on the edge-on canisters

was near the lifting eye. This resulted from secondary impact on a small area of contact with no glass support. Table 8 lists several dimensional changes accompanying impact. Figure 16 shows specimen 2 following a 30-ft edge-on drop.

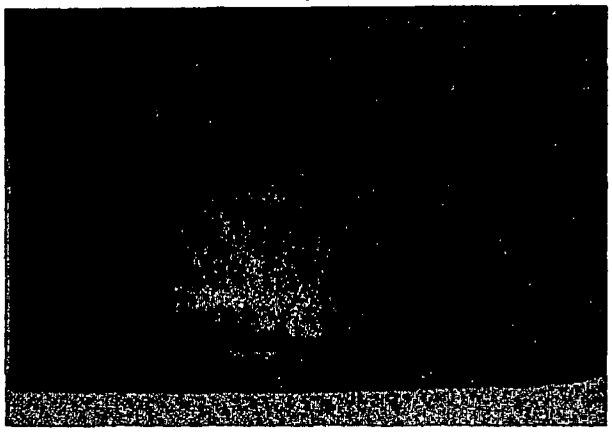
TABLE 8. Large Canister Dimension Changes

Specimen Number	Impact Velocity, fps	Maximum Diameter Increase at Bottom, in.	Maximum Decrease in Length, in.	Radial Indentation at Mid-length, in.	Radial Indentation Near Lifting Eye, in.
2	44	0.37	0.34	--[c]	--
3	15[a]	--	--	∿0.005	--
4	25	0.22	0.16	--	0.62
6	25	0.04	0.13[b]	--	0.54

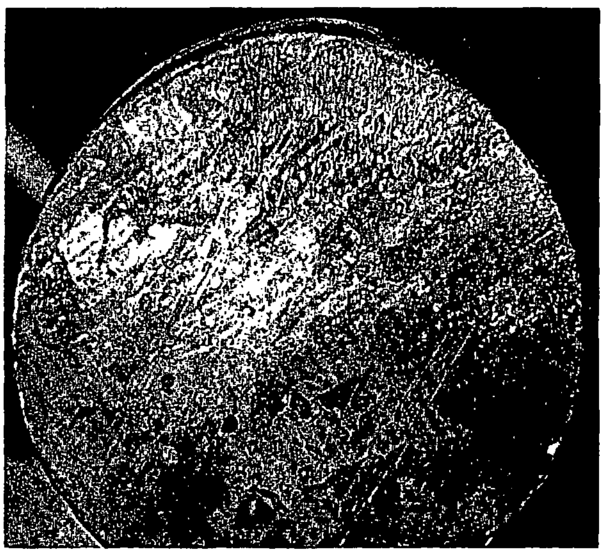
a. Side-on onto penetrator
b. The bottom face was also bulged outward in the axial direction, with the net decrease in length being only 0.03 in.
c. Blanks denote no measurement recorded.

3. Canister Integrity

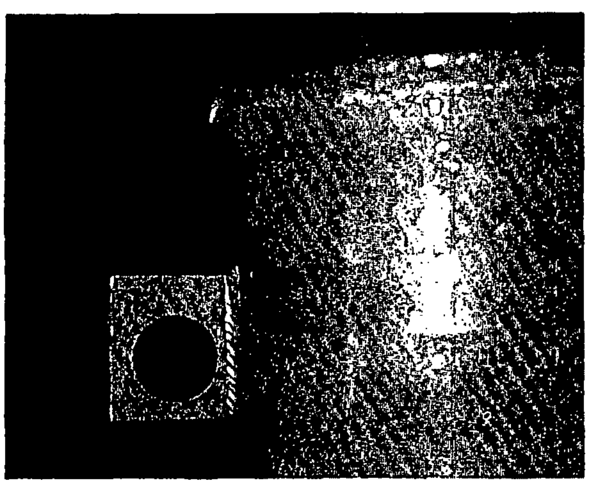
Visual observation and dye penetrant checks revealed no penetrations of canister walls.



Bottom Edge



Bottom Surface



Top End Near
Lifting Eye

FIGURE 16. Large Canister 2 After 44 fps Edge-On Impact

8.0 CANISTER OPENING AND PARTICLE REMOVAL PROCEDURES

LARGE CANISTERS

Because of their size and weight as well as the shell thickness, the large canisters were delivered to the J. A. Jones Company machine shop for initial opening in a large milling machine.

1. Top Opening and Particle Removal

The top end was cut off just below the canister top, about 12 in. above the glass surface. Loose material was brushed into quart cartons.

2. Impact Area Opening

Impact areas were opened in two stages to minimize loss of material. The bottom end was scored across a diameter almost to the glass surface, leaving a thin sheath of steel to be penetrated by hand cutting. A groove approximately the depth of the wall was milled through the canister wall, up each side about 8 in. and then around half the circumference (Figure 17). The section of canister wall thus isolated included the impact area. In a few places the milling cutter did cut through to the glass.

On the side impact canister, the side was milled to produce two longitudinal 8-in. scores 180° apart. The score ends were connected by milling halfway around the canister (Figure 18). One control canister was scored both on the bottom and on the side about midway up but 180° opposite.

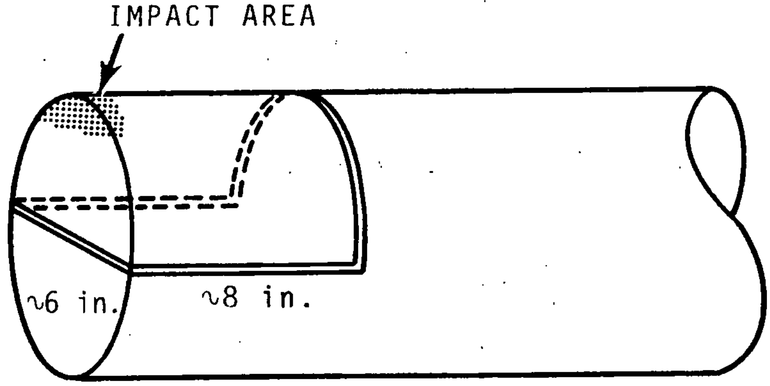


FIGURE 17. Wall Removal Scheme for Large Canisters in Edge-On Impact

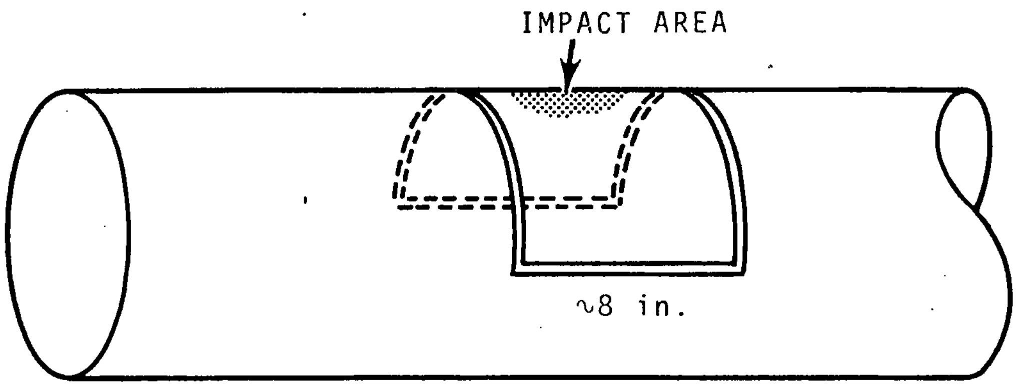


FIGURE 18. Wall Removal Scheme for Large Canister in Side-On Impact

The canisters were then brought to the PNL Atmospheric Sciences Department Laboratory to complete the opening and to remove the fragmented material for particle sizing. Final cutting of the shell was done with a Dremel Moto-Tool, a hand-held, high-speed motor equipped with an abrasive cutting wheel. After the remaining thin steel shell was cut through, it was tapped lightly with a hammer and cold chisel until the cut metal was loose and could be removed. Aluminum foil was placed under the canister to catch particles that fell during opening.

On canister 1 a small amount of glass adhered to the metal shell as it was removed. Breakage apparently occurred during opening. The same occurred with canister 5. In the other cases the metal came away cleanly. On canister 2, as the cutting tool cut almost through the canister, a cracking noise was heard and the cut began to open of itself as if the material were under compression. Nothing unusual was noticed in opening of the other canisters.

Photographs of the area exposed by removing the metal appear in Figures 19-25.

3. Impact Area Particle Removal

Forceps were used to pick out larger pieces. This facilitated removal of smaller pieces which began falling out when the shell was tapped. By means of brushing and tapping, all fragmented material that could be removed was collected.

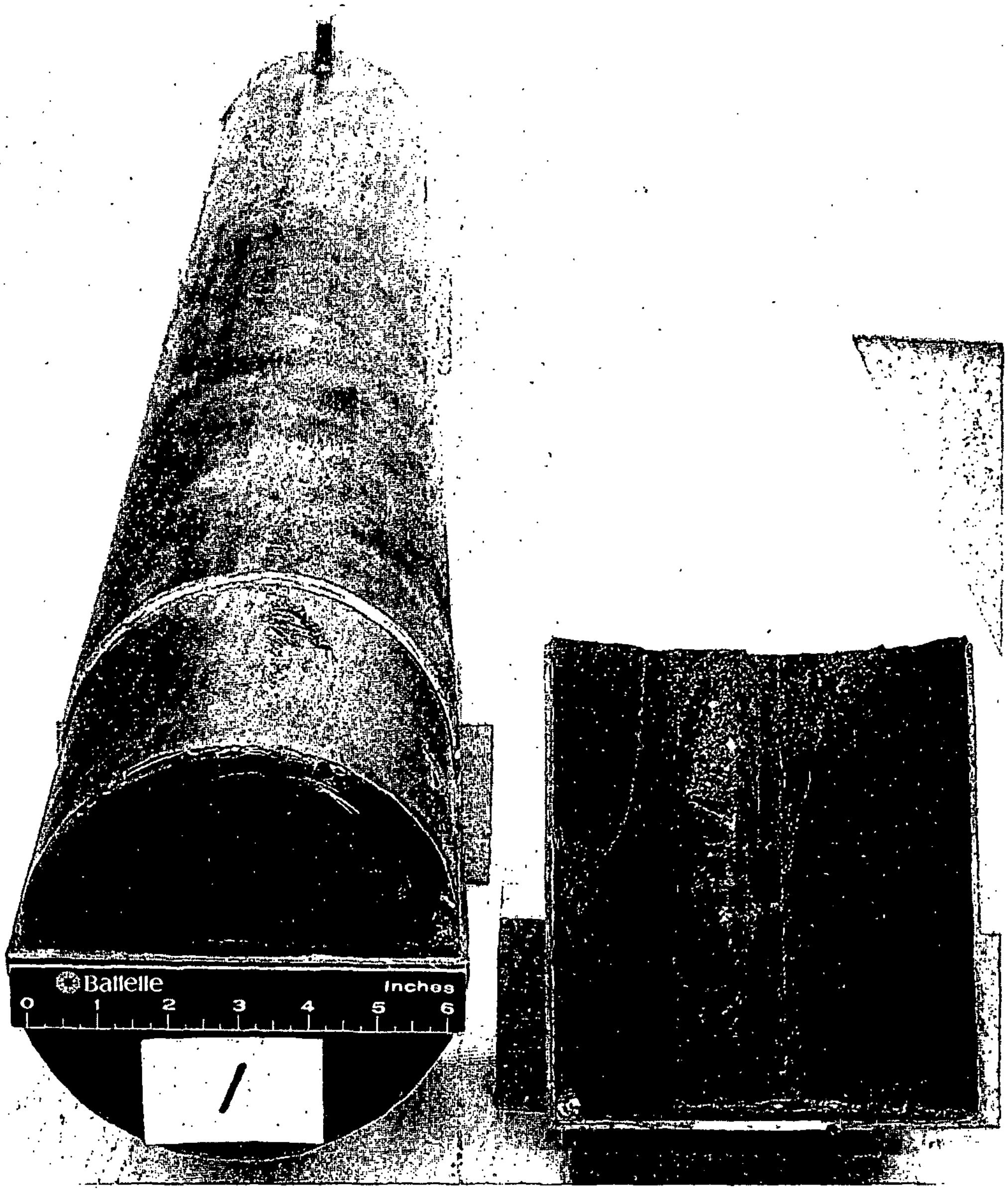


FIGURE 19. Large Canister 1 After Opening

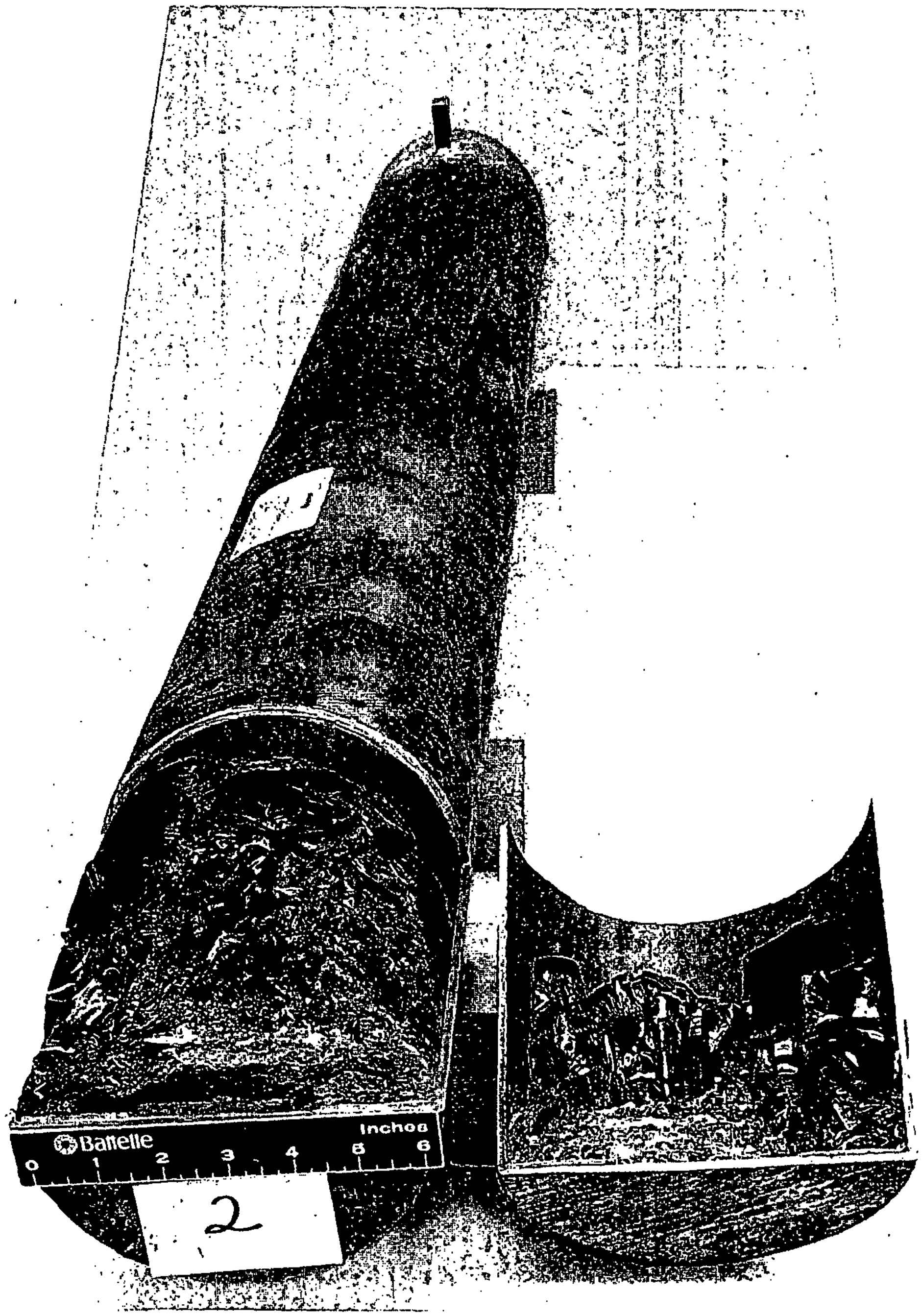


FIGURE 20. Large Canister 2 After Opening

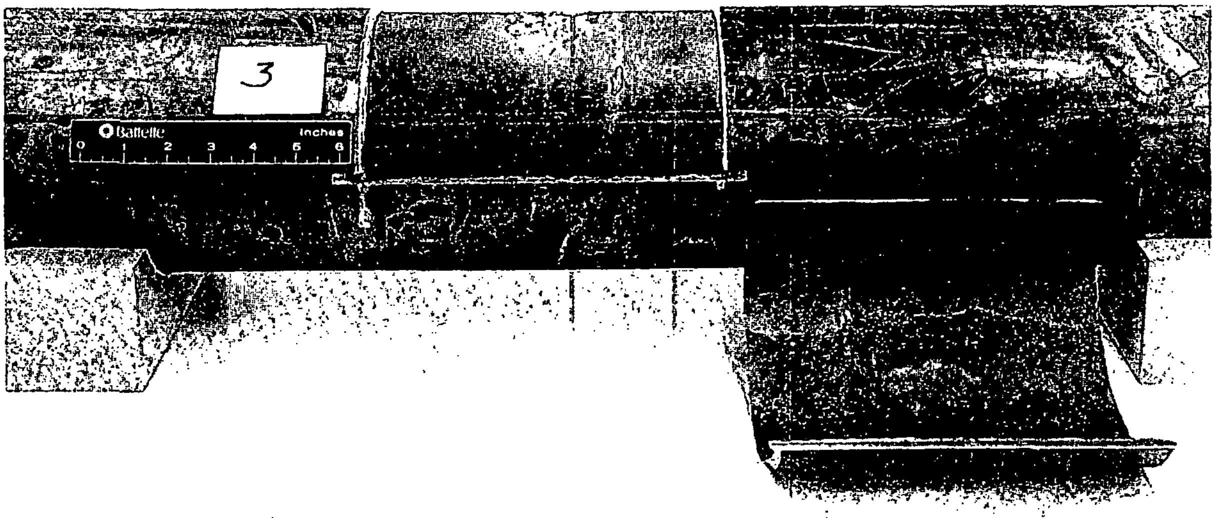


FIGURE 21. Large Canister 3 After Opening

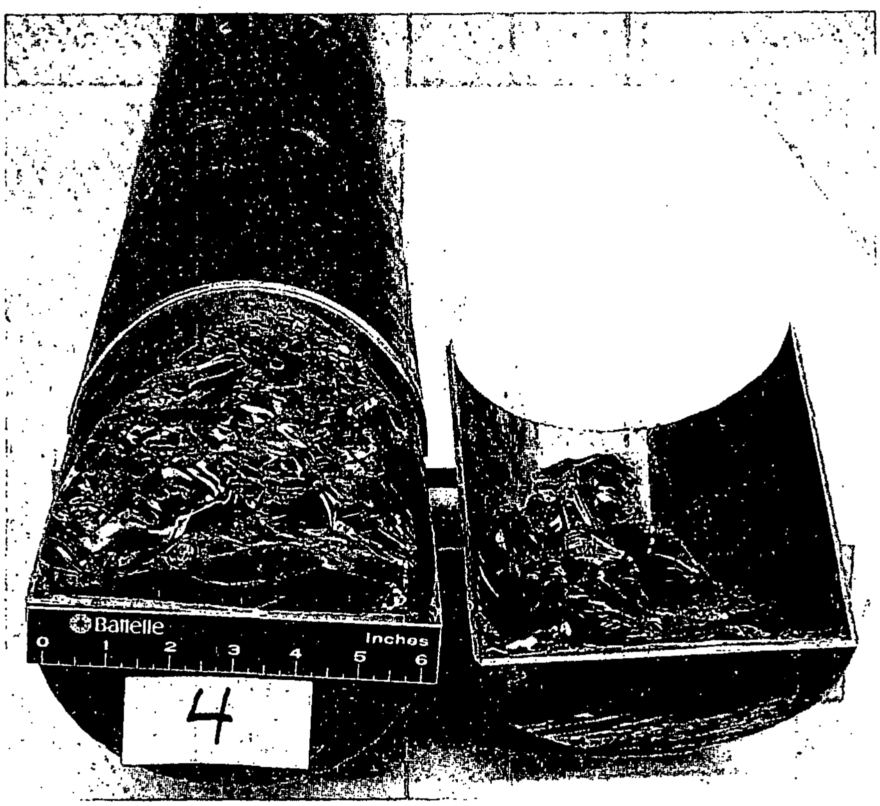


FIGURE 22. Large Canister 4 After Opening

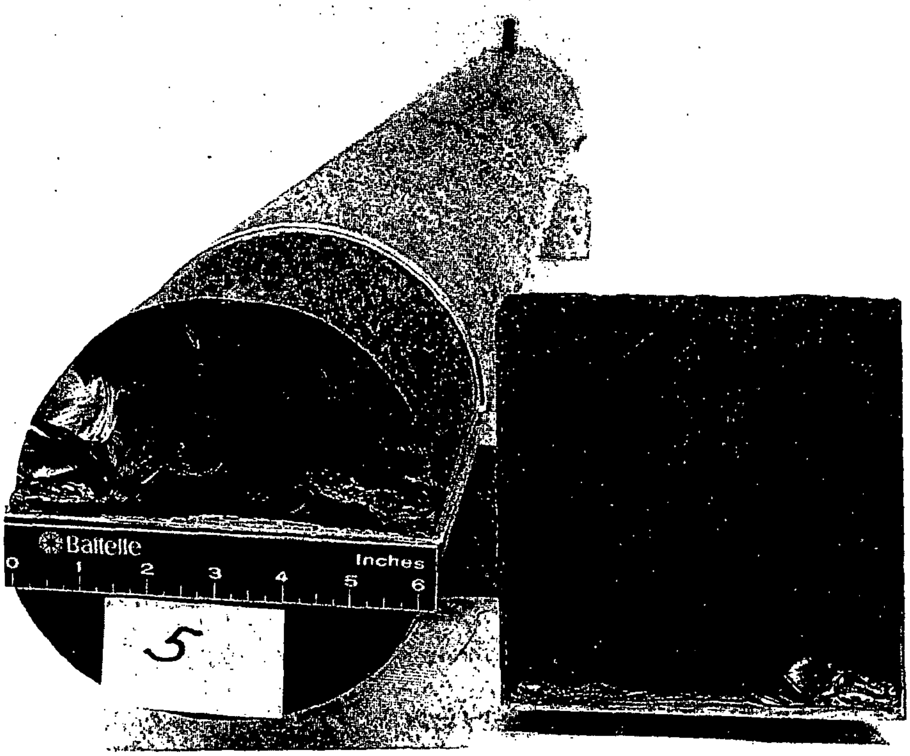


FIGURE 23. Large Canister 5, Edge Area, After Opening

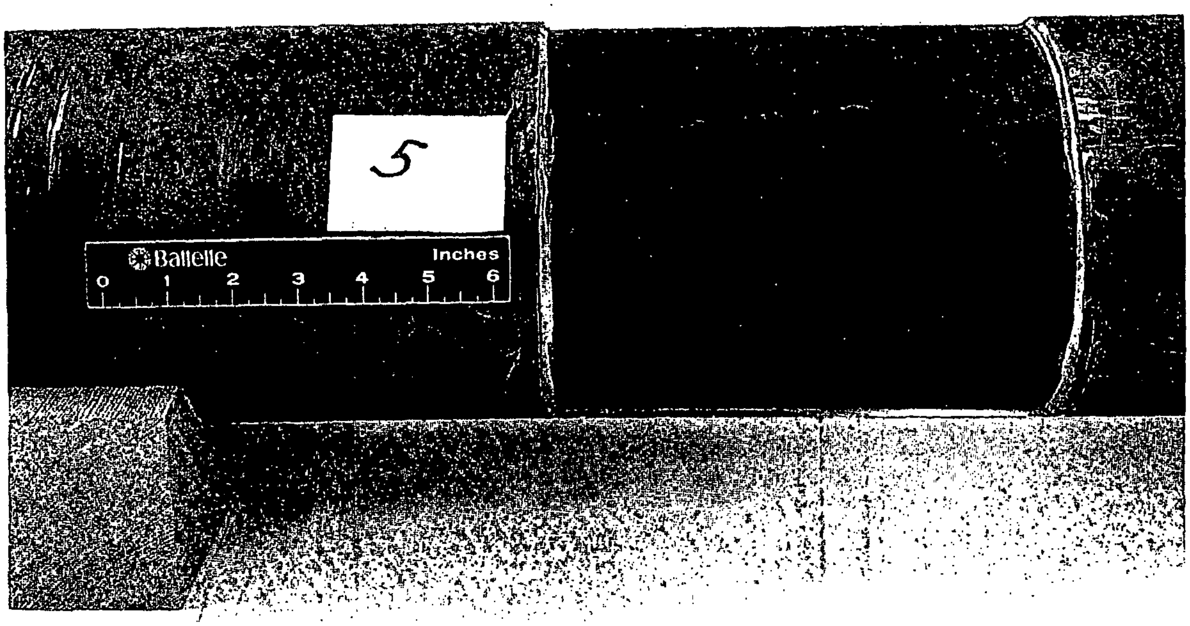


FIGURE 24. Large Canister 5, Mid-Region, After Opening

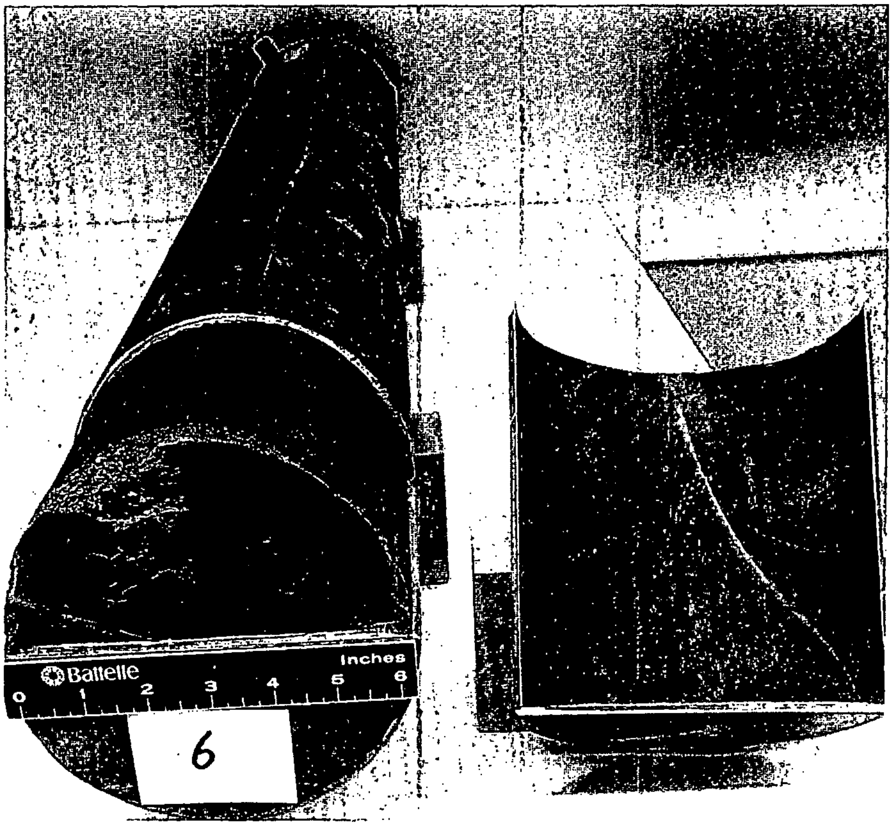


FIGURE 25. Large Canister 6 After Opening

SMALL CANISTERS

After impact testing, the small canisters were sent to the PNL Atmospheric Sciences Department Laboratory for opening, particle removal and sieving.

1. Top Opening and Particle Removal

The canisters were opened in the head space above the glass, just below the canister top. The canister was held in a padded vise to avoid further fracturing of material during opening. The canister was cut with a sharp pipe cutter by slowly rotating the cutter several times, avoiding deformation arising from the contact pressure of the operation.

All glass fragments were then removed from the top area by rolling and by brushing with a camel's hair brush. No attempt was made to force material out, but some that was loose and entrapped was picked out with forceps.

2. Bottom Opening and Particle Removal

Because of the severe impact conditions, it had been expected that the glass would be severely broken up and could be poured out the opened top. However, in all but one canister, after removal of the small amount of broken material from the top, a glass monolith remained between the top and the impact area. The stepwise scheme for opening the bottom of the canisters is explained below.

By means of a milling machine a 5/8-in. hole was cut in the bottom near the impact area. The rotodie cuts through the steel to a predetermined depth and avoids cutting the glass. The glass was removed first by rolling the canister then by tapping it and picking and removing all loose material. A few of these two fractions were sized individually, but later this separation was considered unnecessary and discontinued.

Because a further opening step was needed on some canisters, a 1-3/4-in. hole was cut in the canister bottom, extending the opening to encompass almost the complete bottom area. For canisters yielding no material this was the final step. Other canisters had broken material exposed by this step. This fractured material was removed by tapping the canister and picking out glass fragments where necessary. By brushing, tapping, shaking and inverting the canisters, all material that could be removed was collected.

Certain canisters (10, 11, 12, 19, 20, 21) required still more opening to expose the impact area for particle removal. They were cut by hand around the impact area using a Dremel Moto-Tool.

Figures 26-31 show several small canisters after opening.

Canisters 19 and 20 were cut lengthwise from top to bottom with a glass saw to reveal the interior of the glass monolith (Figure 32). This result and other observations suggested that the fraction of particles recovered was close to unity.

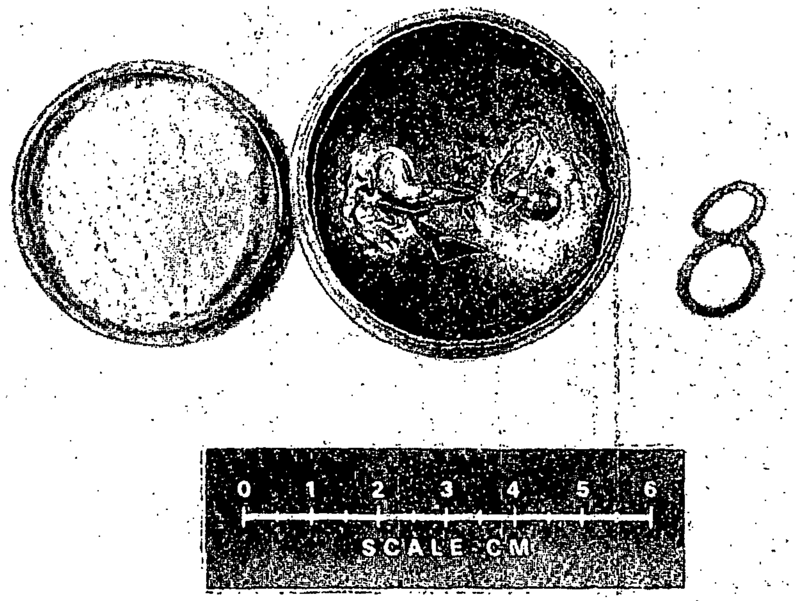


FIGURE 26. Small Canister 8 After Opening, Top View

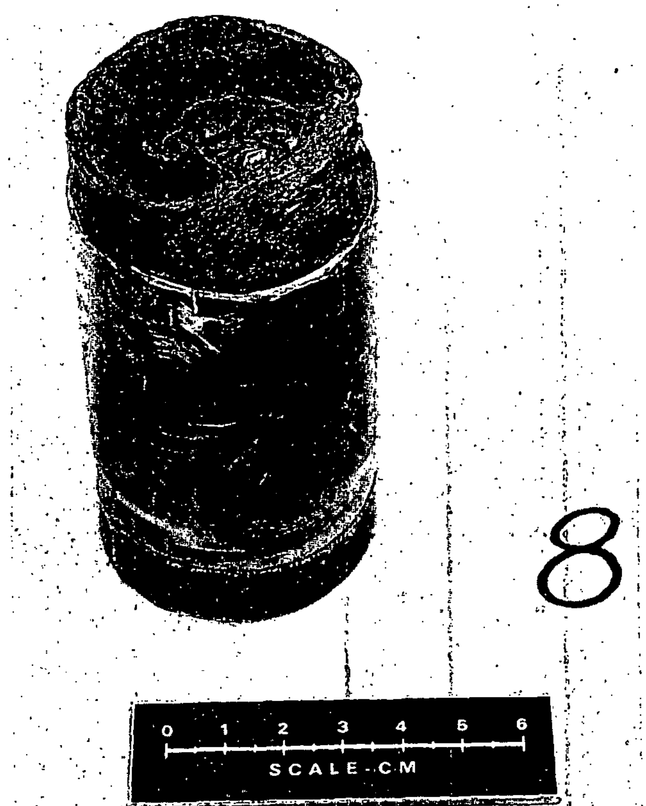


FIGURE 27. Small Canister 8 After Opening, Inverted

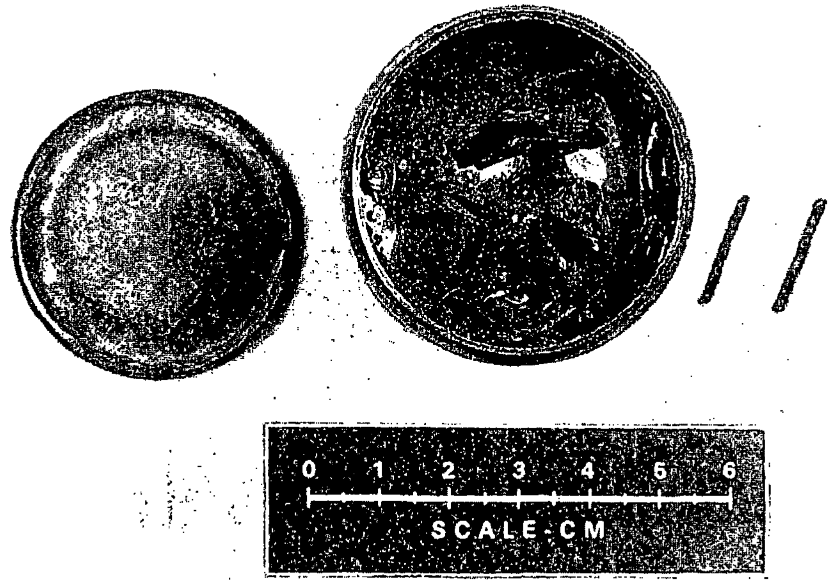


FIGURE 28. Small Canister 11 After Opening, Top View

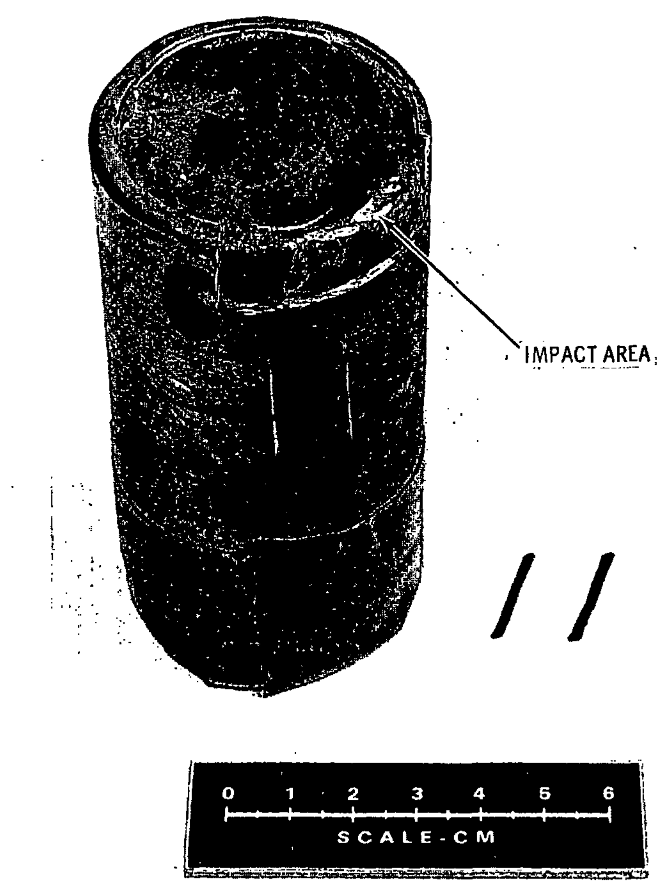


FIGURE 29. Small Canister 11 After Opening, Inverted

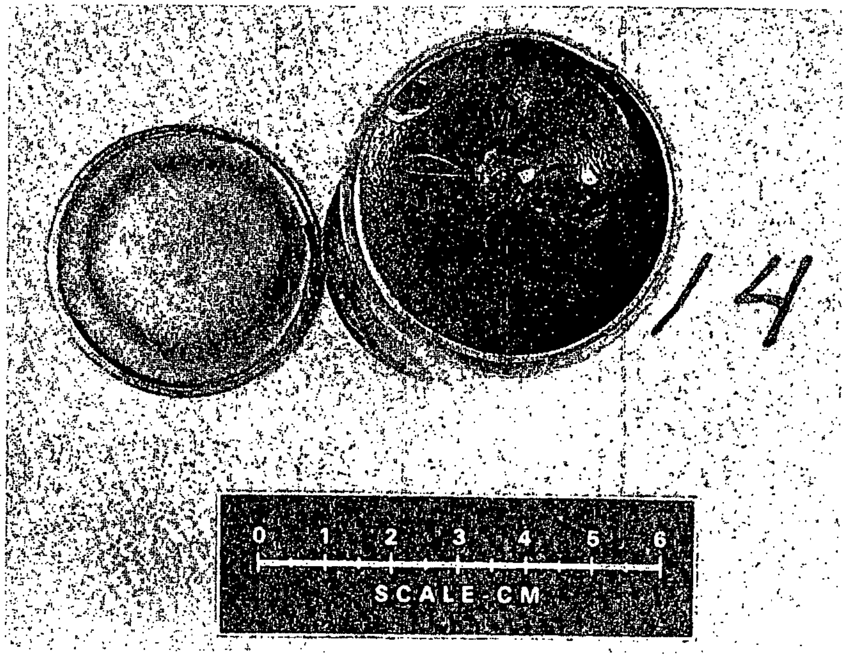


FIGURE 30. Small Canister 14 After Opening, Top View

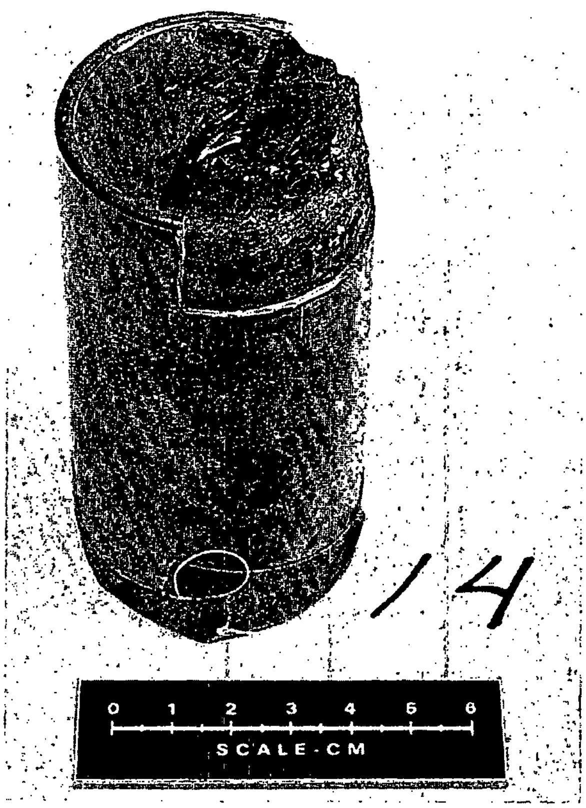


FIGURE 31. Small Canister 14 After Opening, Inverted

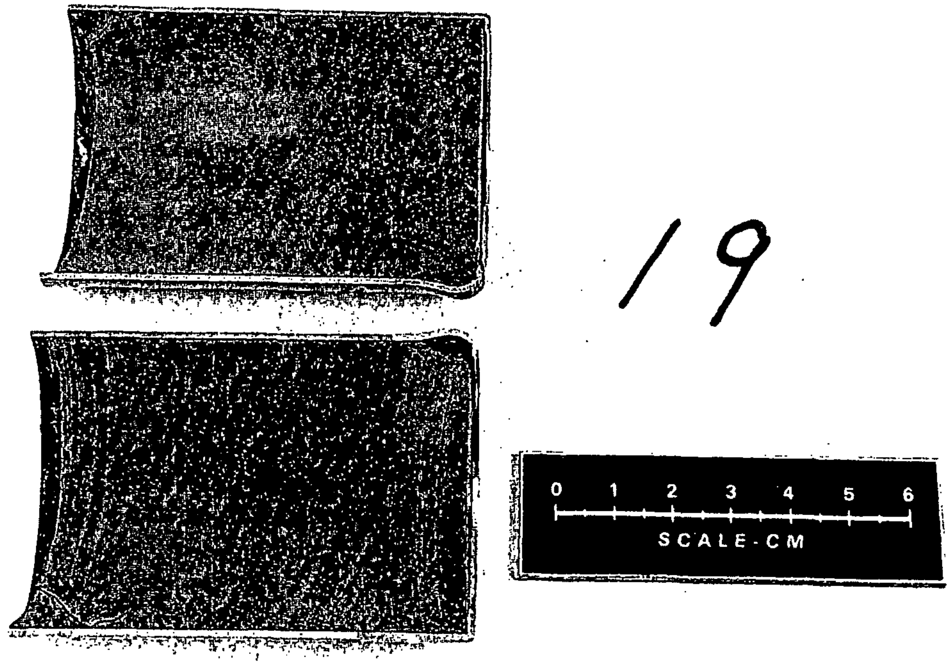


FIGURE 32. Small Canister 19 After Opening and Longitudinal Sectioning

ERRORS INTRODUCED BY THE PARTICLE REMOVAL PROCEDURES

Ideally, the metal canisters could be made to disappear to allow removal of the glass particles. Nonidealities of the canister opening and particle removal procedures are discussed here.

During opening and removal care was taken to avoid generation of new fragments. Handling was held to a minimum since the bare glass is subject to breakage. Despite these precautions, the procedures had a potential for introducing errors into the results in several ways. Cutting and opening operations can introduce new particles by 1) cutting too deeply through the steel and grinding the glass; 2) introducing pieces of ground steel shell into the sample; 3) mechanically stressing the glass.

Though the milling machines used are precise, some material was still generated on a few canisters. If the material was obviously not from impact (as metal shavings), it was not included in the material collection. Little error is expected here.

The milling machine is equipped with a holder to minimize canister deformation. While cutting the canister with the Dremel tool, the operator wiped the area clean frequently to remove generated particles. The small canisters were held by a padded vise while the top was opened by a pipe cutter, thus minimizing deformation of the steel shell. This process is not expected to be a significant source of error.

Loss of material was minimized in the small canisters by taping the top back in place after opening. Bottom areas were placed in a plastic bag after opening. The small canisters were opened above a clean glossy paper. Final opening of the large canisters was done with aluminum foil suspended beneath the canister to catch material. For both large and small canisters, the material was immediately removed to a tared container, which was reweighed and covered.

9.0 PARTICLE SIZING PROCEDURES

LARGE CANISTERS

Broken material, top and bottom, was removed from the canisters and weighed. Lots weighing more than 100 g were sieved on standard Tyler sieves with the following size numbers: 12 (1,700 μ), 20 (841 μ), 70 (210 μ), 100 (149 μ), and 200 (74 μ). A Tyler portable sieve shaker was used. Lots of less than 100 g were sieved by means of an Allen-Bradley sonic sifter, with 210 μ, 149 μ, 74 μ, 37 μ, 20 μ, 10 μ, and 5 μ sieves.

Sieving of the bottom material from canister 2 was initially done through the set of large sieves from No. 12 to No. 200. Since there was a large quantity of fractured material (2493.5 g), this lot was sieved in 4 aliquots and the numerical results combined. After the large material had been removed, the material <74 μ remained to be sized. Two aliquots of this fraction were sieved through fine mesh screens using the Bradley sonic sifter. Since the limit on sample size for sonic sieving is 3 g, it was decided that sieving the entire 72.3 g of material <74 μ would be too time consuming. Another separation was made using the large screens, and this fraction was divided into fractions >44 μ and <44 μ. Aliquots of the <44 μ fraction were then sieved through the sonic sieves: 37 μ, 20 μ, 10 μ, and 5 μ. About 1 g was the optimum quantity of material for this sonic sieve analysis. Bottom fractions from the other canisters presented no unusual problems.

Top material removed at J. A. Jones was found to have metal pieces inextricably incorporated with the sample. Top material from canister 2 was so contaminated with metal pieces that the sizing results were inaccurate. As there were no glass particles <37 μ in any of the top fractions, the omission is not serious.

SMALL CANISTERS

Where there was sufficient sample, the fragments were separated into >74 μ and <74 μ fractions, using a standard No. 200 sieve and shaking for half an hour. On later samples, this procedure was modified because the abrasive glass destroyed the sieve.

The >74 μ size fraction was sieved on Tyler sieves with the following size numbers: 12 (1651 μ), 20 (841 μ), 40 (420 μ), 70 (210 μ), 100 (149 μ), and 200 (74 μ). The samples were shaken on a Tyler mechanical sieve shaker for 1 hr. Sieves were weighed before and after shaking, which gave the quantity collected in each size fraction. After shaking, there was a small amount of material in the solid brass pan below the 74 μ screen. Since the sample had first been divided into >74 μ and <74 μ fractions and the <74 μ material removed for separate sizing, the material in the solid pan was not considered a valid sample. It was considered to consist of newly generated particles. When the procedure was later modified to eliminate the initial split at 74 μ, the shaking time was shortened to 15 min to avoid generation of new material.

The <74 μ size fraction was sized by sonic sieving in an Allen-Bradley sonic sifter, with sieves weighed before and after sifting. This procedure separated the 37 μ, 20 μ, 10 μ, and 5 μ fractions. Since the canisters had experienced different impact velocities and contained different quantities of fines, each canister required individual sizing consideration.

SIZE SAMPLING WITH MICROSCOPE

Two <5 μ fractions (small canister 5 and large canister 2) were sized further using a Bausch and Lomb Microscope with overhead projector. A representative field was selected. Images of all particles within an area along a path were scanned and measured (equivalent circular dimension) until 200 particles had been sized. The results were grouped in the following distribution: >5 μ, 3-5 μ, 1-3 μ, and <1 μ. See Appendix B.

SIEVING ACCURACY

Sizing by means of sieves is rapid and relatively straightforward. However, a sieve cannot make a perfectly sharp separation, especially of irregular particles. Results can be distorted because elongated particles can pass through a sieve opening if the particles are oriented end-on. Also small particles may not pass through a larger opening because they never get immediately next to it. The fraction of particles passing through depends on mesh size and manner of shaking, quantity of sample, moisture content, percentage of particles closely similar in size to the sieve openings, electrostatic attraction and other factors. However, if sieving procedures are standardized, reproducible results with a series of samples can be obtained.

The sieves used for sizing the >74 μ fraction were the sieve size designations proposed by the ASTM International Standards. A mechanical shaker was used to standardize the shaking action. The shaker frame holds up to 13 sieves at a time and imparts both a circular and a tapping motion to the sieves. Recommended sieving times range from 20 to 45 min depending on the material. Because excessive shaking with this material seemed to generate new particles, a 15-min shaking was used as a compromise between new particle generation and complete separation. As the sieves fit well, dust loss was minimal.

If the sample size is too large, agglomeration can occur, particularly on the sonic sieves. In one case of an aliquot from large canister 2, >44 μ, the material seemed to ball up, so smaller aliquots were chosen. The sonic sieving time is inversely proportional to the fraction of open sieve area. Forty-five minutes shaking was found optimum. To avoid weighing errors, the screens were equilibrated to room temperature before and after sieving.

There is some loss during material transfer related to sieving. The significance of this uncertainty is addressed in Section 10.0.

10.0 GLASS IMPACT RESULTS

FRACTION OF INVENTORY BROKEN

1. Large Specimens

Table 9 presents material balances for the large specimens. The pre-impact weight of the nearly-monolithic glass is given, along with the quantities of broken glass collected from various locations on the canister. Broken material retrieved from all locations was conservatively totaled for calculation of the maximum potential release fraction as a direct result of impact. This approach ignores post-impact containment by the canister. The tests showed that, even if a canister failed, generally only a small part of the broken waste glass could move because the remainder of the canister and unbroken glass would provide barriers.

Table 9 indicates that, for edge-on impact specimens 2, 4 and 6, most of the broken glass came from the (bottom) impact end. A small fraction (very small for higher velocity specimen 2) came from the top, caused by spallation or by secondary impact on the top. Side-on impact of specimen 3 against the penetrator resulted in surprisingly little glass breakup near the impact area. Control specimens 1 and 5 indicate the amount of glass breakup during fabrication, handling and opening.

2. Small Specimens

Table 10 summarizes material balances for the small specimens. Section 8.0 described how the bottoms of these canisters were opened in stages--first a 5/8-in. hole, then a 1-3/4-in. hole, then (if necessary) removal of the entire bottom and lower edge. The objective was to estimate how much broken glass would migrate through various-sized holes. As the results were not definitive, the procedure was changed to combine all material gathered from the bottom of the canister. However, in all cases but one the amount of broken material which passed through a 5/8-in. hole was 1/2 to 2 orders of magnitude less than the total quantity of broken bottom material. Inhibition of flow is attributed to compression of the broken

TABLE 9. Large Specimen Material Distribution

Canister	Original Glass Weight, lb_m	Top Material, lb_m	Bottom Material, lb_m	Total Fraction Broken
1	189	∿0	0.0169	0.000089
2	191	∿0.01[e]	5.50	0.029
3	193	0.0514[a]	0.0011[b]	0.00027[c]
4	193	0.105	0.216	0.0017
5	190	0.0394[d]	0.0676	0.00056
6	182	0.122	0.740	0.0047

a. At the canister end containing the void space. The other end was not opened. Less broken material is expected there than that at the void end.
b. At impact area (on side of canister) for side-on drop onto penetrator.
c. This number is less than the total fraction broken. See notes a and b.
d. Plus an additional 0.046 lb_m in one very large chunk (characteristic dimension of 2.4 cm = 24,000 μ).
e. Exact quantity not known because of contamination of the sample by metal shavings.

glass by the canister. Once the canister was opened past the edge, this compression was much reduced and the broken glass easily removed.

Table 10 shows that for only four of the impacted specimens was the top portion of broken glass greater than 10% of the bottom portion. This pattern could be correlated neither with impact velocity nor glass condition. The small canisters did not experience secondary impact.

3. Comparisons

General

Figure 33 plots the "Total Fraction Broken" columns of Tables 9 and 10 versus impact velocity. Points at zero velocity represent control specimens. The general dependence on velocity is evident. If data scatter and the different types of specimens are considered, a linear fit is seen to be a creditable approximation.

TABLE 10. Small Specimen Material Distribution

Specimen	Original Glass Weight, g[a]	Top Material, g	Bottom Material, g	Total Fraction Broken
1	442.5	0.203	-	0.00046
24	451.9	6.384	321.1	0.72
23	439.1	196.9[b]	236.8	0.99
4	452.5	3.097	297.1	0.66
5	440.3	3.877	351.2	0.81
6	444.8	10.083	271.3	0.63
7	443.9	1.437	66.8	0.15
8	433.4	0.387	11.577	0.028
9	458.6	1.772[b]	3.550	0.012
10	427.3	0.358	5.236	0.013
11	439.0	1.967[b]	1.454	0.0078
12	432.0	0.18	4.61	0.011
13	392.4	0.025	-	0.00006
14	463.8	0.096	14.95	0.032
15	439.0	0.036	14.1	0.032
16	447.4	0.043	7.51	0.017
17	429.0	0.051	5.52	0.013
18	462.4	0.017	0.246	0.00057
19	419.9	0.118	1.78	0.0045
20	454.4	0.055	5.337	0.012
21	447.3	0.34[b]	0.208	0.0012
22	445.0	0.026	-	0.00006

a. Obtained by subtracting the average canister weight from the specimen weight and assuming 0.0 g of glass exited during impact.
b. Top portion ≥10% of bottom portion, excepting control specimens 1, 13, 22.

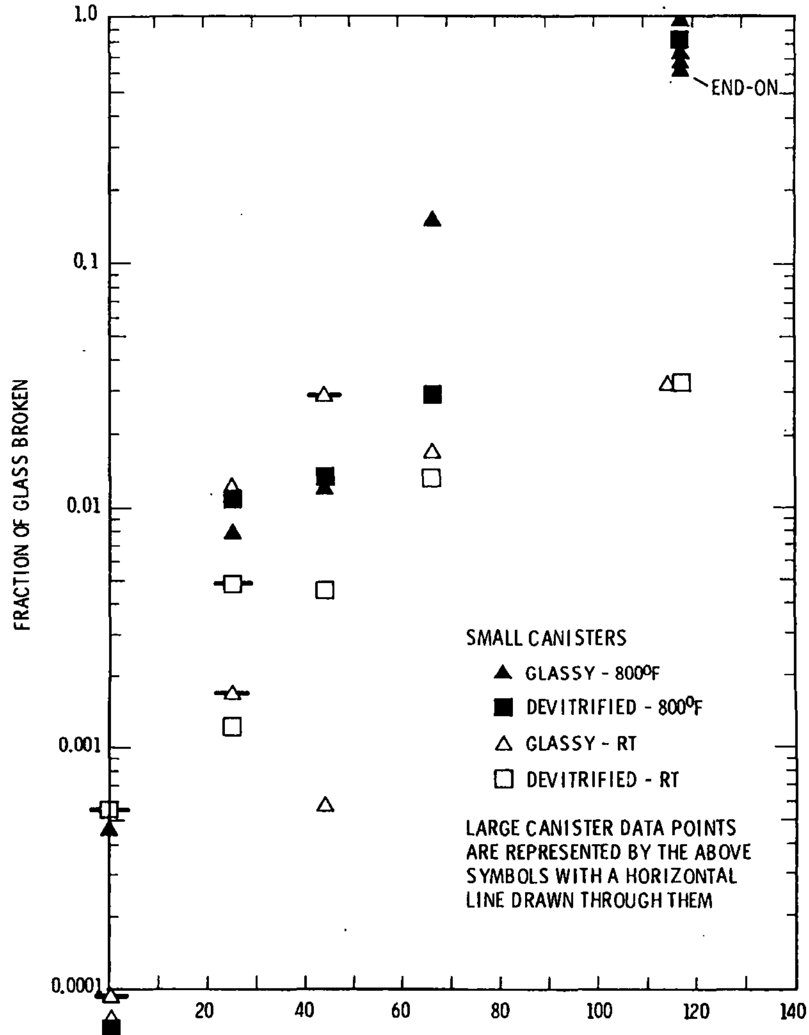


FIGURE 33. Fraction of Glass Broken

Effects of Glass Condition and Test Temperature

For the small specimens, nine pairs of points were compared on the basis of glassy versus devitrified breakup under identical conditions. In four pairs, the glass broke up more; in two pairs, the devitrified; in three pairs, essentially no difference. In no case was the difference more than one order of magnitude. Thus no significant effect of glass condition was apparent. The conclusion holds at both room temperature and elevated temperature.

Two pairs of points for the large specimens indicated greater breakup for the devitrified waste, but the sample size was too small to draw conclusions.

Comparison of small canister data at low and at elevated temperatures leads to a rather surprising conclusion. One might expect less waste breakup at elevated temperature because of increased ductility. However, greater breakup (by up to 1-1/2 orders of magnitude) was observed at elevated temperature in eight of the nine pairs of points compared. (In the ninth case, the difference was very small.) This effect, whose magnitude was generally a factor from 3 to 10, was independent of impact velocity and of glass condition.

It might be suspected that thermal treatment in the impact injection furnace or thermal shock upon ejection and cooldown was responsible for this greater breakup. The evidence is against this explanation. If time at temperature were responsible, devitrified specimens, which experienced a more severe treatment than the specimens impacted at elevated temperature (700°C for 4 days versus 425°C for a few hours), would exhibit greater breakup than glassy specimens. As noted previously, there was no consistent difference between glassy and devitrified specimens. If the ejection and cooldown transient were responsible, one would expect considerable breakup in the elevated-temperature control specimens. However, specimens 1 and 13 exhibited very low breakup fractions. The control specimens fall about where one would expect to find them by extrapolating back to zero velocity.

Another possible explanation is that the glass strength may be significantly less at elevated temperature. However, the modulus of elasticity at 425°C is within 5% of its room temperature value.[34] The failure strain for high-speed loading is expected to be only slightly changed. This waste glass retains its brittle nature, especially at high loading rates, from room temperature to above 425°C, the maximum temperature of the impact tests. The "ductile-brittle" transition is about 500°C.[35]

Another explanation, supported by calculations, can be postulated from review of the glass processing steps. Viscous molten glass is poured into canisters which are held at (or soon increase their temperature to) at least 550°C. On cooling after glass solidification (the glass becomes fairly rigid at 500°C), the stainless steel contracts more than the glass, placing the glass in compression and the steel in tension. Average thermal expansion coefficients of the glass and stainless steel between 500°C and room temperature are approximately 9×10^{-6}/°C and 17×10^{-6}/°C, respectively. The precompressed room-temperature glass is more resistant to tensile stresses which might cause fracture on impact. On heating back to 425°C for elevated temperature tests, the preexisting compressive stresses are greatly reduced, if not eliminated, with a corresponding reduction in impact resistance.

The mismatch in glass and steel radii upon cooling is 3.6 mils for small specimens and 12 mils for large specimens. The calculated[36] contact pressure at room temperature is sufficient to yield the canisters and is expected to be limited to approximately 1700 psi because of the yielding. Thus the glass is stressed to 1700 psi compressive and the canister is slightly into yield with a hoop stress of about 42,000 psi. Upon reheating to 425°C, the contact pressure and glass precompression are eliminated because of the yielding which occurred during the initial cooldown. (With no intervening cooldown to room temperature the contact pressure at 425°C is calculated to be about 600 psi.)

Thus room-temperature precompression is of such magnitude that a significant effect on impact behavior would be expected. The tensile strength of borosilicate glass is typically 9,000-10,000 psi. The observed effect was in the predicted direction and, qualitatively, of the expected magnitude.

Large Versus Small Specimens

The small canisters are not scaled reductions of the large canisters. Because of specimen size limitations on the DWDL impact equipment, the small specimens were shortened from the large specimen L/D value of 9.6 to a value of 2.1, a factor of 4.6.

Canister behavior has been shown to be almost independent of L/D, but the L/D effect on glass behavior was expected to lie between two extremes (temporarily disregarding effects of specimen size). Figures 34 and 35 show two extreme models of breakup for cylinders of different L/D ratios. In one extreme, if glass breakup were a completely localized phenomenon (Figure 34), the amount of glass broken would be expected to be independent of specimen length. The fraction of glass broken would be inversely proportional to specimen length, and the shortened specimen breakup fraction would be 4.6 times that of the full-length specimen. In the other extreme (Figure 35), the L/D value would not be relevant, and shortened and full-length specimens would exhibit identical fractional breakup of the glass.

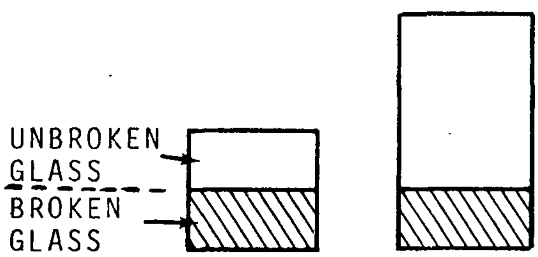


FIGURE 34. Glass Breakup is a Local Phenomenon. Quantity of glass broken is identical for the two equal-radius cylinders.

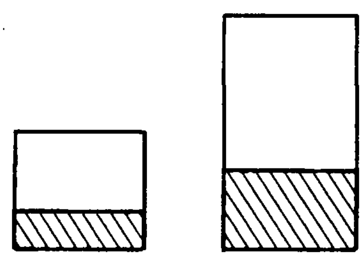


FIGURE 35. Glass Breakup is a Mass/Volume/Area Phenomenon such that the Fraction of Glass Broken is Identical for the Two Cylinders

In the various parts of Section 10, small and large specimen results are compared on the bases of the fractional breakup, the fraction <10 μ, and the surface area produced. The comparison in this subsection is on the basis of fractional breakup.

At 25 and 44 fps, Figure 33 shows greater fractional breakup of the large specimens in two instances and of the small specimens in one instance. Control results show little difference. In these very limited comparisons, the model of Figure 35 appears to be the more representative for fractional breakup.

PARTICLE SIZE DISTRIBUTION

1. Results

Tables of the size distribution of particles recovered from each specimen appear in Appendix A. The data are given in terms of sieve size. For order of magnitude estimates, the data are representative of particle size. More precise estimates require knowledge of particle shape and of sieving effectiveness, which are discussed in detail in the next subsection.

The data for the large specimens are plotted in Figure 36. Small specimen data for 117 fps impact and for controls appear in Figure 37. Intermediate velocity data show similar behavior but are not plotted because the large number of intertwined curves makes visual correlation difficult.

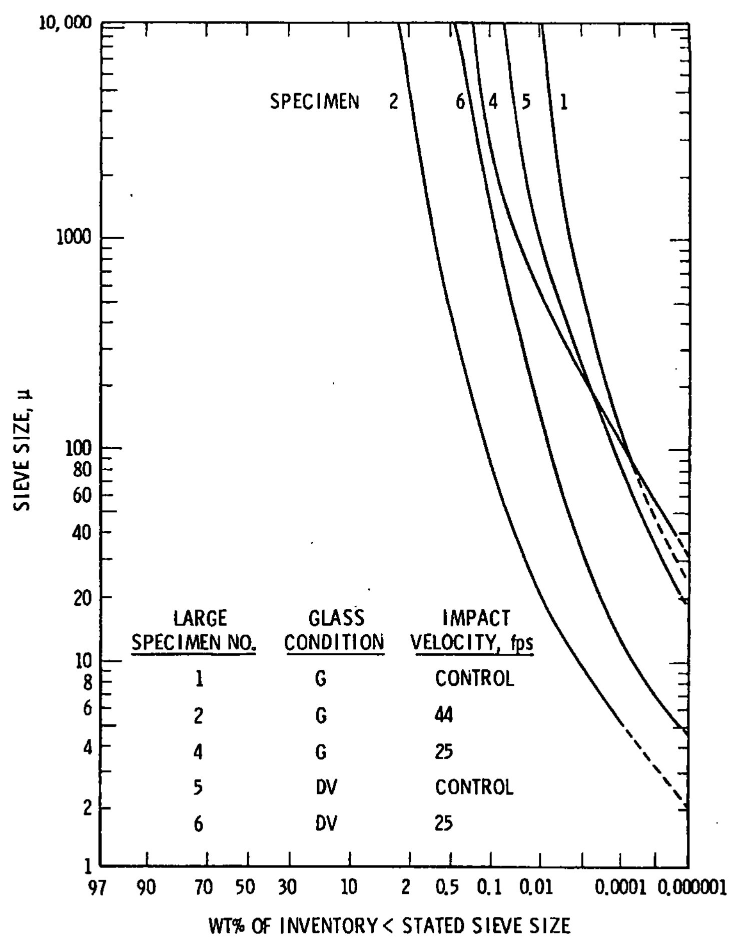


FIGURE 36. Particle Size Distributions for Large Specimens

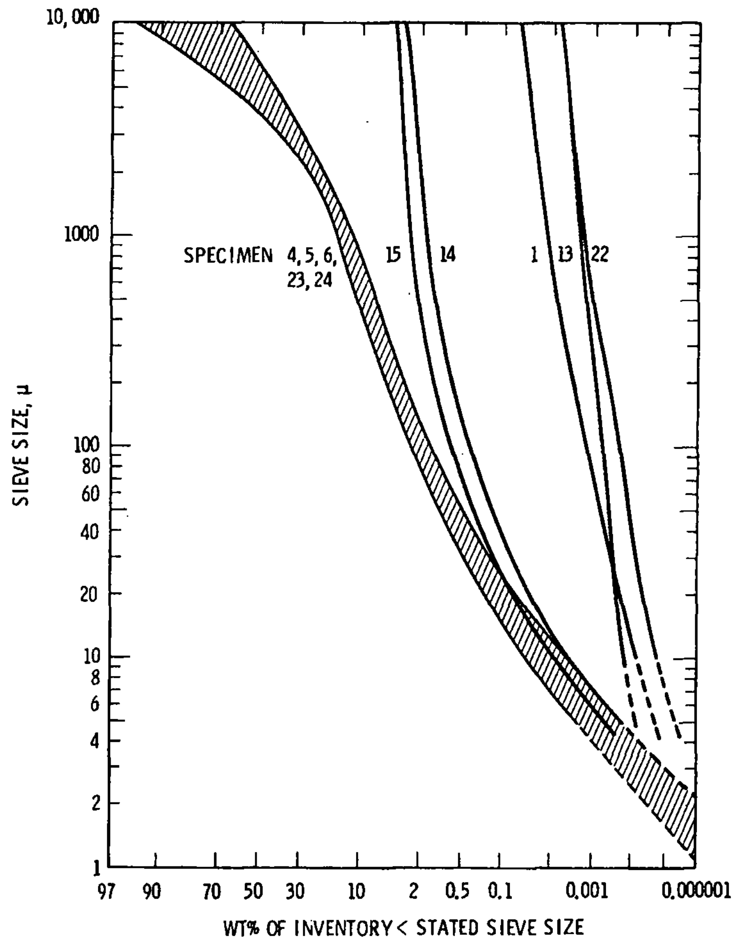


FIGURE 37. Particle Size Distributions for Small Specimens (Controls and 117 fps Specimens Only)

For completeness, the curves were extended beyond the data (generally >1700 μ and <5 μ) of Appendix A. Crude extrapolation to larger sieves was made assuming the total breakup fractions of Table 9 represent the sum of all particles less than some size, L_{max}. The size, L_{max}, of the largest fragment lies between the largest sieve size (1700 μ) and, say, the canister radius (~80,000 μ). For the small specimens, very few particles were larger than 1 cm (10,000 μ). This was the value chosen for L_{max} although a number of particles in the 1-in. range were found in the large specimens. The uncertainty in the value of L_{max} is approximately a factor of 3. Extension to particles <5 μ was performed using the data of the two microscopic sizing samples (Appendix B) tempered with graphical extrapolation. This extension is highly uncertain because it is based on only small samples of material from only two specimens.

2. Comparisons

Detailed comparisons of specimens are difficult with the complete size distribution curves. Because particles >20 μ are not generally of interest in airborne transport, comparisons were made only for the <20 μ fraction. These can be drawn from Figure 38 although the data scatter often obscures the effects of parameter variations. Because few of the size distribution curves cross between 10 μ and 20 μ, the qualitative conclusions drawn from Figure 38 are generally true for the <10 μ fraction also.

Three pairs of points (plus a pair of controls) in Figure 38 facilitate limited comparison of small and large specimen results. As in the preceding subsection, no consistent difference was observed between the two series, scatter between specimens masking any effects of L/D ratio and specimen size.

Comparisons of glassy versus devitrified for 11 pairs of points in Figure 38 indicate no consistent differences either at room temperature or at elevated temperature. The only trend is for a larger sub-20 μ fraction from the devitrified form than from glass in the large specimens. However, this trend is based on comparison of only two pairs of data points.

Nine pairs of data points in Figure 38 were compared on the basis of room temperature versus elevated temperature results. For both glassy and devitrified specimens the result at low impact velocities was for greater breakup at elevated temperature than at room temperature. At higher impact velocities there was no consistent temperature effect.

The greater total breakup at elevated temperature, discussed earlier, results from greater quantities of large ($\gtrsim$ 100 μ) particles. This is evident from Figure 37 if the results for specimens 14 and 15 are compared with the band for specimens 4, 5, 6, 23, and 24. The same effect is seen for impact at 66 and 44 fps.

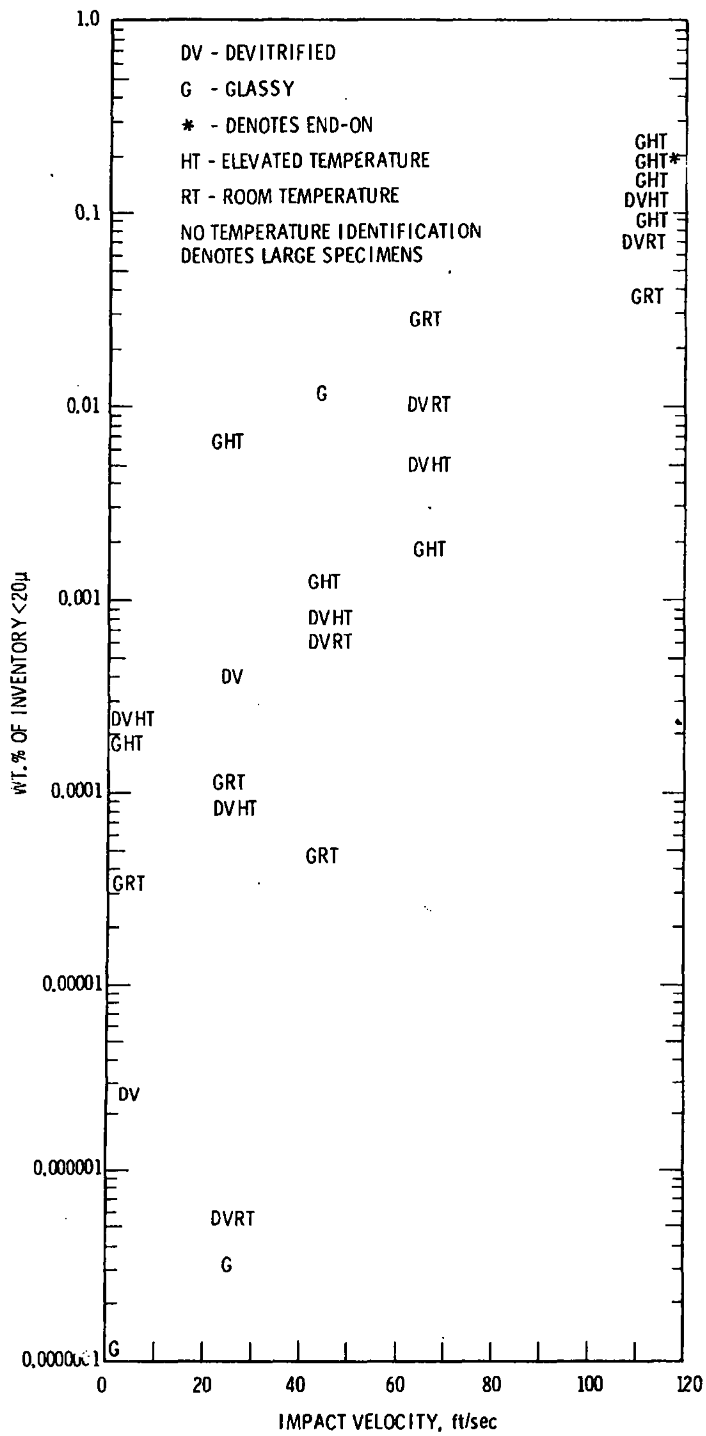


FIGURE 38. Magnitude of Sub-20 µ Fraction for Both Large and Small Specimens

3. A Consideration Regarding Uncertainty

If the sub-5 μ area of the curves of Figure 37 is observed, an uncertainty potentially much more important than that of extrapolation is evident. As mentioned in Section 9.0, if the weight of material recovered from a canister is compared with the total weight of material collected on the sieves, generally a small quantity of material is unaccounted for. It results from material not transferred from containers and from particle dust lost during agitated sieving. The quantity of unaccounted-for material (UFM) is usually greater than the weighing uncertainties.

Representative values of parameters related to UFM are given in Table 11. Considered by themselves, the values of UFM and of the fraction of material unaccounted for (UFM/QW) are well within the limits of acceptable laboratory procedures. However, Figure 37 shows that for particles <5 μ the sieving results are not highly reliable. The control specimens are pictured as having nearly the same <5 μ fraction as the high-velocity impact specimens. This uncertainty may be put into perspective by comparing the last column of Table 11 (UFM/Inventory) with the bottom scale of Figure 37.

TABLE 11. Representative Values of Parameters in Considering Unaccounted-For Material (UFM)

Specimen No.	Description	Estimated $\sum$ Weighing Uncertainties, g	Unaccounted-for Material UFM, g	Quantity Weighed QW, g	$\frac{UFM}{QW}$ %	$\frac{UFM}{Inventory}$ %
Large Canisters						
2	Moderate Velocity	1.2	4.7	2500	0.2	0.005
1	Control	0.003	0.044	8	0.6	0.00005
Small Canisters						
4	High Velocity	1.2	2.5	300	0.8	0.6
22	Control	0.001	0.002	0.026	8	0.0005

The size distribution of the UFM is unknown. If it were identical to that of the remaining material, the uncertainty from this factor would be negligible. If the UFM were all <10 μ, a highly unreasonable situation, the effect on the measured <10 μ fraction would be great. A reasonable limiting case can be proposed. If the UFM is all <60 μ and distributed similarly to the sub-60 μ fraction of the remaining material, the effect on the results is not substantial. If 60 μ is replaced by larger dimensions, the uncertainty in particle sizing becomes smaller, and vice versa.

Although variable from one specimen to another, the UFM effect is generally not considered important for particle sizes >10 μ. The effect is thought to be of some importance at 5 μ and possibly of major importance at sizes <5 μ.

4. <u>Recommended Assumptions for Sub-10 μ Fraction and Its Size Distribution</u>

In the absence of additional data, recommended assumptions for the sub-10 μ fraction as a function of impact velocity are given in Figure 39. Optimistic and pessimistic bounds are shown, corresponding to the data scatter limits. Estimated magnitudes of possible UFM effects are included. It is recalled that the stated impact velocities represent impact onto an essentially unyielding target. For cases in which other bodies deform significantly, such as impact into soil or impact in a protective package, the force-time histories may be greatly changed. Glass breakup may be accordingly reduced to that resulting from granite impact at a much lower equivalent velocity.

In the absence of additional data, the size distribution of the sub-10 μ fraction may be taken from Figure 36 or Figure 37. The curves are seen to be nearly linear on logarithmic probability coordinates in this size range.

Particle shape factors and sieve size to particle size conversion factors for use in connection with Figure 39 are discussed in the next section.

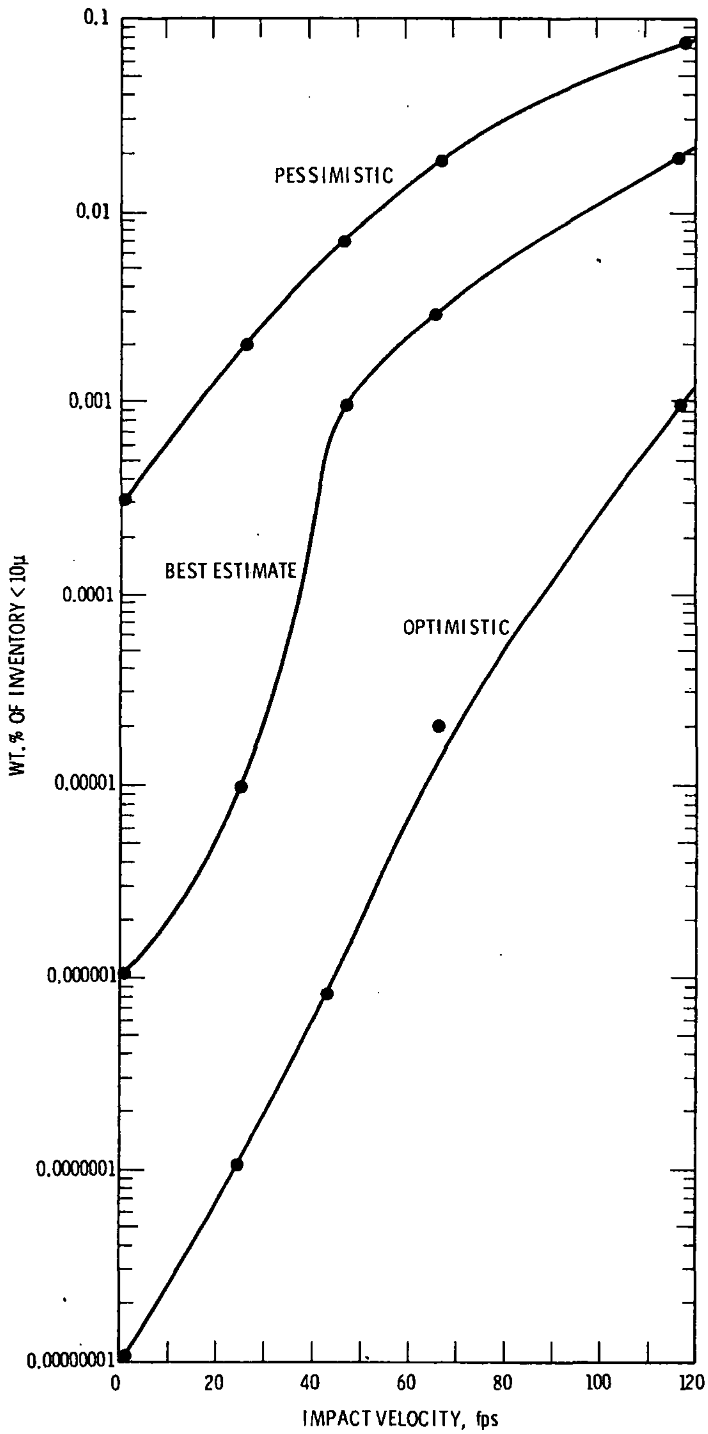


FIGURE 39. Prediction Curves for Sub-10 μ Fines Generation

REPRESENTATIVE PARTICLE SHAPE; SURFACE AREA INCREASE

1. Representative Particle Shape

Precise interpretation of the foregoing size distribution curves requires an assumption of particle shape. The shape also enters into surface area calculations.

The glass particles produced by impact varied in shape from nearly spheric or cubic to plate-like. A representative shape was formulated based on visual and photomicrographic observation. Photomicrographs of samples from two sub-5 μ fractions appear in Appendix B. From these two-dimensional representations, the ratio L_1/L_2, (longest dimension/intermediate dimension) was determined for 64 particles in the 2 to 30 μ range of dimensions. The average ratio was 1.7:1. The third dimension (into the photograph), L_3, was assumed to be the smallest (particles assumed to be lying flat). The average value of the ratio L_3/L_2 was estimated from visual examination of small particles to be 0.5. This average could conceivably range from 0.3 to 0.7. For purposes of modeling the particles as a group, all particles will subsequently be treated as smooth, rectangular parallelepipeds having dimensions in the ratio of 1.7:1:0.5.

Surface areas calculated by means of this assumption of shape will be termed herein "geometric surface areas." This is in distinction to the actual surface areas, which include contributions of surface irregularities, roughness, and porosity. Actual surface areas of common materials, as measured by means of gas adsorption techniques, may be orders of magnitude higher than geometric surface areas. However, because the glass particles are relatively smooth and nonporous, cognizant personnel project a ratio of from 2 to 10, with the lower value more probable.

2. Relation of Particle Size to Sieve Size

The essentially continuous distribution of particle size (not a log-normal distribution) will be approximated by a discrete distribution in which all the material which passes one sieve and is retained on the next smaller sieve is considered to be uniform in size. The size representing

this group of particles is taken to be the arithmetic mean, L, of these two (square) sieve openings.[37,39] Figure 40 illustrates the assumption, which is not expected to introduce significant error. [The dimensions of most consecutive sieve openings are in the ratio of 2:1, giving an arithmetic mean of 1.5. The geometric mean (based on the arithmetic mean of the logarithms) is 1.41.]

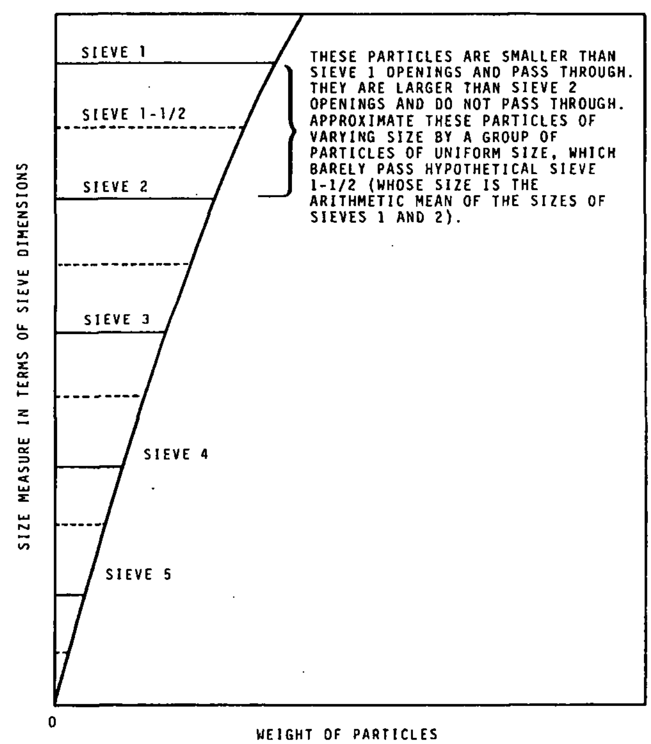


FIGURE 40. Illustration of Sieving Approximation

Related to the above discussion is the fact that a sieve cannot make a perfectly sharp separation. The fraction of particles passing through depends, among other factors, on the duration and manner of shaking.[38] Two simplified extreme cases will be examined to relate particle size to the size of the square holes in the sieve. One extreme involves the highest possible sieving and shaking effectiveness. This case assumes that all of the rectangular parallelepiped particles eventually become oriented so that they can pass end-on through the (arithmetic mean)

sieve opening of size L x L. This case is designated RPEO. The sieve will thus barely pass an RPEO particle of dimensions 1.7L x L x 0.5L. The particle surface area is $6.1L^2$; the mass is $0.85\ \rho L^3$; and the ratio of these is $7.2/(\rho L)$.

The other case involves an extremely low sieving and shaking effectiveness. In this case, none of the particles becomes oriented end-on. Instead, all particles are assumed to pass through the L x L sieve opening sideways. For this case, designated RPSW, the sieve will just barely pass an RPSW particle of dimensions L x 0.59L x 0.29L. The particle surface area is $2.1L^2$; the mass is $0.17\rho L^3$; and the ratio is $12.4/(\rho L)$.

Because the sieving was accompanied by mechanical shaking for periods on the order of an hour, the actual mode of particle passage through the sieves was much closer to the RPEO case than to the RPSW case. Both cases will be carried through the analysis, however, to provide perspective on possible effects of incomplete separation in sieving.

3. Procedure for Calculating Geometric Surface Area

Approximate calculations of geometric surface area were made, based on the preceding approximations and on the concept of specific surface, the surface area per unit mass (A/M). For any number, n, of RPEO particles, all of size 1.7L x L x 0.5L,

$$\frac{A}{M} = \frac{n\ \ 6.1\ L^2}{n\ \ 0.85\rho L^3} = \frac{7.2}{\rho L}$$

as shown earlier. The value of L is the arithmetic mean of the two sieve dimensions bounding the group of particles. Similarly, for any number of RPSW particles of size L x 0.59L x 0.29L, $A/M = 12.4/(\rho L)$. If there are several sieving fractions i, the total area of all particles is

$$A_p = \sum_i \left(\frac{A}{M}\right)_i M_i .$$

Each fraction i would have a different value of A/M; and for a given fraction, the values of A/M differ for RPEO and RPSW particles.

For specimens exhibiting relatively little breakup, the surface area of the remaining unbroken monolith must be included in assessing postimpact surface area. This quantity is approximated geometrically by

$$A_{UB} = 2\left(\frac{\pi D_I^2}{4}\right) + \pi D_I L_I \frac{M_{UB}}{M_I}$$

where D_I is the preimpact diameter of the glass cylinder, L_I and M_I are its initial length and weight, and M_{UB} is the weight of unbroken glass. The ratio of surface areas after and before impact is

$$\frac{A_{new}}{A_I} = \frac{A_p}{A_I} + \frac{A_{UB}}{A_I}$$

where

$$A_I = 2\left(\frac{\pi D_I^2}{4}\right) + \pi D_I L_I \quad .$$

4. <u>Geometric Surface Area Results and Discussion</u>

Fractional increases in surface area, $(A_{new} - A_I)/A_I$, were calculated for all large specimens except No. 3. Small specimens whose particle size distribution curves indicated either the greatest or the least breakup among specimens tested at a given velocity were also included. Results are presented in Figure 41. Each vertical data line represents one specimen. The upper limit of each line represents the area found with the RPSW model, while the RPEO model is represented by the lower limit. The latter model more closely represents actual sieving effectiveness.

Curves representing pessimistic and optimistic predictions bound the wide spread of data. A best-estimate curve was plotted through points about which the data appeared to cluster. Geometric area increases are strongly affected by velocity, ranging from a few percent for the controls to factors of 10 to 100 at 117 fps.

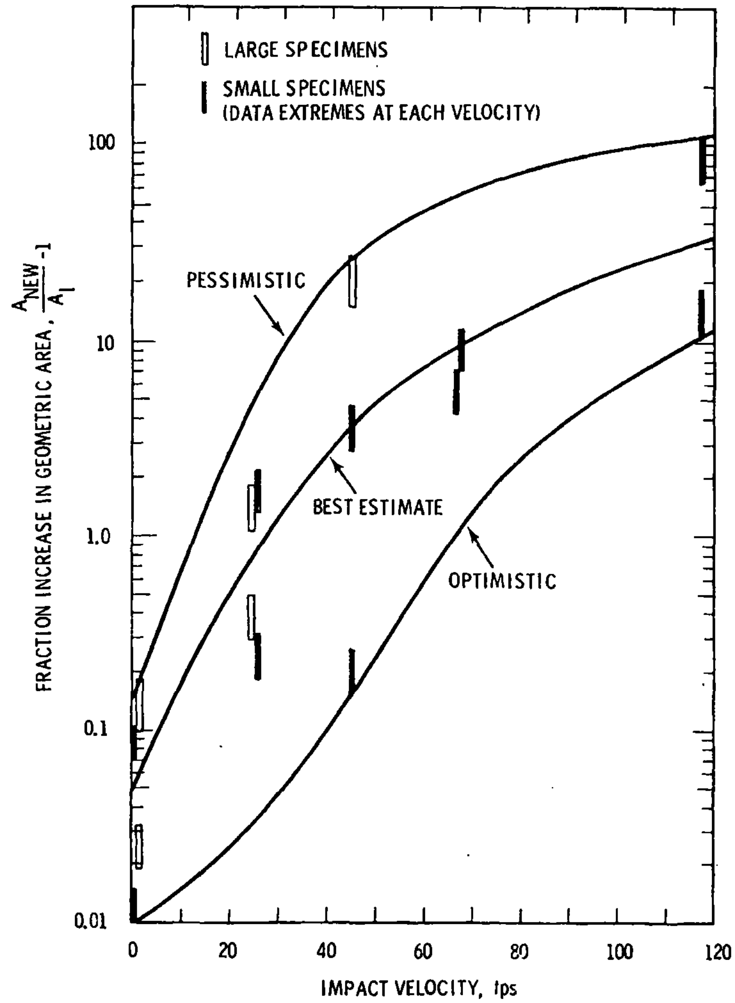


FIGURE 41. Fractional Increase in Geometric Surface Area

Comparisons on the bases of test temperature, waste form and canister size lead to the same conclusions reached for particle size distribution. No consistent effect of waste form was observed for the small specimens. Devitrified waste produced slightly more surface than did glassy waste in the large specimens. Elevated-temperature testing led to consistently higher surface areas. This resulted from the increased quantity of particles $\gtrsim$100 μ; the quantity of particles $\lesssim$100 μ was not markedly affected by test temperature. Finally, no consistent effect of specimen size was apparent when the data were plotted on a fraction-of-inventory basis.

5. Scaling

Extensive theoretical derivations or predictions of impact behavior are beyond the scope of this report. The objective is only to report the test results. Theoretical models, especially those not incorporating empirically determined constants, have generally had limited success in predicting complex impact phenomena. Available theories differ considerably in their predictions. Furthermore, data presented herein indicate that specimens fabricated and tested under supposedly identical conditions can give results which vary significantly. However, dimensional analysis incorporating empirical determination of the constants which arise has had some success in predicting impact behavior.(10,11,14,15) For this reason scaling is briefly discussed in terms of this analytical tool.

Duffey(25) performed a dimensional analysis for multilayered fuel capsules subjected to impact and other mechanical loadings, as well as thermal loading. A set of 19 dimensionless Π-numbers was derived to express the requirements for scaling test conditions and results from small models to full-size specimens. The situation in which specimens differ in size but are constructed of identical materials matches the present tests. Under such conditions, it appears possible to satisfy all of the Π-number requirements except the one involving strain rate effects, which results in contradictory requirements unless the specimens are identical in size. The strength of 304L stainless is not highly sensitive to strain rate at the temperatures of interest for this study.(17) The strain-rate dependence of the glass behavior is unknown.

In certain respects, the two impact test models differed from the representative full-size canister after which they were designed. In these respects the Π-numbers for the two test models would not match the corresponding values for full-size specimens. The difficulty of elevated-temperature, high-speed testing of small specimens of the proper L/D ratio has been mentioned. The small specimens were impacted at a somewhat different angle than that for the large specimens. Targets were not precisely scaled. Neither small nor large specimens duplicated either the filling port or the temperature profile of a self-heating, full-size canister.

However, the results of the control tests and of comparisons between small and large canister data imply that these deficiencies were probably not serious within the context of the present tests. The scatter evident in the reproducibility tests supports this inference (compare small specimens 4, 23 and 24 in Appendix A).

Additional difficulties arise if the dimensional analysis is extended to focus on the glass breakup. Tsai[26] has noted a Π-number involving the glass surface energy which apparently cannot be satisfied unless both models are the same size. However, the overlap of surface area data of the large and small test specimens (Figure 41) indicates again that this deficiency was probably not serious compared with the data scatter.

Tsai's hypothesis illustrates the difficulties of scaling particle results. There are two basic theories of comminution, or pulverization,[39] and they are mutually contradictory.[23] The older and more widely accepted is the Rittinger theory, which states that the work consumed for reduction of particle size in homogeneous materials is directly proportional to the new surface produced. (The divitrified glass could be characterized as having few significant heterogeneities $\gtrsim 1\ \mu$ in size. In the glassy state the scale of significant heterogeneity would be smaller.) The Kick theory states that the work required for crushing a given quantity of homogeneous material is constant for the same size reduction ratio, regardless of the original size. A unifying third theory, intermediate between these, has been proposed[23] more recently.

It can be shown that the theories of Kick and of Rittinger have quite different implications for scaling particle size results from small test specimens to larger full-size specimens of identical geometry under identical test conditions. For illustrating this, it is assumed that the impact is severe and that all particles produced from breakup of a given specimen are identical in size and shape. The scale ratio of the large and small specimens is taken to be $\lambda \equiv L_{fs}/L_t$, where L_{fs} and L_t are dimensional measures of the full-size and test specimens, respectively. Under these conditions Rittinger's Law predicts that the particles from the test specimen will be the same size as those from the full-size specimen, but that the

latter specimen will have λ^3 times as many particles. Kick's Law predicts essentially the opposite scaling effect: equal numbers of particles will result, but each particle from the full-size specimen will be λ times the size of the particles from the test specimen.

Particle size distributions from the small and large specimens of the present tests have been plotted together on a weight fraction basis. Within the uncertainty of the data, there was no apparent effect of specimen size on the results. This conclusion would tend to support the validity of Rittinger's Law for these test conditions and materials. (As mentioned previously, the large and small specimens were identical in radius/thickness ratio, but not in length/diameter ratio.) On this basis, the results for full-scale specimens would not be expected to show significant effects of specimen size. This is especially true because there was a much greater size difference between small and large test specimens than between large test specimens and full-size specimens.

It can also be shown that Kick and Rittinger predict different scaling laws for particle surface areas. Kick predicts that the surface area ratio, $(A_{fs}/A_{fs_o})/(A_t/A_{t_o})$ is unity. Here the subscripts fs, t, and o denote, respectively, full-size specimen, test specimen, and preimpact conditions. Rittinger predicts a value of λ for this ratio. Again, common plotting of the limited comparable data from large and small test specimens shows no consistent difference within the data scatter. This conclusion tends to support the validity of the Kick theory.

The fact that conflicting behavior is implied in the two comparisons above leads one to believe that conclusions regarding scaling laws are not justified on the basis of the limited and scattered data available. (It is unlikely that the effects of differences in geometry and size of the two test models would just counteract each other, both in particle size distribution and in surface area increase.) However, it seems safe to say that any error in scaling the results up to full-size specimens will be small compared with the scatter among specimens of the same size.

6. <u>Shape Conversion Factors for Use with the Particle Size Distribution Curves</u>

The results of subsections 1 and 2 immediately preceding can be used to interpret more precisely the particle size distribution curves. All particles are taken to be 1.7 x 1.0 x 0.5 rectangular parallelepipeds. The fines fraction retained between two consecutive sieve sizes (e.g., 20 μ and 10 μ) is based on the arithmetic mean, L, of the two sieve dimensions (e.g., 15 μ). See Figure 40. The RPEO model of particles passing end-on through the sieves is the better of the extreme cases and gives particles of dimensions 1.7L x L x 0.5L. The RPSW sideways passage model leads to particles of dimensions L x 0.59L x 0.29L.

In the case of the fines fraction smaller than the smallest sieve size, say 10 μ, the above procedure for calculating L fails. A possible modification is this procedure: 1) examine the slope and curvature of the distribution curve in the small particle region, then extrapolate the curve; 2) imagine the imposition of successive sieves of smaller and smaller size (e.g., 5 μ, 2.5 μ, 1.25 μ, . . .); 3) apply the previous rule for calculating L; 4) read off the curve the weight fraction between the two hypothetical sieve sizes; 5) continue the process until the desired lower limit of dimensions or weight of particles is satisfied. See also Reference 39. This procedure requires no assumption of particle size distribution. Instead, extrapolations of the actual particle data (which within the experimental accuracy, do not appear to follow closely any common mathematical formulation) are used.

11.0 USE OF THE RESULTS IN ANALYSIS OF RADIOLOGICAL HAZARDS

The ultimate objective of the impact study was to provide information for estimating radiological hazards of potential accident sequences. However, the data from this study are not immediately usable for direct calculation of radiological hazards. Many important processes must occur following a hypothetical impact, involving canister failure and glass fracture, before radiological exposure of man can result. This section enumerates these intermediate processes, briefly describes analytical techniques for modeling them and discusses post-impact glass characteristics which influence the resulting exposure. Pathways involving airborne transport and groundwater transport are included.

CONSIDERATIONS IN ANALYSIS OF THE AIRBORNE PATHWAY

1. Relationships Between the Properties of Airborne Particles and the Physiological Attributes of Man

Although radiation damage can result from highly radioactive airborne particles which settle onto the skin, this potential is generally secondary in importance to inhalation. From the lung, the particles or a fluid containing the dissolved particles can move to other body sites.

Man's respiratory system has a complex structure which tends to trap particles of certain sizes. The system is basically composed of nasopharyngeal (N-P), tracheobronchial (T-B), and pulmonary (P) compartments. The N-P includes nose, mouth, and air passageways to the tracheal entrance; the T-B includes trachea and bronchi; and P includes bronchioles, alveolar ducts and alveolar sacs. Because the dimensions, air flow rates, and functions are different in each compartment, the fate and effects of a particle entering the respiratory system depend on its size, mass, solubility and other chemical properties, and the isotopes present. These properties affect deposition, retention and transfer to critical body organs. The half-life of the radionuclides in the particle, energy per disintegration, and radiation type are important in determining biological significance. The significance of particle size only is addressed here.

Figure 42 shows the lung deposition site and the estimated fraction of various size particles deposited.[40] Aerodynamic equivalent diameter (diameter of a unit density sphere with the same settling velocity and other aerodynamic properties as the particle in question) is the abscissa. Particles of the same geometric diameter may differ greatly in aerodynamic behavior due to differences in density. Figure 42 shows that particles larger than 7 μ are trapped in the N-P region, whereas most of the submicron particles are retained in the two lung compartments. Thus it is important in the hazard evaluation to know the size distribution, density, and shape of airborne particles which are susceptible to inhalation.

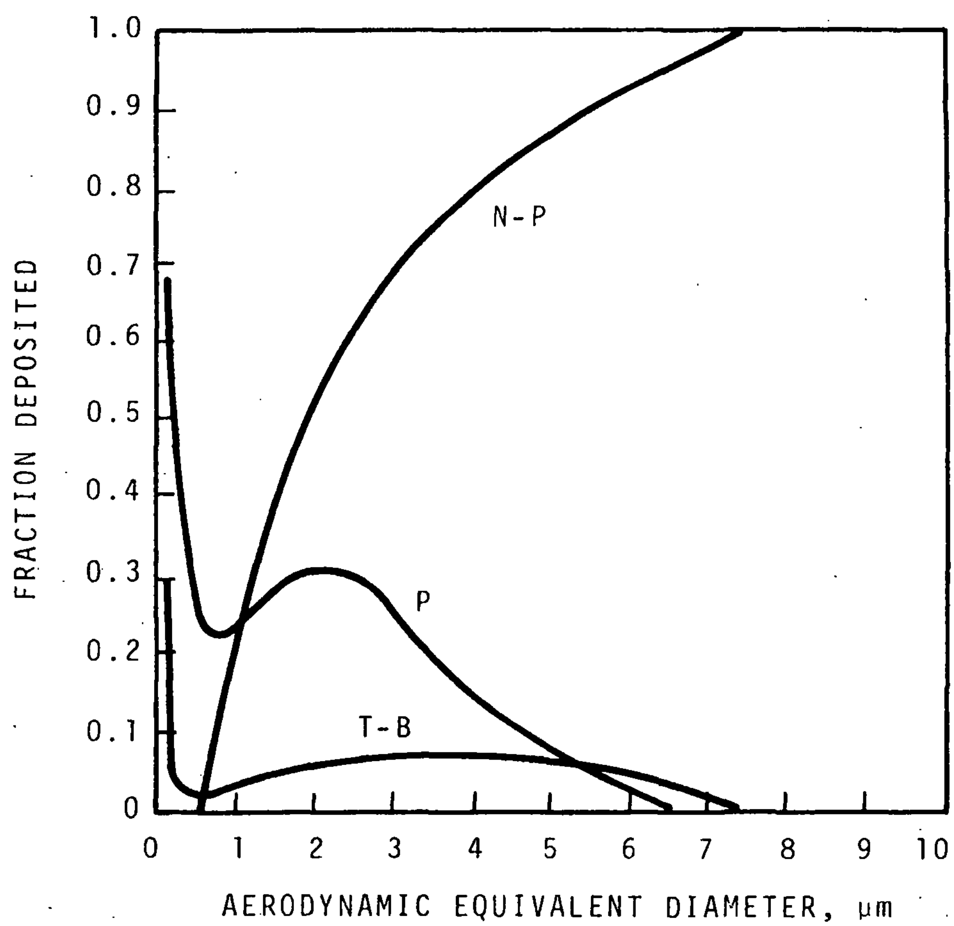


FIGURE 42. Calculated Deposition of Particles in Nasopharyngeal (N-P), Tracheobronchial (T-B), and Pulmonary (P) Compartments, Relative to Number Inhaled.[40]

Once in the lung, radioactive particles irradiate local tissue and adjacent organs. The particles may be dissolved and transferred to the blood and other organs, be swept out of the lung by the ciliated epithelium and delivered to the GI tract, or be engulfed in phagocytes and moved into the lymph system.

2. Particle Resuspension, Transport, Modification, and Removal by Atmospheric Processes

Between the accident site and man's location, atmospheric processes may markedly change the concentration and nature of particles released in an accident.

If a severe impact were to breach a waste container, material could be quickly sent into the air in the near vicinity. Dense and coarse particles (>20 μ) will soon settle back to the ground. Attempts to quantitatively assess entrainment in the initiating event will be frustrated by lack of information of particle behavior as well as the gross assumptions needed for the accident scenario.

Small particles airborne in the accidental release will remain airborne, at least for a period, and permit the wind to carry and diffuse them downwind. Particle concentration will decrease with distance due to turbulent diffusion. Models are available for estimating ground-level concentrations downwind.(41) Depending on atmospheric stability and windspeed, downwind concentrations can vary several orders of magnitude. It is therefore necessary to specify the location and atmospheric conditions prevailing at the time and place of the accident, and the distance downwind at which an individual is located.

Particles deposited on surfaces may subsequently become airborne and constitute a secondary source. Resuspension rates of 10^{-8} to 10^{-10} per second are typical, depending on windspeed.(42)

Precipitation will clean the air of particles and must be considered as a possible modifier of particle size and concentration. Other modifications in the atmosphere may involve gas-particle interactions, solution in

raindrops, condensation of moisture, particle-particle collisions, sublimation, and electrical charge effects.

Aerodynamic and other properties of particles at the source during an accident are important, yet the foregoing discussion shows that modifications will occur prior to contact with man. Measurement of glass particle sizes in this study provides essential information for the ultimate consequences assessment, but is only one of many necessary elements. Source particles larger than 10 μ can be largely ignored as an airborne hazard for physiological reasons and from recognition that particles larger than this are rapidly removed in atmospheric processes.

CONSIDERATIONS IN ANALYSIS OF THE GROUNDWATER PATHWAY

The groundwater pathway of radionuclides to man involves three phases which overlap in time. The first is contact of the waste by flowing groundwater after containment failure, with consequent leaching and dissolution. The second is migration of dissolved nuclides through the soil to surface water. The third includes pathways of nuclides from surface water to interaction with man.

1. Leaching and Dissolution of Nuclides

A postulated incident may involve breach of containers of solidified waste deep within the earth. Groundwater contacts the waste and leaching begins. Alternatively, a container may be breached above ground, possibly in surface water. Leaching can then result from contact with the surface water or with precipitation and runoff. The dissolved nuclides find their way into the groundwater either by way of surface water or by flow down through the soil.

The leaching of nuclides from the waste material is governed by two mechanisms. The first, which accounts for a high initial leach rate, is diffusion of individual nuclides from the interior of the waste to the surface, where they are rinsed off and dissolved by water. This process soon slows due to formation of a surface boundary layer, deficient in free nuclide ions, which retards subsequent migration to the surface. When this

boundary layer has effectively halted nuclide diffusion, the second mechanism, dissolution of the waste material itself, controls the leach rate. For periods during which the relative change in surface area is small, the cumulative amount leached at time t is approximated by $At^{1/2} + Bt$, where A is considerably greater than B. The square root term represents diffusion; the linear term, dissolution. The required time for leaching of nuclides varies from a very short period to thousands of years. It depends on the groundwater composition, the waste incorporation material (borosilicate glass, calcine, etc.), and the degree of fracturing of the waste material prior to or during the incident. The particle size distribution and total surface area are thus important parameters.

The release rate of nuclides into groundwater may or may not significantly affect the intensity of exposure of man, depending on the second phase of the pathway.

2. Migration of Nuclides Through Soil to the Surface Water

Migration of nuclides through the strata and soil column to surface water is controlled by convection, dispersion, adsorption, and radioactive decay. Convection refers to bulk flow of nuclides dissolved in groundwater, at the same speed and direction as the water. Dispersion refers to mixing of the waste solution with the solution located ahead of and behind it in the soil column. Adsorption refers to ion-exchange interaction between the nuclides and the strata or soil particles. The nuclides are retained on the particle surfaces until displaced by further ion exchange and dissolved back into the groundwater. Radioactive decay occurs continuously throughout the entire process. Effective transport rates of radionuclides to surface water can be reduced significantly by retardation from adsorption and dispersion and by disappearance due to radioactive decay.

One dimensional migration of the ith member of a radionuclide chain is described by a set of i linear partial differential equations[43] based on a material balance of the ith chain member and of all preceding chain members j over a differential volume of the soil column. Each equation

j (where $1 \leq j \leq i$) of the set includes terms representing the net change in j inventory from dispersion, convection, adsorption, disappearance by decay and appearance from decay of the preceding chain member. The equations are solved subject to proper boundary conditions. The solution describes the inventory of nuclides at any time and at any point along the soil column, including the point of release to surface water.

3. Pathways of Nuclides from Surface Water to Man

Entrance of nuclides into surface water begins the third phase. This phase involves an intricate biological network of retention and concentration in plants and animals in man's food chain, as well as a direct route to man via consumption of surface or well water and via recreational activities such as swimming and boating.

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APPENDIX A

PARTICLE SIZE DISTRIBUTION TABLE

SMALL SPECIMENS

Percent of Inventory < Stated Sieve Size

Sieve Size, μ	Specimen Number 1	4	5	6	7	8	
1651	-	15.3	19.9	23.3	-	-	
841	-	10.2	13.0	13.6	-	-	
420	-	7.6	9.7	8.5	-	-	
210	0.0025	2.8	3.1	3.4	0.33	0.61	0.
149	0.0019	2.2	2.2	2.3	0.22	0.43	0.
74	0.0011	1.4	1.2	1.2	0.10	0.20	0.
37	0.00057	0.49	0.36	0.44	0.029	0.054	0.
20	-	0.17	0.12	0.18	0.0019	0.0051	0.
10	0.000068	0.0022	0.017	0.0022		0.00092	
5		0.0012	0.00077	0.00030			

Sieve Size, μ	Specimen Number 11	12	13	14	15	16	
1651	-	-	-	-	-	-	
841	-	-	-	-	-	-	
420	-	-	-	-	-	-	
210	0.047	0.030	0.00087	0.72	1.20	0.42	0.
149	0.038	0.021	0.00084	0.56	0.94	0.35	0.
74	0.026	0.010	0.00051	0.33	0.57	0.21	0.
37	0.017	0.0017	0.00033	0.13	0.24	0.088	0.
20	0.0072	0.000093	-	0.036	0.076	0.029	0.
10	0.00041		0.00018	0.0028	0.0083	0.0017	0.
5					0.00055		

Sieve Size, μ	Specimen Number 19	20	21	22	23(b)	24(b)
1651	-	-	-	-	17.2	18.5
841	-	-	-	-	10.7	10.5
420	-	-	-	-	7.1	6.4
210	0.054	0.055	0.013	0.00076	4.6	3.5
149	0.036	0.037	0.0092	0.00047	3.6	2.5
74	0.015	0.016	0.0038	0.00014	1.8	1.3
37	0.0019	0.0012	0.00004		0.66	0.4
20	0.00062	0.00013			0.18	0.11
10	0.0001				0.025	0.018
5					0.0023	0.0026

a. Results incomplete - fines at bottom end not included.
b. Large sieve sizes were 1700, 850, 425, and 212 μ, rather than 1651, 841, 420, and 210 μ.

APPENDIX B

DATA FROM SIZE SAMPLING WITH MICROSCOPE

APPENDIX B

DATA FROM SIZE SAMPLING WITH MICROSCOPE

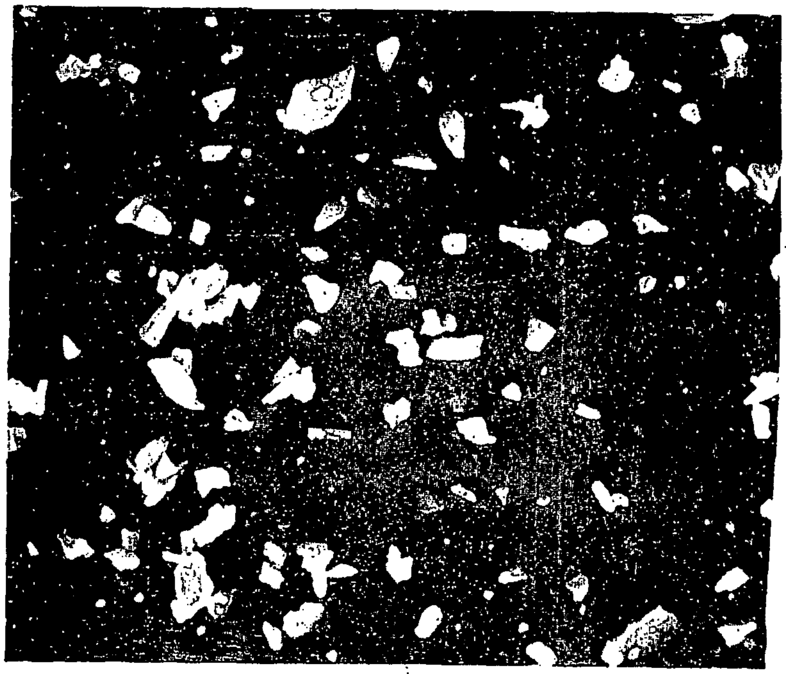
LARGE SPECIMEN 2, <5 μ SIEVE FRACTION

Particle Size,[a] μ	Number of Particles
>5	54
3-5	73
1-3	57
<1	16
	200

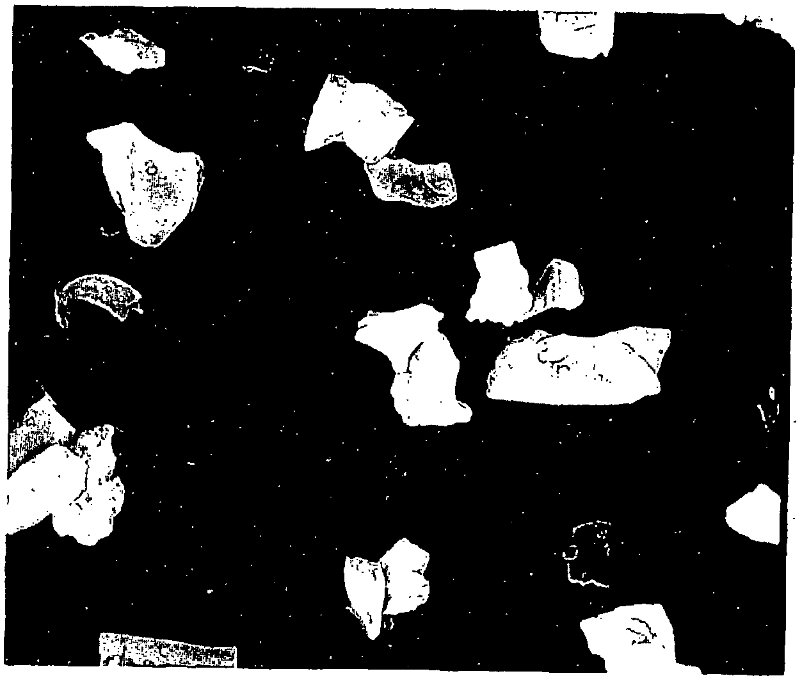
SMALL SPECIMEN 5, <5 μ SIEVE FRACTION

Particle Size,[a] μ	Number of Particles
>5	61
3-5	80
1-3	52
<1	7
	200

a. Equivalent circular dimension.

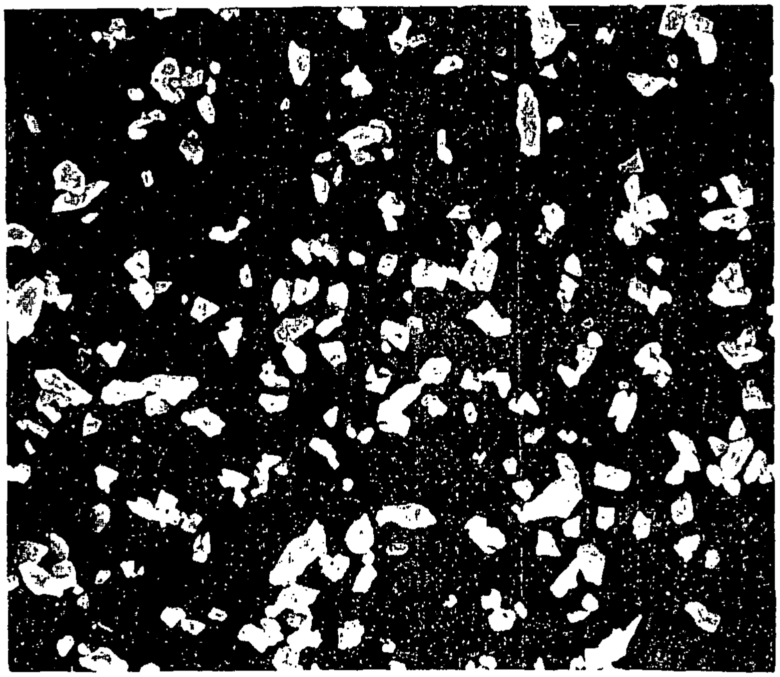


300X



1000X

FIGURE B.1. Photomicrographs of a Sample from the <5 μ Fraction of Large Test Specimen 2



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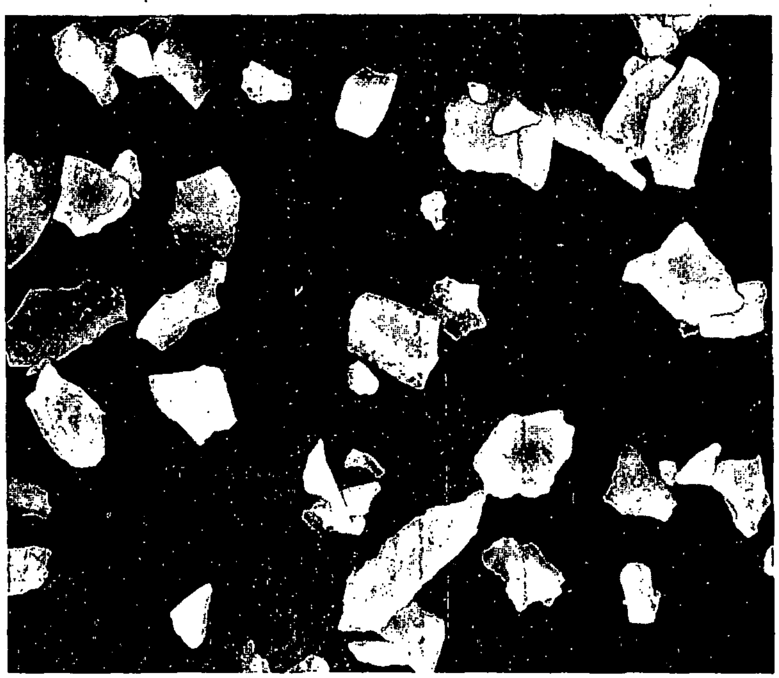

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FIGURE B.2. Photomicrographs of a Sample from the <5 μ Fraction of Small Test Specimen 5

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Page

TABLES

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BSC	Bechtel SAIC Company, LLC
CFR	Code of Federal Regulations
DF	decontamination factor
DOE	Department of Energy
DPC	dual-purpose canister
DUO	depleted uranium oxide
DWPF	Defense Waste Processing Facility
HEPA	high-efficiency particulate air
HLW	high-level waste
HVAC	heating, ventilation and air conditioning
LPF	leak path factor
MAR	material at risk
MMD	mass median diameter
NRC	Nuclear Regulatory Commission
PNNL	Pacific Northwest National Laboratory
SNL	Sandia National Laboratories
SNF	spent nuclear fuel
SRS	Savannah River Site
TAD	transportation, aging and disposal

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1. PURPOSE

The purpose of this calculation is to develop leak path factors (LPF) to be used in evaluating the consequences of normal operations and potential event sequences at the Yucca Mountain Repository. The leak path factors developed in this calculation can be used to calculate the potential radiation dose to an individual who is onsite or lives in the vicinity of the Yucca Mountain site.

The LPF is the fraction of airborne material-at-risk (MAR) that leaves a confinement barrier after the action of depletion mechanisms such as precipitation, gravitational settling of the released particulate material, filtration, or agglomeration, through the confinement barrier. Confinement barriers could be spent fuel cladding, canisters, shipping casks, waste packages, buildings, spent fuel pools, or filters that prevent or mitigate releases of radionuclides. The leak path factor for each of the confinement barriers except for buildings is defined in this calculation as the fraction of airborne MAR that leaves that barrier. Building leak path factors are not addressed in this calculation.

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2.3 DESIGN CONSTRAINTS

None

2.4 DESIGN OUTPUTS

This calculation will be used as input for other calculations.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

No assumption in this analysis requires verification.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1. Small Leak Area

Assumption: Following a postulated event at the repository, a small leak area in a transportation, aging and disposal (TAD) canister, dual-purpose canister (DPC), waste package, shielded-transfer cask or transportations cask is assumed. See the discussion in Sections 6.3.3.3, 6.3.3.4, and 6.3.4 for further information.

Rationale: The canisters (TADs and DPCs) and their containers (waste packages, shielded-transfer casks, aging overpacks, and transportation casks) are large robust items. The TAD canister is handled inside an aging overpack, shielded-transfer cask, waste package or transportation cask at all times except for the actual transfer of the TAD canister from one overpack to another. Likewise, a DPC can be handled inside an aging overpack, a shielded-transfer cask or a transportation cask (Reference 2.2.1, Sections 1.2.2, 5.1.1 and 6.1.1). All of these items, except for the aging overpacks, provide confinement of their contents. Therefore, not only do the TAD canisters and DPCs provide confinement for their contents, they are also protected by the overpack in which they reside.

A transportation package is required to meet the hypothetical accident conditions in accordance with title 10 of the Code of Federal Regulations (CFR) part 71.73 (Reference 2.2.2 [DIRS 176575]), which include a 30-ft free drop in several orientations, a crush test, puncture test, a fully engulfing fire, and immersion. Confinement must be maintained following the hypothetical accident conditions. The TAD canister is required to be designed to a maximum leak rate of 1.5×10^{-12} fraction of canister free volume per second following a 12-inch flat-bottom drop onto a solid carbon steel plate and a maximum leak rate of 9.3×10^{-10} fraction of canister free volume per second following a 3-ft drop while inside an aging overpack (Reference 2.2.3 [DIRS 181403], Sections 3.1.6 and 3.3.6). The leak rate of 1.5×10^{-12} fraction of canister free volume per second is essentially equivalent to the criteria for establishing leak tightness following closure and sealing of the vessel (Reference 2.2.3 [DIRS 181403], Section 3.1.6, and Reference 2.2.4, Section 6.3.1). The waste packages are to be welded vessels and back filled with helium, similar to the TAD canisters (Reference 2.2.1, Sections 4.1.1 and 29.1.1). Since these casks and canisters are robust and are designed to stringent confinement criteria, assuming a small leak area following a postulated event at the repository is conservative. See the discussion in Sections 6.3.3.3, 6.3.3.4, and 6.3.4 for further justification.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 2.1.1) and LS-PRO-0201, *Preclosure Safety Analyses Process* (Reference 2.1.2). Therefore, the approved version is designated as QA:QA.

4.2 USE OF SOFTWARE

The commercially available Microsoft® Office Excel 2003 spreadsheet code, which is a component of Microsoft® Office 2003 Professional, is used to perform standard mathematical and plotting functions, which do not depend on the particular software program. The mathematical results are verified by checks using hand calculations and the graphical representations of the results are visually inspected for verification. Usage of Microsoft® Office 2003 Professional in this calculation constitutes Level 2 software usage, as defined in IT-PRO-0011 (Reference 2.1.3, Attachment 12). Microsoft® Office 2003 Professional is listed in the current *Level 2 Usage Controlled Software Report*. Microsoft Office® Excel 2003 was executed on a PC running the Microsoft® Windows 2003 Service Pack 2 operating system.

4.3 METHODOLOGY

At the Yucca Mountain repository, a consequence analysis is performed to estimate radiation doses to workers and the public as a result of a postulated release of radioactivity following an event sequence. The radiological source term is an input to the dose consequences. The amount of respirable radionuclides released to the ambient environment as a result of an event sequence is defined as the source term and is estimated by a five-component equation (Reference 2.2.5 [DIRS 103756], p. 1-2, Equation 1-1):

$$ST_j = MAR_j \times DR_j \times ARF_j \times RF_j \times LPF_j \qquad \text{(Eq. 1)}$$

where,

- ST_j - the total amount of the j^th nuclide that is released to the environment [Ci]
- MAR_j - the material at risk of the j^th nuclide [Ci]
- DR_j - the damage ratio of the j^th nuclide (i.e., the fraction of MAR_j that is affected by the event sequence) [unitless]
- ARF_j - the airborne release fraction of the j^th nuclide applicable to the event sequence [unitless]
- RF_j - the respirable fraction of the j^th nuclide applicable to the event sequence [unitless]
- LPF_j - the leak path factor for the j^th nuclide applicable to the event sequence [unitless].

For normal operations and event sequences that have the potential of occurring at the Yucca Mountain repository, more than one LPF can be defined. For example, if a shipping cask loaded with a canister with commercial spent fuel is dropped inside a building and the drop results in a breach of confinement, the radioactive material contents of the package can be released from the fuel cladding to the canister, from the canister to the shipping cask, from the shipping cask to the room within the building, and from the building through high efficiency particulate air (HEPA) filters to the atmosphere. In this case, a potential of five LPFs can be defined. $(LPF)_{cladding}$ is defined as the fraction of radioactive material transported from the fuel matrix past the fuel cladding to the cavity of the canister. $(LPF)_{canister}$ is defined as the fraction of radioactive material transported from the canister to the cavity of the shipping cask. $(LPF)_{cask}$ is defined as the fraction of radioactive material transported from the cavity of the cask to the room. $(LPF)_{bldg}$ is defined as the fraction of radioactive material transported from the room or building, and is available to be released to the environment through the heating, ventilation and air conditioning (HVAC) system HEPA filters. And $(LPF)_{HEPA}$ is defined as the fraction of radioactive material released to the environment after passing through the HEPA filters. When multiple LPFs are used, their cumulative effect may be expressed in a single value that combines all LPFs as follows:

$$(LPF)_{sys} = (LPF)_i \times (LPF)_{i+1} \times (LPF)_{i+2} \times .... \qquad \text{(Eq. 2)}$$

where

$(LPF)_i$ = leak path factor for ith confinement barrier (unitless)

This calculation provides leak path factors for casks, DPCs, TAD canisters, waste packages, HEPA filters and fuel pools.

5. LIST OF ATTACHMENTS

6. CALCULATION

The leak path factors for each of the depletion mechanisms are addressed in separate sections.

6.1 HEPA FILTER LEAK PATH FACTORS

Filters are widely used in nuclear ventilation, air cleanup, and confinement systems to remove particulate matter from air and gas streams. High-efficiency particulate air (HEPA) filters are, by definition, throwaway, extended-medium, dry-type filters with:

1. a minimum particle removal efficiency of no less than 99.97 percent for 0.3-μm particles,
2. a maximum pressure drop of 1.0-inch water gauge or 1.3-inch water gauge when clean and operated at its rated airflow capacity, and
3. a rigid casing enclosing the full depth of the pleats. (Reference 2.2.6 [DIRS 167097], Glossary)

The dust-holding capacity of a filter is a function of the type, shape, size, and porosity of the filter as well as the aerosol size, shape, and concentration characteristics to which the filter is exposed. As HEPA filters are designed to filter out the smallest particles, they can accommodate only extremely light particulate loadings without experiencing a rapid pressure drop. Thus, a HEPA filter may be protected by a pre-filter capable of removing the bulk of large particles and fibers, a sprinkler to further reduce particulates, and a demister to prevent water damage to the HEPA filters (Reference 2.2.6 [DIRS 167097], Section 3.3.6).

Theory predicts that the primary mechanisms in filtering particles are diffusion and inertia. Direct interception or impaction is a secondary mechanism (Reference 2.2.6 [DIRS 167097], Section 2.5.2). The particle size of fuel fines that is expected to be typical for the fuel to be received at the Yucca Mountain repository is represented by a lognormal distribution with a mass median diameter (MMD) of 150 μm, a mean geometric diameter of 0.715 μm and a standard deviation (σ) of 3.8 (Reference 2.2.7, Section 6.2.2.4.1). Thus, the HEPA filtration efficiencies are applicable to the service conditions expected at the repository.

A decontamination factor (DF) is a measure of air cleaning effectiveness. It is the ratio of the concentration of a contaminant in the untreated air to the concentration in the treated air (Reference 2.2.6 [DIRS 167097], Glossary). The DF is related to filter efficiency, expressed as a fraction, by:

$$DF = \frac{1}{(1-\eta)} \qquad \text{(Eq. 3)}$$

where

$\eta =$ filter efficiency (unitless)

A leak path factor is the fraction of material that leaves the barrier, or for a filter, it is one minus the filter efficiency.

$$LPF = (1 - \eta) \qquad \text{(Eq. 4)}$$

where

η = filter efficiency (unitless)

Thus, the DF is the reciprocal of the LPF.

$$DF = \frac{1}{LPF} \qquad \text{(Eq. 5)}$$

Therefore, a filter efficiency of 99.97 percent is equivalent to a DF of 3,333, which is equivalent to a LPF of 3×10^{-4}.

To increase the DF of a system, multiple HEPA filters are used in series. Tests at Los Alamos National Laboratory resulted in DFs of 10^4 for stages one and two and somewhat less than 5.0×10^3 for the third stage of a three-stage system, with an average DF of 5.0×10^3 for each of the three stages (Reference 2.2.6 [DIRS 167097], Section 2.5.2). A DF of 5.0×10^3 is equivalent to a filter efficiency of 99.98%. Thus, the tests at Los Alamos National Laboratory resulted in an average filter efficiency of 99.98% or a LPF of 2×10^{-4} for each of the three HEPA filter stages in the three-stage filter system.

The *Nuclear Air Cleaning Handbook* (Reference 2.2.6 [DIRS 167097], Section 2.5.2) states that for purposes of estimating the capability of a multistage HEPA filter installation under normal operating conditions, a DF of $(3.0 \times 10^3)^n$ can be safely used with systems that adhere to the design, construction, testability, and maintainability principles of the *Nuclear Air Cleaning Handbook* or American Society of Mechanical Engineers (ASME) N509 (Reference 2.2.8 [DIRS 176247]). Applying this, the DF of a two stage HEPA filter system would be 9×10^6, which is equivalent to a LPF of 1.1×10^{-7}. Thus, for a two-stage HEPA filter system, the *Nuclear Air Cleaning Handbook* (Reference 2.2.6 [DIRS 167097], Section 2.5.2) recommends a DF of 9×10^6, which is equivalent to a LPF of 1.1×10^{-7}.

The *Nuclear Fuel Cycle Facility Accident Analysis Handbook,* NUREG/CR-6410 (Reference 2.2.9 [DIRS 103695], Section F.2.1.3), states that if a series of HEPA filters is protected by pre-filters, sprinklers, and demisters, efficiencies of 99.9 percent for the first filter and 99.8 percent for all subsequent filters is recommended for accident analysis. This gives a LPF of 0.001 for the first stage and 0.002 for the second stage with a combined LPF of 2.0×10^{-6} for the two-stage system.

Regulatory Guide 1.52 (Reference 2.2.10 [DIRS 171692], Section 6.3) allows accident dose evaluations to credit a 99% removal efficiency for particulate matter filter systems that demonstrate aerosol leak test results of less than 0.05% of the challenge aerosol at rated flow ±10%.

For normal operations and event sequences, a $(LPF)_{HEPA}$ of 0.01 per stage for particulate and cesium is recommended, which is equivalent to a HEPA removal efficiency of 99% per stage. For a two-stage HEPA filtration system, this gives a combined efficiency of 99.99%, which is equivalent to a $(LPF)_{HEPA}$ of 10^{-4} when the series of HEPA filters is protected by pre-filters, sprinklers, and demisters. This is consistent with the guidance of Regulatory Guide 1.52 (Reference 2.2.10 [DIRS 171962], Section 6.3) and conservative with respect to the recommendations of Reference 2.2.6 ([DIRS 167097], Section 2.5.2) and Reference 2.2.9 ([DIRS 103695, Section F.2.1.3). In addition, the Nuclear Regulatory Commission found acceptable a LPF for a two-stage HEPA filtrations system of 10^{-4} for the Mixed Oxide Fuel Fabrication Facility (Reference 2.2.11 [DIRS 177722], page 9-10).

6.2 SPENT FUEL CLADDING

The release fractions for commercial spent nuclear fuel (SNF) are provided in *Commercial SNF Accident Release Fractions* (Reference 2.2.7, Section 7). These release fractions are by definition, the fraction of fuel inventory that is released from the fuel cladding to the next confinement barrier (Reference 2.2.7, Section 7). As such, the LPF for spent fuel cladding must equal one (1) when the release fractions from Section 7 of Reference 2.2.7 are used.

6.3 TRANSPORTATION CASKS AND CANISTERS

The Nuclear Regulatory Commission must approve any package used for shipping nuclear material using the provisions of 10 CFR Part 71 (Reference 2.2.2 [DIRS 176575]). A transportation package is required to meet the hypothetical accident conditions, which include a 30-ft free drop, a crush test, puncture test, a fully engulfing fire, and immersion in accordance with 10 CFR 71.73 (Reference 2.2.2 [DIRS 176575]). The purpose of these stringent requirements is to ensure that the transportation packages are robust enough to withstand accident conditions even though it is unlikely they could be exposed to such conditions. While these tests are for the entire transportation package, which can include a canister within a cask with impact limiters, the canister itself provides structural support and confinement within the shipping cask. A leak path factor can be established for the cask as well as the canister inside the cask, if used.

A review of the literature concerning the fraction of particulate released from a shipping cask, canister or container is performed in this section. It includes an overview of cask and canister impact tests, a review of release fractions cited in literature and a review of particulate retention mathematical models.

Waste to be received at the repository can include spent nuclear fuel and high-level waste sealed within canisters. These canisters can include DPCs for commercial SNF, TAD canisters for commercial SNF, and standardized canisters for the Department of Energy (DOE) SNF and high-level waste. A limited amount of spent nuclear fuel may also be shipped bare in a transportation cask without being sealed in a TAD canister or DPC (Reference 2.2.1, Section 1.2.2 and 4.1.1).

The particle size of fuel fines that is expected to be typical for the fuel to be received at the Yucca Mountain repository is represented by a lognormal distribution with a mass median diameter (MMD) of 150 μm, a mean geometric diameter of 0.715 μm and a standard

deviation (σ) of 3.8 (Reference 2.2.7, Section 6.2.2.4.1). As shown in NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476], Section 7.3.8 and Figure 7.10), deposition processes largely deplete the source distribution of particles with diameters larger than 10 μm. When selecting a LPF value from various LPF models, the most conservative LPF value is taken to develop cask and canister leak path factors. As a result, there is no need for correction factors due to any change of particle size distribution.

Airborne particulate transport is dependent on accident conditions such as structural integrity of the confinement. Depending on the size and location of the breach, the LPF values can range from 0, meaning no release, to 1, meaning all available material is released. Severe accident conditions could result in a gross failure of the confinement. In this case, a conservative LPF of 1 should be used. However, in less severe accident conditions, the impact energy may not be sufficiently large enough to breach the canister and the assumption of a small leak is both appropriate and conservative. A small leak area would result in a small LPF for particulates within the confinement barrier. The LPF as a function of the leak area and pressure is discussed in this section.

As stated earlier, a transportation package is required to meet the hypothetical accident conditions, which include a 30-ft free drop in several orientations, a crush test, puncture test, a fully engulfing fire, and immersion in accordance with 10 CFR 71.73 (Reference 2.2.2 [DIRS 176575]). It is expected that confinement be maintained following the 10 CFR 71.73 hypothetical accident conditions. Therefore, assuming a small leak area following a postulated event at the repository is conservative (Assumption 3.2.1) because no credible repository event has been identified that presents challenges more severe than the 10 CFR 71.73 hypothetical cask accidents.

6.3.1. Impact Tests

Pacific Northwest National Laboratory (PNNL) and Sandia National Laboratories (SNL) have performed many shipping cask and canister impact tests. Many canister drop tests have been performed to demonstrate the capability of canisters, loaded with vitrified high level waste (HLW) or spent nuclear fuel (SNF), to withstand transportation accidents. The results of these tests are summarized and evaluated in this section.

Peterson et al. (References 2.2.13 and 2.2.14 [DIRS 170829 and DIRS 106578]) at PNNL have performed drop tests on canisters filled with simulated high-level waste glass. Wu et al. (Reference 2.2.15 [DIRS 170936], Section 3.2) reviewed and summarized the test results. In the first set of tests (Reference 2.2.13 [DIRS 170829]), four canisters were each subjected to two vertical drops from a height of 30 feet onto an unyielding surface and a horizontal drop from a height of 40 inches onto a solid steel vertical cylinder in a puncture test. No rupture of any of the canisters occurred. A helium leak test and a liquid dye penetrant test conducted after the impacts revealed no leaks and no significant indications of cracks (Reference 2.2.15 [DIRS 170936], Section 3.2.1). In the second set of tests (Reference 2.2.14 [DIRS 106578]), three Savannah River Laboratory waste containers were tested. Two of the canisters were fabricated from 304L stainless steel, and the third was fabricated from titanium. The impact tests were conducted in the same manner as those in Reference 2.2.13 ([DIRS 170829]). The results indicated no failure

and no leak in the stainless steel canisters during a helium leak test. However, a breach did occur in the titanium canister (Reference 2.2.15 [DIRS 170936], Section 3.2.2).

Wu et al. (Reference 2.2.15 [DIRS 170936]) developed a stress analysis model to analyze the effects of a potential drop of a shipping cask and a waste container during waste handling operations. The drop tests from References 2.2.13 and 2.2.14 ([DIRS 170829 and DIRS 106578]) provided technical information about the effects of impact on high-level waste canisters (Reference 2.2.15 [DIRS 170936], Section 3.3). Reasonable agreement was found between the results of a 30 ft drop finite-element analysis using the stress analysis model and the results from the drop test documented in Reference 2.2.14 ([DIRS 106578]) (Reference 2.2.15 [DIRS 170936], Sections 3.2.2 and 3.3.5).

Using the stress analysis model, Wu et al. (Reference 2.2.15 [DIRS 170936], Executive Summary) evaluated several impact scenarios including those for a shipping cask, an empty container, and a loader container. For a shipping cask, the analysis results showed that the maximum stresses occur when the cask rolls off a transfer car and strikes the floor. The maximum stresses do not exceed the allowable stress for the stainless steel, which is the material used in the cask. Therefore, under the test conditions, neither the truck cask nor rail cask should fail. For an empty container, the analysis results show that the maximum stresses occur as the result of a container free-fall of 34 feet or an impact with the hot cell walls. Although the maximum stresses were slightly higher than the allowable stress, the stresses would not result in a fracture of the container. For a loaded container, the analysis results show that the maximum stresses occur when the container falls 2 feet and impacts a 2-inch-diameter object or when it impacts the hot cell walls. Even though the maximum stress is 81,000 psi, which is almost four times as great as the allowable stress for the stainless steel material used, no fracture of the container is expected. The allowable stress for the material is 21,000 psi whereas the ultimate strength is 85,000 psi and the critical fracture strength is 228,000 psi (Reference 2.2.15 [DIRS 170936], Executive Summary).

Drop tests have been performed for full-scale Defense Waste Processing Facility (DWPF) canisters to demonstrate that waste forms in canisters can withstand a 7-meter drop without breach (Reference 2.2.16 [DIRS 101854], Section 8). Seven canisters filled with glass were drop tested from 7 meters by the PNNL personnel in 1988. The canisters were oriented and lifted by a crane until the lowest point on the canister was 7 meters off the ground and then they were released. All seven canisters bounced more than once after the first impact. For those Defense Waste Processing Facility canisters that were dropped on their bottom head, almost no deformation was observed. When these canisters were dropped at an angle on their head, the thicker neck and shoulder buckled and bent. The results of both dye penetrant examinations and helium leak tests demonstrated that no breach of the canisters occurred as a result of the top and bottom drops experienced by each canister.

Drop tests were performed on two full-scale Defense Waste Processing Facility canisters (Reference 2.2.17 [DIRS 141573]). These canisters were filled with simulated high-level waste glass and were dropped from heights of either 0.3 meters or 9.1 meters. The structural integrity of both canisters was not affected by their drop test. Both helium and dye penetrant tests following the drop demonstrated that the integrity of both the fabrication welds and the final

closure welds of the canisters were maintained (Reference 2.2.17 [DIRS 141573]). In addition, nineteen drop tests on nine different glass-filled canisters were performed between 1981 and 1984 at the Savannah River Site (SRS) (Reference 2.2.18 [DIRS 170813]). These drops included a drop of 30 feet onto a flat unyielding surface and a drop of 40 inches onto the top end of a 6-inch diameter bar. No breach of any welds on the dropped stainless steel canisters was observed (Reference 2.2.18 [DIRS 170813]).

DOE standard canister drop tests have been performed at Sandia National Laboratories (Reference 2.2.19 [DIRS 169137], Executive Summary). A total of nine 18-inch-diameter test canisters were used in the tests. Seven of the test canisters were 15-ft long and weighted about 6,000 lbs, while two were 10-ft long and weighted 3,000 and 3,800 lbs. In these tests, seven of the test canisters were dropped from a height of 30 ft onto an essentially unyielding surface and one of the test canisters was dropped from a height of 40 inches onto a 6-inch-diameter puncture post. The last test canister was dropped from a height of 24 inches onto a 2-inch thick vertically oriented steel plate, and then tipped over to impact another 2-inches thick vertically oriented steel plate. All nine canisters experienced varying degrees of damage to their skirts, lifting rings, and pressure boundary components (heads and main body). However, all dropped canisters were found to have maintained their pressure boundary and the four canisters that experienced the most damage were found to be leak tight through helium leak testing performed at Idaho National Laboratory (Reference 2.2.19 [DIRS 169137], Executive Summary).

NUREG-0170 (Reference 2.2.20 [DIRS 101892]) summarizes impact tests reported in References 2.2.21 and 2.2.22 ([DIRS 170801 and 170804]) that were performed by Sandia National Laboratories. These tests simulated accidents involving aircraft. The containers were subjected to the same test requirements to which the Federal Aviation Administration subjects flight recorders prior to certification. Per Figure 5-2 of NUREG-0170 (Reference 2.2.20 [DIRS 101892]), aircraft transportation accidents are divided into eight categories (Categories I through VIII) of increasing severity. The severity of aircraft accidents is based on the impact speed and the fire duration at 1300°K. Table 1 summarizes the severity categories for aircraft transportation accidents without fire.

Table 1. Accident Severity Category Classification Scheme - Aircraft

Severity Category Without Fire	Speed of Impact onto Unyielding Surface	
	(kilometers/hour)	(miles/hour)
I	0-17.6	0-11
II	17.6-48	11-55
III	48-88	30-55
IV	88-128	55-80
V	128-224	80-140
VI	224-304	140-190
VII	304-600	190-370
VIII	>600	>370

Source: Reference 2.2.20 [DIRS 101892], Figure 5-2

All containers survived the impact tests with no structural damage to the inner container after impacts onto unyielding targets at speeds up to those typical of a Category V impact accident (Reference 2.2.20 [DIRS 101892], Section 5.2.3). Several containers from the Sandia impact test exhibited some minor structural damages and cracking in Category VI impacts; however, no verified release occurred. In one Category VII impact test, a container lost 6% of its contents (magnesium oxide powder); while others survived Category VIII impacts with no loss of contents (Reference 2.2.20 [DIRS 101892], Section 5.2.3).

The results of the drop tests discussed above are summarized in Table 2.

Table 2. Summary of Cask and Canister Drop Tests

Cask or Canister Drop Test	Organization Performing the Test	Drop Height	Test Results	References*
Glass filled stainless steel canisters	PNNL	30 ft vertical drop, 40-inch horizontal puncture test drop	No canister breach	Reference 2.2.13 [DIRS 170829]
Glass filled canisters; 2 stainless steel, 1 titanium	PNNL	30 ft vertical drop, 40-inch horizontal puncture test drop	No stainless steel canister breach, titanium canister breach	Reference 2.2.14 [DIRS 106578]
DWPF canister drop	PNNL	7 m	No canister breach	Reference 2.2.16 [DIRS 101854]
DWPF canister drop	SNL	0.3 m or 9.1 m	No canister breach	Reference 2.2.17 [DIRS 141573]
Glass-filled canister drop	SRS	30 ft vertical drop, 40-inch horizontal puncture test drop	No canister breach	Reference 2.2.18 [DIRS 170813]
DOE standard canister drop	SNL	30 ft or 2 ft	No canister breach	Reference 2.2.19 [DIRS 169137]
Plutonium shipping container drop onto unyielding targets	SNL	At speeds typical of Category V to VIII impacts	No release for Category V or VI impacts. Only one container breached and lost 6% of its contents in a Category VII impact; others survived Category VIII impact.	Reference 2.2.21 [DIRS 170801] and Reference 2.2.22 [DIRS 170804]

Note: *See text for specific citation in reference.
DOE=Department of Energy, DWPF=Defense Waste Processing Facility, PNNL=Pacific Northwest National Laboratory, SNL=Sandia National Laboratories, SRS=Savannah River Site

In conclusion, the impact tests summarized here show that both casks and glass canisters are robust and would not be expected to fail under credible conditions associated with repository operations. As the table shows, only one stainless steel container breached following a Category

VII impact test, which is defined as an accident that has an impact speed between 190 and 370 mph. The only possible event that could be in the range of these speeds involves an aircraft crash. The frequency of aircraft crashes has been shown to be less than one chance in 10,000 of occurring before permanent closure of the Yucca Mountain repository; thus, an aircraft crash is not a credible event (Reference 2.2.23, Section 7).

6.3.2. Release Fractions Cited In Literature

Several investigators have estimated the degree of resistance against airborne dispersion of particulate provided by spent nuclear fuel cladding, shipping casks, canisters, and containers. MacDougall et al. (Reference 2.2.24 [DIRS 104779], Table 5-8) has recommended escape factors, or leak path factors, for various combinations of confinement barriers, such as fuel cladding, shipping casks, canisters, and/or containers, against an uncontrolled release. MacDougall et al. (Reference 2.2.24 [DIRS 104779], Table 5-8) recommended leak path factors are shown in Table 3.

Table 3. Leak Path Factors Recommended for Various Combinations of Confinement Barriers

Source Term	LPF
Spent fuel cladding	0.1
Cask	0.1
Container or canister	0.1
Spent fuel in cask	(0.1)(0.1) = 0.01
Spent fuel in container	(0.1)(0.1) = 0.01
Spent fuel in container in cask	(0.1)(0.1)(0.1) = 0.001
HLW canister	0.1
HLW canister in cask	(0.1)(0.1) = 0.01
HLW canister in container	(0.1)(0.1) = 0.01
HLW canister in container in cask	(0.1)(0.1)(0.1) = 0.001

Source: Reference 2.2.24 [DIRS 104779], Table 5-8

Table 3 shows a recommended LPF of 0.1 for each confinement barrier. Note that the fuel cladding LPF should be equal to one (1) when using the release fractions from Section 7 of Reference 2.2.7.

Wilmot (Reference 2.2.25 [DIRS 104724], Table XIX) used a release fraction of 0.05 for particulates and volatiles (Cs, I) for the release from the cavity of a gas-cooled cask to the environment. The release fraction was based on the collective judgment of experts.

In 1977, the NRC issued a generic environmental impact statement, NUREG-0170 (Reference 2.2.20 [DIRS 101892]), which covers the transport of all types of radioactive material by all transport modes (road, rail, air, and water). For the purpose of dose calculations, accidents were divided into eight categories (Categories I through VIII) of increasing severity. Two source term models were developed and used in NUREG-0170 to calculate the dose to the public due to a postulated transportation accident. Table 4 shows the cask release fractions for both truck and

train accidents from NUREG-0170 (Reference 2.2.20 [DIRS 101892], Tables 5-4, 5-5, 5-8 and 5-9).

Model I release fractions are derived from a total release model that is characterized as somewhat unrealistic but which allows simplistic evaluations (Reference 2.2.20 [DIRS 101892], Section 5.2.3). As can be seen in Table 4, Model I release fractions exhibit a step change from 0 to 1 when the accident category changes from II to III. Model II release fractions are derived from a more realistic model that is characterized as still having inherent conservatisms (Reference 2.2.20 [DIRS 101892], Section 5.2.3). Model II release fractions, which change from 0 to 1 more gradually as seen in Table 4, are based on SNL plutonium shipping container test data (References 2.2.21 and 2.2.22 [DIRS 170801 and 170804).

Table 4. NUREG-0170 Model I and Model II Severity and Cask Release Fractions for Spent Fuel Transport by Truck and Rail

Accident Category	Severity Fractions*		Release Fraction Truck and Rail	
	Truck	Rail	Model I	Model II
I	0.55	0.5	0.0	0.0
II	0.36	0.3	0.0	0.0
III	0.07	0.18	1.0	0.01
IV	0.016	0.018	1.0	0.1
V	0.0028	0.0018	1.0	1.0
VI	0.0011	1.3×10^{-4}	1.0	1.0
VII	8.5×10^{-5}	6.0×10^{-5}	1.0	1.0
VIII	1.5×10^{-5}	1.0×10^{-5}	1.0	1.0

Source: NUREG-0170 (Reference 2.2.20 [DIRS 101892], Tables 5-4, 5-5, 5-8, and 5-9)
NOTE: * Fraction of accidents that fall into this severity range.

In the final supplementary environmental impact statement for the Waste Isolation Pilot Plant (Reference 2.2.26 [DIRS 170805], Section D3.3), a fraction of radioactive material released from failed containers into the package cavity, and a fraction of radioactive material released from the package to the environment were used. These fractions were dependent on the severity of the accident and were based on NUREG-0170 Model I release fractions and some other release fractions derived from experiments. For remotely handled casks, the estimated release fractions are 0 for severity category accidents I-IV, 1×10^{-4} for severity category accidents V and VI, and 2×10^{-4} for severity category accidents VII and VIII (Reference 2.2.26 [DIRS 170805], Table D3.17).

The NRC modal study, NUREG/CR-4829 (Reference 2.2.27 [DIRS 101828], Figure 4-5), categorized the potential damage to shipping containers used to transport PWR or BWR spent nuclear fuel according to the magnitude of thermal and mechanical forces that could result from an accident. The thermal and mechanical forces were categorized into 20 regions. Each region is associated with one of the five cask mid-wall temperature ranges; up to 500°F, 500°F to

600°F, 600°F to 650°F, 650°F to 1050°F, and greater than 1050°F, and one of the four ranges of maximum strain on the inner shell of the cask; up to 0.2%, 0.2% to 2%, 2% to 30%, and greater than 30%. For each region, release fractions for inert gas, iodine, cesium, ruthenium, and particulates were given.

Reference 2.2.28 ([DIRS 101802], Volume 1, Appendix D Section A.7.2.2.4 and Appendix I Section I-5.2.2) used the cask release fractions from NUREG/CR-4829 (Reference 2.2.27 [DIRS 101828]) for inert gas, iodine, cesium, ruthenium, and particulates to calculate the potential dose to the public during transportation accidents involving DOE SNF. The cask release fractions developed in NUREG/CR-4829 (Reference 2.2.27 [DIRS 101828]) for commercial PWR fuel are reported in Table I-27 of Reference 2.2.28 ([DIRS 101802]). For accident region R(1,1), which has up to 0.2% strain and up to 500°F cask temperature, no releases occur. The accident region R(3,4), which has up to 30% strain and up to 1050°F cask temperature, has an inert gas release fraction of 0.39, iodine release fraction of 4.3×10^{-3}, cesium release fraction of 2.0×10^{-4}, ruthenium release fraction of 4.8×10^{-5}, and particulate release fraction of 2.0×10^{-6}.

NUREG-1864 (Reference 2.2.29 [DIRS 181343], Sections D.2.5.2.2. and D.4) provides a recommended fraction of the respirable fuel and crud particles that escape a cask containing commercial spent nuclear fuel. The fraction released, or leak path factor, is less than or equal to 0.1 for particulates and crud. The leak path factor for the particular case evaluated, that being a HI-STORM cask with a 100-foot drop, is 0.1 for particles and crud.

In conclusion, leak path factors have been cited and used in the literature. The recommended leak path factors, even for relatively severe accident conditions, have generally ranged from 0 to 0.1 for casks and canisters.

6.3.3. Particulate Retention Models

This section discusses various models available to calculate the leak path factor. These models are based on the theory of particulate deposition or test data. A comparison of these models is discussed in this section.

6.3.3.1. The Sutter et al. Correlation

Sutter et al. (Reference 2.2.30 [DIRS 170832]) have conducted leak tests using depleted uranium oxide (DUO) powder to simulate PuO_2 powder leaked from a breached container under postulated accident conditions. Three hundred and seventy experimental runs using DUO in the plutonium oxide leak studies were defined by type of apparatus and by type of opening, or leak path, combined with chamber pressure and duration of run. Two sets of apparatus were used: Above Powder Leak Apparatus (APLA) for leaks above the powder level and Under Powder Leak (UPL) apparatus for leaks below the powder level. Leak paths were through three types of openings: orifices, short capillaries, and long capillaries. These openings varied in diameter from 20 to 276 μm. Selection of openings and the appropriate apparatus determined the hardware characteristics for a run (Reference 2.2.30 [DIRS 170832], Summary and Conclusions; Appendix B).

For each run a chamber pressure between 5 and 1000 psig, and duration of run time during which the apparatus was at the selected pressure, was between 0 and 360 minutes. Some runs with multiple openings were made on the APLA. For the UPL, some runs were made using mechanical agitation; others were not. All APLA runs had powder agitation. The tests were conducted with an initial mass of 3 kg (Reference 2.2.30 [DIRS 170832], Introduction). However, a series of test with the UPL apparatus was made to assess the effect of varying the initial amount of DUO between 25 g and 300 g (Reference 2.2.30 [DIRS 170832], page B-36). Test results indicate that as the initial mass increased above 100 g, the amount of DUO that leaked through the aperture did not significantly change (Reference 2.2.30 [DIRS 170832], page B-36).

The DUO powder has a mass median diameter (MMD) of 1 μm, which is a 3.5-μm aerodynamic equivalent diameter, and 95% of its mass was associated with particles of 10-μm or less (Reference 2.2.30 [DIRS 170832], pg. 29). The MMD of fuel fines generated during a spent fuel rod burst event postulated for the Yucca Mountain repository is about 150 μm (Reference 2.2.7, Section 6.2.2.4.1). Because it would be expected that releases for larger particles would be less than for smaller particles, the data for DUO, a fine powder with a MMD of 1 μm, provides conservative estimates for releases of fuel fines during postulated events at the Yucca Mountain repository.

To perform an experiment, an aperture, either an orifice or capillary, was cemented in a filter-loaded collection chamber. The chamber was placed in the apparatus and the upstream pressure was increased to the predetermined level and maintained at that level for the designated time. The experiment was than terminated by turning off the air and allowing the vessel to depressurize. All of the DUO powder that passed through the aperture as a result of the pressurization cycle was sampled and analyzed. Seventeen thin-plate orifices with bore diameters ranging from 20 to 200 μm, and 12 capillaries, 0.76 and 2.54 cm long with nominal diameters of 50 to 250 μm, were used to simulate leaks.

The initial experiments indicated aperture diameter and increasing pressure to be significant parameters for powder transmission, and seemed to indicate a correlation with airflow rate. Further investigation of the data confirmed the significance of the diameter and pressure parameters with the influence of the diameter to be more important than the pressure. The following correlations for the amount of DUO that leaked through the aperture were developed by a statistical analysis of the experimental data.

For low flow cases, $\ell n(A\sqrt{P}) < 10.5$, where A is the area in μm^2 and P is the pressure in psig, the expected average and upper limit values were 33 μg and 46 μg, respectively, for below powder leaks; 5 μg and 6 μg, respectively, for above powder leaks (Reference 2.2.30 [DIRS 170832], Appendix B, Table B1). The report recommends using the average or upper limit for low flow cases.

As stated earlier, the tests were conducted with an initial mass of 3 kg (Reference 2.2.30 [DIRS 170832], Introduction). However, twenty-one tests with the UPL apparatus were made to assess the effect of varying the initial amount of DUO between 25 g and 300 g (Reference 2.2.30 [DIRS

170832], page B-36). Test results indicate that as the initial mass increased above 100 g, the amount of DUO that leaked through the aperture did not significantly change (Reference 2.2.30 [DIRS 170832], Figure B8). The maximum normal internal pressure of a cask or canister is nominally 100 psig (Reference 2.2.2 [DIRS 176575], Part 71.4). Although the amount of material leaking out was generally independent of the mass of the material in the test vessel (Reference 2.2.30 [DIRS 170832], Table B21), these initial values can be used to approximate leak path factors. The initial mass is taken as 3 kg (3×10^9 μg), since only 21 of the 370 tests had different initial masses. For these low flow cases, the upper limit leakage values lead to a LPF for below powder leaks of 2×10^{-8} (46 μg divided by 3×10^9 μg) and a LPF for above powder leaks of 2×10^{-9} (6 μg divided by 3×10^9 μg).

For high flow cases, $\ell n(A\sqrt{P}) > 10.5$, again with A in μm^2 and P in psig, the amount of DUO leaked through the aperture is predicted by:

$$\ell n(M) = a + b_1 \ell nA + b_2\sqrt{P} \qquad \text{(Eq. 4)}$$

where

A = area of the aperture (μm^2)
P = pressure (psig)
M = mass of DUO leaked through the aperture (μg)
a, b_1, b_2 = coefficients defined in Table 5

Equation (4) can be transformed into the leak path factor, LPF, as follows:

$$LPF = \frac{M}{M_0} = \frac{1}{M_0} Exp(a + b_1 \ell nA + b_2\sqrt{P}) \qquad \text{(Eq. 5)}$$

where

LPF = leak path factor or fraction of DUO mass leaked out of the vessel (unitless)
M_0 = initial DUO mass in the vessel (μg)

Coefficients a, b_1, and b_2 in Equations (4) and (5) are dependent on the leak configuration and the location of the leak. Values of these coefficients are given in Table 5. Again, using an initial DUO mass of 3 kg, the LPFs can be determined.

Table 5. Coefficients Used in Equations 4 and 5

Coefficients	**UPL Orifices**	**APLA Orifices**	**Capillaries**	**Unspecified Configuration***
a	-10.2848	-14.1959	-17.9875	-14.2790
b_1	1.6080	1.7906	2.1658	1.8280
b_2	0.0449	0.1095	0.1170	0.1052

NOTE: *least squares fit for all observations (UPL orifices, APLA orifices, and capillaries)
UPL=under powder leak, APLA=above powder leak apparatus

Source: Reference 2.2.30 [DIRS 170832], Appendix B

Using Equation 5, leak path factors for orifices and capillaries ranging from 10 to 10,000 μm in diameter and pressures at 0, 25, 50 and 100 psig were determined and the results of the calculations are reported in Attachment I. The maximum normal internal pressure of a cask or canister is nominally 100 psig (Reference 2.2.2 [DIRS 176575], Part 71.4). The results show that the LPF increases with increasing aperture diameters and pressures. The results also show, as indicated in Attachment I, that the capillary configuration results in the highest amount of DUO release out of the vessel and hence the highest LPF.

During some of the test runs, orifices or capillaries either plugged immediately when the sampling system was pressurized, or they became partially plugged with loss of powder flow although without complete cessation of airflow. Six percent of the orifices used became totally plugged and 3% became partially plugged during experiments. Seventeen percent of the capillaries plugged immediately and 10% were suspected of plugging. Capillaries, with more extensive surface area exposed to airborne powder than orifices, can plug at the face, or particles can deposit in the length of the leak path, leading to bridging and eventual flow blockage. This additional area available for deposition could account for the 17% plugging of capillaries compared to 6% for orifices where plugging occurred primarily at the orifice face (Reference 2.2.30 [DIRS 170832], Pages 37 through 39).

The overall conclusions from this study are:

- Diameter and pressure were both significant, although diameter was the most important parameter in powder leakage.
- The opening orifice or capillary types and location above or below the static powder level affected powder transmission.
- The amount of powder covering a leak did not affect the leak below the static powder level because of powder compaction.
- The duration of a run had no statistically discernible effect on powder transmitted in time up to 24 hours.
- Agitation did not influence the flow from a leak below the static powder level.
- Leakage below the static powder level maximized at 100 psig for openings less than 100 μm.
- Plugging was a frequent occurrence, as discussed above.
- Efforts to increase the powder leakage by various procedures were unsuccessful.

6.3.3.2. Vaughan Plugging Model

During several of the PNNL tests (Reference 2.2.30 [DIRS 170832]), orifices or capillaries either plugged immediately when the sampling system was pressurized, or they became partially plugged with loss of powder flow although without complete cessation of airflow. Plugging is an important phenomenon for orifices or capillaries smaller than 1,000 μm in diameter as discussed in and indicated in the figure of Reference 2.2.31 ([DIRS 170836], pp. 507 to 508).

A simple model of plugging of pipes from aerosol deposition is discussed in this section. A simple method (Reference 2.2.31 [DIRS 170836], pp. 507 to 508) was developed to account for the decrease in the flow cross-sectional area as a result of particle deposition inside the pipe and the eventually plugging of the pipe. An expression for the time-dependent mass of the deposited particles as a function of the maximum thickness of the particles deposited on the wall was derived. The deposition rate was related to the suspended mass concentration, the volumetric flow rate, the collection efficiency, and the proportion of the pipe cross-sectional area still open. The two expressions were combined to form a final integrated expression for the total mass of aerosol carried through the pipe prior to complete plugging of the pipe. The simple model estimated the mass of the aerosol that transmitted prior to the pipe plugging to the dimensions of the pipe and a dimensional factor, K. The model given in the text of Reference 2.2.31 ([DIRS 170836], pp. 507 to 508) relates mass to K and the cube of the radius of the pipe, where K is equal to 10 g/cm^3. The figure plots the model, showing mass versus pipe diameter. When using the K equal to 10 g/cm^3, the figure is actually plotting KD^3 (Reference 2.2.31 [DIRS 170836], pp. 507 to 508).

Morewitz (Reference 2.2.32 [DIRS 170827]) also reported pipe plugging test data and attempted to correlate the data with the Vaughan plugging model. Plugging was reported for diameters ranging from 0.002 to 26.5 cm. Of the approximately 30 data points reported by Morewitz (Reference 2.2.32 [DIRS 170827]), about 25 were for pipe diameters of less than 1 cm and most pipe diameters used were less than 0.1 cm. The model used by Morewitz related the mass to the cube of the pipe diameter with a dimensional factor, K, in units of g/cm^3 (KD^3). The data for pipe bend, straight sections, different entrance conditions, and a variety of flow and aerosol conditions were combined to yield a range of values for K, equal to 30 g/cm^3 ± 20. The suggested range of the K values does not include the data points for the very smallest diameters. Reference 2.2.31 ([DIRS 170836], pp. 507 to 508) noted that the simple model was derived under the assumption that the collection efficiency of the particles is independent of the particle size and gas flow rate. The factor K is assumed to be a function of the geometry of the deposited particles, the density of the particles, and the particle collection efficiency.

Reference 2.2.33 ([DIRS 170810]) also compared the Vaughan simple model of plugging, using the cube of the diameter (KD^3), with a turbulent transport model. Thus, the Vaughan plugging model, as depicted in the figure of Reference 2.2.31 ([DIRS 170836], pp. 507 to 508), and used in Reference 2.2.32 ([DIRS 170827]) and Reference 2.2.33 ([DIRS 170810]) is as follows:

$$M = KD^3 \qquad \text{(Eq. 6)}$$

where

M = aerosol mass transmitted prior to plugging (g)
K = dimensional factor (g/cm^3)
D = pipe diameter (cm)

Reference 2.2.31 ([DIRS 170836], pp. 507 to 508) reported a K value of about 10 g/cm^3 and Reference 2.2.32 ([DIRS 170827]) reported a range of K values of 30 $g/cm^3 \pm 20$. Table 6 shows the leak path factors derived using Equation 6 using K values of 10, 30 and 50 g/cm^3 with an initial mass of 3,000 g so that a comparison can be made with the Sutter et al. model in Section 6.3.3.4.

Table 6. Vaughan Plugging Model

D (mm)	K=10 g/cm³		K=30 g/cm³		K=50 g/cm³	
	Mass (g)	LPF[1]	Mass (g)	LPF[1]	Mass (g)	LPF[1]
0.01	1.00×10^{-8}	3.33×10^{-12}	3.00×10^{-8}	1.00×10^{-11}	5.00×10^{-8}	1.67×10^{-11}
0.05	1.25×10^{-6}	4.17×10^{-10}	3.75×10^{-6}	1.25×10^{-9}	6.25×10^{-6}	2.08×10^{-9}
0.1	1.00×10^{-5}	3.33×10^{-9}	3.00×10^{-5}	1.00×10^{-8}	5.00×10^{-5}	1.67×10^{-8}
0.25	1.56×10^{-4}	5.21×10^{-8}	4.69×10^{-4}	1.56×10^{-7}	7.81×10^{-4}	2.60×10^{-7}
0.5	1.25×10^{-3}	4.17×10^{-7}	3.75×10^{-3}	1.25×10^{-6}	6.25×10^{-3}	2.08×10^{-6}
1	1.00×10^{-2}	3.33×10^{-6}	3.00×10^{-2}	1.00×10^{-5}	5.00×10^{-2}	1.67×10^{-5}
1.129	1.44×10^{-2}	4.80×10^{-6}	4.32×10^{-2}	1.44×10^{-5}	7.20×10^{-2}	2.40×10^{-5}
3.568	4.54×10^{-1}	1.51×10^{-4}	1.36	4.54×10^{-4}	2.27	7.57×10^{-4}
5	1.25	4.17×10^{-4}	3.75	1.25×10^{-3}	6.25	2.08×10^{-3}
10	10	3.33×10^{-3}	30	1.00×10^{-2}	50	1.67×10^{-2}

NOTE: [1] LPF is calculated from Equation 6 and an initial mass of 3,000 g.

6.3.3.3. Cask Retention Model Used in NUREG/CR-6672

NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476]) documents the methodology and results of the study performed to reexamine the risks of transporting spent fuel that was documented in NUREG-0170 (Reference 2.2.20 [DIRS 101892]). Shipping casks for the transportation of spent nuclear fuel are generally available in three weight classes, legal weight truck, overweight truck, and rail, and with three gamma-shielding materials, steel, lead, and depleted uranium (Reference 2.2.12 [DIRS 152476], Section 4.1).

Finite element analyses of truck and rail casks have been performed and documented in NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476]). Leakage through elastomeric truck and rail cask seals due to cask impact was predicted. Based on the results of finite element analysis of cask impacting an unyielding surface and a thermal analysis from the resulting fire, a cask leak area of 1 mm^2 was assumed for truck casks with elastomer o-ring seals following a 120 mph impact (Reference 2.2.12 [DIRS 152476], Sections 7.2.5.1 and 7.2.5.2). For rail casks at the impact speed of 60 mph with a resultant fire, a leak area of 0.18 mm^2 was calculated. The leak area was increased to 1 mm^2 to be consistent with the leak area determined for the truck casks

(Reference 2.2.12 [DIRS 152476], Section 7.3.8). Event sequences involving drops or collisions at the Yucca Mountain repository are expected to result in impact forces less than the impact forces following a 60-mph impact without a subsequent fire. Therefore, the release fractions derived in NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476]) corresponding to a 1 mm^2 leak area can be reasonably applied to potential event sequences at the Yucca Mountain repository.

In NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476]), the fractions of Kr, UO_2, TeO, CsOH, and CsI released from the interior of a Type B TN-125 cask were calculated using the MELCOR code (Reference 2.2.12 [DIRS 152476], Section 7.3.8). It was assumed that the cask was pressurized to 5 atm by failure of all of the fuel rods in the cask during a high-speed collision and then depressurizes to atmospheric pressure at a rate determined by the cask seal leak area. The results show that for leak paths with cross-sectional areas of 4 and 100 mm^2, particle deposition largely depleted the source distribution of particles with diameters larger than 10 μm (Reference 2.2.12 [DIRS 152476], Section 7.3.8). The use of the data presented in NUREG/CR-6672 for Yucca Mountain is appropriate because the train and truck casks being evaluated are used for shipping commercial spent nuclear fuel, thus the source distribution of particles would be similar. The cask-to-environment release fraction for UO_2 is plotted as a function of the size of cask seal failure (leak area) as shown in Figure 1, which is a reproduction of Figure 7.11 of Reference 2.2.12 ([DIRS 152476]). The y-axis variable, one minus cask retention fraction, shown in Figure 1, is equivalent to the leak path factor. The cask-to-environment release fraction increases as the leak area increases. This is expected since, after pressurization due to the failure of the fuel rods, cask depressurization times decrease as the cask seal leak area increases. Thus, a large leak area means a short depressurization time, little time for fuel fines and fission products to deposit on cask interior surfaces, and consequently larger cask-to-environment release fractions. In Figure 1, a cask-to-environment release fraction of 0.02 for fuel fines (UO_2) corresponds to a leak area of 1 mm^2. A cask-to-environment release fraction of 0.02, corresponding to a 1-mm^2-leak area, was used in NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476], Section 7.3.8) for the releases of fuel fines during a transportation accident.

For the release of crud from a shipping cask, which are corrosion products on fuel rod surfaces, a spallation factor of 0.1 and a cask-to-environment release fraction of 0.02 were used in NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476], Section 7.3.6 and 7.3.8).

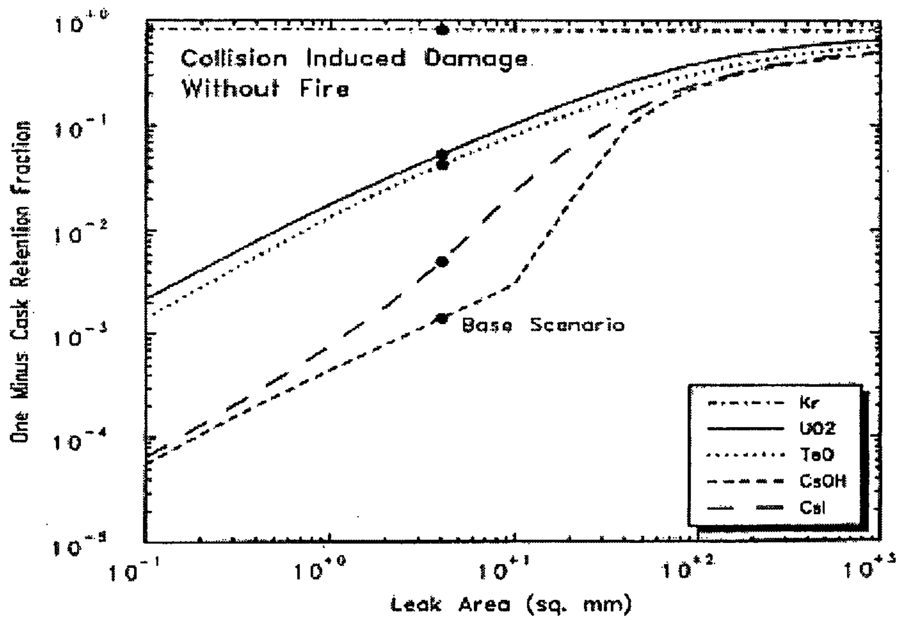


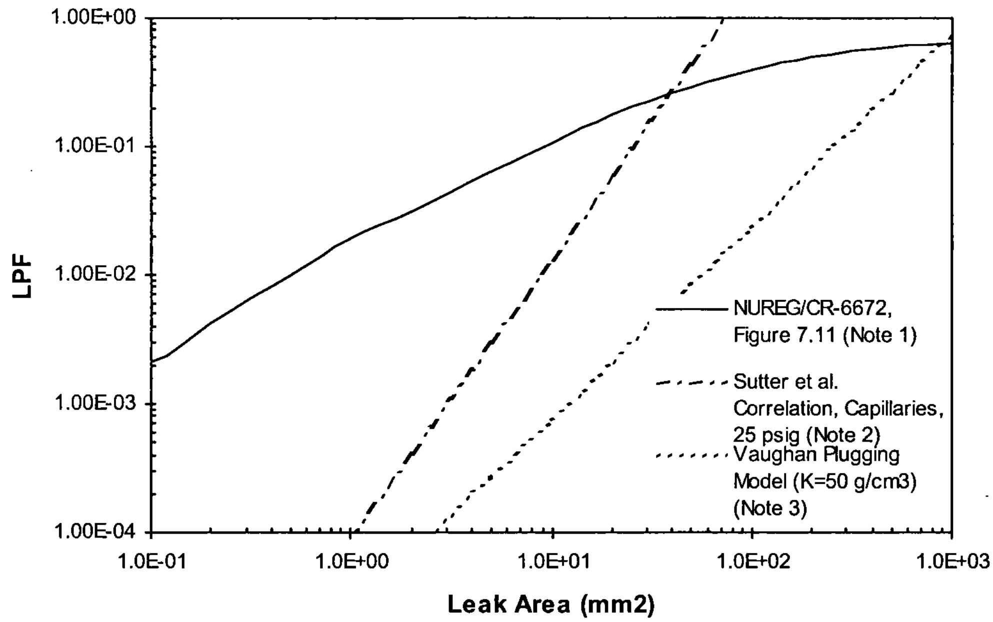
Figure 1. Dependence of Cask-to-Environment Release Fractions (leak path factors) on the Size of the Cask Failure (leak area)

As stated earlier, event sequences involving drops or collisions at the Yucca Mountain repository are expected to result in impact forces less than the impact forces following a 60-mph impact. Therefore, the release fractions derived in NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476]) corresponding to a 1 mm^2 leak area can be reasonably applied to potential event sequences at the Yucca Mountain repository.

6.3.3.4. Comparisons of Models

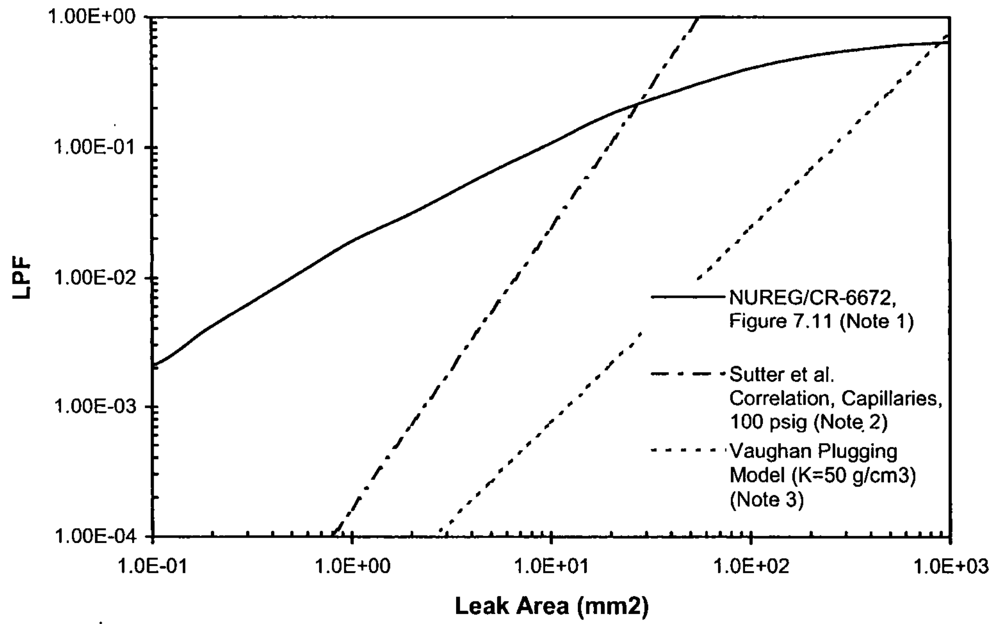
A plot of LPF, or one minus the cask retention fraction, as a function of the leak area taken from NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476], Figure 7.11) for UO_2, as shown in Figure 1, is shown in Figure 2 and Figure 3, together with the Sutter et al. correlation using the configuration that results in the largest LPF (capillaries) (Section 6.3.3.1) and the Vaughan plugging model using the K value that gives the highest LPF (K=50 g/cm^3) (Section 6.3.3.2). The LPF reported in NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476]) as a function of the leak area was calculated using the MELCOR code (Reference 2.2.12 [DIRS 152476], Section 7.3.8). All three models predict that LPF increases with the increasing leak area. For the cask leak area of 1 mm^2 or smaller, the LPF reported in NUREG/CR-6672 is at least two orders of magnitude larger than the LPF values calculated by the Sutter et al. correlation or the Vaughan plugging model. The NUREG/CR-6672 LPF model is more conservative than the Sutter et al. correlation or the Vaughan plugging model primarily because the plugging phenomenon frequently observed in small orifices or capillaries are not modeled in the MELCOR code. Because of the conservatism in the MELCOR code results, a LPF calculated by the MELCOR code as reported in NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476], Section 7.3.8), is used

in selecting LPF values for a shipping cask, a plutonium can, a disposable canister, a TAD canister or a waste package.



NOTES: (1) Reference 2.2.12 [DIRS 152476], Figure 7.11
(2) Reference 2.2.30 [DIRS 170832], Summary and Conclusions; Appendix B
(3) Reference 2.2.31 [DIRS 170836], pp. 507 to 508

Figure 2. Comparison of Models at 25 psig



NOTES: (1) Reference 2.2.12 [DIRS 152476], Figure 7.11
(2) Reference 2.2.30 [DIRS 170832], Summary and Conclusions; Appendix B
(3) Reference 2.2.31 [DIRS 170836], pp. 507 to 508

Figure 3. Comparison of Models at 100 psig

6.3.4. Recommendation for Casks and Canisters

Welded canisters and mechanically closed casks are used at the Yucca Mountain repository. NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476], Section 7.3.6 and 7.3.8) recommends a 1 mm^2 leak area for both a mechanically sealed, that is, bolted, train cask following a 60-mph impact with a resultant fire and a mechanically sealed truck cask following a 120 mph impact with a resultant fire. For conservatism, it is recommended that a leak area 10 times the recommended leak area of NUREG/CR-6672 (Reference 2.2.12 [DIRS 152476]) be used for potential event sequences at the repository. Applying a LPF to welded canisters that is based on a leak area that is ten times the leak area predicted for bolted casks is very conservative. Using the NUREG/CR-6672 correlation depicted in Figures 2 and 3, a leak area of 10 mm^2 results in a LPF of 0.1, which is more conservative than the LPFs predicted by the Sutter et. al. correlation (Reference 2.2.30 [DIRS 170832]) or the Vaughan Plugging model (Reference 2.2.31 [DIRS 170836], pp. 507 to 508). A LPF of 0.1 is also equal to the recommended LPF for commercial spent nuclear fuel and crud particles cited in NUREG-1864 (Reference 2.2.29 [DIRS 181343], Sections D.2.5.2.2. and D.4).

6.4 SPENT FUEL POOL

If an event occurs in the spent fuel pool of the Wet Handling Facility that results in the release of radionuclides from the fuel, the release will be directly in the pool water. NRC provides guidance to the nuclear utilities on evaluating the radiological consequences of fuel handling accidents. Since the operations involving the spent fuel pool at the repository are similar to operations in the spent fuel pool at utility sites, the NRC guidance on fuel handling accidents can be applied to an event involving the spent fuel pool of the Wet Handling Facility.

Regulatory Guide 1.25, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors* (Reference 2.2.34 [DIRS 107691], pg. 25.2), provides criteria for evaluating a fuel handing accident. The regulatory position provided states that all of the gap activity in the damaged rods is released and consists of 10% of the total noble gases other than Kr-85, 30% of the Kr-85, and 10% of the total radioactive iodine in the rods at the time of the accident. The iodine gap inventory is composed of inorganic species (99.75%) and organic species (0.25%). The pool decontamination factors for the inorganic and organic species are 133 and 1, respectively, giving an overall effective decontamination factor of 100, which means that 99% of the total iodine released from the damaged rods is retained by the pool water. This difference in decontamination factors for inorganic and organic iodine species results in the iodine above the fuel pool being composed of 75% inorganic and 25% organic species. The retention of noble gases in the pool is negligible. These decontamination factors are valid if the pool water depth is at least 23 ft above the damaged fuel. A summary of the guidance provided by Regulatory Guide 1.25 (Reference 2.2.34 [DIRS 107691], pg. 25.2) is given in Table 7, which also shows the resulting leak path factors, which are equivalent to one over the decontamination factors, and the fractions released from the pool, which are equivalent to the release fractions times the leak path factors.

Table 7. Recommendations from Regulatory Guide 1.25

Group	Release Fraction (RF)	Decontamination Factor (DF)	Leak Path Factor (LPF) (1/DF)	Fraction Released from Pool (RF ×LPF)
Noble Gases (other than Kr-85)	0.1	1	1	0.1
Kr-85	0.3	1	1	0.3
Iodine	0.1	100	0.01	1.0×10^{-3}
Particulates	N/A	N/A	N/A	N/A

Source: Regulatory Guide 1.25 (Reference 2.2.34 [DIRS 107691], pg. 25.2)

The Nuclear Regulatory Commission's traditional methods for calculating the radiological consequences of design basis accidents are described in a series of regulatory guides and Standard Review Plan chapters, which were developed to be consistent with the TID-14844 (Reference 2.2.35 [DIRS 178858]) source terms and whole body and thyroid dose guidelines (Reference 2.2.36 [DIRS 166293], Section A). Since the publication of TID-14844 (Reference 2.2.35 [DIRS 178858]), significant advances have been made in understanding the timing, magnitude, and chemical form of fission product releases from severe nuclear power plant

accidents. In 1995, the NRC published NUREG-1465, *Accident Source Terms for Light-Water Nuclear Power Plants, Final Report* (Reference 2.2.37 [DIRS 169798]), referred to as alternative source terms. The total effective dose criteria (TEDE) are expected to be used with the alternative source terms and not with results calculated with TID-14844 source terms (Reference 2.2.36 [DIRS 166293], Section A).

Regulatory Guide 1.183, *Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors* (Reference 2.2.38 [DIRS 173584], Appendix B), provides criteria for evaluating a fuel handling accident when using the alternative source terms, and the total effective dose equivalent criteria.

Reference 2.2.38 ([DIRS 173584], Appendix B) states that, upon a fuel handling accident in a pool, all of the gap activity is instantaneously released into the fuel pool. The radionuclides that should be considered include xenons, kryptons, halogens, cesiums, and rubidiums. The chemical form of radioiodine released from the fuel to the spent fuel pool should be assumed to be 95% cesium iodide (CsI), 4.85% elemental iodine, and 0.15% organic iodide. The CsI released to the pool is assumed to completely and instantaneously dissociate in the pool water and re-evolve as elemental iodine. If the depth of water above the damaged fuel is 23 feet or greater, the decontamination factors for the elemental and organic species of are 500 and 1, respectively, giving an overall effective decontamination factor of 200, which means that 99.5% of the total iodine released from the damaged rods is retained by the water. This difference in decontamination factors for elemental (99.85%) and organic (0.15%) species results in the iodine above the water being composed of 57% elemental and 43% organic species. The retention of noble gases in the water is negligible (decontamination factor of 1). The pool water retains all particulate radionuclides.

These retention or decontamination factors given in Regulatory Guide 1.183 (Reference 2.2.38 [DIRS 173584], Appendix B) are applicable only when using the release fractions provided in Section 3 of the Regulatory Guide 1.183. A summary of the guidance provided by Regulatory Guide 1.183 (Reference 2.2.38 [DIRS 173584], Section 3 and Appendix B) is given in Table 8.

Table 8. Recommendations from Regulatory Guide 1.183

Group	Release Fraction (RF)	Decontamination Factor (DF)	Leak Path Factor (LPF) (1/DF)	Fraction Released from Pool (RF ×LPF)
I-131	0.08	200	0.005	4.0×10^{-4}
Kr-85	0.10	1	1	0.10
Other Noble Gases (Xe, Kr)	0.05	1	1	0.05
Other Halogens (I)	0.05	200	0.005	2.5×10^{-4}
Other Halogens (Br)	0.05	1*	1	0.05
Alkali Metals (Cs, Rb)	0.12	Infinite	0	0

NOTE: *Not specified, thus one (1) is used.
Source: Reference 2.2.38 ([DIRS 173584], Section 3 and Appendix B)

Since 10 CFR Part 63 (Reference 2.2.39 [DIRS 176544]) provides dose criteria in terms of TEDE, the guidance of Regulatory Guide 1.25 (Reference 2.2.34 [DIRS 107691]) shown in

Table 7, is not applicable. The guidance of Regulatory Guide 1.183 (Reference 2.2.38 [DIRS 173584], Section 3 and Appendix B) as shown in Table 8 is used since it provides criteria for evaluating a fuel handling accident when using the alternative source terms, and the total effective dose equivalent criteria.

7. RESULTS AND CONCLUSIONS

The following leak path factors are to be used in dose assessments.

7.1 HEPA FILTERS

A $(LPF)_{HEPA}$ of 0.01 per stage for particulate and cesium, which is equivalent to a HEPA removal efficiency of 99% per stage is to be used for normal operations and event sequences. For a two-stage HEPA filtration system, this gives a combined efficiency of 99.99% for two stages or a $(LPF)_{HEPA}$ of 10^{-4} when the series of HEPA filters is protected by pre-filters, sprinklers, and demisters. Refer to Section 6.1 for the discussion of the $(LPF)_{HEPA}$.

7.2 SPENT FUEL CLADDING

No LPF for fuel cladding is given in this calculation. Refer to Section 6.2 for further discussion.

7.3 TRANSPORTATION CASKS AND CANISTERS

It is recommended that a LPF of 0.1 be used for canisters, such as DPCs and TADs, and for transportation casks and waste packages. Refer to Section 6.3 for the rationale.

7.4 SPENT FUEL POOL

The leak path factors for the nuclides potentially released in the spent fuel pool are listed in Table 9. Refer to Section 6.4 for further discussion.

Table 9. Spent Fuel Pool Leak Path Factors

Group	Leak Path Factor (LPF)
I-131	0.005
Kr-85	1
Other Noble Gases (Xe, Kr)	1
Other Halogens (I)	0.005
Other Halogens (Br)	1
Alkali Metals (Cs, Rb)	0

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ATTACHMENT I.

SUTTER ET AL. LEAK PATH FACTOR TABLES

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Microsoft® EXCEL spreadsheet calculations have been performed using Equations (4) and (5) to calculate the mass and fraction of DUO leaked out of the test vessel for leak areas ranging from 0.01 mm to 10 mm and pressures at 0, 25, 50 and 100 psig. The fraction of DOU leaked out of the test vessel is the leak path factor for particulate. The leak path factor is calculated based on an initial DUO inventory of 3 kg. The parameters a, b_1, and b_2 are from Table 5. The calculation results are summarized in Tables I-1 through I-16.

Table I-1. Leak Path Factor for UPL Orifices at 0 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-10.2848	1.608	0.0449	0.01	7.85×10^{-05}	0	3.81×10^{-08}	1.27×10^{-11}
-10.2848	1.608	0.0449	0.03	7.07×10^{-04}	0	1.30×10^{-06}	4.34×10^{-10}
-10.2848	1.608	0.0449	0.05	1.96×10^{-03}	0	6.74×10^{-06}	2.25×10^{-09}
-10.2848	1.608	0.0449	0.07	3.85×10^{-03}	0	1.99×10^{-05}	6.63×10^{-09}
-10.2848	1.608	0.0449	0.1	7.85×10^{-03}	0	6.26×10^{-05}	2.09×10^{-08}
-10.2848	1.608	0.0449	0.25	4.91×10^{-02}	0	1.19×10^{-03}	3.97×10^{-07}
-10.2848	1.608	0.0449	0.3	7.07×10^{-02}	0	2.14×10^{-03}	7.14×10^{-07}
-10.2848	1.608	0.0449	0.5	1.96×10^{-01}	0	1.11×10^{-02}	3.69×10^{-06}
-10.2848	1.608	0.0449	0.7	3.85×10^{-01}	0	3.27×10^{-02}	1.09×10^{-05}
-10.2848	1.608	0.0449	1	7.85×10^{-01}	0	1.03×10^{-01}	3.43×10^{-05}
-10.2848	1.608	0.0449	1.129	$1.00 \times 10^{+00}$	0	1.52×10^{-01}	5.07×10^{-05}
-10.2848	1.608	0.0449	3.568	$1.00 \times 10^{+01}$	0	$6.16 \times 10^{+00}$	2.05×10^{-03}
-10.2848	1.608	0.0449	5	$1.96 \times 10^{+01}$	0	$1.82 \times 10^{+01}$	6.07×10^{-03}
-10.2848	1.608	0.0449	7	$3.85 \times 10^{+01}$	0	$5.38 \times 10^{+01}$	1.79×10^{-02}
-10.2848	1.608	0.0449	10	$7.85 \times 10^{+01}$	0	$1.69 \times 10^{+02}$	5.64×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-2. Leak Path Factor for UPL Orifices at 25 psig

a	b1	b2	D (mm)	A (mm2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-10.2848	1.608	0.0449	0.01	7.85×10^{-05}	25	4.77×10^{-08}	1.59×10^{-11}
-10.2848	1.608	0.0449	0.03	7.07×10^{-04}	25	1.63×10^{-06}	5.44×10^{-10}
-10.2848	1.608	0.0449	0.05	1.96×10^{-03}	25	8.43×10^{-06}	2.81×10^{-09}
-10.2848	1.608	0.0449	0.07	3.85×10^{-03}	25	2.49×10^{-05}	8.30×10^{-09}
-10.2848	1.608	0.0449	0.1	7.85×10^{-03}	25	7.84×10^{-05}	2.61×10^{-08}
-10.2848	1.608	0.0449	0.25	4.91×10^{-02}	25	1.49×10^{-03}	4.98×10^{-07}
-10.2848	1.608	0.0449	0.3	7.07×10^{-02}	25	2.68×10^{-03}	8.94×10^{-07}
-10.2848	1.608	0.0449	0.5	1.96×10^{-01}	25	1.39×10^{-02}	4.62×10^{-06}
-10.2848	1.608	0.0449	0.7	3.85×10^{-01}	25	4.09×10^{-02}	1.36×10^{-05}
-10.2848	1.608	0.0449	1	7.85×10^{-01}	25	1.29×10^{-01}	4.30×10^{-05}
-10.2848	1.608	0.0449	1.129	$1.00 \times 10^{+00}$	25	1.90×10^{-01}	6.35×10^{-05}
-10.2848	1.608	0.0449	3.568	$1.00 \times 10^{+01}$	25	$7.70 \times 10^{+00}$	2.57×10^{-03}
-10.2848	1.608	0.0449	5	$1.96 \times 10^{+01}$	25	$2.28 \times 10^{+01}$	7.60×10^{-03}
-10.2848	1.608	0.0449	7	$3.85 \times 10^{+01}$	25	$6.73 \times 10^{+01}$	2.24×10^{-02}
-10.2848	1.608	0.0449	10	$7.85 \times 10^{+01}$	25	$2.12 \times 10^{+02}$	7.06×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-3. Leak Path Factor for UPL Orifices at 50 psig

a	b1	b2	D (mm)	A (mm2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-10.2848	1.608	0.0449	0.01	7.85×10^{-05}	50	5.23×10^{-08}	1.74×10^{-11}
-10.2848	1.608	0.0449	0.03	7.07×10^{-04}	50	1.79×10^{-06}	5.97×10^{-10}
-10.2848	1.608	0.0449	0.05	1.96×10^{-03}	50	9.26×10^{-06}	3.09×10^{-09}
-10.2848	1.608	0.0449	0.07	3.85×10^{-03}	50	2.73×10^{-05}	9.10×10^{-09}
-10.2848	1.608	0.0449	0.1	7.85×10^{-03}	50	8.60×10^{-05}	2.87×10^{-08}
-10.2848	1.608	0.0449	0.25	4.91×10^{-02}	50	1.64×10^{-03}	5.46×10^{-07}
-10.2848	1.608	0.0449	0.3	7.07×10^{-02}	50	2.94×10^{-03}	9.81×10^{-07}
-10.2848	1.608	0.0449	0.5	1.96×10^{-01}	50	1.52×10^{-02}	5.07×10^{-06}
-10.2848	1.608	0.0449	0.7	3.85×10^{-01}	50	4.49×10^{-02}	1.50×10^{-05}
-10.2848	1.608	0.0449	1	7.85×10^{-01}	50	1.41×10^{-01}	4.71×10^{-05}
-10.2848	1.608	0.0449	1.129	$1.00 \times 10^{+00}$	50	2.09×10^{-01}	6.96×10^{-05}
-10.2848	1.608	0.0449	3.568	$1.00 \times 10^{+01}$	50	$8.46 \times 10^{+00}$	2.82×10^{-03}
-10.2848	1.608	0.0449	5	$1.96 \times 10^{+01}$	50	$2.50 \times 10^{+01}$	8.34×10^{-03}
-10.2848	1.608	0.0449	7	$3.85 \times 10^{+01}$	50	$7.39 \times 10^{+01}$	2.46×10^{-02}
-10.2848	1.608	0.0449	10	$7.85 \times 10^{+01}$	50	$2.33 \times 10^{+02}$	7.75×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-4. Leak Path Factor for UPL Orifices at 100 psig

a	b1	b2	D (mm)	A (mm2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-10.2848	1.608	0.0449	0.01	7.85×10^{-05}	100	5.97×10^{-08}	1.99×10^{-11}
-10.2848	1.608	0.0449	0.03	7.07×10^{-04}	100	2.04×10^{-06}	6.81×10^{-10}
-10.2848	1.608	0.0449	0.05	1.96×10^{-03}	100	1.06×10^{-05}	3.52×10^{-09}
-10.2848	1.608	0.0449	0.07	3.85×10^{-03}	100	3.12×10^{-05}	1.04×10^{-08}
-10.2848	1.608	0.0449	0.1	7.85×10^{-03}	100	9.81×10^{-05}	3.27×10^{-08}
-10.2848	1.608	0.0449	0.25	4.91×10^{-02}	100	1.87×10^{-03}	6.23×10^{-07}
-10.2848	1.608	0.0449	0.3	7.07×10^{-02}	100	3.36×10^{-03}	1.12×10^{-06}
-10.2848	1.608	0.0449	0.5	1.96×10^{-01}	100	1.74×10^{-02}	5.79×10^{-06}
-10.2848	1.608	0.0449	0.7	3.85×10^{-01}	100	5.12×10^{-02}	1.71×10^{-05}
-10.2848	1.608	0.0449	1	7.85×10^{-01}	100	1.61×10^{-01}	5.38×10^{-05}
-10.2848	1.608	0.0449	1.129	$1.00 \times 10^{+00}$	100	2.38×10^{-01}	7.94×10^{-05}
-10.2848	1.608	0.0449	3.568	$1.00 \times 10^{+01}$	100	$9.64 \times 10^{+00}$	3.21×10^{-03}
-10.2848	1.608	0.0449	5	$1.96 \times 10^{+01}$	100	$2.85 \times 10^{+01}$	9.52×10^{-03}
-10.2848	1.608	0.0449	7	$3.85 \times 10^{+01}$	100	$8.42 \times 10^{+01}$	2.81×10^{-02}
-10.2848	1.608	0.0449	10	$7.85 \times 10^{+01}$	100	$2.65 \times 10^{+02}$	8.84×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-5. Leak Path Factor for APLA Orifices at 0 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-14.1959	1.7906	0.1095	0.01	7.85×10^{-05}	0	1.69×10^{-09}	5.64×10^{-13}
-14.1959	1.7906	0.1095	0.03	7.07×10^{-04}	0	8.65×10^{-08}	2.88×10^{-11}
-14.1959	1.7906	0.1095	0.05	1.96×10^{-03}	0	5.39×10^{-07}	1.80×10^{-10}
-14.1959	1.7906	0.1095	0.07	3.85×10^{-03}	0	1.80×10^{-06}	5.99×10^{-10}
-14.1959	1.7906	0.1095	0.1	7.85×10^{-03}	0	6.45×10^{-06}	2.15×10^{-09}
-14.1959	1.7906	0.1095	0.25	4.91×10^{-02}	0	1.72×10^{-04}	5.72×10^{-08}
-14.1959	1.7906	0.1095	0.3	7.07×10^{-02}	0	3.30×10^{-04}	1.10×10^{-07}
-14.1959	1.7906	0.1095	0.5	1.96×10^{-01}	0	2.05×10^{-03}	6.85×10^{-07}
-14.1959	1.7906	0.1095	0.7	3.85×10^{-01}	0	6.85×10^{-03}	2.28×10^{-06}
-14.1959	1.7906	0.1095	1	7.85×10^{-01}	0	2.46×10^{-02}	8.19×10^{-06}
-14.1959	1.7906	0.1095	1.129	$1.00 \times 10^{+00}$	0	3.80×10^{-02}	1.27×10^{-05}
-14.1959	1.7906	0.1095	3.568	$1.00 \times 10^{+01}$	0	$2.34 \times 10^{+00}$	7.79×10^{-04}
-14.1959	1.7906	0.1095	5	$1.96 \times 10^{+01}$	0	$7.83 \times 10^{+00}$	2.61×10^{-03}
-14.1959	1.7906	0.1095	7	$3.85 \times 10^{+01}$	0	$2.61 \times 10^{+01}$	8.71×10^{-03}
-14.1959	1.7906	0.1095	10	$7.85 \times 10^{+01}$	0	$9.37 \times 10^{+01}$	3.12×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-6. Leak Path Factor for APLA Orifices at 25 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-14.1959	1.7906	0.1095	0.01	7.85×10^{-05}	25	2.92×10^{-09}	9.75×10^{-13}
-14.1959	1.7906	0.1095	0.03	7.07×10^{-04}	25	1.49×10^{-07}	4.98×10^{-11}
-14.1959	1.7906	0.1095	0.05	1.96×10^{-03}	25	9.31×10^{-07}	3.10×10^{-10}
-14.1959	1.7906	0.1095	0.07	3.85×10^{-03}	25	3.11×10^{-06}	1.04×10^{-09}
-14.1959	1.7906	0.1095	0.1	7.85×10^{-03}	25	1.11×10^{-05}	3.72×10^{-09}
-14.1959	1.7906	0.1095	0.25	4.91×10^{-02}	25	2.97×10^{-04}	9.89×10^{-08}
-14.1959	1.7906	0.1095	0.3	7.07×10^{-02}	25	5.70×10^{-04}	1.90×10^{-07}
-14.1959	1.7906	0.1095	0.5	1.96×10^{-01}	25	3.55×10^{-03}	1.18×10^{-06}
-14.1959	1.7906	0.1095	0.7	3.85×10^{-01}	25	1.18×10^{-02}	3.95×10^{-06}
-14.1959	1.7906	0.1095	1	7.85×10^{-01}	25	4.25×10^{-02}	1.42×10^{-05}
-14.1959	1.7906	0.1095	1.129	$1.00 \times 10^{+00}$	25	6.56×10^{-02}	2.19×10^{-05}
-14.1959	1.7906	0.1095	3.568	$1.00 \times 10^{+01}$	25	$4.04 \times 10^{+00}$	1.35×10^{-03}
-14.1959	1.7906	0.1095	5	$1.96 \times 10^{+01}$	25	$1.35 \times 10^{+01}$	4.51×10^{-03}
-14.1959	1.7906	0.1095	7	$3.85 \times 10^{+01}$	25	$4.52 \times 10^{+01}$	1.51×10^{-02}
-14.1959	1.7906	0.1095	10	$7.85 \times 10^{+01}$	25	$1.62 \times 10^{+02}$	5.40×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-7. Leak Path Factor for APLA Orifices at 50 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-14.1959	1.7906	0.1095	0.01	7.85×10^{-05}	50	3.67×10^{-09}	1.22×10^{-12}
-14.1959	1.7906	0.1095	0.03	7.07×10^{-04}	50	1.88×10^{-07}	6.25×10^{-11}
-14.1959	1.7906	0.1095	0.05	1.96×10^{-03}	50	1.17×10^{-06}	3.89×10^{-10}
-14.1959	1.7906	0.1095	0.07	3.85×10^{-03}	50	3.90×10^{-06}	1.30×10^{-09}
-14.1959	1.7906	0.1095	0.1	7.85×10^{-03}	50	1.40×10^{-05}	4.66×10^{-09}
-14.1959	1.7906	0.1095	0.25	4.91×10^{-02}	50	3.72×10^{-04}	1.24×10^{-07}
-14.1959	1.7906	0.1095	0.3	7.07×10^{-02}	50	7.15×10^{-04}	2.38×10^{-07}
-14.1959	1.7906	0.1095	0.5	1.96×10^{-01}	50	4.45×10^{-03}	1.48×10^{-06}
-14.1959	1.7906	0.1095	0.7	3.85×10^{-01}	50	1.49×10^{-02}	4.95×10^{-06}
-14.1959	1.7906	0.1095	1	7.85×10^{-01}	50	5.33×10^{-02}	1.78×10^{-05}
-14.1959	1.7906	0.1095	1.129	$1.00 \times 10^{+00}$	50	8.23×10^{-02}	2.74×10^{-05}
-14.1959	1.7906	0.1095	3.568	$1.00 \times 10^{+01}$	50	$5.07 \times 10^{+00}$	1.69×10^{-03}
-14.1959	1.7906	0.1095	5	$1.96 \times 10^{+01}$	50	$1.70 \times 10^{+01}$	5.66×10^{-03}
-14.1959	1.7906	0.1095	7	$3.85 \times 10^{+01}$	50	$5.67 \times 10^{+01}$	1.89×10^{-02}
-14.1959	1.7906	0.1095	10	$7.85 \times 10^{+01}$	50	$2.03 \times 10^{+02}$	6.77×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-8. Leak Path Factor for APLA Orifices at 100 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-14.1959	1.7906	0.1095	0.01	7.85×10^{-05}	100	5.05×10^{-09}	1.68×10^{-12}
-14.1959	1.7906	0.1095	0.03	7.07×10^{-04}	100	2.58×10^{-07}	8.61×10^{-11}
-14.1959	1.7906	0.1095	0.05	1.96×10^{-03}	100	1.61×10^{-06}	5.37×10^{-10}
-14.1959	1.7906	0.1095	0.07	3.85×10^{-03}	100	5.37×10^{-06}	1.79×10^{-09}
-14.1959	1.7906	0.1095	0.1	7.85×10^{-03}	100	1.93×10^{-05}	6.42×10^{-09}
-14.1959	1.7906	0.1095	0.25	4.91×10^{-02}	100	5.13×10^{-04}	1.71×10^{-07}
-14.1959	1.7906	0.1095	0.3	7.07×10^{-02}	100	9.85×10^{-04}	3.28×10^{-07}
-14.1959	1.7906	0.1095	0.5	1.96×10^{-01}	100	6.14×10^{-03}	2.05×10^{-06}
-14.1959	1.7906	0.1095	0.7	3.85×10^{-01}	100	2.05×10^{-02}	6.83×10^{-06}
-14.1959	1.7906	0.1095	1	7.85×10^{-01}	100	7.35×10^{-02}	2.45×10^{-05}
-14.1959	1.7906	0.1095	1.129	$1.00 \times 10^{+00}$	100	1.13×10^{-01}	3.78×10^{-05}
-14.1959	1.7906	0.1095	3.568	$1.00 \times 10^{+01}$	100	$6.99 \times 10^{+00}$	2.33×10^{-03}
-14.1959	1.7906	0.1095	5	$1.96 \times 10^{+01}$	100	$2.34 \times 10^{+01}$	7.80×10^{-03}
-14.1959	1.7906	0.1095	7	$3.85 \times 10^{+01}$	100	$7.81 \times 10^{+01}$	2.60×10^{-02}
-14.1959	1.7906	0.1095	10	$7.85 \times 10^{+01}$	100	$2.80 \times 10^{+02}$	9.34×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-9. Leak Path Factor for Capillaries at 0 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-17.9875	2.1658	0.117	0.01	7.85×10^{-05}	0	1.96×10^{-10}	6.54×10^{-14}
-17.9875	2.1658	0.117	0.03	7.07×10^{-04}	0	2.29×10^{-08}	7.62×10^{-12}
-17.9875	2.1658	0.117	0.05	1.96×10^{-03}	0	2.09×10^{-07}	6.97×10^{-11}
-17.9875	2.1658	0.117	0.07	3.85×10^{-03}	0	8.98×10^{-07}	2.99×10^{-10}
-17.9875	2.1658	0.117	0.1	7.85×10^{-03}	0	4.21×10^{-06}	1.40×10^{-09}
-17.9875	2.1658	0.117	0.25	4.91×10^{-02}	0	2.23×10^{-04}	7.43×10^{-08}
-17.9875	2.1658	0.117	0.3	7.07×10^{-02}	0	4.91×10^{-04}	1.64×10^{-07}
-17.9875	2.1658	0.117	0.5	1.96×10^{-01}	0	4.49×10^{-03}	1.50×10^{-06}
-17.9875	2.1658	0.117	0.7	3.85×10^{-01}	0	1.93×10^{-02}	6.42×10^{-06}
-17.9875	2.1658	0.117	1	7.85×10^{-01}	0	9.03×10^{-02}	3.01×10^{-05}
-17.9875	2.1658	0.117	1.129	$1.00 \times 10^{+00}$	0	1.53×10^{-01}	5.09×10^{-05}
-17.9875	2.1658	0.117	3.568	$1.00 \times 10^{+01}$	0	$2.23 \times 10^{+01}$	7.44×10^{-03}
-17.9875	2.1658	0.117	5	$1.96 \times 10^{+01}$	0	$9.62 \times 10^{+01}$	3.21×10^{-02}
-17.9875	2.1658	0.117	7	$3.85 \times 10^{+01}$	0	$4.13 \times 10^{+02}$	1.38×10^{-01}
-17.9875	2.1658	0.117	10	$7.85 \times 10^{+01}$	0	$1.94 \times 10^{+03}$	6.46×10^{-01}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-10. Leak Path Factor for Capillaries at 25 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-17.9875	2.1658	0.117	0.01	7.85×10^{-05}	25	3.52×10^{-10}	1.17×10^{-13}
-17.9875	2.1658	0.117	0.03	7.07×10^{-04}	25	4.10×10^{-08}	1.37×10^{-11}
-17.9875	2.1658	0.117	0.05	1.96×10^{-03}	25	3.75×10^{-07}	1.25×10^{-10}
-17.9875	2.1658	0.117	0.07	3.85×10^{-03}	25	1.61×10^{-06}	5.37×10^{-10}
-17.9875	2.1658	0.117	0.1	7.85×10^{-03}	25	7.55×10^{-06}	2.52×10^{-09}
-17.9875	2.1658	0.117	0.25	4.91×10^{-02}	25	4.00×10^{-04}	1.33×10^{-07}
-17.9875	2.1658	0.117	0.3	7.07×10^{-02}	25	8.81×10^{-04}	2.94×10^{-07}
-17.9875	2.1658	0.117	0.5	1.96×10^{-01}	25	8.05×10^{-03}	2.68×10^{-06}
-17.9875	2.1658	0.117	0.7	3.85×10^{-01}	25	3.46×10^{-02}	1.15×10^{-05}
-17.9875	2.1658	0.117	1	7.85×10^{-01}	25	1.62×10^{-01}	5.40×10^{-05}
-17.9875	2.1658	0.117	1.129	$1.00 \times 10^{+00}$	25	2.74×10^{-01}	9.14×10^{-05}
-17.9875	2.1658	0.117	3.568	$1.00 \times 10^{+01}$	25	$4.01 \times 10^{+01}$	1.34×10^{-02}
-17.9875	2.1658	0.117	5	$1.96 \times 10^{+01}$	25	$1.73 \times 10^{+02}$	5.76×10^{-02}
-17.9875	2.1658	0.117	7	$3.85 \times 10^{+01}$	25	$7.42 \times 10^{+02}$	2.47×10^{-01}
-17.9875	2.1658	0.117	10	$7.85 \times 10^{+01}$	25	$3.48 \times 10^{+03}$	Not Calculated

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-11. Leak Path Factor for Capillaries at 50 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-17.9875	2.1658	0.117	0.01	7.85×10^{-05}	50	4.49×10^{-10}	1.50×10^{-13}
-17.9875	2.1658	0.117	0.03	7.07×10^{-04}	50	5.23×10^{-08}	1.74×10^{-11}
-17.9875	2.1658	0.117	0.05	1.96×10^{-03}	50	4.78×10^{-07}	1.59×10^{-10}
-17.9875	2.1658	0.117	0.07	3.85×10^{-03}	50	2.05×10^{-06}	6.84×10^{-10}
-17.9875	2.1658	0.117	0.1	7.85×10^{-03}	50	9.63×10^{-06}	3.21×10^{-09}
-17.9875	2.1658	0.117	0.25	4.91×10^{-02}	50	5.09×10^{-04}	1.70×10^{-07}
-17.9875	2.1658	0.117	0.3	7.07×10^{-02}	50	1.12×10^{-03}	3.74×10^{-07}
-17.9875	2.1658	0.117	0.5	1.96×10^{-01}	50	1.03×10^{-02}	3.42×10^{-06}
-17.9875	2.1658	0.117	0.7	3.85×10^{-01}	50	4.41×10^{-02}	1.47×10^{-05}
-17.9875	2.1658	0.117	1	7.85×10^{-01}	50	2.07×10^{-01}	6.88×10^{-05}
-17.9875	2.1658	0.117	1.129	$1.00 \times 10^{+00}$	50	3.49×10^{-01}	1.16×10^{-04}
-17.9875	2.1658	0.117	3.568	$1.00 \times 10^{+01}$	50	$5.10 \times 10^{+01}$	1.70×10^{-02}
-17.9875	2.1658	0.117	5	$1.96 \times 10^{+01}$	50	$2.20 \times 10^{+02}$	7.34×10^{-02}
-17.9875	2.1658	0.117	7	$3.85 \times 10^{+01}$	50	$9.45 \times 10^{+02}$	3.15×10^{-01}
-17.9875	2.1658	0.117	10	$7.85 \times 10^{+01}$	50	$4.43 \times 10^{+03}$	Not Calculated

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-12. Leak Path Factor for Capillaries at 100 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-17.9875	2.1658	0.117	0.01	7.85×10^{-05}	100	6.32×10^{-10}	2.11×10^{-13}
-17.9875	2.1658	0.117	0.03	7.07×10^{-04}	100	7.37×10^{-08}	2.46×10^{-11}
-17.9875	2.1658	0.117	0.05	1.96×10^{-03}	100	6.73×10^{-07}	2.24×10^{-10}
-17.9875	2.1658	0.117	0.07	3.85×10^{-03}	100	2.89×10^{-06}	9.64×10^{-10}
-17.9875	2.1658	0.117	0.1	7.85×10^{-03}	100	1.36×10^{-05}	4.52×10^{-09}
-17.9875	2.1658	0.117	0.25	4.91×10^{-02}	100	7.18×10^{-04}	2.39×10^{-07}
-17.9875	2.1658	0.117	0.3	7.07×10^{-02}	100	1.58×10^{-03}	5.27×10^{-07}
-17.9875	2.1658	0.117	0.5	1.96×10^{-01}	100	1.45×10^{-02}	4.82×10^{-06}
-17.9875	2.1658	0.117	0.7	3.85×10^{-01}	100	6.21×10^{-02}	2.07×10^{-05}
-17.9875	2.1658	0.117	1	7.85×10^{-01}	100	2.91×10^{-01}	9.70×10^{-05}
-17.9875	2.1658	0.117	1.129	$1.00 \times 10^{+00}$	100	4.92×10^{-01}	1.64×10^{-04}
-17.9875	2.1658	0.117	3.568	$1.00 \times 10^{+01}$	100	$7.19 \times 10^{+01}$	2.40×10^{-02}
-17.9875	2.1658	0.117	5	$1.96 \times 10^{+01}$	100	$3.10 \times 10^{+02}$	1.03×10^{-01}
-17.9875	2.1658	0.117	7	$3.85 \times 10^{+01}$	100	$1.33 \times 10^{+03}$	4.44×10^{-01}
-17.9875	2.1658	0.117	10	$7.85 \times 10^{+01}$	100	$6.24 \times 10^{+03}$	Not Calculated

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-13. Leak Path Factor for Unspecified Configuration at 0 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-14.279	1.828	0.1052	0.01	7.85×10^{-05}	0	1.83×10^{-09}	6.11×10^{-13}
-14.279	1.828	0.1052	0.03	7.07×10^{-04}	0	1.02×10^{-07}	3.39×10^{-11}
-14.279	1.828	0.1052	0.05	1.96×10^{-03}	0	6.58×10^{-07}	2.19×10^{-10}
-14.279	1.828	0.1052	0.07	3.85×10^{-03}	0	2.25×10^{-06}	7.51×10^{-10}
-14.279	1.828	0.1052	0.1	7.85×10^{-03}	0	8.30×10^{-06}	2.77×10^{-09}
-14.279	1.828	0.1052	0.25	4.91×10^{-02}	0	2.36×10^{-04}	7.88×10^{-08}
-14.279	1.828	0.1052	0.3	7.07×10^{-02}	0	4.61×10^{-04}	1.54×10^{-07}
-14.279	1.828	0.1052	0.5	1.96×10^{-01}	0	2.98×10^{-03}	9.94×10^{-07}
-14.279	1.828	0.1052	0.7	3.85×10^{-01}	0	1.02×10^{-02}	3.40×10^{-06}
-14.279	1.828	0.1052	1	7.85×10^{-01}	0	3.76×10^{-02}	1.25×10^{-05}
-14.279	1.828	0.1052	1.129	$1.00 \times 10^{+00}$	0	5.86×10^{-02}	1.95×10^{-05}
-14.279	1.828	0.1052	3.568	$1.00 \times 10^{+01}$	0	$3.93 \times 10^{+00}$	1.31×10^{-03}
-14.279	1.828	0.1052	5	$1.96 \times 10^{+01}$	0	$1.35 \times 10^{+01}$	4.50×10^{-03}
-14.279	1.828	0.1052	7	$3.85 \times 10^{+01}$	0	$4.62 \times 10^{+01}$	1.54×10^{-02}
-14.279	1.828	0.1052	10	$7.85 \times 10^{+01}$	0	$1.70 \times 10^{+02}$	5.67×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-14: Leak Path Factor for Unspecified Configuration at 25 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-14.279	1.828	0.1052	0.01	7.85×10^{-05}	25	3.10×10^{-09}	1.03×10^{-12}
-14.279	1.828	0.1052	0.03	7.07×10^{-04}	25	1.72×10^{-07}	5.74×10^{-11}
-14.279	1.828	0.1052	0.05	1.96×10^{-03}	25	1.11×10^{-06}	3.71×10^{-10}
-14.279	1.828	0.1052	0.07	3.85×10^{-03}	25	3.81×10^{-06}	1.27×10^{-09}
-14.279	1.828	0.1052	0.1	7.85×10^{-03}	25	1.40×10^{-05}	4.68×10^{-09}
-14.279	1.828	0.1052	0.25	4.91×10^{-02}	25	4.00×10^{-04}	1.33×10^{-07}
-14.279	1.828	0.1052	0.3	7.07×10^{-02}	25	7.79×10^{-04}	2.60×10^{-07}
-14.279	1.828	0.1052	0.5	1.96×10^{-01}	25	5.04×10^{-03}	1.68×10^{-06}
-14.279	1.828	0.1052	0.7	3.85×10^{-01}	25	1.73×10^{-02}	5.75×10^{-06}
-14.279	1.828	0.1052	1	7.85×10^{-01}	25	6.36×10^{-02}	2.12×10^{-05}
-14.279	1.828	0.1052	1.129	$1.00 \times 10^{+00}$	25	9.91×10^{-02}	3.30×10^{-05}
-14.279	1.828	0.1052	3.568	$1.00 \times 10^{+01}$	25	$6.65 \times 10^{+00}$	2.22×10^{-03}
-14.279	1.828	0.1052	5	$1.96 \times 10^{+01}$	25	$2.28 \times 10^{+01}$	$7.6 2 \times 10^{-03}$
-14.279	1.828	0.1052	7	$3.85 \times 10^{+01}$	25	$7.82 \times 10^{+01}$	2.61×10^{-02}
-14.279	1.828	0.1052	10	$7.85 \times 10^{+01}$	25	$2.88 \times 10^{+02}$	9.60×10^{-02}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-15: Leak Path Factor for Unspecified Configuration at 50 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-14.279	1.828	0.1052	0.01	7.85×10^{-05}	50	3.85×10^{-09}	1.28×10^{-12}
-14.279	1.828	0.1052	0.03	7.07×10^{-04}	50	2.14×10^{-07}	7.13×10^{-11}
-14.279	1.828	0.1052	0.05	1.96×10^{-03}	50	1.38×10^{-06}	4.62×10^{-10}
-14.279	1.828	0.1052	0.07	3.85×10^{-03}	50	4.74×10^{-06}	1.58×10^{-09}
-14.279	1.828	0.1052	0.1	7.85×10^{-03}	50	1.75×10^{-05}	5.82×10^{-09}
-14.279	1.828	0.1052	0.25	4.91×10^{-02}	50	4.98×10^{-04}	1.66×10^{-07}
-14.279	1.828	0.1052	0.3	7.07×10^{-02}	50	9.69×10^{-04}	3.23×10^{-07}
-14.279	1.828	0.1052	0.5	1.96×10^{-01}	50	6.27×10^{-03}	2.09×10^{-06}
-14.279	1.828	0.1052	0.7	3.85×10^{-01}	50	2.15×10^{-02}	7.15×10^{-06}
-14.279	1.828	0.1052	1	7.85×10^{-01}	50	7.91×10^{-02}	2.64×10^{-05}
-14.279	1.828	0.1052	1.129	$1.00 \times 10^{+00}$	50	1.23×10^{-01}	4.11×10^{-05}
-14.279	1.828	0.1052	3.568	$1.00 \times 10^{+01}$	50	$8.27 \times 10^{+00}$	2.76×10^{-03}
-14.279	1.828	0.1052	5	$1.96 \times 10^{+01}$	50	$2.84 \times 10^{+01}$	9.47×10^{-03}
-14.279	1.828	0.1052	7	$3.85 \times 10^{+01}$	50	$9.72 \times 10^{+01}$	3.24×10^{-02}
-14.279	1.828	0.1052	10	$7.85 \times 10^{+01}$	50	$3.58 \times 10^{+02}$	1.19×10^{-01}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

Table I-16: Leak Path Factor for Unspecified Configuration at 100 psig

a	b_1	b_2	D (mm)	A (mm^2)	P (psig)	Amount Leaked (g)	Leak Path Factor
-14.279	1.828	0.1052	0.01	7.85×10^{-05}	100	5.25×10^{-09}	1.75×10^{-12}
-14.279	1.828	0.1052	0.03	7.07×10^{-04}	100	2.91×10^{-07}	9.71×10^{-11}
-14.279	1.828	0.1052	0.05	1.96×10^{-03}	100	1.88×10^{-06}	6.28×10^{-10}
-14.279	1.828	0.1052	0.07	3.85×10^{-03}	100	6.45×10^{-06}	2.15×10^{-09}
-14.279	1.828	0.1052	0.1	7.85×10^{-03}	100	2.38×10^{-05}	7.92×10^{-09}
-14.279	1.828	0.1052	0.25	4.91×10^{-02}	100	6.77×10^{-04}	2.26×10^{-07}
-14.279	1.828	0.1052	0.3	7.07×10^{-02}	100	1.32×10^{-03}	4.40×10^{-07}
-14.279	1.828	0.1052	0.5	1.96×10^{-01}	100	8.54×10^{-03}	2.85×10^{-06}
-14.279	1.828	0.1052	0.7	3.85×10^{-01}	100	2.92×10^{-02}	9.74×10^{-06}
-14.279	1.828	0.1052	1	7.85×10^{-01}	100	1.08×10^{-01}	3.59×10^{-05}
-14.279	1.828	0.1052	1.129	$1.00 \times 10^{+00}$	100	1.68×10^{-01}	5.59×10^{-05}
-14.279	1.828	0.1052	3.568	$1.00 \times 10^{+01}$	100	$1.13\ 10^{+01}$	3.75×10^{-03}
-14.279	1.828	0.1052	5	$1.96 \times 10^{+01}$	100	$3.87 \times 10^{+01}$	1.29×10^{-02}
-14.279	1.828	0.1052	7	$3.85 \times 10^{+01}$	100	$1.32 \times 10^{+02}$	4.41×10^{-02}
-14.279	1.828	0.1052	10	$7.85 \times 10^{+01}$	100	$4.87 \times 10^{+02}$	1.62×10^{-01}

NOTE: A=area, D=diameter, P=pressure, UPL=Upper Powder Leak

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WVMP SAR Reference 4-9

Material Receiving Inspection and Release (MRIR) Report #04-1152, West Valley Nuclear Services Company, West Valley, New York, October 15, 2004.

Material Receiving Inspection and Release

MRIR # 04-1152

Page 1 of 1

Purchase Order/Credit Card 19-104320	Material Description: West Valley Melter Container
Supplier WMG, inc.	
Drawing Spec No: 4005-DW-001, shts 1-8. Rev No rev 4	
Requisitioner: T J. Jones	QAR: Robert Czyzewski

Inspection Requirements	Requirements Met Yes	No
1. Material does not show any shipping damage.	X	
2. Material received is as specified on purchase order. Including gaskets (Items 8 and 9 on Bill of Materials)	X	
3. No suspect/counterfeit parts are used. (A193-B7 w/washers specified as Item #6 on Bill of Materials)	X	
4. Documentation Package Received.	X	
5. Certificate of Conformance Received and acceptable.	X	
6. Package marked with the following: - USA - TYPE-IP2	X	

CF No. N/A	Inspected By/Date: Paula Ciszak 10/15/04

Comments N/A

Distribution: Requisitioner

QA Purchase Order File

Warehouse (Purchasing, General Accounting)

QA DCC (Original)

ORIGINAL

WVMP SAR Reference 5-5

Characterization of DWPF Melter One Glasses, WSRC-TR-2003-00477, Rev 0, Cozzi, A.D. and Pareizs, J.M., Westinghouse Savannah River Company, Aiken, South Carolina, October 2003.

2432955

WSRC-TR-2003-00477

Characterization of DWPF Melter One Glasses

by

A. D. Cozzi

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

J. M. Pareizs

DOE Contract No. **DE-AC09-96SR18500**

WSRC-TR-2003-00477
October 16, 2003

Characterization of DWPF Melter One Glasses

A.D. Cozzi
J.M. Pareizs

Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, SC 29808

SAVANNAH RIVER SITE

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC09-96SR18500

DISCLAIMER

Immobilization Technology Section
Savannah River Technology Center
Westinghouse Savannah River Company

WSRC-TR-2003-00477
Rev. 0

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Savannah River Technology Center
Aiken, SC 29808

SAVANNAH RIVER SITE

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC09-96SR18500

Author: A.D. Cozzi	**Signature:**	**Organization:** ITS	**Date:** 10/20/03
Author: J.M. Pareizs	**Signature:**	**Organization:** ITS	**Date:** 10/21/03
Technical Reviewer: N.E. Bibler	**Signature:**	**Organization:** ITS	**Date:** 10/21/03
Technical Reviewer: D.K. Peeler	**Signature:**	**Organization:** ITS	**Date:** 10/21/03
Level 3 Manager: E.W. Holtzscheiter	**Signature:**	**Organization:** ITS	**Date:** 10/22/03
Level 4 Manager: S.L. Marra	**Signature:**	**Organization:** ITS	**Date:** 10/22/03
Customer: J.E. Occhipinti	**Signature:**	**Organization:** DWPF-Eng	**Date:** 10-29-03

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Executive Summary

The Defense Waste Processing Facility's (DWPF) first melter operated continuously for more than eight years. In November 2002 it was decided to replace the melter. As part of the decommissioning and replacement of the first DWPF melter, three samples were collected from the melter, one from the melter surface and two from the core sampler. The melter samples were analyzed for chemical composition and crystal content.

The interface layer glass appeared as a typical pour stream. The surface was dark and reflective with no obvious inclusions. Little information could be obtained from visual observation of the core glasses. The surfaces were coarse from the sample sectioning.

The materials and methods used to sample to melter core influenced the analytical results. The stainless steel sampler contributed measurable amounts of chromium to the samples. The retrieval of the samples after the melter had cooled permitted the core glasses to crystallize extensively. The crystalline species were consistent with long slow cooling.

The consistency of the compositions throughout the melter, from the interface layer to the two melt pool samples to a previously collected pour stream sample, indicate that there is no measurable stratification of actinides or noble metals.

CSEM/EDS analysis of the core samples suggest that the smooth areas are glass, the inclusions are predominantly iron/silicon compounds and that some of the debris on the surface is alumina from the sectioning blade. CRXD analysis identified the inclusions as aegirine (acmite). CSEM analysis of the interface layer did not reveal any appearance other than glass. CXRD analysis confirmed the amorphous state of the interface layer.

Introduction

The Defense Waste Processing Facility's (DWPF) first melter operated continuously for more than eight years, including six years of radioactive operations – more than three times its design life. It produced more than 1,300 waste glass canisters, about 27 percent of the projected total canisters for DWPF. In November 2002 it was decided to replace the melter. Prior to melter shutdown, one sample was taken and a sampler was put in place to retrieve additional samples from the melt pool.

SRTC delivered four samplers to DWPF to collect samples. Two samplers were designed to remove a surface sample from the melt pool while the other two samplers were designed to remove core samples to provide a cross section of the melt pool.

As part of the decommissioning and replacement of the first DWPF melter, three samples were collected from the melter, one from the melter surface and two from the core sampler. The melter samples were analyzed for chemical composition and crystal content.

Objective

The objective of this task is to inspect, characterize and evaluate glass samples from the melter surface and the melt pool. The interface layer was sampled to provide data to aid in the identification and cause of the layer[1]. Two samples of the melt pool were obtained from two depths in the melter. Two depths were chosen to compare relative concentrations of noble metal and actinides to evaluate

concerns regarding settling of denser species. It should be recognized as the melt pool samples cooled in the melter, no definite conclusions could be drawn from the amount of crystalline species present.

Discussion

Sample Collection

Interface Layer

A platinum boat sampler was used to sample of the interface layer from the surface of the glass pool that remained after the cold cap was burned off (prior to melter shutdown). The interface layer sample was taken through the north feed tube nozzle, approximately two feet north of melter center. The sampler was lowered into the melter by the crane until it just broke the surface and filled with glass. It was then lifted out and allowed to cool. The interface sample was removed from the boat using the extractor provided by DWPF Engineering. Slightly more than 45 grams of sample were retrieved from the platinum boat. It is believed that a representative sample of the surface layer was obtained during the sampling.

Core Samples

Two samples from the core of the melt pool were obtained from different heights in the melter. The core samples were also obtained through the north feed tube. After glass draw-down via the pour spout was completed, leaving approximately 16 inches of glass in the melter, the stainless steel core sample tube was slowly lowered into the pool till it hit bottom. It was then left in place during melter cooldown. Figure 1 shows the average cooling schedule of the upper and lower thermocouples. It is assumed that the core samples experienced a cooling curve bounded by the two curves in Figure 1. The melter cooled over several days[2], Figure 1. Upon retrieval, the bottom of the sampler broke off and remained in the melter, discontinuing the attempt to sample the very bottom of the glass pool. The remaining sampler was sectioned with a predominantly aluminum oxide saw to retrieve the "upper" and "lower" core samples. DWPF-Engineering estimated that the lower sample was four to six inches above the melter bottom and the upper sample was ten" to fifteen inches above the bottom. An effort was made to retrieve glass from the interior of the core samples. The extractor used for platinum boat samples was used to punch out glass near the center of the core samples. This was done to minimize the influence of the stainless steel sampling tube on the composition and crystallization products of the glass.

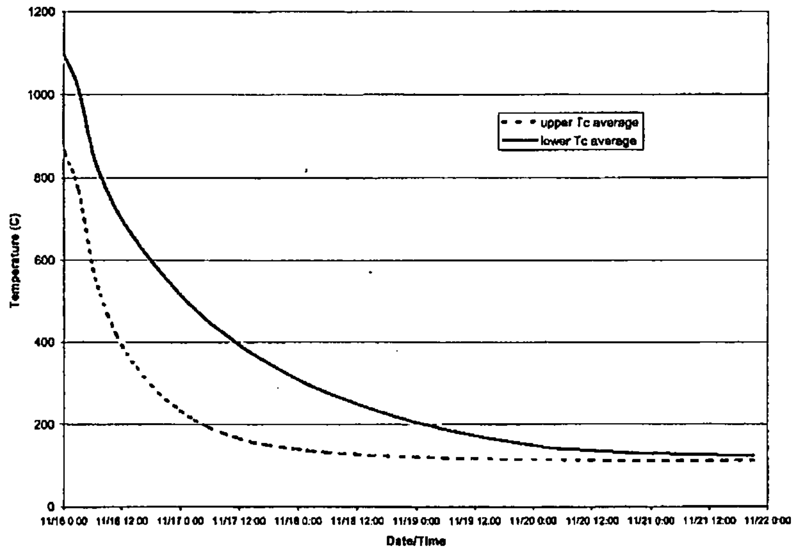

Figure 1. Measured Cooldown Rate of melter one.

Sample Analysis

Visual Observations

The three (one interface layer and two core) samples were placed in the Savannah River Technology Center (SRTC) Shielded Cells, removed from their primary containers, and photographed. Figure 2 is A) the interface layer sample and B) the lower core sample (The upper core sample appeared comparable to the lower core sample). The interface sample was contained in a platinum sampling boat and appeared black and shiny similar to previous pour stream samples[3]. The surfaces of both of the core samples were coarse and low luster from the sectioning procedure. It also appeared that the cutting process smeared the stainless steel sampler across some of the glass surface.

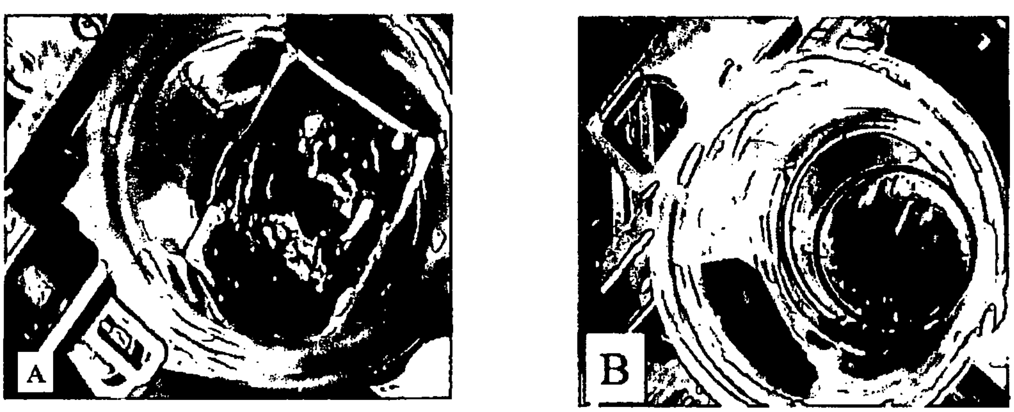

Figure 2. A) Interface layer in platinum sampler, and B) lower core sample in stainless steel sampler (within black circle).

Chemical Compositions

Samples were prepared for dissolution by pulverizing a portion of the sample using agate balls and vial. Four replicates of each of the glass samples were dissolved by two methods* to account for all of the elements of interest. The resulting solutions from the dissolutions were analyzed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) by the SRTC Analytical Development Section (SRTC-ADS). Table 1 is the average composition of four replicates of the three samples. Boron and silicon values are determined from the sodium peroxide/sodium hydroxide dissolution. The use of boron in the acid dissolution method precludes the use of boron values reported in acid dissolution samples. Sodium and zirconium values are determined solely from the acid dissolution method. The use of sodium peroxide and sodium hydroxide to perform the fusion in zirconium crucibles excludes the use of reported sodium and zirconium values obtained by this method. In the upper core sample, two of the acid dissolutions were incomplete (oxides did not total >95%) and were discarded. In the lower core sample, one of the acid dissolutions was incomplete (oxides did not total >95%) and was discarded. The composition of the interface layer is similar to both core samples as well as a pour stream sample taken in FY02[3].

Table 1. Composition of the Interface Layer Glass and the Core Glasses with Previously Reported Composition from a Pour Stream Glass (Wt.%) (NM-Not Measured).

	Interface Layer	Upper Core	Lower Core	Pour Stream*
Al_2O_3	4.13	4.08	4.02	4.22
B_2O_3	7.63	7.54	7.54	7.31
CaO	1.33	1.42	1.35	1.39
Cr_2O_3	0.19	0.37	0.36	0.06
CuO	0.02	0.02	0.02	0.07
Fe_2O_3	13.09	13.38	12.93	12.29
La_2O_3	0.02	0.04	0.04	0.02
Li_2O	3.20	3.11	3.05	3.29
MgO	2.37	2.35	2.27	2.35
MnO	1.54	1.51	1.47	2.14
Na_2O	11.12	10.52	10.07	11.38
NiO	0.73	0.80	0.78	0.54
SO_3	0.94	1.21	1.19	NM
SiO_2	48.96	52.36	52.36	48.73
TiO_2	0.04	0.04	0.04	0.05
U_3O_8	3.21	3.19	3.14	3.57
ZnO	0.07	0.07	0.06	0.09
ZrO_2	0.08	0.07	0.07	0.09
Sum	98.67	102.08	100.76	52.53

* Sampled during filling of canister S01753.

The solutions that resulted from acid dissolution of the three samples also were analyzed to gain more detailed information about the composition of the samples not available by ICP-AES. Noble metals resulting from neutron fission of U-235 and a sampling of other U-235 fission products as well as other select actinides were analyzed by Inductively Coupled Mass Spectroscopy (ICP-MS) and other radioactive species were analyzed by counting. Concentrations in weight percent along with the

* ADS-2502 – Sodium Peroxide/Sodium Hydroxide Dissolutions of Sludge and Glass for Elemental and Ion Analysis.
ADS-2227 – Acid Dissolution of Glass and Sludge for Elemental Analysis.

respective concentrations measured in the pour stream sample are given in Table 2. The isotopes Co-60, Cs-137, Eu-154, Eu-155, and Am-241 were measured by gamma counting. All others were measured by ICP-MS. Results were consistent among the three current (one interface and two core samples) glasses and the previous pour stream glass for the gamma emitters and actinides. Although the core samples were similar in noble metal content, both of the core samples were depleted in noble metals with respect to the interface layer and the pour stream glass. As mentioned in the previous section, incomplete dissolution of the core samples could skew the noble metal concentrations. It is most likely that the undissolved portions of the core glasses consisted primarily of crystals that formed during melter cooldown and that a disproportionate amount of the noble metals would contained in these undissolved crystals and would therefore not be available for measurement via ICP-MS.

Table 2. Isotopic Concentrations (wt.%) of the Three Melter One Glasses and the Pour Stream Glass. (NR – nor reported)

	Isotope	Interface Layer	Upper Core	Lower Core	Pour Stream[3]
	Co-60	1.46E-07	1.37E-07	1.39E-07	1.54E-07
	Tc-99	2.96E-04	1.52E-04	1.34E-04	2.75E-04
Noble Metals	Ru-101	4.03E-03	2.92E-04	2.72E-04	2.97E-03
	Ru-102	3.78E-03	2.60E-04	2.73E-04	2.89E-03
	Rh-103	3.90E-03	3.19E-04	3.33E-04	6.22E-04
	Ru-104	2.38E-03	NR	NR	1.91E-03
	Pd-105	1.92E-04	2.07E-04	1.53E-04	2.07E-04
	Cd-112	1.06E-02	8.95E-03	6.43E-03	1.06E-02
	Cs-137	1.00E-04	9.65E-05	9.76E-05	1.03E-04
	La-139	7.14E-03	3.91E-02	1.07E-02	6.54E-03
	Nd-143	3.77E-03	6.39E-03	3.38E-03	6.10E-03
	Eu-154	9.02E-07	9.08E-07	9.30E-07	8.45E-07
	Eu-155	2.26E-07	2.65E-07	2.56E-07	2.52E-07
	Th-232	5.94E-03	8.14E-03	1.13E-02	NR
	U-235	1.28E-02	1.21E-02	1.27E-02	NR
	U-238	2.93E+00	2.81E+00	2.95E+00	NR
	Pu-239	4.09E-03	4.22E-03	4.97E-03	NR
	Am-241	3.20E-04	3.09E-04	3.05E-04	2.85E-04

Contained Scanning Electron Microscopy

For contained scanning electron microscopy with energy dispersive spectroscopy (CSEM/EDS), the samples ranged from eight to twelve milligrams to minimize the interference of radiation with the detector and personnel exposure. The small size of the sample limits the representative nature of the analysis. That is, there is an assumption that the eight to twelve milligram sample is representative of the larger sample from which it was collected. This is fair in homogeneous samples, however, in partially crystallized or otherwise heterogeneous samples the representative character of the sample could be questioned.

The interface layer is uniform across the sample, Figure 3. The debris on the surface is from sample preparation and, when the image is viewed using the backscatter electron imaging (BSI) mode, Figure 4, the debris is of similar overall composition as the main sample (i.e., the "shaded" or color is similar).

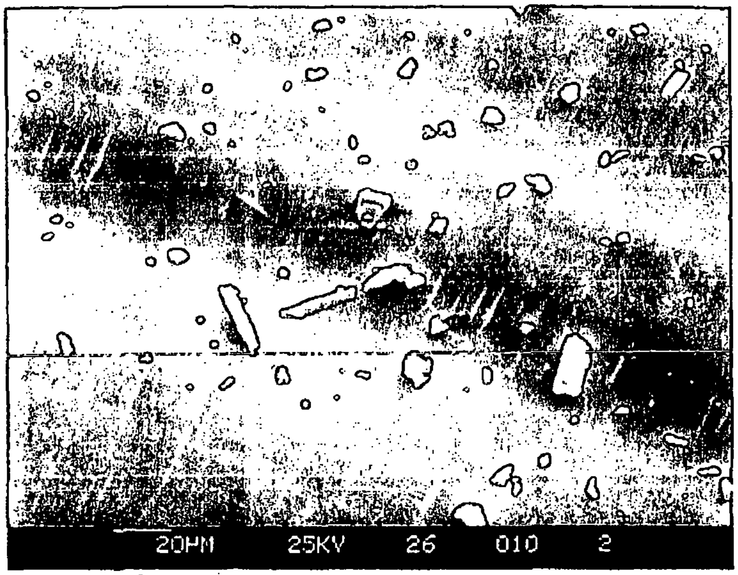

Figure 3. Interface layer glass, 500x.

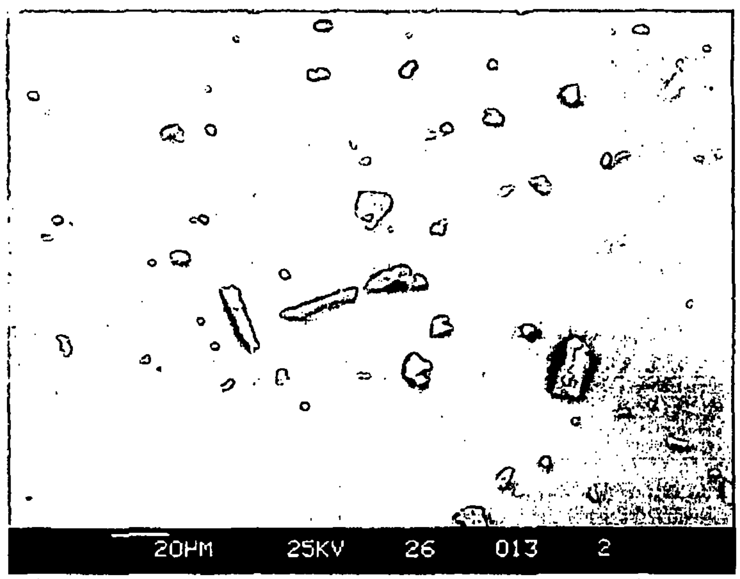

Figure 4. Interface layer glass from Figure 3, viewed using BSI.

The upper and lower core samples exhibited similar features under microscopic examination. Figure 5is the upper core secondary electron image (SEI) of a typical core particle. The texture of the core samples is indicative of a heavily crystallized glass. The mirror and hackle marks in Figure 5 are confined to areas devoid of inclusions. In addition to the debris seen in the image of the interface layer the glass contains a significant quantity of inclusions. The circled features in the figure are typical of the inclusions noted.

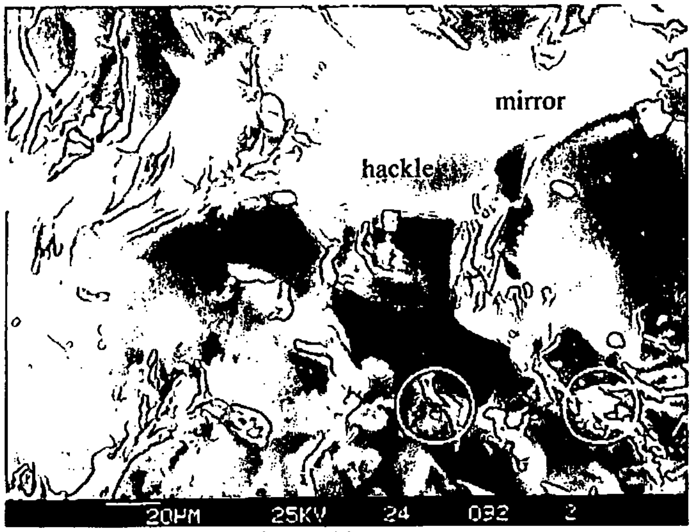

Figure 5. Upper core glass, 500x.

Figure 6 is the BSI image of the sample. Energy dispersive spectroscopy (EDS) evaluations were performed on the spots labeled "A" and "B".

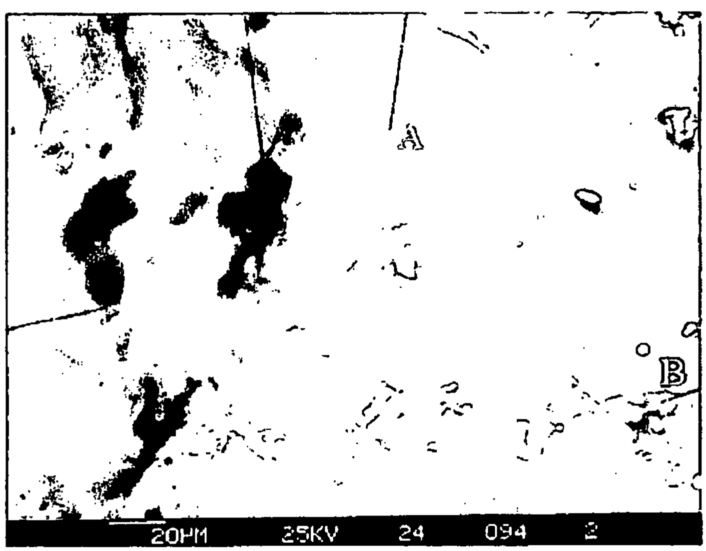

Figure 6. BSI image of upper core glass in Figure 5.

The radioactivity associated with the core glasses limited the ability of the EDS analysis to identify any but the major components of the areas being investigated. The radioactive components can "flood" the EDS detector, limiting the amount of time a spot can be counted. Therefore only sample components with strong signals (from high concentrations) can be easily identified. The interference was such that the EDS analysis was not possible for the interface layer glass. Figure 7 is the associated EDS spectrum of spot "A" in Figure 6 and the corresponding area in Figure 5 and most closely resembles a typical glass sample. Silicon is identified as a major component and iron as a secondary component. The other glass components present in quantities that would be expected to be identified are sodium and boron. In this spectrum, the sodium peak is masked by the leading edge of

the silicon peak. Boron is too light an element to be detected with this method. The gold (Au) and palladium (Pd) present in all of the spectra is the conductive coating used to prepare the samples. Figure 8 is spot "B" from Figure 6, which corresponds to the inclusion in Figure 5, identifies iron, in addition to silicon, as a major component of the feature. Aluminum is also identified as part of the area.

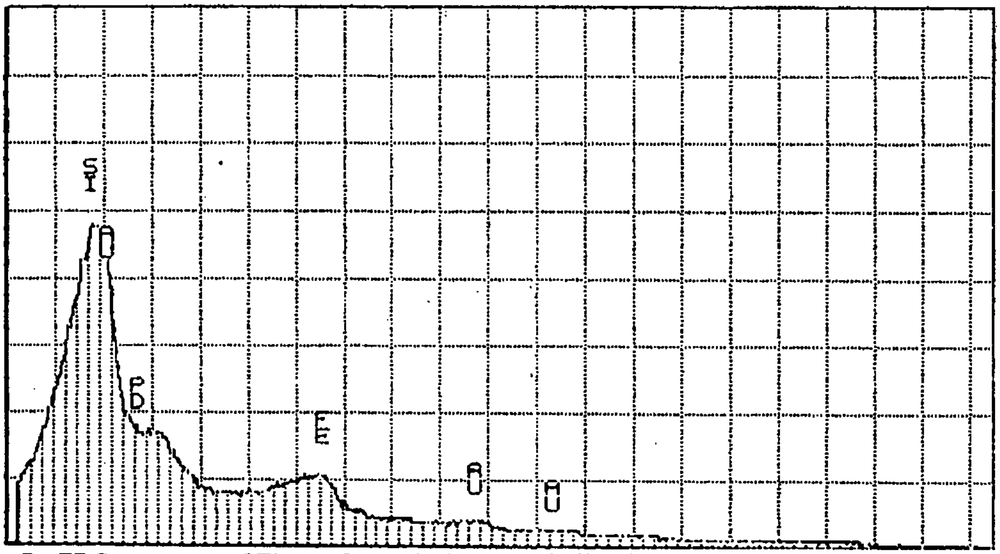

Figure 7. EDS spectrum of Figure 6 spot "A". Au-Pd alloy is used to provide a conductive coating on the sample.

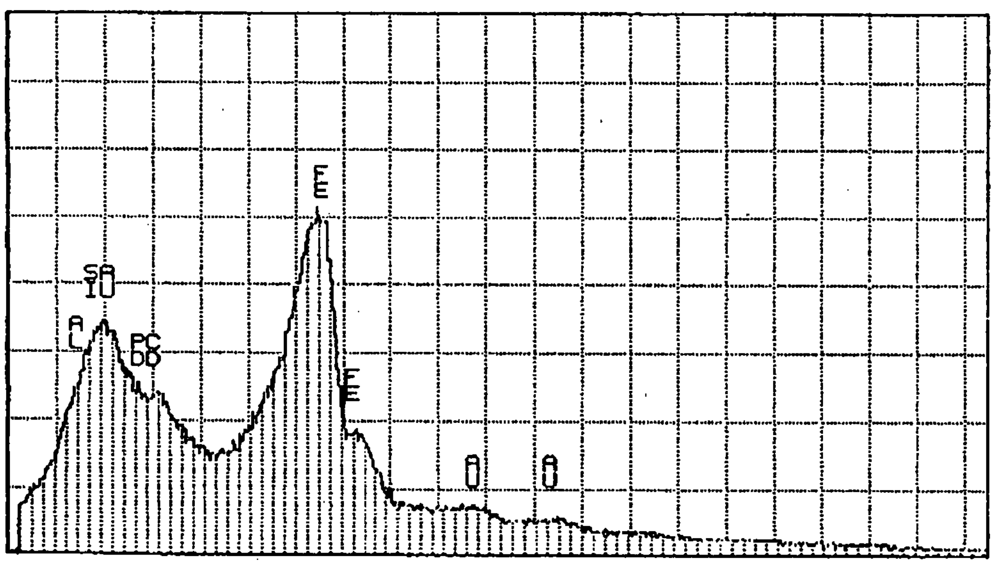

Figure 8. EDS spectrum of Figure 6 spot "B". Au-Pd alloy is used to provide a conductive coating on the sample.

Contained X-ray Diffraction Analysis

For contained x-ray diffraction analysis (CXRD), sample masses were between 15 and 35 milligrams. As with the CSEM samples, the small size of the CXRD samples could limit the representative nature of the samples. Although large samples are preferred for improved signal to noise ratios, the ALARA program encourages the minimization of personnel exposure to radioactive samples. The XRD pattern of the interface layer sample was typical of a borosilicate glass and free of any indicators of crystalline matter, Figure 9. As opposed to the interface layer sample that was collected from the melter prior to shut down of the power (and rapidly cooled to room temperature), the core samples were collected after the melter had cooled significantly as shown in Figure 1. The CXRD analyses of the core samples were similar to each other and indicated the presence of three distinct phases. Along with the amorphous hump associated with a glassy phase, a spinel phase and a clinopyroxene phase were identified. The clinopyroxene phase is the major phase and was identified as aegirine (acmite)[†]. The spinel phase most likely resembles trevorite[‡] as identified in prior DWPF samples[3]. Figure 10 is the CXRD pattern for the lower core sample.

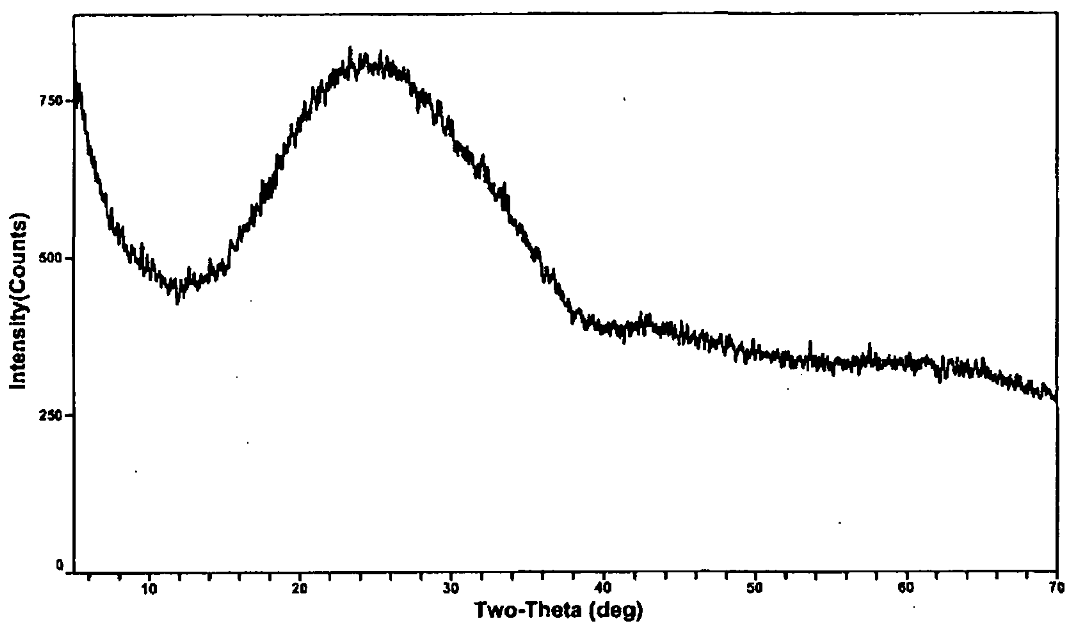

Figure 9. CXRD pattern of the interface layer sample.

[†] Aegirine ICDD card 71-1066 $NaFe(Si_2O_6)$
[‡] Trevorite ICDD card 10-0325 $NiFe_2O_4$

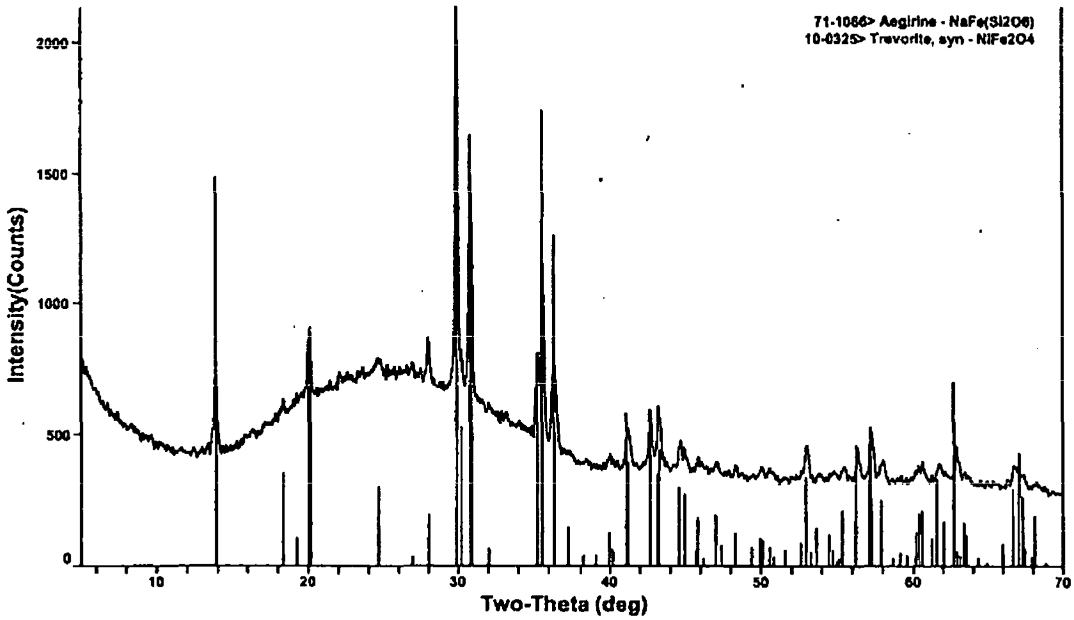

Figure 10. CXRD patter of the lower core sample.

Conclusions

Visual Observations

The interface layer glass appeared as a typical pour stream sample as described in Reference 3. It is therefore possible that a sample of the actual interface layer was not obtained. The surface was dark and reflective with no obvious inclusions. Little information could be obtained from visual observation of the core glasses. The surfaces were coarse from the sample sectioning.

Chemical Compositions

All three of the melter samples, the interface layer, the upper core and the lower core samples, were similar in composition to each other and the pour stream glass sampled in Reference 3 for the elements measured using ICP-AES. Both of the core samples were enriched in chromium. This can be attributed to.chromium contribution from the stainless steel sampler. It is evident that the attempt to reduce the influence of the materials of construction of the sampler (stainless steel) on the chemical analysis was not completely successful.

For the elements analyzed by gamma counting (Co-60, Cs-137, Eu-154, Eu-155, and Am-241), the results were consistent among the three melter samples as well as the pour stream sample analyzed previously.

Elements associated with the fission of U-235 were consistent among the three melter samples as well as the pour stream sample analyzed previously with the exception of noble metals in the two core samples. Both the upper and lower core samples were depleted in the noble metals analyzed (Ru-101, Ru-102, Rh-103, and Pd-105). This can be attributed to the sole use of the mixed acid dissolutions for ICP-MS analyses. The core samples both contained significant quantities of crystallized material.

The mixed acid dissolution is not as aggressive as the fusion dissolution and, based on ICP-AES results, did not fully dissolve the core samples. It is probable that the apparent noble metal depletion in the core samples results from the noble metals participating in the formation of the crystalline phases.

The consistency of the compositions throughout the melter, from the interface layer to the two melt pool samples to a previously collected pour stream sample, indicate that there is no measurable stratification of the more massive actinides or noble metals. These are of interest because increased levels of these elements could contribute to either a criticality concern (actinide segregation) or a reduction in melter life (settling of noble metals).

Contained Scanning Electron Microscopy

The interface layer glass was uniform in appearance. EDS analysis of the sample was not possible due to the radiation emitted flooding the detector. The core samples were similar to each other in appearance. Both samples had a heavily textured surface with inclusions. EDS analysis suggests that the smooth areas are glass, the inclusions are rich in iron and silicon and that some of the debris on the surface is alumina from the sectioning blade.

Contained X-ray Diffraction

X-ray diffraction analysis of the interface layer glass indicated that the sample was amorphous. Analysis of the core samples identified aegirine (acmite) and trevorite (spinel) as the two crystalline phases. These results are consistent with results reported during waste glass compositional region development work[4-5]. An amorphous hump in the spectra suggests that significant quantities of amorphous material remain in the sample.

References

1 D.F. Bickford, D.K. Peeler, M.E. Smith, and D.C. Witt, "DWPF Melter Interface Layer – Possible Causes/Solutions Matrix (U), SRT-GPD-2002-00069, July 2002.

2 H.N. Guerrero, "Final Comparison of Predicted vs. Actual DWPF Melter Cool Down Rate," SRT-ETF-2003-00003, January 2003.

3 A.D. Cozzi and N.E. Bibler, "Characterization of DWPF Macrobatch 3 (Mb3) Glass Samples Received 08/13/2002," SRT-GPD-2002-00147, December 2002.

4 C.M. Jantzen, D.F. Bickford, and D.G. Karraker, "Time-Temperature Transformation Kinetics in SRL Waste Glass," in Advances in Ceramics, 8, American Ceramic Society, Westerville, OH pp.30-38 (1984).

5 C.A. Cicero, S.L. Marra and M.K. Andrews, "Phase Stability Determinations of DWPF Waste Glasses," WSRC-TR-93-227, Rev. 0, May 1993.

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Document No. WSRC-TR-2003-00477	
Title: Characterization of DWPF Metler One Glass	Requested Approval Date

Primary Author/Contact	Location	Phone No.	Position	User ID
A. D. Cozzi	999-W	819-8414		

Organization Code	Organization (No Abbreviations)
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November 17, 2003

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Document Number: WSRC-TR-2003-00477
Author's Name: A. D. Cozzi
Location: 999-W Phone 819-8414
Department: SRTC/Immobilization Technology Section
Document Title: Characterization of DWPF Melter One Glasses

Presentation/Publication:
Meeting/Journal:

Location: NA
Meeting Date:

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The Defense Waste Processing Facility's first melter operated continuously for more thaneight years. In November 2002 it was decided to replace the melter. As part of the decommissioning and replacement of the first DWPF melter, three samples were collected from the melter, one from the melter surface and two from the core sampler. The melter samples were analyzed for chemical composition and crystal content.

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WVMP SAR Reference 5-7

Savannah River Nuclear Solutions Criticality Safety Methods Manual, Chapter 5, Standard Material Compositions for Nuclear Criticality Safety Calculations, SRNS-IM-2009-00035, Revision 3, Savannah River Nuclear Solutions, Aiken, South Carolina, January 2014.

CRITICALITY SAFETY METHODS MANUAL

Table 1.Specifications of Materials Commonly Associated with Criticality Analysis (cont.)

Material/Formula	Density, g/cc	Element / Isotope	Weight Percent	Atom Percent	Atom Density, At/ b-cm
Concrete, Magnuson[8]	2.147	H	0.3319	5.97	4.25748E-03
		C	10.532	15.91	1.13374E-02
		O	49.943	56.63	4.03600E-02
		Na	0.1411	0.11	7.93547E-05
		Mg	9.4200	7.03	5.01113E-03
		Al	0.7859	0.53	3.76600E-04
		Si	4.2100	2.72	1.93812E-03
		S	0.2483	0.14	1.00118E-04
		Cl	0.0523	0.03	1.90736E-05
		K	0.9445	0.44	3.12337E-04
		Ca	22.631	10.24	7.30092E-03
		Ti	0.1488	0.06	4.01927E-05
		Mn	0.0512	0.02	1.20497E-05
		Fe	0.5595	0.18	1.29538E-04
Concrete, Oak Ridge[8]	2.2995	H	0.6186	10.67	8.49878E-03
		C	17.519	25.35	2.01981E-02
		O	41.018	44.56	3.55019E-02
		Na	0.02706	0.02	1.62995E-05
		Mg	3.265	2.34	1.86024E-03
		Al	1.083	0.70	5.55831E-04
		Si	3.448	2.13	1.70007E-03
		K	0.1138	0.05	4.03056E-05
		Ca	32.129	13.93	1.11013E-02
		Fe	0.7784	0.24	1.93019E-04
Concrete, Regular [6, 8] (Recommended for use in RBOF/L-Basin analysis.[7])	2.30	H	1.0	16.80	1.37417E-02
		O	53.2	56.32	4.60557E-02
		Na	2.9	2.14	1.74719E-03
		Al	3.4	2.13	1.74537E-03
		Si	33.7	20.32	1.66197E-02
		Ca	4.4	1.86	1.52063E-03
		Fe	1.4	0.42	3.47232E-04
Concrete, Rocky Flats[8]	2.321	H	0.75	13.33	1.04004E-02
		C	5.52	8.23	6.42367E-03
		N	0.02	0.03	1.99580E-05
		O	48.49	54.29	4.23615E-02
		Na	0.63	0.49	3.83027E-04
		Mg	1.25	0.92	7.18849E-04
		Al	2.17	1.44	1.12413E-03
		Si	15.50	9.89	7.71388E-03
		S	0.19	0.11	8.28194E-05
		K	1.37	0.63	4.89763E-04
		Ca	23.00	10.28	8.02130E-03
		Ti	0.10	0.04	2.92003E-05
		Fe	1.01	0.32	2.52790E-04

[8] NUREG/CR-0200, Revision 6, *Standard Composition Library.*

WVMP SAR Reference 6-1

Characterization of DWPF Melter One Glasses, WSRC-TR-2003-00477, Rev 0, A.D. Cozzi and J.M. Pareizs, Westinghouse Savannah River Company, Aiken, South Carolina, October 2003.

2432955

WSRC-TR-2003-00477

Characterization of DWPF Melter One Glasses

by
A. D. Cozzi
Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

J. M. Pareizs

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A.D. Cozzi
J.M. Pareizs

Westinghouse Savannah River Company
Savannah River Technology Center
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Table of Contents

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Executive Summary

The Defense Waste Processing Facility's (DWPF) first melter operated continuously for more than eight years. In November 2002 it was decided to replace the melter. As part of the decommissioning and replacement of the first DWPF melter, three samples were collected from the melter, one from the melter surface and two from the core sampler. The melter samples were analyzed for chemical composition and crystal content.

The interface layer glass appeared as a typical pour stream. The surface was dark and reflective with no obvious inclusions. Little information could be obtained from visual observation of the core glasses. The surfaces were coarse from the sample sectioning.

The materials and methods used to sample to melter core influenced the analytical results. The stainless steel sampler contributed measurable amounts of chromium to the samples. The retrieval of the samples after the melter had cooled permitted the core glasses to crystallize extensively. The crystalline species were consistent with long slow cooling.

The consistency of the compositions throughout the melter, from the interface layer to the two melt pool samples to a previously collected pour stream sample, indicate that there is no measurable stratification of actinides or noble metals.

CSEM/EDS analysis of the core samples suggest that the smooth areas are glass, the inclusions are predominantly iron/silicon compounds and that some of the debris on the surface is alumina from the sectioning blade. CRXD analysis identified the inclusions as aegirine (acmite). CSEM analysis of the interface layer did not reveal any appearance other than glass. CXRD analysis confirmed the amorphous state of the interface layer.

Introduction

The Defense Waste Processing Facility's (DWPF) first melter operated continuously for more than eight years, including six years of radioactive operations – more than three times its design life. It produced more than 1,300 waste glass canisters, about 27 percent of the projected total canisters for DWPF. In November 2002 it was decided to replace the melter. Prior to melter shutdown, one sample was taken and a sampler was put in place to retrieve additional samples from the melt pool.

SRTC delivered four samplers to DWPF to collect samples. Two samplers were designed to remove a surface sample from the melt pool while the other two samplers were designed to remove core samples to provide a cross section of the melt pool.

As part of the decommissioning and replacement of the first DWPF melter, three samples were collected from the melter, one from the melter surface and two from the core sampler. The melter samples were analyzed for chemical composition and crystal content.

Objective

The objective of this task is to inspect, characterize and evaluate glass samples from the melter surface and the melt pool. The interface layer was sampled to provide data to aid in the identification and cause of the layer[1]. Two samples of the melt pool were obtained from two depths in the melter. Two depths were chosen to compare relative concentrations of noble metal and actinides to evaluate

concerns regarding settling of denser species. It should be recognized as the melt pool samples cooled in the melter, no definite conclusions could be drawn from the amount of crystalline species present.

Discussion

Sample Collection

Interface Layer

A platinum boat sampler was used to sample of the interface layer from the surface of the glass pool that remained after the cold cap was burned off (prior to melter shutdown). The interface layer sample was taken through the north feed tube nozzle, approximately two feet north of melter center. The sampler was lowered into the melter by the crane until it just broke the surface and filled with glass. It was then lifted out and allowed to cool. The interface sample was removed from the boat using the extractor provided by DWPF Engineering. Slightly more than 45 grams of sample were retrieved from the platinum boat. It is believed that a representative sample of the surface layer was obtained during the sampling.

Core Samples

Two samples from the core of the melt pool were obtained from different heights in the melter. The core samples were also obtained through the north feed tube. After glass.draw-down via the pour spout was completed, leaving approximately 16 inches of glass in the melter, the stainless steel core sample tube was slowly lowered into the pool till it hit bottom. It was then left in place during melter cooldown. Figure 1 shows the average cooling schedule of the upper and lower thermocouples. It is assumed that the core samples experienced a cooling curve bounded by the two curves in Figure 1. The melter cooled over several days[2], Figure 1. Upon retrieval, the bottom of the sampler broke off and remained in the melter, discontinuing the attempt to sample the very bottom of the glass pool. The remaining sampler was sectioned with a predominantly aluminum oxide saw to retrieve the "upper" and "lower" core samples. DWPF-Engineering estimated that the lower sample was four to six inches above the melter bottom and the upper sample was ten" to fifteen inches above the bottom. An effort was made to retrieve glass from the interior of the core samples. The extractor used for platinum boat samples was used to punch out glass near the center of the core samples. This was done to minimize the influence of the stainless steel sampling tube on the composition and crystallization products of the glass.

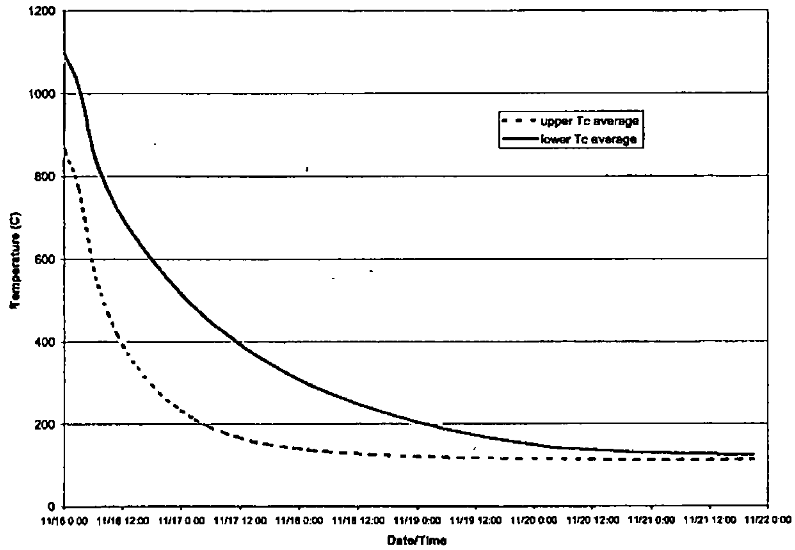

Figure 1. Measured Cooldown Rate of melter one.

Sample Analysis

Visual Observations

The three (one interface layer and two core) samples were placed in the Savannah River Technology Center (SRTC) Shielded Cells, removed from their primary containers, and photographed. Figure 2 is A) the interface layer sample and B) the lower core sample (The upper core sample appeared comparable to the lower core sample). The interface sample was contained in a platinum sampling boat and appeared black and shiny similar to previous pour stream samples[3]. The surfaces of both of the core samples were coarse and low luster from the sectioning procedure. It also appeared that the cutting process smeared the stainless steel sampler across some of the glass surface.

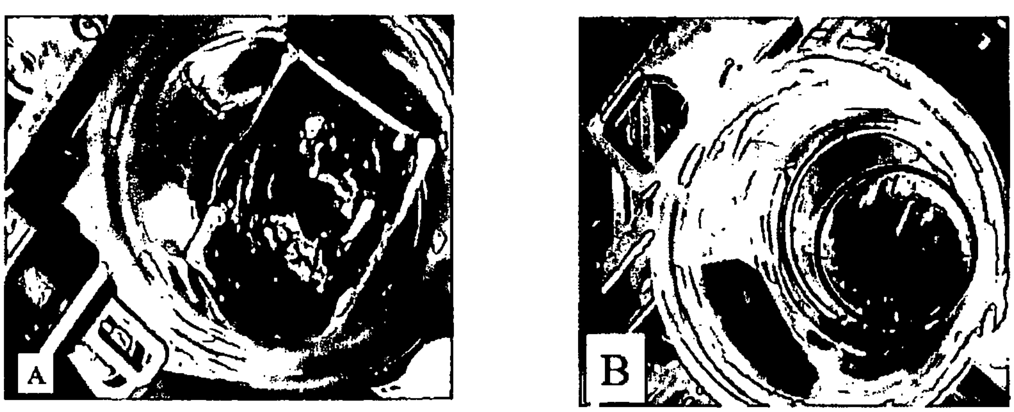

Figure 2. A) Interface layer in platinum sampler, and B) lower core sample in stainless steel sampler (within black circle).

Chemical Compositions

Samples were prepared for dissolution by pulverizing a portion of the sample using agate balls and vial. Four replicates of each of the glass samples were dissolved by two methods* to account for all of the elements of interest. The resulting solutions from the dissolutions were analyzed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) by the SRTC Analytical Development Section (SRTC-ADS). Table 1 is the average composition of four replicates of the three samples. Boron and silicon values are determined from the sodium peroxide/sodium hydroxide dissolution. The use of boron in the acid dissolution method precludes the use of boron values reported in acid dissolution samples. Sodium and zirconium values are determined solely from the acid dissolution method. The use of sodium peroxide and sodium hydroxide to perform the fusion in zirconium crucibles excludes the use of reported sodium and zirconium values obtained by this method. In the upper core sample, two of the acid dissolutions were incomplete (oxides did not total >95%) and were discarded. In the lower core sample, one of the acid dissolutions was incomplete (oxides did not total >95%) and was discarded. The composition of the interface layer is similar to both core samples as well as a pour stream sample taken in FY02[3].

Table 1. Composition of the Interface Layer Glass and the Core Glasses with Previously Reported Composition from a Pour Stream Glass (Wt.%) (NM-Not Measured).

	Interface Layer	Upper Core	Lower Core	Pour Stream*
Al_2O_3	4.13	4.08	4.02	4.22
B_2O_3	7.63	7.54	7.54	7.31
CaO	1.33	1.42	1.35	1.39
Cr_2O_3	0.19	0.37	0.36	0.06
CuO	0.02	0.02	0.02	0.07
Fe_2O_3	13.09	13.38	12.93	12.29
La_2O_3	0.02	0.04	0.04	0.02
Li_2O	3.20	3.11	3.05	3.29
MgO	2.37	2.35	2.27	2.35
MnO	1.54	1.51	1.47	2.14
Na_2O	11.12	10.52	10.07	11.38
NiO	0.73	0.80	0.78	0.54
SO_3	0.94	1.21	1.19	NM
SiO_2	48.96	52.36	52.36	48.73
TiO_2	0.04	0.04	0.04	0.05
U_3O_8	3.21	3.19	3.14	3.57
ZnO	0.07	0.07	0.06	0.09
ZrO_2	0.08	0.07	0.07	0.09
Sum	98.67	102.08	100.76	52.53

* Sampled during filling of canister S01753.

The solutions that resulted from acid dissolution of the three samples also were analyzed to gain more detailed information about the composition of the samples not available by ICP-AES. Noble metals resulting from neutron fission of U-235 and a sampling of other U-235 fission products as well as other select actinides were analyzed by Inductively Coupled Mass Spectroscopy (ICP-MS) and other radioactive species were analyzed by counting. Concentrations in weight percent along with the

* ADS-2502 – Sodium Peroxide/Sodium Hydroxide Dissolutions of Sludge and Glass for Elemental and Ion Analysis.
ADS-2227 – Acid Dissolution of Glass and Sludge for Elemental Analysis.

respective concentrations measured in the pour stream sample are given in Table 2. The isotopes Co-60, Cs-137, Eu-154, Eu-155, and Am-241 were measured by gamma counting. All others were measured by ICP-MS. Results were consistent among the three current (one interface and two core samples) glasses and the previous pour stream glass for the gamma emitters and actinides. Although the core samples were similar in noble metal content, both of the core samples were depleted in noble metals with respect to the interface layer and the pour stream glass. As mentioned in the previous section, incomplete dissolution of the core samples could skew the noble metal concentrations. It is most likely that the undissolved portions of the core glasses consisted primarily of crystals that formed during melter cooldown and that a disproportionate amount of the noble metals would contained in these undissolved crystals and would therefore not be available for measurement via ICP-MS.

Table 2. Isotopic Concentrations (wt.%) of the Three Melter One Glasses and the Pour Stream Glass. (NR – nor reported)

	Isotope	Interface Layer	Upper Core	Lower Core	Pour Stream[3]
	Co-60	1.46E-07	1.37E-07	1.39E-07	1.54E-07
	Tc-99	2.96E-04	1.52E-04	1.34E-04	2.75E-04
Noble Metals	Ru-101	4.03E-03	2.92E-04	2.72E-04	2.97E-03
Noble Metals	Ru-102	3.78E-03	2.60E-04	2.73E-04	2.89E-03
Noble Metals	Rh-103	3.90E-03	3.19E-04	3.33E-04	6.22E-04
Noble Metals	Ru-104	2.38E-03	NR	NR	1.91E-03
Noble Metals	Pd-105	1.92E-04	2.07E-04	1.53E-04	2.07E-04
	Cd-112	1.06E-02	8.95E-03	6.43E-03	1.06E-02
	Cs-137	1.00E-04	9.65E-05	9.76E-05	1.03E-04
	La-139	7.14E-03	3.91E-02	1.07E-02	6.54E-03
	Nd-143	3.77E-03	6.39E-03	3.38E-03	6.10E-03
	Eu-154	9.02E-07	9.08E-07	9.30E-07	8.45E-07
	Eu-155	2.26E-07	2.65E-07	2.56E-07	2.52E-07
	Th-232	5.94E-03	8.14E-03	1.13E-02	NR
	U-235	1.28E-02	1.21E-02	1.27E-02	NR
	U-238	2.93E+00	2.81E+00	2.95E+00	NR
	Pu-239	4.09E-03	4.22E-03	4.97E-03	NR
	Am-241	3.20E-04	3.09E-04	3.05E-04	2.85E-04

Contained Scanning Electron Microscopy

For contained scanning electron microscopy with energy dispersive spectroscopy (CSEM/EDS), the samples ranged from eight to twelve milligrams to minimize the interference of radiation with the detector and personnel exposure. The small size of the sample limits the representative nature of the analysis. That is, there is an assumption that the eight to twelve milligram sample is representative of the larger sample from which it was collected. This is fair in homogeneous samples, however, in partially crystallized or otherwise heterogeneous samples the representative character of the sample could be questioned.

The interface layer is uniform across the sample, Figure 3. The debris on the surface is from sample preparation and, when the image is viewed using the backscatter electron imaging (BSI) mode, Figure 4, the debris is of similar overall composition as the main sample (i.e., the "shaded" or color is similar).

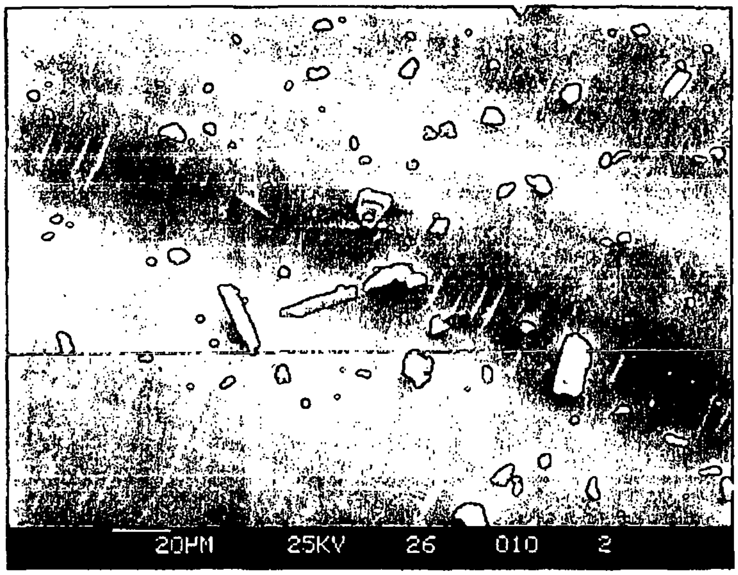

Figure 3. Interface layer glass, 500x.

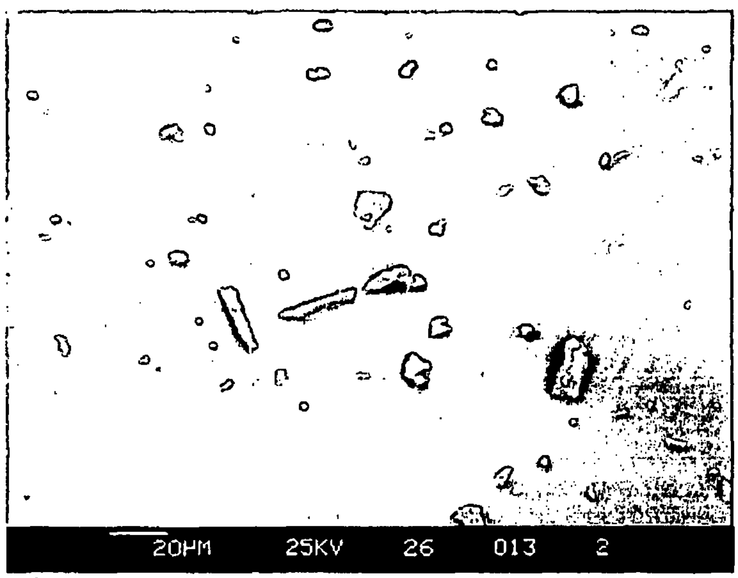

Figure 4. Interface layer glass from Figure 3, viewed using BSI.

The upper and lower core samples exhibited similar features under microscopic examination. Figure 5is the upper core secondary electron image (SEI) of a typical core particle. The texture of the core samples is indicative of a heavily crystallized glass. The mirror and hackle marks in Figure 5 are confined to areas devoid of inclusions. In addition to the debris seen in the image of the interface layer the glass contains a significant quantity of inclusions. The circled features in the figure are typical of the inclusions noted.

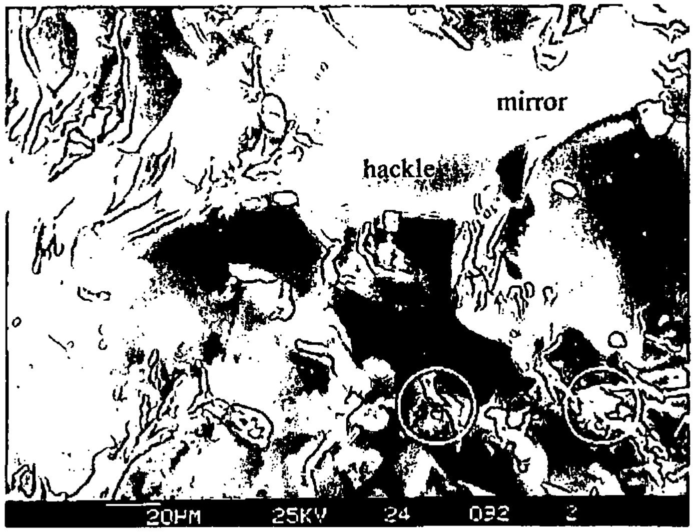

Figure 5. Upper core glass, 500x.

Figure 6 is the BSI image of the sample. Energy dispersive spectroscopy (EDS) evaluations were performed on the spots labeled "A" and "B".

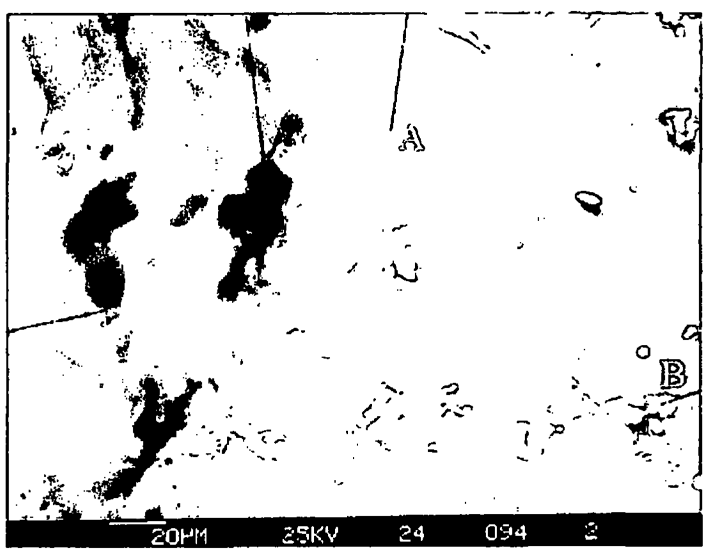

Figure 6. BSI image of upper core glass in Figure 5.

The radioactivity associated with the core glasses limited the ability of the EDS analysis to identify any but the major components of the areas being investigated. The radioactive components can "flood" the EDS detector, limiting the amount of time a spot can be counted. Therefore only sample components with strong signals (from high concentrations) can be easily identified. The interference was such that the EDS analysis was not possible for the interface layer glass. Figure 7 is the associated EDS spectrum of spot "A" in Figure 6 and the corresponding area in Figure 5 and most closely resembles a typical glass sample. Silicon is identified as a major component and iron as a secondary component. The other glass components present in quantities that would be expected to be identified are sodium and boron. In this spectrum, the sodium peak is masked by the leading edge of

the silicon peak. Boron is too light an element to be detected with this method. The gold (Au) and palladium (Pd) present in all of the spectra is the conductive coating used to prepare the samples. Figure 8 is spot "B" from Figure 6, which corresponds to the inclusion in Figure 5, identifies iron, in addition to silicon, as a major component of the feature. Aluminum is also identified as part of the area.

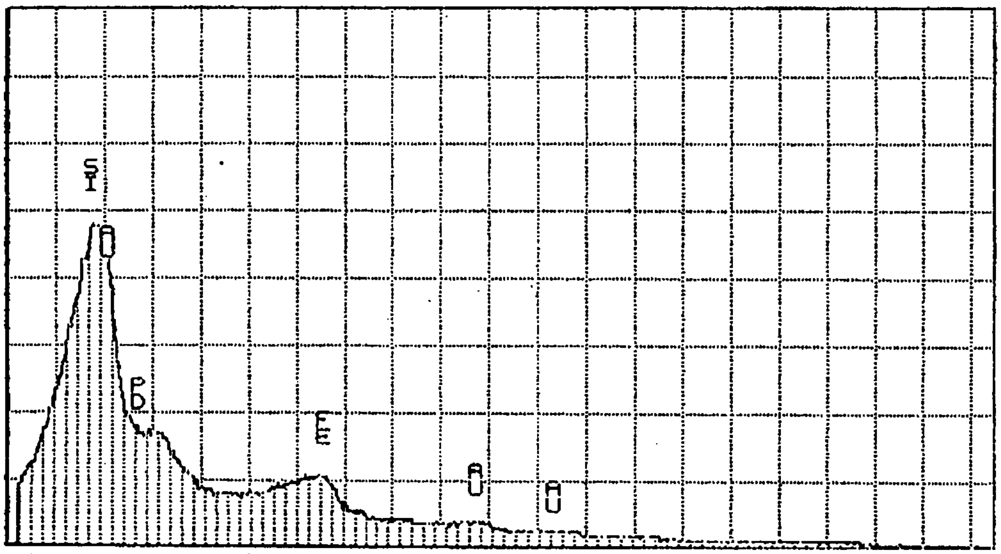

Figure 7. EDS spectrum of Figure 6 spot "A". Au-Pd alloy is used to provide a conductive coating on the sample.

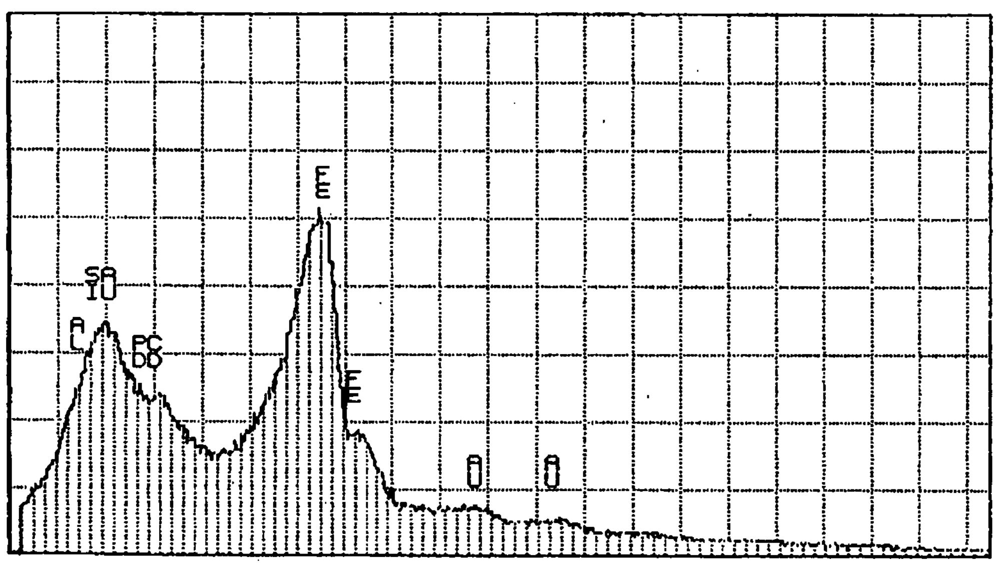

Figure 8. EDS spectrum of Figure 6 spot "B". Au-Pd alloy is used to provide a conductive coating on the sample.

Contained X-ray Diffraction Analysis

For contained x-ray diffraction analysis (CXRD), sample masses were between 15 and 35 milligrams. As with the CSEM samples, the small size of the CXRD samples could limit the representative nature of the samples. Although large samples are preferred for improved signal to noise ratios, the ALARA program encourages the minimization of personnel exposure to radioactive samples. The XRD pattern of the interface layer sample was typical of a borosilicate glass and free of any indicators of crystalline matter, Figure 9. As opposed to the interface layer sample that was collected from the melter prior to shut down of the power (and rapidly cooled to room temperature), the core samples were collected after the melter had cooled significantly as shown in Figure 1. The CXRD analyses of the core samples were similar to each other and indicated the presence of three distinct phases. Along with the amorphous hump associated with a glassy phase, a spinel phase and a clinopyroxene phase were identified. The clinopyroxene phase is the major phase and was identified as aegirine (acmite)[†]. The spinel phase most likely resembles trevorite[‡] as identified in prior DWPF samples[3]. Figure 10 is the CXRD pattern for the lower core sample.

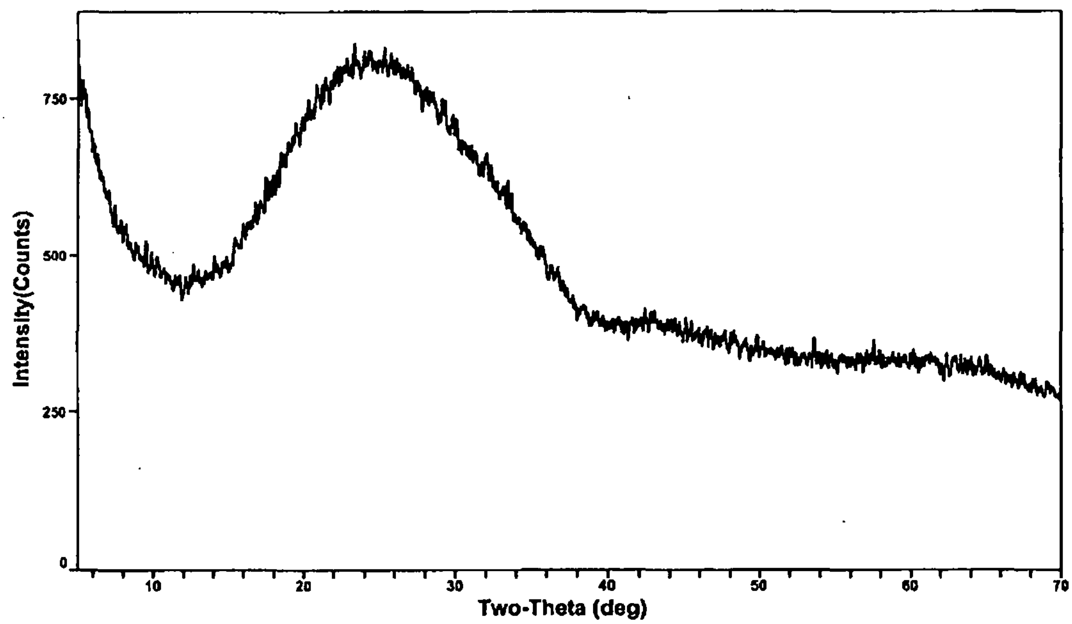

Figure 9. CXRD pattern of the interface layer sample.

† Aegirine ICDD card 71-1066 $NaFe(Si_2O_6)$
‡ Trevorite ICDD card 10-0325 $NiFe_2O_4$

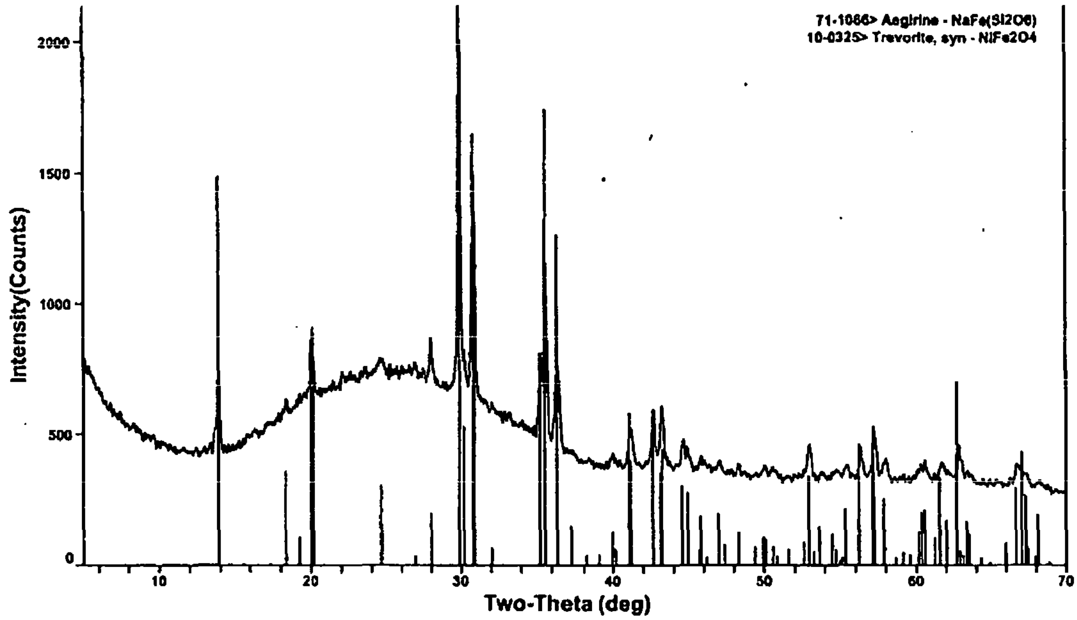

Figure 10. CXRD patter of the lower core sample.

Conclusions

Visual Observations

The interface layer glass appeared as a typical pour stream sample as described in Reference 3. It is therefore possible that a sample of the actual interface layer was not obtained. The surface was dark and reflective with no obvious inclusions. Little information could be obtained from visual observation of the core glasses. The surfaces were coarse from the sample sectioning.

Chemical Compositions

All three of the melter samples, the interface layer, the upper core and the lower core samples, were similar in composition to each other and the pour stream glass sampled in Reference 3 for the elements measured using ICP-AES. Both of the core samples were enriched in chromium. This can be attributed to chromium contribution from the stainless steel sampler. It is evident that the attempt to reduce the influence of the materials of construction of the sampler (stainless steel) on the chemical analysis was not completely successful.

For the elements analyzed by gamma counting (Co-60, Cs-137, Eu-154, Eu-155, and Am-241), the results were consistent among the three melter samples as well as the pour stream sample analyzed previously.

Elements associated with the fission of U-235 were consistent among the three melter samples as well as the pour stream sample analyzed previously with the exception of noble metals in the two core samples. Both the upper and lower core samples were depleted in the noble metals analyzed (Ru-101, Ru-102, Rh-103, and Pd-105). This can be attributed to the sole use of the mixed acid dissolutions for ICP-MS analyses. The core samples both contained significant quantities of crystallized material.

The mixed acid dissolution is not as aggressive as the fusion dissolution and, based on ICP-AES results, did not fully dissolve the core samples. It is probable that the apparent noble metal depletion in the core samples results from the noble metals participating in the formation of the crystalline phases.

The consistency of the compositions throughout the melter, from the interface layer to the two melt pool samples to a previously collected pour stream sample, indicate that there is no measurable stratification of the more massive actinides or noble metals. These are of interest because increased levels of these elements could contribute to either a criticality concern (actinide segregation) or a reduction in melter life (settling of noble metals).

Contained Scanning Electron Microscopy

The interface layer glass was uniform in appearance. EDS analysis of the sample was not possible due to the radiation emitted flooding the detector. The core samples were similar to each other in appearance. Both samples had a heavily textured surface with inclusions. EDS analysis suggests that the smooth areas are glass, the inclusions are rich in iron and silicon and that some of the debris on the surface is alumina from the sectioning blade.

Contained X-ray Diffraction

X-ray diffraction analysis of the interface layer glass indicated that the sample was amorphous. Analysis of the core samples identified aegirine (acmite) and trevorite (spinel) as the two crystalline phases. These results are consistent with results reported during waste glass compositional region development work[4-5]. An amorphous hump in the spectra suggests that significant quantities of amorphous material remain in the sample.

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Primary Author/Contact	Location	Phone No.	Position	User ID
A. D. Cozzi	999-W	819-8414		

Organization Code	Organization (No Abbreviations)
L3100A	Savannah River Technology Center/Immobilization Technology Section

Other Authors	Key Words (list 3)
J. M. Pareizs	DWPF, Melter, Glass

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November 17, 2003

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(7-98) p. 1 of 2
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US DEPARTMENT OF ENERGY
ANNOUNCEMENT OF U. S. DEPARTMENT OF ENERGY (DOE) SCIENTIFIC AND TECHNICAL INFORMATION (STI)

RECORD STATUS (select one):
X.. New ......Revised Data .....Revised STI Product

Part I: STI PRODUCT DESCRIPTION

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X.. 1. **Technical Report**
  a. Type: ☒ **Topical** ☐ **Semiannual** ☐ **Annual** ☐ **Final** Other **(specify)** ....
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...... 7. **Patent Application**
  a. Date Filed *(mm/dd/yyyy)* ___/___/___
  b. Date Priority *(mm/dd/yyyy)* ___/___/___
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B. STI PRODUCT TITLE Characterization of DWPF Melter One Glasses

C. AUTHOR(s) A. D. Cozzi

E-mail Address(*es*):

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K. DESCRIPTION/ABSTRACT

The Defense Waste Processing Facility's first melter operated continuously for more thaneight years. In November 2002 it was decided to replace the melter. As part of the decommissioning and replacement of the first DWPF melter, three samples were collected from the melter, one from the melter surface and two from the core sampler. The melter samples were analyzed for chemical composition and crystal content.

US DEPARTMENT OF ENERGY

ANNOUNCEMENT OF U. S. DEPARTMENT OF ENERGY (DOE) SCIENTIFIC AND TECHNICAL INFORMATION (STI)

DOE F 241.1 (p. 2 of 2)

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C. CONTACT AND RELEASING OFFICIAL

1. Contact (*if appropriate, the organization or site contact to include in published citations who would receive any external questions about the content of the STI Product or the research information contained therein*)
   Name and/or Position Jeanette Brooks, Manager, WSRC Management Information Programs
   E-mail ______ Phone (803) 725-2500
   Organization Westinghouse Savannah River Company
2. Releasing Official X I verify that all necessary reviews have been completed (e.g. Patent, Copyright, ECI, UCNI, etc.)
   Released by (*name*) Jeanette Brooks Date (*mm/dd/yyyy*) 12/15/2003
   E-Mail ______ Phone (803) 725-2500

WVMP SAR Reference 7-5

Remove Melter from Vitrification Facility, WVNSCO work instruction package VFS-112008-WIP, West Valley Nuclear Services Company, West Valley, December 2004.

Pages 3-5

5.0 PROCEDURE DETAILS

5.1 Special Tools and Equipment

The following special tools and equipment, provided by WVNSCO, need to be staged for installation of the container cover plates:

- Rigging and lifting attachments (i.e., slings, hoist rings, shackles, etc.), inspected, tagged, and ready for use
- Torque wrench and adapters for installation of 5/16" SHCS's (i.e., 0 to 50 ft-lb range)
- Torque wrench, adapters, and torque multiplier capable of applying 500 ft-lb, inspected and ready for use
- Two (2) 2-3/8" sockets (i.e., for the 1-1/2" bolts and nuts)
- Two (2) 2-3/8" open wrenches
- Two (2) 1-5/8" sockets (i.e., for the 1" bolts and nuts)
- Two (2) 1-5/8" open wrenches
- Two (2) 1/4" hex bit sockets (i.e., for the 5/16" SHCS's)
- Four (4) spud wrenches
- Anti-galling lubricant (nickel antiseize, or equivalent)
- Silicone rubber sealant (Dow 732 - clear, or equivalent)
- Caulk guns
- WVNSCO approved gasket adhesive

5.2 Installation of the Melter Container Cover Plate

5.2.1 Perform an ALARA pre-job.

5.2.2 Stage the Melter container cover plate horizontally on wood cribbing under the Load Out crane, **in a low dose area,** and as close as possible to the loaded container, in preparation for installation.

5.2.3 Clean the container cover plate gasket seating area, if necessary, with isopropyl alcohol, or equivalent approved cleaning solution.

5.2.4 Align the cover plate to the container by aligning the cover lift tabs to the slots in the container top skirt to guide it into position. Use pry bars and the pry bar slots, if necessary, to complete the final cover alignment of the cover to the container.

5.2.5 WVDP RP shall verify dose rates and revise the radiation protection controls, as necessary, prior to continuing work.

INSP HOLD Witness the installation of "anti-galling lubricant" and the torquing of the cover plate attachment bolts to 500 ft-lbs (450 ft-lbs to 550 ft-lbs).

Actual torque applied: 520 ft-lb

Tool No. 35245 Cal Due Date: 9/13/05

INSP: Joyce Abbott (Signature) 11/14/04 (Date)

NOTE: A minimum of 30 bolts and washers are required to be installed for installation of grout or installation of securement devices, prior to movement of Melter package at the West Valley site. All 32 bolts and washers are required to be installed prior to transport of the package from the West Valley site. Step 5.2.6b can be performed at any time after receipt of the remaining two (2) bolts, but must be performed prior to transport of the package from West Valley.

5.2.6a Apply "anti-galling lubricant" to the threads of each of the 1-1/2" diameter bolts, then tighten thirty (30) of the bolts and washers to "snug tight" attach the cover plate to the Melter container (Note that a minimum of four (4) bolts are required to hold the cover plate to the container). Torque the bolts to 500 ft-lbs (450 ft-lbs to 550 ft-lbs) using a calibrated torque wrench. Use a crisscross tightening sequence that alternately tightens the bolts located 180 degrees apart. Perform the crisscross torquing sequence for three (3) torque increments starting at 200 ft-lbs, then 400 ft-lbs, and finally 500 ft-lbs. The tightening to the final torque value of 500 ft-lbs shall be performed by tightening the bolts sequentially clockwise.

INSP HOLD Witness the installation of "anti-galling lubricant" and the torquing of the cover plate attachment bolts to 500 ft-lbs (450 ft-lbs to 550 ft-lbs).

Bolt 18 cannot be made to fit flush to lid all others are acceptable Joyce Abbott 11/14/04
11-15-04 - Bolt fixed & torqued to 500 ft lbs. J Abbott 11-15-04

Actual torque applied: 500 ft-lb

Tool No. 33745 Cal Due Date: 9/13/05

INSP: Joyce Abbott 11/14/04
Signature Date

5.2.6b Apply "anti-galling lubricant" to the threads of each of the remaining two (2) 1-1/2" diameter bolts, then tighten the bolts and washers to 500 ft-lbs (450 ft-lbs to 550 ft-lbs) using a calibrated torque wrench.

5.2.7 Disconnect the rigging from the hoist rings, then remove the hoist rings from the cover plate tabs.

5.2.8 WVDP RP shall perform the "loaded package" survey and again revise the radiation protection controls, as necessary, prior to continuing work. Surveys shall be provided to the WMG representative.

5.3 Installation of the Melter Securement Devices

NOTE: The Melter securement devices shall be installed if the low density cellular concrete is not placed in the Melter container prior to movement of the packaged Melter on site.

5.3.1 Install Melter securement devices in accordance with Reference 3.1.5 (drawing 4005-DW-007, (current revision) "West Valley Melter Securement Device.")

5.4 Installation of the Melter Container Grout Port Plugs

This section is included to provide the user with instructions for installation of the grout port plugs following the placement of low density cellular concrete (not covered by this procedure) into the Melter container. It assumes that the threaded holes in the container, into which the 5/16" socket head cap screws (SHCS's) will be attached, and the associated gasket seating surfaces, have been cleaned (or verified clean) prior to beginning this work.

WVMP SAR Reference 7-6

Weigh and Prepare Melter Container TC 474 for Grouting at the Rail Packaging and Staging Area, CHBWV work instruction package W1303663, CH2M Hill-B&W West Valley, LLC, West Valley, New York, completed October 2013.

Pages 8 - 11

5.6.7 Use hand tools in the glove bag to pry the device and slightly separate it from the container allowing the container to vent into the glove bag.

5.6.8 Allow the container to vent into the glove bag and the PVU to take up vented air.

5.6.9 After the container is vented THEN unscrew and remove the four bolts.

5.6.10 Carefully pull the securement device completely out of the melter container and into the glove bag.

5.6.11 Remove scrape and clean any gasket material (neoprene) and or RTV from the recessed area of port.

5.6.12 If required wipe down the inside of the glove bag and recessed area of port using Wypalls and Windex.

5.6.13 Twist the glove bag at the port and tape.

5.6.14 Allow the ventilation to suck air out of the bag and allow the bag to collapse.

5.6.15 Peel bag away from container and j-seal the bag.

5.6.16 RC perform survey around port area.

A. **IF** removable contamination levels are >20 dpm/100cm² alpha and >200dpm/100cm² beta/gamma.

THEN DDWO decontaminate surfaces to <20 dpm/100cm² alpha and <200dpm/100cm² beta/gamma.

B. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

5.6.17 Bag glove bag containing the securement device as rad waste using waste profile VGAS.001 and remove 4"duct from bag.

5.7 Install Container Plug into port left by removal of securement Device. *(See Photo on Attachment A Page 2 and "Melter Container Plug Details" SKJHS052913)*

5.7.1 RTV new gasket onto new 6" Deep plug.

5.7.2 Lubricate 5/16" x 3 ¾" long Cap Screws with a small amount of never seez (or equal)

5.7.3 Position plug into recessed area of container port.

5.7.4 Install Cap Screws and tighten (hand tight).

FC1> A. Torque each to 35 ft lbs. (+or- 4 ft lbs) QA to witness torqueing.

[+] QA Print/Sign/Date Paul Kaiser Paul Kaiser 9-10-13

[+] Calibrated Torque Wrench ID# 41-TW-18

[+] Calibration Due Date ~~12-31-13~~ 12-31-13

B. Apply RTV in the gap around the top of the port cover.

C. RC perform survey around port area.

1. **IF** removable contamination levels are >20 dpm/100cm² alpha and >200dpm/100cm² beta/gamma.

THEN DDWO decontaminate surfaces to <20 dpm/100cm² alpha and <200dpm/100cm² beta/gamma.

2. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

OR

5.7.5 If Cap screws cannot be made, remove screws and plug, secure penetration with temp cover, position shield blanket, and notify WGS and cog engineer

A. RC perform survey around port area.

1. **IF** removable contamination levels are >20 dpm/100cm^2 alpha and >200dpm/100cm^2 beta/gamma.

   THEN DDWO decontaminate surfaces to <20 dpm/100cm^2 alpha and <200dpm/100cm^2 beta/gamma.

2. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

5.8 Remove port cover. (Top of container on West Side). *(See Photo on Attachment A Page 2, and SK-NJA-071613 Sheet 10 of 18 (Step 10 for reference)*

5.8.1 DDWO field install herculite or equivalent around port.

5.8.2 Run a 4" duct from the PVU for ventilation. Alternately, an environmentally sampled HEPA vacuum may be used.

5.8.3 Loosen and remove the three 5/16" SHCS cap screws securing the port cover.

5.8.4 Use ½" lift eye or T-handle, and lift the port cover and separate it from the container.

A. Remove the port cover and bag as waste using waste profile VGAS.001 .

5.8.5 RC perform survey around port area.

A. **IF** removable contamination levels are >20 dpm/100cm^2 alpha and >200dpm/100cm^2 beta/gamma.

1. **THEN** DDWO decontaminate surfaces to <20 dpm/100cm^2 alpha and <200dpm/100cm^2 beta/gamma.

2. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

5.8.6 Remove scrape and clean any gasket material (neoprene) and or RTV from the recessed area of port recessed area drop into waste container.

5.8.7 Remove herculite or equivalent from the port area.

5.8.8 RC perform survey around port area.

A. **IF** removable contamination levels are >20 dpm/100cm^2 alpha and >200dpm/100cm^2 beta/gamma.

1. **THEN** DDWO decontaminate surfaces to <20 dpm/100cm^2 alpha and <200dpm/100cm^2 beta/gamma.

2. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

5.9 Install Grouting Support Assembly. *(See Sketch SKJHSO52813 Melter Vessel Grouting Support Assembly and SK-NJA-071613 Sheet 10 of 18 (Step 10 for reference))*

[+] 5.9.1 Ensure to CLOSE all valves on the Grouting Support Assembly and install all caps.

WGS or Designee Print/Sign/Date ANDREW RUPP / Andrew Rupp 9-10-2013

5.9.2 Place the Grouting Support Assembly (with gasket) inside of the port.

5.9.3 Install three 5/16" x 2 ¼" Hex Head Bolts with washers through the hole pattern securing the assembly to the container.

5.9.4 Tighten all bolts wrench tight.

5.9.5 If bolts cannot be made, remove screws and Grouting Support Assembly, secure penetration with temp cover, position shield blanket, and notify WGS and cog engineer

5.9.6 RC perform survey around port area.

A. **IF** removable contamination levels are >20 dpm/100cm² alpha and >200dpm/100cm² beta/gamma.

1. **THEN** DDWO decontaminate surfaces to <20 dpm/100cm² alpha and <200dpm/100cm² beta/gamma.

2. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

5.10 Remove Vertical securement Device #1. (top of container North Side) *(See Photo on Attachment A Page 3, WMG Sketch "Securement Device 4OO5-DWOO7" and SK-NJA-071613 Sheet 11 of 18 (Step 11 for reference)*

NOTE: *Either of 5.10.1 or 5.10.2 may be performed to remove the vertical securement device form the North Port. (if device will not fit out the port using 5.10.1 then 5.10.2 may be used instead to cut the rod)*

5.10.1 **Pull the whole device from the container**

A. Place herculite or equal around Jack Screw Port cover prior to removing port cover. North

AR 9-11-13 ~~B. Remove the threaded pipe cap from the securement device half coupling~~

C. ~~Install~~ Drill and tap the securement device cap (SKJHS062513), for installation of 3/8"-16 UNC thread.

D. Remove the four screws holding flange in place. AR 9-11-13 DK 9-11-13

E. Place sleeving approximately 6 feet long around the diameter of the securement device and seal to container.

F. Secure the sleeving to the flange.

[+] G. Complete WV-2180, if needed AR 9-11-13 DK 9-11-13

H. If a rigging sketch is needed then obtain one from Engineering.

I. Rig to the securement device, if needed AR 9-11-13 DK 9-11-13

J. Lift the device up and out of the container.

K. Tape sleeving and perform and umbilical cut.

L. Remove sleeving from port area.

M. RC perform survey around port area.

1. **IF** removable contamination levels are >20 dpm/100cm² alpha and >200dpm/100cm² beta/gamma.

a. **THEN** DDWO decontaminate surfaces to <20 dpm/100cm² alpha and <200dpm/100cm² beta/gamma.

b. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

OR

5.10.2 **Cut the threaded rod**

A. Place herculite or equal around Jack Screw Port cover prior to removing port cover.

AR 9-11-13 DK 9-11-13 ~~B. Remove the threaded pipe cap from the securement device half coupling.~~

C. ~~Install~~ Drill and tap the securement device cap (SKJHS062513), for installation 3/8"-16 UNC thread

D. Remove the four screws holding flange in place. AR 9-11-13 DK 9-11-13

E. Place sleeving approximately 12 feet long around the diameter of the securement device and seal to container.

F. Secure the sleeving to the flange.

[+] G. Complete WV-2180, if needed.

H. Rig to the top of the Securement Device, if needed.

I. Lift the Securement Device flange section up approximately 1ft above the container and hold.

J. Install cribbing under flange to safely prop it up at approximately 1 ft high.

K. Disconnect rigging from fork lift.

L. Tape sleeving tight to threaded rod for contamination control during cutting.

M. Drape a sheet of herculite over the securement device and tape on three sides to create a small tent.

N. Run a 4" duct from the PVU for ventilation. Alternately, an environmentally sampled HEPA vacuum may be used.

O. Use a reciprocating saw or equivalent to cut the threaded rod. (Allow the lower section of rod to fall into the waste container)

P. Tape to and secure open edges (on threaded rod)

Q. Remove sleeving from port area.

R. RC perform survey around port area.

1. IF removable contamination levels are >20 dpm/100cm² alpha and >200dpm/100cm² beta/gamma.

a. **THEN** DDWO decontaminate surfaces to <20 dpm/100cm² alpha and <200dpm/100cm² beta/gamma.

b. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

S. Remove herculite tent.

5.10.3 Bag the securement device and herculite.

5.10.4 Remove the securement device from the top of container.

5.10.5 Package and remove waste using waste profile VGAS.001.

5.11 Plug port on North Side *(See Photo on Attachment A Page 2)*

NOTE: *The Plug (4") and Cap Screws (5/16 x 2 ¾" SHCS) required by this section are different sizes than those items required by Section 5.7.*

5.11.1 RTV new gasket onto new 4" Deep plug.

5.11.2 Lubricate *(5/16 x 2 ¾" SHCS)* long Cap Screws with a small amount of never seez (or equal)

5.11.3 Position plug into recessed area of container port.

5.11.4 Install Cap Screws and tighten (hand tight).

FC1> A. Torque each to 35 ft lbs. (+or- 4 ft lbs) QA to witness torqueing.

[+] QA Print/Sign/Date Christopher Barton / Christopher Barton 9/16/13

[+] Calibrated Torque Wrench ID# 41-TW-18

[+] Calibration Due Date 12/31/13

B. Apply RTV in the gap around the top of the port cover.

C. RC perform survey around port area.

1. **IF** removable contamination levels are >20 dpm/100cm² alpha and >200dpm/100cm² beta/gamma.

WVMP SAR Reference 7-7

Melter Waste Package Grouting Implementation/QA Plan, Revision 2, CH2M Hill-B&W West Valley, LLC, West Valley, New York, October 23, 2013.

(pages 1 – 4)

MELTER WASTE PACKAGE GROUTING IMPLEMENTATION/QA PLAN
(SUBJECT TO CHANGE BASED ON ENCOUNTERED CONDITIONS)
(Rev 2, October 23, 2013)

1.0 BACKGROUND

The current Certificate of Conformance for the melter waste package, as designed and provided by WMG, Inc., indicates:

> *"Packaging requirements, prior to shipment, include the addition of Low Density Cellular Concrete (LDCC) at a density that yields a minimum compressive strength of 1,000 PSI. The maximum gross weight of the completed package shall not exceed 390,000 pounds."*

GeoScience Group was awarded a contract to develop a LDCC recipe that meets these criteria and provide such material to the WVDP for placement into the melter waste package.

1.1 1,000 Pounds Per Square Inch (PSI) Specification

As indicated in Section 2.2 of the Statement of Work (SOW) (Mix Design), GeoScience is required to:

> *"... submit a mix design for the proposed grout, to meet the above specification requirements. The mix design shall be proven by laboratory testing (e.g., compressive strength tests) with the results submitted to CHBWV for approval prior to grout placement. If the schedule does not permit sufficient time to perform a 28 day compressive strength test, then the compressive strength test results for 3, 5, 7, etc. day tests shall meet or exceed the expected strength results plotted on the strength cure for the designated mix design."*

As of October 23, 2013, the 70 pounds per cubic foot (PCF) wet-density LDCC recipe mocked up at Wayne Concrete by GeoScience on September 30, 2013 has resulted in four (4) day cylinder breaks ranging from 520 to 900 PSI with the latest 22 day breaks at >1,000 PSI for all the 3"x6" cylinders (Attachment D). It is anticipated that the PSI results will continue to graph upward as the curing cycle continues through the ASTM spec-required 28th day break on October 28, 2014. It appears worst case is that the PSI results do not continue to graph upward but remain at the 22 day PSI results (i.e., results would not trend downward).

1.1.1 Lifts

As also required in Section 2.2 of the SOW (Mix Design), to be conservative and for risk management purposes, GeoScience's has determined that the grout should be added to the melter waste package in two lifts (i.e., ~three (3) to six (6) cement trucks per day for two (2) days). The two (2) lift approach:

- Further insures the integrity of the cellular structure of the grout is maintained
- Reduces time-limit stresses associated with emptying six (6) cement trucks into the package in one day versus all 12 in one (1) day, and
- If deployment issues require abandonment of first day grouting activities (e.g., unexpected rad concerns), then only six (6) truckloads of grout would be wasted versus 12.

1.2 390,000 Pound Maximum Gross Weight Capacity

The melter waste package has an approximate height, length, and width of 13 feet and currently weighs 160 tons. The annular void space that is required to be filled is approximately 910 cubic feet. However, passive migration of the LDCC in spent equipment cavities may occur which would increase the volume to 1025 cubic feet. [See Attachment A how void space volume was calculated]. [The maximum void space calculation was validated by WMG in June 2013 (see Attachment B)]. Upon completion of grouting, the package must weigh less than 390,000 pounds as measured by CHBWV.

The 2004 SOP 300-07 Appendix D for the melter waste package (TC-474) states that the pre-grout weight of the melter waste package, that was determined using a crane, was 318,200 lbs (with lift lugs). The only crane on site at the time that was capable of performing the lift was the 500 ton gantry; the gantry would have been lifting eight 55 ton shackles and other assorted rigging.

In September 2013, the melter waste package was re-weighed using WIP# 1303663 with 310,672.1 pounds or 155.34 tons being recorded. The 2013 weighing method used (as explained in the WIP) would result in a more accurate weight than the 2004 500 ton gantry method by its very nature and allow cost effective weighing of the container while grouting. The more accurate weight is reflected in a new SOP 300-07 Appendix D data sheet for the waste package (TC-474) (supporting documentation is also in container file) [See Attachment C]

The annular void space in the melter waste package needs to be grouted to meet the package's Certificate of Conformance. If only the annular void space was grouted, the final gross weight of the grouted package would be far less than its currently stated 390,000 capacity. However, there are open penetrations in the melter inside the package which may allow grout to enter the melter cavity, which is not required. Using a grout with a PCF of 70 (see above) and assuming as a worst case the entire melter cavity if passively filled with grout, the entire package may weigh between 377,710 to 387,477 pounds (as compared to the current package maximum gross weight capacity of 390,000 pounds) [The conclusion that the grouted package, assuming all voids were filled with grout, would weigh below the package's gross weight capacity was validated by WMG in June 2013 (see Attachment B)]. (Although the Certificate of Conformance does not state that the annular void space needs to be "filled" nor a requirement as to how such is qualified, the above reflects a scenario where the final level of grout comes to approximately six to twelve inches from the inside top of the melter package to insure that grout is not allowed to come out of the penetrations on top of the waste package and the melter is encased in grout.)

2.0 RISK MANAGEMENT

2.1 1,000 PSI Specification

28-day PSI data will be generated, by its nature, after the grout is placed into the melter waste package. (Note: although the ASTM C495 spec for LDCC recognizes the 28-day cure period for LDCC, if required, but not anticipated, the use of 56-day break data to confirm achievement of the 1,000 PSI requirements is an option.) As such, a high degree of confidence is needed to insure such results will be obtained. In other words, once the melter package is filled with grout and if subsequent associated grout cylinder breaks do not meet 1,000 PSI (or the package weights more than 390,000 lbs, as discussed below), since we will not be able to remove the grout easily, the entire grouted waste package we will have to repackaged which will cost millions of dollars and may not even be feasible (size and weight restrictions will not allow rail/road transport of such a package).

Recipe mockups at 70 PCF indicate 22 day breaks exceeding the 1,000 PSI specification. As an additional risk management option, in discussions with WMG, it appears the 1,000 PSI may be very conservative and that models could be re-run at a lower PSI (e.g., 750 PSI) to determine if a less stringent PSI grout could be used and still meet regulatory requirements for the package (for an ~$45,000). If the less conservative PSI meets regulatory requirements, WMG would modify the Certificate of Conformance appropriately to reflect the new PSI requirement. Given the 22-day cylinder data [>1,000 PSI for all 3"x6" cubes, worst case potential that the PSI through 28 days (October 28, 2013) would stay at 22-day levels and not decrease (would expect it to increase)], the re-modeling by WMG and their Russian subcontractor will not be performed unless needed after the waste package is grouted and 28-day cylinder break data is received.

2.2 390,000 Pound Maximum Gross Weight Capacity Specification

Assuming a 70 PCF grout is realized and the entire package void space and the entire melter cavity becomes filled with grout due to open penetrations on one (1) side (a unplugged discharge chute/pour spout approximately half way down the side of the melter) and on top of the melter [R1, R2 (~5" open plenum / glass thermowell ports)], it is anticipated that there will be an approximately 2,500 to 12,300 pound cushion

before the package's rated weight capacity of 390,000 pounds is reached.

Risk management actions to be taken in the field include, as discussed more below, include re-weighing the waste package as it is being filled and using optics to determine height of grout as the package is being filled.

As an additional risk management option, in discussions with WMG, it appears, like the package PSI spec, the weight capacity spec may also be very conservative and that models could be re-run to determine a higher weight capacity that would still meet regulatory requirements (for ~$45,000).

If the worst case scenario is realized (entire melter cavity if passively filled with grout in addition to the required annular void space), a calculated cushion of between 2,500 and 12,300 pounds is expected before the maximum gross weight capacity of the package is reached. Field activities, as discussed in more detail below will be utilized to insure the package weight does not exceed 390,000 pounds. As such, the re-modeling by WMG and their Russian subcontractor will not be performed unless needed.

3.0 IMPLEMENTATION/QUALITY ASSURANCE WORK PLAN

3.1 Meeting PSI Spec

As indicated in Section 2.5 of the SOW (Testing and Laboratory Services) GeoScience's is required to:

"*2.5.1 The subcontractor shall provide testing and laboratory services from a third party independent testing laboratory. The independent testing laboratory shall have a qualified quality control field representative present each day of grout placement, including the batch plant testing operation.*

2.5.1.2 The quality control field representative shall test each load of grout for wet density, to assure that it falls within the specified range, in accordance with ASTM C-138.

2.5.1.3 The quality control field representative shall cast a minimum of 8 test cylinders per day, for each container placement, to be taken at a point in the discharge line that has been subjected to a maximum head pressures developed in the discharge line. Test specimens shall be prepared, handled, cured and tested for compressive strength in accordance with the requirements of ASTM C495."

3.1.1 Wet Density Range (corresponding to SOW Section 2.5.1.2)

One sample from each concrete truck load (after the addition of the foam additive) will be taken. The PCF will be required to be between 68 and 72 PCF (with a goal of 70 to 72) for each truck (or an average of all the day's trucks) to reflect a nominal PCF of between 70 and 72 PCF inside the melter waste package. The 70 to 72 PCF range inside the melter was calculated as indicated in Table A.

3.1.2 PSI Test Cylinders (corresponding to SOW Section 2.5.1.3)

For additional risk management purposes, for each cement truck load that passes wet density testing, test cylinders will be cast (not just one truck per day as indicated in SOW Section 2.5.1.3). Grout volume to fill the cylinders will be taken at a sample station located post-grout at a location that has been subjected to the maximum head pressures developed in the discharge line. Cylinders may be stored in cure box. For one of the trucks on each day of grouting, a full sequence of test cylinders will be generated and tested, at a minimum, as follows:

- 2 cylinders for 8-day breaks
- 4 cylinders for 28 day breaks
- 4 cylinders for 56-day breaks (if needed)
- Contingency: 2 cylinders

For the remainder of the trucks to be used in a particular day, the following sequence of test cylinders may also be generated, at a minimum. For each day of grouting, these remaining truck cylinders will be broken only if the full sequence of cylinders for that day fails to display 1,000 PSI at 28 days. If these cylinders are broken, the 28 day (or 56 day) results from all broken cylinders will be averaged together, with the data generated from the other days of grouting, to document the final PSI of the grout inside the waste package.

- 4 cylinders for potential 28-day breaks
- 4 cylinders for potential 56-day breaks (if needed)

3.2 Meeting Gross Weight Capacity Spec

The largest unknown factor relative to staying below the melter waste package's stated gross weight capacity of 390,000 pounds is to what degree grout is going to enter the melter's cavity via open penetrations R1 and R2 located on top of the melter (approximately 20" from underside of top of waste container) and the one non-plugged discharge chute located approximately half way down the melter's side. As such, the tentative plan to monitor the weight of the package is being filled is as follows. Although subject to change, while pouring the lifts, the melter is anticipated to be weighed before the level of the open penetrations in the side and top of the melter are approached. As the grout level approaches the penetrations and after the penetrations are immersed in grout, more frequent weighing may occur. Visual and dose rate readings will be collected to determine the approximate height of the grout within the package. Once the waste package weighs approximately 387,000 pounds, no further grout will most likely be added to maintain a 3,000 pound cushion.

WVMP SAR Reference 7-8

Grout Melter Container TC-474 at the Rail Packaging and Staging Area, CHBWV work instruction package W1303694, CH2M Hill-B&W West Valley, LLC, West Valley, New York, completed November 2013.

Pages 9 - 10

b. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

5.10.4 Inspect port for grout clean and remove grout from port if needed.

5.10.5 Perform Section 5.11 to install container plug.

5.11 Install Container Plug into port left by removal of Grout Support Assembly. *(See "Melter Container Plug Details" SKJHS052913)* AR 11/5/13 DK 11/5/13 AR 11/5/13 DK 11-5-13

5.11.1 RTV ~~new~~ gasket onto ~~new~~ 4" Deep plug.

5.11.2 Lubricate (5/16 x 2 ¾" SHCS) long Cap Screws with a small amount of never seez (or equal)

5.11.3 Position plug into recessed area of container port.

5.11.4 Install Cap Screws and tighten (hand tight).

A. Torque each to 35 ft lbs. (+or- 4 lbs) QA to witness torqueing.

[+] QA Print/Sign/Date Paul Kaiser / Paul Kaiser 11-5-13

[+] Calibrated Torque Wrench ID# 41-TW-18

[+] Calibration Due Date 12-31-13

B. Apply RTV in the gap around the top of the port cover.

C. RC perform survey around port area.

AR 10-17-13 DK 10-17-13

1. IF removable contamination levels are >20 dpm/100cm² alpha and /or >200dpm/100cm² beta/gamma THEN.

a. DDWO decontaminate surfaces to <20 dpm/100cm² alpha and <200dpm/100cm² beta/gamma.

b. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

OR

5.11.5 If Cap screws cannot be made, remove screws and plug, secure penetration with temp cover, position shield blanket, and notify WGS and cog engineer

A. RC perform survey around port area.

AR 10-17-13 DK 10-17-13

1. **IF** removable contamination levels are >20 dpm/100cm² alpha and /or >200dpm/100cm² beta/gamma **THEN**.

a. DDWO decontaminate surfaces to <20 dpm/100cm² alpha and <200dpm/100cm² beta/gamma.

b. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured.

5.12 Remove vent ducting, box filter and knock out pot.

NOTE: *Keep PVU running during vent line breakdown. The PVU will remain running until directed to be secured by the Cognizant Engineer.*

5.12.1 Close the 4" Ball Valve on the Grouting Support Assembly on the (vent side) of the container. (vent assembly)

5.12.2 Disconnect the 4" vent duct from the vent assembly and bag open ends.

5.12.3 Disconnect vent duct from the Knock Out Pot and bag open ends on each.

5.12.4 Disconnect duct (bag open ends) from the filter box. Bag filter box as waste using waste profile VGAS.001.

5.12.5 Dispose of the ventilation duct as waste using waste profile VGAS.001.

5.12.6 Check knock-out drum for liquids.

A. If ≥ 2 gallons of liquid is collected THEN Sample for interceptor acceptance Per Attachment A "Liquid Sampling Instructions".

B. IF < 2 gallons of liquid is collected THEN obtain field pH of the liquid and check for visible oil sheen and provide results to WPD. If pH is ≤2 or ≥12.5, See Attachment A, Step 1.1.4.

5.12.7 Set-up contamination area with herculite on container around the port.

5.12.8 Disconnect grout inlet valve assembly.

WARNING:

EXCESS GROUT MAY OVERFLOW FROM PORT WHEN DISCONNECTING VALVE ASSEMBLY. GROUT IS POTENTIALLY CONTAMINATED.

5.12.9 Tape & cut sleeving between valve assembly & port to maintain seal on container.

5.12.10 Remove sleeving and Inspect port for grout.

5.12.11 RC survey prior to cleaning port.

A. RC perform survey around port area.

AR 10-17-13 DC 10-17-13

1. IF removable contamination levels are >20 dpm/100cm² alpha and/or >200dpm/100cm² beta/gamma.

2. THEN DDWO decontaminate surfaces to <20 dpm/100cm² alpha and <200dpm/100cm² beta/gamma.

3. Waste created during decontamination shall be disposed with profile VGAS.001. Windex cans shall be emptied and punctured

5.12.12 Inspect port for grout clean and remove grout from port if needed.

5.12.13 Perform Section 5.13 to install container plug.

5.13 Install Container Plug into port left by removal of Grout Support Assembly. *(See "Melter Container Plug Details" SKJHS052913)* AR 11/5/13 DC 11-5-13 AR 11/5/13 DC 11-5-13

5.13.1 RTV ~~new~~ gasket onto ~~new~~ 4" Deep plug.

5.13.2 Lubricate *(5/16 x 2 ¾" SHCS)* long Cap Screws with a small amount of never seez (or equal)

5.13.3 Position plug into recessed area of container port.

5.13.4 Install Cap Screws and tighten (hand tight).

A. Torque each to 35 ft lbs. (+or- 4 lbs) QA to witness torqueing.

[+] QA Print/Sign/Date Paul Kaiser / Paul Kaiser 11-5-13

[+] Calibrated Torque Wrench ID# 41-TW-18

[+] Calibration Due Date 12-31-13

B. Apply RTV in the gap around the top of the port cover.

C. RC perform survey around port area.

1. IF removable contamination levels are >20 dpm/100cm² alpha and >200dpm/100cm² beta/gamma THEN.

WVMP SAR Reference 7-9

Administration of Work Instruction Packages, EP-5-002, Revision 37, CH2M Hill-B&W West Valley, LLC, West Valley, New York, March 19, 2014.

CHBWV West Valley Decommissioning Team

CH2MHILL • B&W West Valley, LLC

ENGINEERING PROCEDURES

TITLE: ADMINISTRATION OF WORK INSTRUCTION PACKAGES

1.0 PURPOSE

This engineering procedure provides instructions for the administration of Work Instruction Packages (WIPs) including development, revision, cancellation, closeout, and periodic review/recall of issued WIPs.

The administration of WIPs is a Worker Safety and Health Administrative Control program as identified in Addendum 1, "WVDP Worker Safety and Health Plan" (WVDP/WSHP) to WVDP-310, "WVDP Integrated Safety Management System (ISMS) Description." The WVDP/WSHP includes a program statement associated with each Worker Safety and Health Administrative Control program. In accordance with 10 CFR 851.11(c)(1), any proposed change (i.e., modification, addition, or deletion) to EP-5-002 that would invalidate the program statement in the WVDP/WSHP requires prior DOE approval.

2.0 GENERAL

2.1 Terms used in this procedure are defined in Attachment A, "Definitions."

2.2 Attachment B, "Writing Guidelines and Document Structure," assists originators with WIP formatting and writing guidelines.

2.3 Attachment C, "Reviewer/Planning Team Selection Checklist," is provided to assist in identifying the required reviewer/planning team members for WIP development.

2.4 When necessary, approval signatures may be obtained via telecon or the use of emails. Attachment D, "Telecon/Email Approvals," provides the method for obtaining approvals via telecon or email.

3.0 WIP DEVELOPMENT PROCESS

This section may be performed in the order that best suits the efficiency of time and effort to develop and issue WIPs.

3.1 Originator: Defines the scope of the WIP, identifies the hazards associated with the work, and develops the work instructions. To accomplish this task:

3.1.1 Perform a scoping assessment of the assigned task with the work group(s) that will use the final instruction as well as applicable support groups, including hazard control specialists (HCS), as deemed appropriate. The scoping assessment should include a walkdown of the proposed tasks to assess actual field conditions.

3.1.2 Refer to historical files (e.g., completed work instructions, related operating procedures, lessons learned documents) for guidance and experience that can be incorporated into the work instructions.

3.1.3 Refer to available resources (CHBWV Intranet Lessons Learned, WVDP Operating Experience Program Coordinator, Occurrence Reports [ORPS], and/or DOE lessons learned system) for lessons learned information on activities similar to those being proposed. Incorporate applicable lessons learned information into the work process and/or identify the information for inclusion into training or briefing material, if applicable.

3.1.4 Identify hazards using form WV-3909, "Activity Hazards Analysis" (AHA).

NOTE *The originator may obtain a Work Control Number (WIP number) from Work Control at any time.*

3.1.5 Develop WIP using form WV-2571, "WVDP Work Instruction Package (WIP Form)" and guidelines in Attachment B, "Writing Guidelines and Document Structure."

3.1.6 Include hazard controls in the WIP in accordance with WV-921, *Hazards Identification and Analysis.* Ensure that hazard controls not specifically discussed in the WIP are captured in other permits (e.g., RWP, IWP) or are identified on the Pre-Job Briefing form (WV-3745) as required by WV-921.

NOTE *When the risks to the planning team outweigh the potential benefits of the walkdown, a tabletop review using photographs and drawings with group discussion may be performed in-lieu of the walkdown, as approved by the Work Review Group Coordinator (WRGC).*

3.2 Work Group Supervisor and/or Originator lead Planning Team Walkdowns in accordance with SOP 00-46, *Work Instruction Walkdowns, Pre-Job and Daily Briefings and Post-Job Feedback/Lessons Learned,* as needed during the development and review of the work package.

3.3 The originator sends an electronic copy of the WIP draft and supporting documents to the planning team participants and any other required reviewers identified on Attachment C for review and approval.

3.3.1 Discuss and ensure applicable HCSs concur with hazard mitigations addressed in the WIP.

3.3.2 Regulatory Strategy shall evaluate and approve all WIPs to determine whether or not each WIP is a RCRA Operating Record and determine whether all applicable environmental and regulatory requirements are addressed in the WIP.

3.4 Work Review Group Coordinator (WRGC) performs a Work Control Management review of the WIP and ensures the following:

3.4.1 The WIP was developed following the processes in this procedure.

3.4.2 Hazards and controls identified by the hazard analysis process are incorporated into the WIP and supporting documents (e.g., RWP, IWP, GDP).

3.5 A USQD Evaluator determines the applicability of WV-914, *Unreviewed Safety Question Process (USQP),* to the proposed activity and indicates if Form WV-3306 is required.

3.6 The Responsible Manager (RM) and Operations Manager approves the WIP and ensures the following:

A. Referenced permits do not provide conflicting directions, PPE, or other mitigations and controls.

B. Post maintenance tests are specific, have acceptance criteria, and are approved by the appropriate Cognizant Systems Engineer and Operations authorization.

3.7 Additional Management Review Processes

3.7.1 Final Interactive Meeting for High Hazard or Complex Work (see def.)

A. Held when deemed necessary by the Responsible Manager.

B. The Final Interactive WIP review meeting is a face-to-face review of the draft work order with planning team members, which allows the reviewers to improve the final product based on the shared discussions.

C. During the interactive WIP review meeting, the following contingency planning techniques will be discussed and documented in the meeting minutes:

1. What is the critical work scope
2. What can go wrong when performing the work scope
3. What Error likely situations/Error precursors are applicable to performing the work scope
4. What are the Defenses in depth barriers to improve safety when performing the work scope

3.7.2 Hazard Review Board (HRB)

A. Convened at senior management discretion for particularly complex/high hazard tasks (e.g., work in High Radiation Area; work with high electrical hazards or fire hazards, work requiring fall protection, work involving cranes, work affecting facility design).

B. The HRB focuses on the implementation of Integrated Safety Management principles, best practices, lessons learned and key elements of the Voluntary Protection Program. (Refer to EMD-002).

C. Upon satisfactory completion of the HRB, the Hazard Review Board Chairman will document with signature on WV-2571 indicating approval to perform work.

3.8 The originator forwards WIP to Work Control for issuance when WIP is approved.

3.9 Work Control reviews the WIP for completeness, makes data entry, and issues the WIP with all supporting documents (e.g., RWP, IWP, GDP).

3.10 If Work Control is not available, (e.g., off-shift, weekends, and holidays) originator performs the following:

3.10.1 Obtains the Work Control Number, if not already assigned, from the Daily Log Book located in the PSO Supervisor's office and enters the number on WV-2571.

3.10.2 Writes "Issued" and the date and time on the cover page.

3.10.3 Ensures a copy of the cover page is placed under the cover of the logbook.

3.10.4 Ensures that Work Control is notified the next working day.

4.0 WORK INSTRUCTION PACKAGE REVISION PROCESS

4.1 Type of Change Determination

The originator and WGS determine the type of change to be used by utilizing the following guidelines as approved by the RM or Work Review Group Coordinator (WRGC):

4.1.1 A direct document change (DDC) may be used when:

A. Change does NOT exceed the boundaries of the original scope.

B. Hazards originally reviewed are NOT increased, no new additional hazards are identified, and no hazard mitigations are added or modified.

C. Change does NOT modify the process that generated a previously identified hazard.

D. Change does NOT affect technical identification (e.g., valve designation).

E. Hazard is identified and mitigated in the work instructions but unintentionally left unchecked in the AHA or requires additional clarification.

F. Limiting conditions or acceptance criteria are NOT changed.

G. The change DOES NOT affect QA activities, requirements, or functions.

H. The change DOES NOT affect Regulatory Strategy activities or requirements.

I. The change DOES NOT affect a critical step, hold or verification point step.

J. Hazardous energy boundaries are NOT changed or added.

4.1.2 Examples of changes that may be performed as a DDC are:

A. Corrections of typographical errors, misspellings, worker designations, correcting a cross-reference to another step, updating the reference number to a permit or JSA or other administrative corrections.

B. Addition or deletion of steps, if the above requirements are met.

C. Sequence of steps is changed that DOES NOT affect the intent or any critical steps.

4.1.3 A Field Change (FC) shall be used when:

A. Change is outside the boundaries of the original scope.

B. Hazards originally reviewed are increased, additional hazards are identified, or hazard mitigations are added or modified.

C. Limiting conditions or acceptance criteria are changed.

D. The change affects QA activities, requirements, or functions.

E. The change affects Regulatory Strategy activities or requirements.

F. The change affects a critical step, hold or verification point step.

G. Hazardous energy boundaries are changed or added.

H. A partially worked WIP is cancelled (see Section 5.3).

4.2 Direct Document Changes (DDC)

NOTE *When the originator of the WIP is not available (e.g., off-shift) and the work needs to be performed, another person having the qualifications of an originator may act as the originator to write the DDC.*

4.2.1 The originator reviews the Activity Hazards Analysis (WV-3909) to confirm that the modifications do not increase or add to the hazards originally reviewed.

4.2.2 If a hazard is identified and mitigated in the work instructions but unintentionally left unchecked in the AHA checklist, then update AHA checklist and annotate or provide additional clarification in the hazard control/mitigation section.

4.2.3 The originator performs a DDC as follows:

A. Annotates the changed step(s) or information in the work instruction and lines out/deletes step(s) or information no longer applicable

B. The originator and WGS reviews and approves each DDC by initialing and dating.

C. The originator provides a copy of DDC to Work Control.

4.3 Field Changes (FC)

NOTE1 *When the originator of the WIP is not available (e.g., off-shift) and the work needs to be performed, another person having the equal qualifications of an originator (see Attachment A for qualifications) may act as the originator to perform the FC.*

NOTE2 *For field changes that are required immediately in the field, it is acceptable to obtain Form WV-1085 and hand write the change, then obtain signatures per telecon.*

4.3.1 If performing an electronic field change, the originator checks for and incorporates all previous DDCs in the electronic FC.

4.3.2 The originator determines the FC number by reviewing the entire document for previous FCs. The next sequential number following the last FC is used.

4.3.3 The originator completes form WV-1085, "Work Instruction Package (WIP) Field Change Form."

4.3.4 Include change lines for each revision change - indicate changes, additions, and deletions in the DRAFT review copies using the Track Changes feature.

4.3.5 The originator annotates the changes with the symbol FC# (where # represents the number of the FC, e.g.,FC1, FC2, FC3) in the left margin of the items changed.

4.3.6 The originator reviews the original Activity Hazards Analysis (WV-3909), if not done already, to determine if the FC imposes additional hazards, hazardous situations or increases hazards/consequences which have not been evaluated and updates WV-3909 in accordance with WV-921, as needed.

NOTE *HCSs should work with the WGS to determine applicable permit requirements and hazard mitigations prior to and/or during the walkdown.*

4.3.7 The WGS or designee performs a walkdown in accordance with SOP 00-46, *Work Instruction Walkdowns, Pre-Job and Daily Briefings and Post-Job Feedback/Lessons Learned.* This includes coordination with applicable support groups (e.g., RS, Safety) and work groups (e.g., Maintenance) if applicable.

4.3.8 The originator provides the description of the FC including additional hazards and controls required and pages affected that are required to be replaced.

4.3.9 The originator provides the reason(s) the FC was necessary.

4.3.10 The originator obtains signatures from all other departments and work groups affected by the change. See Attachment D for assistance in determining affected groups.

4.3.11 If Regulatory Strategy requires change to the status of the document as an RCRA Operating Record, change the designation on the original cover page and initial and date.

4.3.12 USQD Evaluator determines the applicability of WV-914, *Unreviewed Safety Question Process (USQP)*, to the proposed activity and indicates if Form WV-3306 is required.

4.3.13 The Responsible Manager (or designee) and the Operations Manager approves the FC.

NOTE *FC pages supersede existing pages of the WIP. All sign-offs are made on the latest FC page unless the steps were already performed.*

4.3.14 Work Control reviews WV-1085 for completeness and issues the FC.

4.3.15 If Work Control is not available (e.g., off-shift, weekends, holidays), the WGS or originator performs the following:

A. Writes "Issued" and the date and time on the Field Change form.

B. Ensures a copy of the Field Change is placed under the cover of the Daily Log Book located in the PSO Shift Supervisor's office.

C. Ensures that Work Control is notified the next working day.

5.0 WORK INSTRUCTION PACKAGE CANCELLATION PROCESS

5.1 Voiding Work Instruction Packages

NOTE *Only WIPs given a number, but NOT issued, may be voided.*

Voided WIP's shall be recorded as such in the CMMS database

5.2 Canceling Work Instruction Packages (Work NOT started)

5.2.1 The originator and WGS complete WV-2571.

5.2.2 The originator forwards WV-2571 to Work Control.

NOTE *A partially worked WIP may be canceled if a task is no longer required to be completed or is replaced by another work instruction.*

5.3 Canceling Partially Worked Work Instruction Packages

5.3.1 The originator forwards the entire WIP (including permits [e.g., ALARA PRE/Post Job briefings, IWP, GDP] that were used) to Work Control.

5.3.2 Work Control will determine if DDC, Field Change or Cancellation per 5.2 is required.

6.0 WORK INSTRUCTION PACKAGE COMPLETION, REVIEW, AND DOCUMENTATION

6.1 The WGS conducts a post-job review in accordance with SOP 00-46. Where lessons learned/problems encountered or input from the workers indicate that there is a benefit for the review, the WGS documents feedback on form WV-2573, "Work Package Status Log and Post-Job Feedback/ Lessons Learned." The WGS also indicates if lessons learned apply on WV-2571.

6.2 When required, the WGS conducts a post-job of ALARA jobs in accordance with WV-984, *ALARA Program*. The WGS attaches a copy of Form WV-3118, "West Valley Demonstration Project, ALARA Post-Job Review," to the WIP.

6.3 The WGS verifies documents (e.g., IWP, HWP, Pre-Job Briefing) associated with the WIP are in the WIP folder.

6.4 The originator and WGS verify completion of the work and sign on WV-2571.

6.5 For WIPs used to perform maintenance on site equipment, the originator shall provide a brief description of the work performed and the cause of the problem if known on form WV-2573 and Work Control will enter this information into the CMMS database.

6.6 Originator forwards the WIP to Work Control.

6.7 Work Control reviews the completed WIP to ensure package is properly prepared for storage and transfers the closed out WIP to Records in accordance with WVDP-262, *WVDP Records Management Program Plan.*

7.0 PERIODIC REVIEW AND RECALL OF WORK INSTRUCTION PACKAGES

7.1 Work Control performs a periodic review and 90 day recall on all work instructions for:

7.1.1 Any WIP in which work has not commenced and notifies the applicable WGS.

7.1.2 Any WIP that has been authorized and work performed but not worked in 90 days.

7.1.3 Any WIP that has significant multiple revisions (more than 5 or content is no longer clearly defined)

7.2 The WGS and originator determine if the work still needs to be performed and if the WIP is in compliance with current requirements.

7.3 If it is determined that the work instruction is no longer needed, the WGS or originator closes out the WIP by canceling it per step 5.0.

7.4 If it is determined that the work needs to be performed but the work instruction does not meet current requirements, the originator should field change the WIP or cancel the WIP and issue a new one.

8.0 RECORDS

The following forms, data sheets, logs, reports, or any other form of documentation are considered records and when created are to be prepared, maintained, and transferred to Records in accordance with WVDP-262 and WVDP-529. Refer to the CHBWV Master File Plan for further information.

8.1 Work Instruction Package (WV-2571, attachments, and associated documents).

8.2 Work Instruction Package (WIP) Field Change (WV-1085and associated documents0

9.0 REFERENCES

NOTE *Refer to E-docs for the latest version of WVDP Controlled Documents. Refer to the S:/WPFORMS folder for the latest revision of WVDP forms used in this procedure.*

EP-3-007	*Engineering Change Notice*
SHIP-108	*Job Safety Analysis* (and form WV-3043)
SHIP-201	*Industrial Work Permits* (and form WV-1107)
SOP 00-04	*Lock, Tag, and Confirm Procedure*
SOP 00-11	*Troubleshooting and Maintenance of Electrical Equipment*
SOP 00-30	*System and Component Labeling*
SOP 00-38	*Administration of Hoisting and Rigging Activities*
SOP 00-46	*Work Instruction Walkdowns, Pre-Job and Daily Briefings and Post-Job Feedback/Lessons Learned* (and forms WV-2573 and WV-3745)
SOP 00-49	*Control of Temporary Modifications* (and form WV-3811)
SOP 00-52	*Conduct of Operations*
SOP 00-54	*Minor Work Request*
SOP 300-07	*Waste Generation, Packaging, and On-Site Transportation*
WV-370	*Underground Utility Review Policy* (and forms WV-3521 and WV-3522)
WV-914	*Unreviewed Safety Question Process (USQP)* (and form WV-3306)
WV-921	*Hazards Identification and Analysis* (and form WV-3909)
WV-984	*ALARA Program* (and forms WV-2404, WV-4281 and WV-3118)
WVDP-010	*WVDP Radiological Controls Manual*
WVDP-106	*WVDP Conduct of Operations Applicability Matrix*
WVDP-111	*CH2M HILL • B&W West Valley, LLC Quality Assurance Program*
WVDP-200	*West Valley Demonstration Project (WVDP) Waste Acceptance Manual*
WVDP-227	*WVDP Facility Identification and Categorization Matrix*
WVDP-204	*WVDP Quality List Q-List*
WVDP-262	*WVDP Records Management Plan*
WVDP-274	*Maintenance Implementation Plan (MIP)*
WVDP-352	*WVDP Site Welding Manual* (and form WV-1888)
WVDP-357	*WVDP Issues Reporting Program*
WVDP-485	*Work Control*
WVDP-529	*WVDP Records Disposition Plan*

10.0 ATTACHMENTS

Attachment A, "Definitions"
Attachment B, "Writing Guidelines and Document Structure"
Attachment C, "Reviewer/Planning Team Selection Checklist"
Attachment D, "Telecon/Email Approvals"

ATTACHMENT A
DEFINITIONS
(Page 1 of 5)

1. Activity Hazard Analysis (AHA) – an activity hazard analysis that documents: 1) Hazards Controls Specialists (HCSs) included in the work planning process; 2) identification of specific task activities where hazards are present; 3) identification of hazards applicable to the specific tasks; and 4) incorporation of the mitigation of the hazards into the work document/associated documents using a hierarchy of controls whenever elimination is not possible.

2. Bench Top – a small scale mockup used when the size of the modeling is restrictive.

3. Cognizant Manager – the manager, or designee, with the technical cognizance over the work to be performed.

4. Cognizant System Engineer (SE) – the individual with design cognizance over the system or the work to be performed, who is officially recognized as responsible for a specific system. See the Cognizant Responsibility List for an up-to-date listing of all SEs.

5. Criticality Safety Engineer (CSE) – an individual that is responsible for providing support to the Nuclear Criticality Safety Program, including the preparation of Nuclear Criticality Safety Evaluations (NCSEs) and for providing recommendations to the Engineering Manager with respect to Criticality Control Zones (CCZs). See the Technical Specialist List for an up-to-date listing of CSEs.

6. Critical Work Steps – steps which have significant importance to safety, the safety basis, or are regulatory in nature and require the continuous presence of supervision during completion.

7. Facility Manager – an individual, or designee, that authorizes work in their assigned facility. The Cognizant Responsibility List maintains the list of currently identified Facility Managers.

8. High Hazard or Complex Work – Work that meets any of the following criteria:

   - Performed at or above ALARA trigger levels;
   - First-of-a-type complex work evolution;
   - Critical lifts;
   - Certain types of elevated work (per ESH&Q direction);
   - Facility demolitions;
   - Electrical work with the potential of encountering live conductors;
   - Confined Space entry (per ESH&Q direction);
   - Non-routine hazardous, radiological, or mixed waste packaging or transportation;
   - Certain types of Hot work activities;
   - Non-routine electrical troubleshooting or repair work;
   - Any other activity as prescribed by senior management.

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DEFINITIONS
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9. Independent Verification – verification performed INDEPENDENTLY of the initial application to verify the isolation point has been correctly identified:

   - NOT performed by the person who performed the original activity;
   - NOT done at the same time as the original activity. There must be enough time and distance between the original activity and verification to ensure that they are independent of each other.

10. Mockup – performance of a proposed work activity or portion of a work activity in a low risk, low hazard environment using actual, exact, or nearly exact replica models of the equipment, system, or area. The purpose of the mockup is to evaluate and/or develop the hazard controls, sequencing, tooling and/or ability to perform the actual work activity.

11. Operating Experience Program Coordinator – an individual that interfaces with functional organizations to assist in accessing information systems for identification of potential lessons learned for incorporation into work documents.

12. Operations Manager – for purposes of this procedure, the Operations Manager or designee responsibilities are:

   - Provide prerequisites and facility initial conditions requirements to Originators/Planners during the development of Work Control document (WCD).
   - Authorize, release and coordinate work activities;
   - Ensure facility conditions are established, (including LOTO), to support performance of scheduled maintenance activities;
   - Ensure that the appropriate Unreviewed Safety Questions (USQ) actions are completed per WV-914, Unreviewed Safety Question Process (USQP) prior to the modification of a Hazard Category 1, 2, or 3 facilities;
   - Ensure post maintenance testing or functional testing is incorporated into the WCD;
   - Ensure prescribed post maintenance testing is performed and properly documented;

13. Originator– an individual assigned to prepare a WIP/WCD that has completed Q071 Work Planning TRVC TR1486Q and is responsible for the following:

   - Leads the Planning Team in work site walkdowns, work scope definition, job hazard identification, analysis and control selection, and WCD development;
   - Reviews Lessons Learned database and feedback for entries with applicability to the work to be performed;
   - Develops the WCD incorporating input from the Planning Team, the RM, and appropriate task related requirements;
   - Coordinates WCD comment resolution and submits the package for concurrence by Work Group Supervisor and relevant Subject Matter Experts (SME/HCSs) and approval by the RM;
   - Confirms the WCD is ready to issue and forwards to Work Control for issuance.

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14. Permits – written documents specifying hazard controls for identified hazards, such as an Industrial Work Permit (IWP), Radiation Work Permit (RWP), Ground Disturbance Permit (GDP), Confined Space Entry Permit, Hot Work Permit (HWP).

15. Planning Team - the Planning Team consists of personnel/departments identified as applicable in Attachment C, "Reviewer/Planning Team Selection Checklist," (e.g., Hazard Control Specialists (HCSs)/SMEs identified on the AHA, Work Review Group Coordinator, applicable system engineers and other support groups). The Planning Team provides an integrated approach to the review and issuance of work documents by participating in the walkdown, development, review and approval process.

16. Planning Team Walkdown –HCSs/SMEs identified on the AHA and other support groups from the Planning Team as deemed necessary by the Originator or Work Group Supervisor perform Planning Team walkdowns in accordance with SOP 00-46. Planning Team walkdowns may be performed at various times during the work package generation process and may consist of multiple walkdowns, meetings, and individual or smaller group settings based upon resource availability and need.

17. Planner – an individual that has completed Q071 Work Planning TRVC TR1486Q and is responsible for the following:

    - May act as the Originator to prepare and issue a WIP/WCD.
    -
    - Ensures work is ready to commence as scheduled (e.g., obtains required tooling and parts, coordinates the integration of controls and preparation of the required permits (e.g., industrial work permits (IWP), radiological work permits (RWP), hot work permits, confined space permits)).

18. Responsible Manager – for purposes of this procedure, the Responsible Manager (RM) or designee, is the individual responsible for organizing, scheduling, and approving expenditures for individual, specific projects in progress at the WVDP

    - Reviews and approves all WCDs;
    - Reviews and approves changes to WCDs;

19. Routine Work – work performed that is well understood, repeated regularly, and is within recognized skill-of-the-craft attributes.

20. Source Requirements - requirements that are directly implemented by a controlled document. The following are some examples of source requirements: DOE, Federal, State, or Local laws or regulatory requirements; Process Safety Requirements (PSRs); Waste Qualification Reports (WQRs); Documented Safety Analysis (DSA); Industry Codes and Standards; and other requirements and contractual commitments.

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| 21. Subject Matter Expert (SME/HCSs) – are drawn from various site functions (e.g., Radiological Controls, Safety, Industrial Hygiene, Engineering, etc. – See Technical Specialists List in Web Publishing):

- Participates in the work site job/task walkdowns, job hazard analysis and control selection, and WCD development as part of the Planning Team when assigned;
- Ensures Planning Team decisions are consistent with programmatic requirements;
- Reviews WCDs to ensure that the hazard controls have been incorporated consistent with programmatic requirements;
- Participates in development of WCD instructions ensuring that the steps with safety basis or other regulatory permit requirements are properly incorporated;
- Specifies inspections and acceptance criteria, identifies hold and witness points;
- Reviews subcontractor prepared documents for suitability;
- Reviews completed WCDs to ensure that required data is properly recorded in accordance with programmatic requirements;
- Concurs with the WCD as part of the approval process.

22. Use Classification – determines the manner in which a work instruction must be used in the field. The Use Classification for WIPs is as follows:

- Critical Use – WIPs are classified as Critical Use and require the worker(s) to have the work instruction present and open with each step performed exactly as written. Initials and/or signoffs shall be made, where required, at the time the step is performed or as directed in the WIP.
- Reference Use – Sections and steps considered as Reference Use may be performed out of sequence and/or in parallel. Sections and steps must be specified as such.

23. WIP – Work Instruction Package that is used for more complex and infrequently performed work, with moderate to high consequences of improper performance:

- Contain detailed step-by-step instructions with a suggested or required sequence of performance;
- Require the highest level of review and approval;
- Require activity level work instructions in the body which include work steps, special requirements, hazards, and controls.

24. Work Group Supervisor – for purposes of this procedure, the Work Group Supervisor (WGS) is the individual responsible for the supervision of workers safely performing work activities, assuring work is performed continuously within scope, and in compliance with written instructions. In addition:

- Participates as a Planning Team member in the WCD walkdown
- Concurs with the WCD, confirming workability, as part of the approval process;
- Ensures the WCD is approved and work is released;
- Conducts Pre-Job Briefings to review scope of work, hazards and controls with assigned workers;
- Ensures that the prerequisites for work have been performed;
- Ensures hazard controls are implemented;
- Ensures that personnel executing the work have attended the Pre-Job Briefing or are briefed separately;

ATTACHMENT A
DEFINITIONS
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- Ensures a pre-issuance and workability walkdown is conducted
- Ensures referenced documents are current prior to start of work;
- Ensures workers are aware of their responsibility to stop work and notify supervision whenever changing conditions or unidentified hazards are encountered or work practices compromise quality or safety;
- Reviews training requirements and ensures workers are qualified to perform their duties;
- Supervises work activities to meet WCD requirements;
- Ensures the safety and health of workers during the conduct of work activities including proper wearing of PPE;
- Ensures a proper turnover of work status when transferring WGS responsibilities and documents in Work Package Status log (WV-2573);
- Ensures that good housekeeping practices are followed during performance of work, and that work areas are cleaned and restored after completion of work.
- Conducts a post-job review and documents feedback / lessons learned on (WV-2573).

25. Work Package Status Log and Post-Job Feedback / Lessons Learned (WV-2573) – a log that **SHALL** be added to a WIP that provides the WGS or designee a place to record information pertinent to the performance of the WIP. This includes information such as the status of field work, changes in conditions, issues and events which have influenced or may influence work performance or schedule, notifications made or concurrences obtained on operational decisions, or any other information relevant to the job task, personnel, equipment, or planning. A section of this log is for documentation of post-job feedback / lessons learned.

26. Work Review Group – for the purpose of this instruction, the Work Review Group (WRG) is part of the iterative Planning Team process that participates in the work site job/task walkdowns, activity hazard analysis (AHA) and hazard control/mitigation selection, WCD development, and review and approval. This process is also applicable to procedures developed in accordance with DCIP-100, "Controlled Document Preparation".

27. Work Review Group Coordinator – for the purpose of this instruction, the WRGC is the Work Control Management responsible for:
    - Screens requests for work ensuring work scope and associated boundaries are clearly defined;
    - Ensures Planning Team is comprised of the appropriate personnel (e.g., planner/originator, workers, operations, safety and health Subject Matter Experts (SME), other SMEs/HCSs, etc.);
    - Working with the Planning Team, determines the type of work document to be used for each work task based upon the criteria established for work types which takes into account the degree of hazards, and complexity of the work activity;
    - Ensures the WIP was developed following the processes in this procedure;
    - Ensures hazards and controls identified by the HIM process are incorporated into the WIP;
    - Conducts periodic assessments of the work control process in accordance with Contractor Assurance System guidance.

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE

NOTE *This attachment is a guideline for proper writing style. There may be exceptions wherein the authors and work groups may use a different style or method.*

The following is a list of sections that are used when writing a Work Instruction Package. Included is a description of each section. ALL section headings are required. If there is no information or need for a section, the originator shall enter "NONE," or equivalent, under the section heading (the reason for requiring all section headings is to maintain numbering consistency for all sections, e.g., Section 5.0 PERFORMANCE will always be Section 5.0).

Microsoft WORD shall be used for preparing all WIPs.

1.0 Scope

1.1 This section provides supplemental information the originator believes will help users understand the purpose of and reason for the task to be completed including:

1.1.1 A clear definition of the work scope, major tasks, and associated boundaries required.

1.1.2 Critical steps (see def.).

1.2 DO NOT include action statements, warnings, cautions, or other statements that are critical to the completion of the task.

2.0 Precautions and Limitations

NOTE *Any precaution or limitation that applies to an individual action step should be written as a warning or caution and placed just before the affected section or step.*

2.1 This section delineates precautions and limits that must be considered for multiple steps, sections, or throughout the procedure.

2.2 Precautions alert users to actions and conditions that represent actual and potential hazards to personnel or possible damage to equipment or establish abnormal conditions.

2.3 General hazards and controls may be listed in this section.

2.4 Limitations define the boundaries that must not be exceeded to ensure the work is performed safely.

2.5 In general, do no put actions steps in this section. If action is required in response to the precaution or limitation, provide action steps at the appropriate location in the procedure. There may be exceptions where a required response best fits with the precaution.

3.0 Material/Special Tools and Equipment

3.1 This section lists all material, special tools, measuring and test equipment, parts and supplies necessary to perform the procedure that must be staged prior to commencing the procedure. Do not specify ordinary craft tools such as standard pliers and wrenches or materials/tools and equipment normally found in the area.

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WRITING GUIDELINES AND DOCUMENT STRUCTURE
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NOTE *If using foam containing isocyanates (e.g., Handi-Foam), see Attachment B, step 5.1.24.*

3.2 If using a chemical, list the chemical name and product number and include an MSDS with the product number used.

4.0 Prerequisites

This section identifies actions that must be completed and the requirements and conditions that must be met before the user commences the Performance Section. The following information may also be included in 5.0 Performance Section:

4.1 Field Preparations – provide instructions for any field activities that must be completed before continuing with the procedure. This includes:

4.1.1 Initial Conditions – specify the physical parameters associated with an area, facility, system, component operation, or job, which are the conditions required prior to the initiation of work.

NOTE *See SOP 00-04, "Lock, Tag, and Confirm Procedure," for LOTO requirements.*

4.1.2 Lockout/Tagout of Equipment

A. Specify all equipment and components which require LOTO for the safe performance of the work. DO NOT specify any LOTO requirements in the performance section that can be performed prior to the commencement of the work.

B. Specify the type of LOTO required (e.g., Operations, Single Point, Multi-Point)

C. If the work instruction includes lockout/tagout instructions where an operations lock is not required per SOP 00-04, identify all LOTO points and include required independent verifications in the work instruction.

D. If the work instruction includes the use of a Multi-Point LOTO, include a step to obtain/verify the NOS Manager's approval to use a Multi-Point LOTO as required by SOP 00-04.

4.1.3 Performance of Valve Lineups – specify the valve(s) position and description with independent verification required.

4.2 Required Permits - include those not listed on WV-2571 or WV-1085.

4.3 Completion of Mockup - If a mockup or bench top is used, a prerequisite should be included requiring verification of the completion of the mockup or bench top and satisfactory incorporation of all changes resulting from the mockup or bench top.

4.4 Training Requirements– include required Health and Safety Training and any other additional training required.

4.5 Approvals and Notifications – provide instructions to ensure that all necessary notifications are made and approvals are obtained before initiating the procedure.

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE

5.0 Performance

5.1 General Guidelines

5.1.1 Organize activities in the logical order they will be performed.

5.1.2 Specify sections and steps that are Reference Use. This may be written as a note stating something similar to the following: "The steps in the following section may be performed out of sequence and/or in parallel with concurrence from the WGS."

5.1.3 DO NOT write steps that state "Perform activities to verbal instructions,' or "at the direction of….," etc. Originators, or other personnel authorized by the originator, may make decisions and provide field instructions for clarification of work steps that are within the scope of the work and hazard controls. Steps that allow decision making within specific parts of the procedure are permitted.

5.1.4 Do not write action steps containing multiple actions unless necessary to ensure proper performance of the work.

5.1.5 Avoid action steps that require workers to convert numbers from one unit of measure to another. If conversions are required, provide an aid. Specify numbers at the same precision and the same units of measure as those marked on, or indicated by the instrument. Specify appropriate limits and tolerances for parameters. Be consistent with the readable accuracy of the instrument.

5.1.6 If someone other than the primary user of the procedure is responsible for performing an action step, identify the department or group to perform the task.

5.1.7 Steps within WIPs may direct actions to be performed in other supporting documents (e.g., IWP's, RWP's, Confined space permits, Hot Work permits, SOPs).

5.1.8 At the originator's discretion, if only a few steps of an SOP are to be performed in the work instruction, or a deviation from an SOP is needed, the originator should add excerpted steps to the WIP and not mention the SOP. If specific section(s) of an SOP is specified to be performed as part of the work instruction, specify the SOP number, revision to be used, applicable section(s) number, and section(s) description. If the SOP is referenced in its entirety, the revision and FC number are not needed.

5.1.9 Use of Conditional action steps. Steps to direct the performer to NOT perform or bypass the applicable step. Conditional action steps are used when a decision is based upon the occurrence of a condition or a combination of conditions.

Conditional action steps use the following terms:

- IF or WHEN to present the condition
- THEN to present the action
- OR, AND, OTHERWISE, or OR ELSE to present more complex conditions

5.1.10 If a task or step cannot be performed and provisions have not been made to allow the step to NOT be performed or bypassed, then a revision to the WIP is required.

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE

5.1.11 All references to equipment or components must match label plate identifiers. Where a drawing and label plate is not consistent, an ECN or an Issue Documentation Form (IR) is to be initiated and issued. Temporary tags may be used as an interim measure in accordance with SOP 00-30, *System and Component Labeling.*

5.1.12 Write work instructions to the level of detail consistent with the qualifications and training of the expected users as well as commensurate to the level of detail necessary to perform the work.

5.1.13 The chosen method of implementing the hazard control from the hazard analysis into the work documents is appropriate. The stated hazard control in the hazard analysis may have several ways to implement the control, but the intent of the control is maintained.

5.1.14 Control selection is based upon the following hierarchy: (1) hazard elimination or reduction; (2) engineered controls; (3) administrative controls; (4) personal protective equipment.

5.1.15 The level of control established for a hazard is maintained throughout the activity or until the hazard has been eliminated or reduced (controls can be graded to level of hazard reduction).

5.1.16 Provisions are also included to assure evaluation of the possibility of creating additional hazards due to selected controls (e.g., excessive PPE causing heat exhaustion) and also evaluate the possibility of negative synergistic effects of selected controls.

5.1.17 If the WIP performs sampling for data collection, the sampling shall comply with the applicable planning procedure (e.g., Sampling and Analysis Plan [SAP] or Data Quality Objectives [DQOs].

5.1.18 If the WIP installs/removes a Temporary Modification (TM), include instructions to complete WV-3811, "Temporary Modification Control," in the WIP. See SOP 00-49, *Control of Temporary Modifications*, for instructions concerning TMs.

5.1.19 If the WIP involves underground or utilities work, or penetrating the surface of a floor, wall or ceiling; at a minimum perform the following:

A. Complete a Ground Disturbance Permit (GDP).

B. Conduct a thorough review of drawings (including as-built) to determine the presence of electrical conduit, mechanical piping (e.g., air, water, steam, chemical), and structural steel in the ground, floor, wall, or ceiling.

C. Conduct interviews with Cognizant System Engineer and/or facility personnel that are familiar with the area where the work will be performed.

D. Conduct non-destructive techniques, when practical, to verify the presence or absence or electrical conduit or mechanical piping.

E. Consider the potential for cooling water from cutting/drilling/core boring to create radiological or electrical issues (conduit or piping may become a flow path to energized circuits or adjacent areas).

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE

5.1.20 If the WIP involves physical isolation of piping or electrical conduit by cutting or mechanical means:

A. Include step(s) in the WIP requiring independent verification of isolation points prior to cutting. Independent verification shall be performed as defined in Attachment A.

NOTE *Once physical isolation is complete and piping/conduit being removed is properly labeled per SOP 00-30, remaining cut points are no longer required to be marked in the field.*

B. Indicate that isolation points shall be clearly marked in the field.

C. Reference SOP 00-30, Section 5.6, for labeling instructions and requirements applicable to D&D work.

D. Attach a photo, drawing, or sketch that indicates all isolation points.

5.1.21 Identify steps in the procedure which implement specific source requirements (refer to Attachment D of DCIP-100) per one of the following:

A. Reference the source document in the left margin adjacent to the step:

Example:

PSR-3 [3] Make sure Blower 15K-20 is operating.

B. Place the text and source requirement in a box format prior to the step that it applies:

Example:

Radiological control records SHALL be maintained as necessary to document compliance with the requirements of 10 CFR 835. 10 CFR 835.704(c)

C. List the source requirement after the text in bold or as a reference statement.

Example:

Radiological control records SHALL be maintained as necessary to document compliance with the requirements of 10 CFR 835.
10 CFR 835.704(c).

OR

Radiological control records SHALL be maintained as necessary to document compliance with the requirements of 10 CFR 835. (Refer to 10 CFR 835.704(c).)

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE
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5.1.22 If the WIP has embedded within it a mechanism allowing additional work without requiring a field change, the following must be met:

A. The change or addition does NOT alter the original scope of the work and is still within the risks, hazards and location(s) that were originally analyzed and documented on WV-3909 and USQP.

B. The change mechanism is authorized by the WRGC.

C. Examples of acceptable use of this approach are:

1. Taking additional samples at different locations within the same project area.
2. Adding tasks to a work instruction package for Maintenance to perform shop work.
3. Packaging and handling multiple waste components within the same project area when component-specific instructions are required.
4. Introducing the use of different remotely operated tools within the same project area to perform the same task (e.g., mechanical size reduction, using different types of saws or shears).
5. Providing additional guidance in performance of existing task activities where limiting conditions or acceptance criteria are NOT changed, or does NOT affect a critical step, hold or verification point step.
6. Using work travelers for repetitious tasks such as logging the contents of waste containers.

D. Signatures are obtained from departments that are directly affected by the added work instructions.

1. If the addition will involve any changes to facilities as described in the documented safety analysis, involve tests or experiments, or differ from assumptions or limitations in the USQD for the WIP, a USQD Evaluator must review and determine if USQP Form WV-3306 is required.
2. Include QA for the following:
   a. The work is Quality Level 'C' or 'B' as defined by WVDP-204 (Q-List) or WVDP-111, section 1.4.2 (QA Program).
   b. The work will involve QA acceptance testing or verification
   c. The work involves a Critical Lift activity.
   d. The work will involve RCRA or Regulatory Closure Plans.
   e. The work involves the use of any Measuring and Test Equipment (calibration).
   f. The work involves Load Testing of H&R equipment.
   g. The work will involve Welding, or Nondestructive Examination.
   h. The work will involve pressure testing to ensure process line/system integrity (e.g. Hydro, or Pneumatic) or any In-Service Leak testing.
   i. The work will involve the utilization of LOKRING's.
   j. The work will utilize concrete expansion anchors or adhesive anchors (excluding core boring machine anchors).

5.1.23 If the WIP involves application of fixatives for radiological purposes, specify the approved fixatives and method of application. Radiological Controls (RC) must approve and/or specify the type of fixatives used and the methods of application.

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE

5.1.24 If the WIP involves the use of foam containing isocyanates (e.g., Handi-Foam), include instructions to track the amount used and the location used.

5.1.25 If the WIP includes the use of a LOTO in the Performance Section,

A. Specify the type of LOTO required (e.g., Operations, Single Point, Multi-Point)

B. If a non-operations LOTO is specified, identify all LOTO points and include required independent verifications in the work instruction.

C. If the use of a Multi-Point LOTO is specified, include a step to obtain/verify the NOS Manager's approval to use a Multi-Point LOTO as required by SOP 00-04.

5.2 Critical Steps, Verifications, Notifications, Data Recording, and Hold Points

5.2.1 **Critical Steps** are steps with significant importance to safety, safety basis, or are regulatory in nature and require the continuous presence of supervision during completion.

5.2.2 **Verifications** confirm that an action, including filling out paperwork, was performed accurately.

5.2.3 **Hold Points** are where an action or condition is required to be satisfied and signed off before proceeding with the activity.

5.2.4 **Notifications** inform another person or department of the starting or stopping of an activity.

5.2.5 For steps requiring signoff or data recording:

A. Place a "[+]" in the left margin.

B. Indicate who is to sign and where the individual is to sign.

C. Indicate where data recording is to be made if it is not immediately at the action step to be performed.

D. Specify the expected method of verification to be used (e.g., personal observation, direct report of a worker, review of official records).

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE

5.3 Warnings, Cautions, and Notes

Warnings, Cautions, and Notes are information that is NOT action steps. They are essential to the safe and effective completion of work step(s) which follow. Use **Warnings** to alert workers of actual or potential hazards that may harm personnel.

Example

WARNING
ELECTRICAL HAZARD: Unmarked electrical systems or systems that penetrate walls, ceilings, and floors shall be identified / verified or considered as energized. No electrical activities shall be performed without positive confirmation / zero energy verification to protect personnel from arc, shock, blast, electrocution hazards.

5.3.1 Use **Cautions** to alert workers of actual or potential hazards that may damage equipment or facilities, or harm the environment.

Example

CAUTION
To prevent a potential release to the environment or spread of contamination: Anticipate the probability of abandoned tanks, vessels and piping containing residual liquids.

5.3.2 Use **Notes** to assist in making decisions or to improve performance of action steps.

Example

NOTE *The following steps 5.0.1 through 5.0.7 may be performed out of sequence and throughout the work instruction to support work activities.*

5.3.3 Place Warnings, Cautions, and Notes immediately before and on the same page as the step to which they apply.

5.3.4 Warnings and Cautions shall include the hazard(s), consequence of the hazard(s), and any critical time constraints, when applicable.

5.3.5 Do NOT include actions in Warnings, Cautions, or Notes.

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE

6.0 Post Maintenance Testing

When operability of equipment has been affected while performing a procedure and operability has to be verified before returning the equipment to service, include action steps that specify these tests.

6.1 Unless otherwise specified in the work instruction, the Post Maintenance Testing Section is considered "Critical Use."

6.2 Include testing acceptance criteria and tolerances.

6.3 Specify testing requirements, including documenting data sheet and verification that the results meet acceptance criteria.

7.0 Post Completion Configuration

Ensure steps are written in the Performance and/or Post Maintenance Testing Sections to perform the necessary actions to achieve the conditions stated in this section. Performance steps (except WGS verification) are not to be placed in this section.

7.1 List intended final conditions of the area, equipment, systems, etc. that were affected by the performance of the WIP and have been verified by the WGS.

7.2 Include a step for signoff by the WGS to document verification of the following (examples):

7.2.1 All personnel locks/tags are removed.

7.2.2 The work area has been cleaned up (e.g., disposal of waste generated, all temporary utilities used for the job such as extension cords and hoses have been removed).

7.2.3 System(s) and/or equipment are/is ready for turnover to the applicable operations group.

8.0 References

8.1 List the documents used to create the work instructions and those used for the performance of work associated with the work instruction.

8.2 List applicable drawings, P&IDs, and electrical one-line drawings.

8.3 Include a list of required design, process, and instrument drawings with the work instruction, if applicable. Include the revision number, sheet number(s), and Engineering Change Notice (ECN) numbers, if pending.

8.4 List SOPs where WIP users must perform actions contained within the referenced SOP (e.g., "Perform hoisting and rigging activities in accordance with SOP 00-38.")

9.0 Source Requirements

9.1 List source requirements documents and the specific sections of those documents which are implemented by the procedure.

ATTACHMENT B
WRITING GUIDELINES AND DOCUMENT STRUCTURE

10.0 Attachments

10.1 When the work instruction includes opening, modifying, or removing part of a system containing radioactive or hazardous materials or energy sources such that personnel or the environment are potentially exposed to the hazard, the system boundaries shall be identified on a marked up P&ID or isometric drawing, sketch, diagram, or a photograph accompanying the work instruction indicating the isolations/engineering barriers surrounding the work area. The system status (e.g., active, abandoned, pressurized, vacuum) is to be verified and considered in the hazard analysis and controls.

10.2 Include information in an attachment/appendix when it is more convenient to locate the information outside the main body of the procedure.

10.3 Attachments should be numbered independently.

10.4 Reference all attachments in the WIP.

ATTACHMENT C
REVIEWER/PLANNING TEAM SELECTION CHECKLIST
(Page 1 of 1)

Situation	Required Reviewers
All work packages	Work Group Supervisor Facility Manager Work Review Group Coordinator
Hazard present in area of expertise (i.e., hazard identified as "Yes" on WV-3909)	HCS specified on WV-3909
Work steps performed by personnel other than the work group.	Department performing work step
Work activities performed by subcontractors under the direction of a Subcontractor Technical Representative (STR)	STR
Any work activity performed by Maintenance **NOTE:** *NA if the Work Group Supervisor is the Maintenance Supervisor.*	Maintenance
Work activities performed on equipment, or in an area, under PSO's cognizance.	PSO
Work activities performed on equipment, or in an area, under an Operations Supervisor's cognizance other than PSO.	Applicable Operations Supervisor
Work activities affect a system or involve work on a system.	Applicable System Engineers
Work activities under the cognizance of an engineer other than the System Engineer or the Originator.	Cognizant Engineer
Work activities involve QA review, inspection, verification, or oversight activities: ➢ The work is Quality Level 'C' or 'B' as defined by WVDP-204 (Q-List) or WVDP-111, section 1.4.2 (QA Program) ➢ The work will involve QA acceptance testing or verification ➢ The work involves a Critical Lift activity ➢ The work will involve RCRA or Regulatory Closure Plans ➢ The work involves the use of any Calibrated Measuring and Test Equipment ➢ The work involves Load Testing of H&R equipment ➢ The work will involve Welding, or Nondestructive Examination ➢ Will the work involve any pressure testing to ensure process line/system integrity (e.g. Hydro, or Pneumatic) or any In-Service Leak testing ➢ The work will involve the utilization of LOKRING's ➢ The work will utilize concrete expansion anchors or adhesive anchors (excluding core boring machine anchors)	QA
Work identified as High Level Waste (See WVDP-200).	HLW Process and WQR Compliance Engineer
Any other department affected by the work activities.	Applicable departments

ATTACHMENT D
TELECON/EMAIL APPROVALS
(Page 1 of 1)

The following may be used to obtain and document telecon or email approvals when the person required to sign (signatory) is not physically present.

To obtain the signatory's approval, the originator or his designee should perform the following:

A. Contact the signatory via telephone, email, or other means of communication.

B. Provide the signatory with a description of the purpose and scope of the work instruction and read verbatim the part of the work instruction explaining what the signatory is being asked to approve.

C. Provide the signatory with any additional information needed to fully explain what is to be approved.

D. Answer any questions the signatory may have.

NOTE *The signatory shall NOT grant approval until satisfied and fully understands what is to be approved.*

E. Once the signatory has approved, the originator or designee documents approvals as follows:

1. Telecon approval - as shown in the following example:

Jim Jones for Bob Brown per telecon 12/17/99

2. E-mail approval - as shown in the following example:

See attached e-mail approval 12/17/99

a. Print the e-mail message and attachments (if applicable) and retain with the record copy of the work control document (Ref.: WVDP-262).

WVDP RECORD OF REVISION CONTINUATION FORM

Rev. No.	Description of Changes	Revision On Page(s)	Dated
31	General Revision - Administrative changes and Revised Attachment A, "Definitions" with additional responsibilities for WGRC, RM, WGS, Planner and SMEs/HCSs Revised Attachment B, "Writing Guidelines and Document Structure" This change affects WIP originators, HCS, SME's, and Responsible Managers	ALL	12/01/11
32	General Revision - Administrative changes. Revised QA section 3.4.6 to include QA review required for Regulatory Strategy RCRA Plans, and Critical lifts only. This change affects WIP originators and QA.	ALL	08/16/12
33	Minor Revision – Administrative changes. 3.23 & 9.0 Updated title of SOP 00-46. Steps 3.4.3, 4.3.8 A and Attachment B revised USQD Originator and Safety Analyst to USQD Evaluator. Attachment A-Changed ESH&Q to Engineering Manager. Added WVDP-227 to the references. Engineering, Records, Work Control and Planners are impacted by this change.	 2, 9 3, 7 9, 22 11	10/31/12
34	General Revision - Administrative changes. Steps affected are 3.2, 3.4, 4.1 thru 4.4, 5.1, 6.5, 9.0 and Attachments A and B. Revision changes documentation of hazard analysis on AHA or JSA. Revised QA review applicability, Revised Field Change process to include hand-written WV-1085. Clarified Attachment guidance. This change affects WIP originators and QA.	ALL	12/ 17/12
35	Minor Revision – Administrative changes: Deleted form WV-3743 in reference section, form is cancelled. Clarified documentation for obtaining telecon/e-mail approvals in Attachment C. This change affects WIP originators	 9 26	01/08/13

WVDP RECORD OF REVISION CONTINUATION FORM

Rev. No.	Description of Changes	Revision On Page(s)	Dated
36	General Revision Added requirement for Originator to ensure that hazard mitigations not specifically addressed in the WIP are captured elsewhere in the work package (e.g., RWP, IWP, Pre-Job Brief). Added new attachment D for determining required reviewers. Text in the procedure related to determining reviewers was deleted as the requirements are captured in this attachment. Deleted reference to the TRT as TRT actions are outside the scope of this procedure. Deleted part of note allowing USQ signatures to be obtained per telecon. Deleted detail on planning team walkdown and referred to SOP 00-46 for performance Deleted Training from the Material/Special Tools and Equipment Section as training requirements are contained in the Prerequisite Section Added steps in the performance section of Attachment B on specific requirements pertaining to the use of LOTOs. Modified requirements for using a DDC for clarity and consistency with SOP 00-54. Deleted definitions in Attachment A that are no longer refered to in this procedure. Added requirement to track foam use when using foam containing isocyanates in Attachment B. Clarified definitions for Originator and Planner. Attachments reordered to follow the procedure flow. Additional editorial changes made throughout. This change affects WIP Originators/Planners.	All	09/05/13
37	Administrative Changes. Added a new step 4.3.4, requiring all current field changes be identified by a change line generated by utilizing the Microsoft Word "Track Changes" function. Revised step 4.3.5 to simplify the symbol used to identify field changes. Revised Attachment "A", Definitions, deleting requirement that Cognizant System Engineer (SE) be a trained work instruction originator, and incorporated language from WV-921, "Hazards Identification and Analysis" into the definition of Hazard Control Specialists. Paginated Attachment "D". These changes affects WIP Originators/Planners, System Engineers, and Hazard Control Specialists.	All	03/19/14

8-6

WVMP SAR Reference 8-6

Receipt Inspection, Quality Assurance Procedure QP 10-2, Revision 15, CH2M Hill-B&W West Valley, LLC, West Valley, New York, October 22, 2013

West Valley Decommissioning Team

CH2MHILL • B&W West Valley, LLC

QUALITY PROCEDURES

TITLE: Receiving Inspection

GENERAL REVISION

1.0 PURPOSE

This procedure establishes the method to be followed for planning and performance of material receipt inspection by Quality Assurance personnel.

This procedure details the method to conduct inspection of items when receiving inspection is required for Quality Levels A, B, C, and selected N items.

2.0 REQUIREMENTS, REFERENCES, AND FORMS

Refer to E-DOCS for the latest version of WVDP Controlled Documents. Refer to the S:\WPFORMS directory and/or site standards word processing templates for the latest revision of WVDP forms used in this procedure.

2.1 Requirements

2.1.1 WVDP-111 "CH2M HILL • B&W West Valley, LLC Quality Assurance Program"

2.2 References

2.2.1 QP 4-1, "Procurement Document Review"

2.2.2 QP 10-1, "Inspection"

2.2.3 QP 15-2, "QA Hold Tag Procedure"

2.2.4 WVDP-204, "WVDP Quality List Q-List"

2.2.5 WVDP-310, "WVDP Safety Management System (SMS) Description"

2.2.6 WVDP-357, "WVDP Issues Reporting Program Manual"

2.2.7 WV-620, "Purchase Requisitions and Supplements"

2.2.8 WV-695, "Procurement Card Purchases"

2.2.9 PROP- 11, "Warehouse Receiving, Storage, Inventory, and Withdrawal "

2.3 Forms

2.3.1 WV-3245 - Material Receiving Inspection and Release (MRIR)

2.3.2 WV-0172 - CHBWV Procurement Card Requisition Checklist, for QA signature and inspection criteria.

3.0 GENERAL INFORMATION

3.1 Quality Assurance Receiving Inspector - performs inspections and tests per the acceptance criteria provided on the Material Receiving Inspection and Release (MRIR) and approved procurement document.

3.2 Quality Assurance Representative (QAR)

3.2.1 Reviews procurement documents such as: Purchase Requisitions (PR), Procurement Technical Specifications or attachments to Purchase Requisitions, Purchase Requisition Change Orders, and Credit Card Orders (CCO) per QP 4-1.

3.2.2 Plans inspections, concurs with inspection acceptance criteria and ensures a MRIR is prepared with the requisitioner based on information contained in the purchase requisition, or credit card order.

3.2.3 The inspection criteria should include consideration for verifying completeness, markings, calibrations, adjustments, protection from damage or other characteristics as required to verify the quality and conformance of the item(s) to specified requirements. Quality records are required to be examined for adequacy and completeness.

3.2.4 Items may be added to procurement documents as desirable quality attributes, such as painted surfaces being smooth and free of visible imperfections in waste boxes, even though these attributes do not affect the integrity or DOT rating of the box. Quality will inspect for such attributes if they are listed in the applicable procurement documentation.

3.2.5 Provisions shall be made for prohibiting delivery or acceptance of suspect/counterfeit items.

3.3 Receipt Inspection is required for items identified as Quality Level A, B or C per WVDP-111and WVDP-204, including credit card orders, unless other inspection provisions have been approved by QA.

3.4 Personnel shall always be cognizant of Integrated Safety Management System (ISMS) policies/objectives when planning and performing inspections.

4.0 PROCEDURE

4.1 Inspection Criteria

4.1.1 The QAR reviews the procurement document per QP 4-1 and concurs with the receipt inspection acceptance criteria established by the requisitioner per WV-620 and/or WV-695.

4.1.2 The QAR establishes a MRIR in the W:\MRIR drive if required. If the W:\MRIR file does not contain a procurement specific MRIR a standard receipt inspection MRIR can be used (W:\MRIR\STNDMRIR) as denoted on the copy of the procurement document. The QAR shall designate the applicable standard MRIR which is to be used.

4.1.3 The QAR shall ensure that the procurement document and MRIR acceptance criteria is adequate for the procurement and that a Material Receiving Inspection and Release (MRIR) is prepared for Receiving Inspection that includes the inspection acceptance criteria. As a minimum, basic acceptance criteria shall include:

Item(s) ordered is the item(s) received;
There is no shipping damage;
Item(s) is not suspect/counterfeit (ref: form WV-0141);
MSDS is received or is on file, and is item specific if a chemical containing material is ordered.

4.2 Inspection Performance

4.2.1 The QAR enters the procurement information into the QA reports database and creates an informational file.

4.2.2 Inspector is notified that items requiring receipt inspection have arrived. Inspector obtains approved procurement document and MRIR.

NOTE *Typically, items are delivered to the warehouse, tagged "Hold for QA Inspection" by warehouse personnel and placed in the QA hold cage. Some items that are too large for the cage or are delivered to another location (e.g., hard stand, Vit Test Facility) are staged for receipt inspection at their drop location.*

4.2.3 Inspect the item(s) per the MRIR and the approved procurement document as reference.

4.2.4 If item(s) is/are acceptable:

Obtain an MRIR number from QA reports.

Complete and issue MRIR. Original certificates must also be retained with the MRIR. For credit card receipts, attach a copy of the CHBWV Procurement Card Requisition (WV-0172) as part of the MRIR. The requisitioner receives copies of the MRIR, certifications and the original packing slip.
Apply Accept Tag or QA release stamp to the item(s), as appropriate.
Release the item from QA Receiving Inspection area.

NOTE *Some items are received as multiples within a single or several containers. For example, small bolts packaged within a single plastic bag. If determined to be acceptable by receipt inspection, the package may be released for use if stored within a controlled, secure area that tracks usage. The MRIR for such items will be specific in detail to describe the multiple items.*

4.2.5 If Item(s) is/are unacceptable, discuss the discrepancy with the requisitioner and proceed as follows:

A. Documentation Inadequacy

If documentation is insufficient (e.g. missing, incorrect documents, or insufficient data) and requisitioner agrees to obtain corrected documentation, keep item(s) in QA hold cage area or ensure the "Hold for QA Inspection" tag is on the item.

When acceptable documentation is received, follow 4 .2.4.

If acceptable documentation is not received in 30 days, implement WVDP-357.

B. Substitutions, minor changes and damage

If unacceptability was caused by substitution of material, wrong quantity, minor change etc. and the discrepancy is considered acceptable by requisitioner, complete the MRIR with documented written requisitioner approval on the MRIR, or attach email authorization.

If unacceptability is caused by substitution of material or shipping damage, which makes the material unacceptable, the material or item(s) may be returned. Issue a MRIR marking the Requirements Met column with an X in the NO column opposite the criteria not met and note that the item is to be returned to the vendor in the Comments section.

NOTE *Coordination of the decision to return must be with the concurrence of the requisitioner and the Purchasing agent.*

Inform warehouse personnel that the material must be returned to the vendor and request that they prepare the L Order to allow the material to be shipped off site. A QAR will verify that the material has been shipped off site by signing the L-Order for QA.

C. Quality Requirements Not Met
If quality requirements are not met and the item(s) or material requires disposition or further justification for acceptance, implement WVDP-357 and process per 5.2.6.

4.2.6 Processing Nonconforming Item(s)

Place Hold Tag(s) on the item(s) per QP 15-2.

Maintain the item(s) in QA Hold Area or segregate.

Note the Issue Report (IR) number on the MRIR, retain the MRIR and a copy of the IR with the PO file until disposition has been received.
Follow the requirement of the dispositioned Issue Action Documentation Form, document the disposition and IR closure date in the comment section of the MRIR:

1) If disposition is "Use-as-is," complete the Material Release section of the MRIR, remove the Hold Tag per QP 15-2, place Accept Tag, and release the item(s) from the QA Hold Area.
2) If disposition is "Rework" remove the Hold Tag per QP 15-2 when item(s) is/are acceptable and complete MRIR. Use of a Conditional Release tag may be required.
3) If disposition is "Repair" use acceptance criteria as defined in the Issue Action Documentation Form, if applicable. Upon completion of the repairs(s) and a successful re-inspection, remove the Hold Tag per QP 15-2 and complete MRIR. Use of a conditional release tag may be required.
4) If disposition is "Scrap," ensure that the material is scrapped by destroying the item or by placing the item in an on-site scrap receptacle for the proper type of material.
5) If the disposition is "Return to Vendor" secure a copy of the completed L Order. This will show the item shipped off site.

NOTE *Conditional Release Tags may be attached to material to allow further testing, repair, rework, or mock-up work. See Attachment B.*

5.0 <u>RECORDS</u>

5.1 The following forms, data sheets, logs, reports, or any other form of documentation are considered records and when created are to be prepared, maintained, and transferred to Records in accordance with WVDP-262 and WVDP-529. Refer to the CHBWV Master File Plan for further information

NOTE *Original MRIR reports for Purchase Orders and QA documentation (eg. certifications, test reports) are sent to purchasing. For Credit Card orders, the original MRIR reports and QA documentation (e.g. certifications, test reports) are sent to the Purchase Card Holder.*

5.1.1 WV-3245, Material Receiving Inspection and Release (MRIR)

5.1.2 WV-0172, WVES Procurement Card Requisition and Certifications received with Credit Card Orders.

6.0 ATTACHMENTS

Attachment A Accept Tag & "Q.A. RELEASE" Stamp
Attachment B Conditional Release Tag

ATTACHMENT A
ACCEPT TAG

ACCEPT TAG
(Green)

ACCEPT TAG	
P.O.____________	MRIR ________
Insp. By_______	Date________
Piece____________	Of____________

Accept Tag will contain the following information:

1. Purchase Order number
2. Material Inspection and Release (MRIR) number
3. Initials of the Inspector who determined that the item(s) were acceptable
4. Date material was accepted.
5. If multiple pieces or parts are received at one time, multiple tags will be issued for the same MRIR number. This avoids loss of control. Tags might read "Piece 1 of 6," "Piece 2 of 6"; this increased piece count is continued until all pieces/parts have been tagged or a "QA Released" stamp may be utilized when quantities are high. The "QA Released" stamp may be used on boxes within which the procured items are not suitable for stamping or tagging. For example, PPE filters contained within boxes may have just the boxes stamped since it is impractical and unsafe to tag or stamp each individual filter.

Example of Q.A. Release Stamp

QA RELEASED

ATTACHMENT B
CONDITIONAL RELEASE TAG

CONDITIONAL RELEASE TAG

(Yellow)

CONDITIONAL RELEASE

Limiting Condition ________________
____
____
____

PO/WIP/etc.__________ IR_________
Inspector:
Print Name__________________________
Sign__________________ DATE ________
DO NOT REMOVE THIS TAG

This tag may be used to allow further testing, repair, rework, fit-up or mock-up prior to full release. The item shall not be allowed to be used for its intended use until the condition is met. After the testing, repair, rework or mock-up is complete, the item may be released or a red Hold Tag may be required to continue control of the item.

WVDP RECORD OF REVISION

Rev. No.	Description of Changes	Revision On Page(s)	Dated
6	Added 7.2.5.1 to clarify how items that are unacceptable are handled.	3	04/14/03
	Procedure also updated to the requirements of DCIP-100 (e.g., modified section 8, "Records Maintenance," added titles and pagination to attachments, changed font throughout)	All	
	This change affects QA.		
7	This change is made to add a reference to location of receipt inspection MRIR, add a note concerning items delivered to the warehouse, change QA receiving area references to QA hold cage, update step to place a red hold tag on the item received, delete step 6.2.5.1, and update procedure per DCIP-100. This change affects QA.	1-3	04/13/04
8	Adds explanation for Drawing/Specification block on MRIR and change numbers accordingly on example form	10-11	01/24/05
	Changed days to implement WVDP-357 from 90 to 30 days.	3	
	This change affects QA		
9	Added a note for clarification		
	Revised wording; added P-Card statement	3	12/27/05
	Added to item 5 to address other items	6	
	Updated "Conditional Release Tag" as shown.	7	
	This change affects QA		
10	General Revision Clarified and added information to general instructions. Deleted form WV-3245 from procedure. This change affects QA	All	10/10/06
11	General Revision Update to WVES template Update sections to reflect current department activities This change affects QA	1, 5	04/15/09
12	Periodic Review - Revision		12/03/09
	Clarified inspection criteria.	2	
	Update Records responsibilities.	5	
	Minor editorial changes throughout. These changes affect QA.		

WVDP RECORD OF REVISION CONTINUATION FORM

Rev. No.	Description of Changes	Revision On Page(s)	Dated
13	Combined Responsibilities with General Information.	2	09/16/10
	Added Section 4.2.3	2	
	Delineated Section 5.1 Inspection Criteria	2	
	Section 5.2.5 separated paragraphs into sections A. B. C.	3	
	Replace PO and PR with procurement document and/or approved procurement document.	All	
	Minor editorial comments.	All	
	These changes affect QA.		
14	General Revision- minor document revision to address CHBWV Transition Team Blue Sheet & Terminology Replacement Matrix Comments. Updated company logo & name, department names, etc., throughout. Other editorial format changes made as needed. These changes are administrative in nature and have no direct affect on any department.	All	04/23/12
15	General Revision- New bullet added in General Information moved 3.2.4 to 3.2.5 and added new bullet 3.2.4 to address mechanism by which quality attributes are added to receipt inspections that are not requirements but are desired by the requisitioner. These changes are administrative in nature and have no direct affect on any department.	All	10/22/13

Job Messages

XEROX

SelentK

Document Name: Reference 8-6.pdf

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%%[ ProductName: Xerox 4127 Copier/Printer with FreeFlow Print Server ]%%
%%[Page: 1]%%
%%[Page: 2]%%
%%[Page: 3]%%
%%[Page: 4]%%
%%[Page: 5]%%
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%%[Page: 9]%%
%%[Page: 10]%%
%%[Page: 11]%%
%%[LastPage]%%
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WVMP SAR Reference 8-8

Material Receiving Inspection and Release (MRIR) report #04-1152, West Valley Nuclear Services Company, West Valley, New York, October 15, 2004.

Material Receiving Inspection and Release

MRIR #	04-1152
Page 1 of 1	

Purchase Order/Credit Card 19-104320	Material Description: West Valley Melter Container
Supplier WMG, inc.	
Drawing Spec No: 4005-DW-001, shts 1-8. Rev No: rev 4	
Requisitioner: T.J. Jones	QAR: Robert Czyzewski

Inspection Requirements	Requirements Met Yes	No
1. Material does not show any shipping damage.	X	
2. Material received is as specified on purchase order. Including gaskets (Items 8 and 9 on Bill of Materials)	X	
3. No suspect/counterfeit parts are used. (A193-B7 w/washers specified as Item #6 on Bill of Materials)	X	
4. Documentation Package Received.	X	
5. Certificate of Conformance Received and acceptable.	X	
6. Package marked with the following: - USA - TYPE-IP2	X	

IF No. N/A	Inspected By/Date: Paula Ciszak 10/15/04

Comments N/A

Distribution: Requisitioner	Warehouse (Purchasing, General Accounting)
QA Purchase Order File	QA DCC (Original)

ORIGINAL

Job Messages

XEROX

SelentK

Document Name: Reference 8-8.pdf

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%%[ ProductName: Xerox 4127 Copier/Printer with FreeFlow Print Server ]%%
%%[Page: 1]%%
%%[Page: 2]%%
%%[Page: 3]%%
%%[LastPage]%%
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WVMP SAR Reference 8-9

Nondestructive Test Reports MT-110-04, VT-35-04, X-R-I Testing Division of X-Ray Industries, Inc., Troy, Michigan, October 13, 2004

XRI TESTING Division of X-Ray Industries, Inc.

The American Tank & Fabricting Co.
12314 Elmwood Avenue
Cleveland, OH 44111

Report Number: MT-110-04

Date: 10/13/2004

Shop Order # 40945-0000

P. O.# 19-104320-C-LH

Magnetic Particle Inspection

Inspec. Operation # NA

PART #: 4005-DW-001-Rev.3 | QUANTITY 1 Assembly

INSPECTION PERFORMED IN ACCORDANCE WITH:

STANDARD AWSD1.1 2004
PROCEDURE AWSD1.1 2004

PROD METHOD		YOKE METHOD	
TWO DIRECTIONS	N/A	TWO- DIRECTIONS	YES
CONTINUOUS	N/A	CONTINUOUS	YES
HWDC N/A DC	N/A	AC	YES
COLOR CONTRAST POWDER	N/A	COLOR CONTRAST POWDER	See Note
SPACING	N/A	SPACING	< 6"
AMPERAGE	N/A	NOTE: ETHER 8A RED OR #1 GRAY POWDER USED AT THE DISCRETION OF THE INSPECTOR	

QUANTITY	DESCRIPTION		RESULTS	
1 Assembly	MT Backgrooves	JT 1	Accept	9/1/2004
		JT 2	Accept	9/1/2004
		JT 3	Accept	9/2/2004
		JT 5	Accept	9/7/2004
	Item	7A	Accept	9/1/2004
		7B	Accept	9/2/2004
		7C	Accept	9/3/2004
		7D	Accept	9/9/2004
		7E	Accept	9/8/2004
		7F	Accept	9/1/2004
		7G	Accept	9/3/2004
		7H	Accept	9/3/2004
		JT 26	Accept	9/1/2004
		JT 27	Accept	9/2/2004
		JT 28	Accept	9/2/2004
		JT 29	Accept	9/1/2004
	Backgroove of 4 lifting lugs	JT 34	Accept	9/24/2004

Inspected by: [signature]
John J Kubit
[signature]
T.A. Ward

Ryan Pratt

Certification: SNT-TC-1A
Level: II

XRI TESTING Division of X-Ray Industries, Inc.

The American Tank & Fabricting Co.
12314 Elmwood Avenue
Cleveland, OH 44111

Report Number: VT-35-04

Date: 10/13/2004

Shop Order # 40945-0000 P. O.# 19-104320-C-LH

Visual Inspection

Magnetic Particle Inspection Inspec. Operation # NA

PART #: 4005-DW-001-Rev. 3 | QUANTITY 1 Assembly

INSPECTION PERFORMED IN ACCORDANCE WITH:

STANDARD AWSD1.1 2004

PROCEDURE AWSD1.1 2004

PROD METHOD				YOKE METHOD		
TWO DIRECTIONS	N/A			TWO- DIRECTIONS	YES	
CONTINUOUS	N/A			CONTINUOUS	YES	
HWDC	N/A	DC	N/A	AC	YES	
COLOR CONTRAST POWDER			N/A	COLOR CONTRAST POWDER		See Note
SPACING			N/A	SPACING	< 6"	
AMPERAGE			N/A	NOTE: ETHER 8A RED OR #1 GRAY POWDER USED AT THE DISCRETION OF THE INSPECTOR		

QUANTITY	DESCRIPTION		RESULTS		
1 Assembly	VT, MT Final Welds	JT 1	Accept	9/7/2004	9/19/2004
		JT 2	Accept	9/2/2004	
		JT 3	Accept	9/7/2004	9/17/2004
		JT 4	Accept	9/11/2004	9/17/2004
		JT'S 5,6,7	Accept	9/15/2004	9/22/2004
		JT 8	Accept	9/11/2004	9/17/2004
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		JT'S 20,21	Accept	9/11/2004	9/17/2004
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		JT'S 24,25	Accept	9/21/2004	9/22/2004
		JT,S 26,27,28,29	Accept	9/23/2004	
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	ITEM'S	7D,7C	Accept	9/22/2004	
	ITEM'S	7E,7G	Accept	9/23/2004	
	4Lift Lugs	JT'S 32,36,34	Accept	9/27/2004	9/28/2004
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WVMP SAR Reference 8-10

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West Valley Demonstration Project

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WVDP SITE WELDING MANUAL

Cognizant Author: P. J. Mussel

Cognizant Manager: A. Upshaw

CHBWV
West Valley Decommissioning Team

CH2MHILL • B&W West Valley, LLC
10282 Rock Springs Road
West Valley, New York USA 14171-9799

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WVDP SITE WELDING MANUAL

SECTION 1 - WELDING MANUAL GENERAL REQUIREMENTS

1.0 PURPOSE

1.1 This manual presents CHM2HILL B&W West Valley, LLC Company (CHBWV) policy and requirements for welding and brazing at West Valley Demonstration Project (WVDP). Policies set forth in this manual apply to all welding performed on site.

The manual provides direction for welding activities performed by CHBWV personnel, the administrative direction for development and issuance of new or revised welding procedures, CHBWV welder performance certification, weld filler control, and responsibility for control of this manual.

When welding is to be accomplished on site or off site by a subcontractor/vendor, welding shall be in accordance with the provisions of Section 1.7, "Welding by Subcontractor/Supplier/Others."

1.2 Responsibilities

1.2.1 The Site Engineering Manager shall be responsible for implementation and revision as necessary of this manual; development and revision of Weld Procedure Specifications (WPS) and their Procedure Qualification Records (PQR); and support for welder performance qualification testing. The Site Engineering Manager may delegate this responsibility to a designated welding Subject Matter Expert (SME) in the Technical Specialist List.

1.2.2 The Quality Assurance Manager (QAM) is responsible for assuring compliance to this manual.

1.2.3 The Nuclear Operations and Storage Facility Manager or designee shall be responsible for personnel training, welder qualifications, filler metal control, assigning qualified personnel to specific tasks, and implementing written procedures.

1.2.4 CHBWV Welders, Welding Operators, and Brazers (Welders) are responsible for knowing the extent of their certifications and performing assigned tasks in accordance with this manual and written procedures.

1.2.5 Where responsibilities are assigned by position title, it shall be understood that the person holding that position may delegate the responsibilities to other(s) who are qualified to perform the task with that person's manager's concurrence.

1.2.6 Cognizant Engineers who generate CHBWV work instructions requiring welding per EP-5-002 shall complete form WV-1888.

1.2.7 Performance of Nondestructive Examination (NDE) as described in this manual shall be performed by current ASNT-TC-1A certified NDE Level II or III personnel.

1.3 Definitions

1.3.1 Welders/Welding Operators Performance Qualification Record (WPQ): A document with basic criteria established for welder/welding operator qualification used to determine the welders ability to produce welds meeting prescribed standards.

1.3.2 Welding Procedure Specification (WPS): A written qualified welding procedure prepared to provide direction for making production welds.

1.3.3 Procedure Qualification Record (PQR): A record of the welding data used to weld a test coupon to qualify the WPS. The PQR is a record of variables recorded during the welding of the test coupons and contains the test results of the tested specimens. Recorded variables normally fall within a small range of the actual variables that will be used in production welding.

NOTE *Other terms and definitions shall be in accordance with AWS A3.0 - Terms and Definitions.*

1.4 Welding Symbols

1.4.1 All drawings and sketches that require welding shall use welding symbols as shown in AWS A2.4 (latest revision). Symbols for Welding and Nondestructive Examination.

1.5 Filler Metal, Issuance and Control

1.5.1 Filler metal and electrodes shall be procured, controlled, stored, and issued in accordance with approved CHBWV procedures.

1.5.2 Low hydrogen covered electrodes shall be stored at a minimum temperature of 250°F. Recording charts will be used to verify temperatures. Temperature monitoring devices for weld rod ovens shall be calibrated in accordance with approved CHBWV procedures.

1.5.3 Traceability of filler material shall be to the point of issuance (CHBWV Warehouse) unless otherwise specified by the SME on form WV-1888 within the work document.

1.5.4 A Senior Specialist DDWO/Craft (Mechanic) or Maintenance Supervisor will authorize warehouse requisition/withdrawal for obtaining filler material containers. Only undamaged containers will be transferred.

1.5.5 Once filler material is requisitioned/withdrawn from Warehouse stock, all electrodes shall then be placed in locked storage locker(s) within its original container indicating the type, size, heat and/or lot number.

1.5.6 Upon opening each low hydrogen electrode container, the Senior Specialist DDWO/Craft (Mechanic) will store the entire contents in a locked weld rod holding oven. A tag containing type, size, and heat and/or lot number will be affixed to the container.

1.5.7 A Senior Specialist DDWO/Craft (Mechanic) or Maintenance Supervisor will issue weld filler material to qualified welders by entering the following information into the Weld Filler Issuance Log:

A. Employee badge number
B. Process as applicable: e.g. SMAW or GTAW
C. Filler material description: e.g. E7018, 1/8"; ER70S-2, 1/8"
D. Date of issuance
E. Time of issuance
F. Quantity issued in pounds
G. Applicable work document or task number

1.5.8 Low hydrogen covered electrodes shall either be issued in quantities that can be used within four (4) hours, or shall be contained in heated portable rod caddies. Portable rod caddies do not require calibration.

1.5.9 Welders are responsible for discarding used stubs, damaged electrodes as well as low hydrogen electrodes which have been exposed to air (removed from the holding oven) for a period greater than four (4) hours.

1.5.10 Upon completion of work, each welder shall place their unique ID on form WV-1888 of the work document (if applicable) and when required, enter the heat/lot number(s).

1.5.11 A Senior Specialist DDWO/Craft (Mechanic) or Maintenance Supervisor shall monitor and initial/date the rod oven chart recorder daily (for days worked). As part of this monitoring, the temperatures since the last verification shall also be reviewed for potential temperature deficiency.

1.5.12 The Senior Specialist DDWO/Craft (Mechanic) or Maintenance Supervisor shall immediately report any temperature discrepancy which is outside the prescribed limits to the supervisor, and QA..

1.6 Other Joining Processes

1.6.1 Welding processes other than fusion welding and torch brazing of metallic components are not controlled by this manual.

1.6.2 Processes such as resistance spot welding, soldering, non code-related torch brazing or bonding/fusion of non-metallic components are a DDWO/Craft specific skill which may be employed by CHBWV without qualified procedures or specific qualification tests.

1.6.3 Situations may arise where special training and/or qualification on processes or techniques are warranted. The responsible cognizant engineer may then coordinate with the SME to develop joining processes per manufacturer's installation instructions and/or applicable codes.

1.6.4 Stud welding procedures for special projects may be developed by the cognizant engineer and the SME and documented on the work document.

1.7 Welding by Subcontractor/Supplier/Others

1.7.1 When welding is to be accomplished on site by a subcontractor/supplier/other (e.g. fixed price purchase order), welding program(s) and welding activities shall be in accordance with the contract documents. The welding program shall be approved by CHBWV per contract requirements prior to commencement of welding activities.

1.7.2 Equipment solely owned by a supplier under current CHBWV rental/lease agreement (e.g. Liquid Nitrogen tank manifold), may be installed/serviced on site by the supplier or authorized representative. WPS, PQR and welder qualification are the responsibility of the supplier. Control of filler material shall be at the discretion of the SME and Cog Eng.

1.7.3 Equipment (e.g. excavator, dozer) solely owned by suppliers, or CHBWV protegee for D&D activities may be serviced on site by the owner or authorized representative. WPS, PQR and welder qualification are the responsibility of the equipment owner. Control of filler material shall be at the discretion of the SME and Cog. Eng. Any modification or repair and any related testing/inspection shall be the owners responsibility.

1.8 Records

1.8.1 The following forms, data sheets, logs, reports, or any other form of documentation are considered records and when generated are to be prepared, maintained, and transferred to Records in accordance with WVDP-262 and WVDP-529. Refer to the CHBWV Master File Plan for further information.

A. Weld Rod Oven Temperature Data
B. Welding Procedure Specification
C. Procedure Qualification Record
D. Welder Performance Qualification
E. Brazing Procedure Specification
F. Brazer Performance Qualification
G. CHBWV Weld Data Sheet

1.9 Forms / Templates

Template - "Welding Procedure Specification"
WV-2524, "Procedure Qualification Record"
WV-2525, "Welder Performance Qualification"
Template - "Brazing Procedure Specification"
WV-2527, "Procedure Qualification Record (Brazing)"
WV-2528, "Brazer Performance Qualification"
WV-2529, "CHBWV Weld Data Sheet"
WV-1888, "Procedures, Inspections and Controls Checklist"

1.10 References

AWS Codes "American Welding Society"
ASME Codes "American Society of Mechanical Engineers"
EP-5-002, "Administration of Work Instruction Packages"
WVDP-111, "Quality Assurance Program"
WVDP-204, "WVDP Quality List Q-List"
WVDP-262, "WVDP Records Management Plan"
WVDP-485, "Work Control"
WVDP-529, "WVDP Records Disposition Plan"
ANSI Z49.1, "Safety in Welding, Cutting and Allied Processes"
ASNT-TC-1A, "Recommended Practice for Nondestructive Testing Personnel Qualification and Certification"
CHBWV Technical Specialist List

SECTION 2 - QUALIFICATION OF CHBWV WELDERS, WELDING OPERATORS AND BRAZERS (WELDERS)

2.1 General

2.1.1 Performance qualification tests shall be conducted by SME using qualified procedures in accordance with ASME Section IX or applicable AWS code. Successful completion of performance qualification shall be documented on form WV-2525 or WV-2528 as applicable.

2.1.2 Quality Assurance shall be notified prior to performance qualification testing. The Quality Assurance representative reserves the right to witness all performance qualification tests.

2.2 General Performance Qualification Testing

2.2.1 A welder may take performance qualification tests with individual processes on separate test coupons or a combination of welding processes in a single test coupon at the direction of the appropriate SME.

2.2.2 Welders and Welding Operators shall typically demonstrate ability on full penetration groove welds, unless the procedure to be used during production is limited to fillet welds.

2.2.3 Base metals used for welder qualification may be substituted for the base metal specified in the WPS in accordance with the applicable code.

2.2.4 Production welds shall not be used to qualify welders.

2.3 Specific Performance Qualification Testing

2.3.1 The SME shall coordinate the performance test to ensure all essential variables for each process of the selected WPS/BPS are satisfied.

2.3.2 The SME shall document acceptable performance testing information by completing form WV-2525 or WV-2528.

2.3.3 Quality Assurance shall perform in-process surveillance(s) during Welder performance testing. If performed, the surveillance shall assure the following:

- Materials appropriate to the WPS/BPS are used.
- Filler metal used is as specified on the WPS/BPS.
- Test position is as specified by the SME, coupon orientation is marked.
- Fit up and internal alignment are as specified by the SME.
- Tack welds are tapered as required.
- Root pass is visually acceptable in accordance with paragraph 2.3.4 below.
- Random examination of intermediate pass cleaning and condition.

2.3.4 After making a qualification test weld and prior to preparing the test specimens, the test coupon shall be visually inspected and accepted by Quality Assurance in accordance with the applicable code.

2.3.5 Appropriate tests shall be used to determine the degree of soundness and ductility of weld joints as determined by the SME.

2.3.6 Final signature of welder's or welding operator's test form shall be the responsibility of the SME. The test may be terminated at any time if, in the opinion of the SME, the welder fails to exhibit the required skill needed to satisfactorily complete the test.

2.3.7 At the discretion of the SME, test specimens may be discarded after evaluation.

2.3.8 Upon successful qualification, the welder shall be issued an identification symbol that shall be recorded on the Form WV-2525/WV-2528. The welder shall record this symbol or name when required on the appropriate work documents.

2.3.9 In the event a welder fails to meet the test acceptance criteria, a retest may be allowed at the discretion of the SME in accordance with applicable code.

2.4 Maintenance of Qualification - Period of Effectiveness

2.4.1 Certification for Welders qualified in any one process shall remain in effect for 180 days from the date the Welder last successfully used that process.

A. Successful use of a process is accomplished by a fabrication or repair weld made by a certified welder and documented through a work document or task.

B. The Period of Effectiveness (welder qualification maintenance) for each welder is maintained through MM262Q-SMAW and MM265Q-GTAW.

2.4.2 When there is a specific reason to question the ability of a welder by a qualified weld inspector, the welder may be retested with concurrence of the SME. If the first retest fails, the qualifications shall be revoked.

2.5 The SME shall maintain a list of all certified CHBWV welders under his/her cognizance that indicates the WPSs each person is qualified to use.

SECTION 3 - CHBWV WELDING AND BRAZING PROCEDURE QUALIFICATION

3.1 Requirements for WPS/BPS Development

3.1.1 Welding and Brazing Procedure Specifications and, if required, their associated Procedure Qualification Record(s) (PQR) shall be developed in accordance with ASME Section IX or applicable AWS code.

3.1.2 When a new or revised WPS/BPS is required, the SME or designee will develop it.

3.1.3 The SME may elect to adopt a WPS/BPS qualified by other corporate divisions in lieu of performing additional PQR testing. The SME may also utilize a procedure qualification from another division, in accordance with the ASME or AWS Code. The WPS/BPS shall be identified in accordance with requirements of this manual.

3.1.4 If qualification is required, the SME shall prepare an informational preliminary procedure specification for use during procedure qualification. The preliminary procedure specification shall contain the necessary information (essential and non-essential variables) required for the particular process to be used. This information may include but is not limited to:

3.1.5

- Coupon size (thickness/diameter)
- Filler metals/electrodes to be used
- Welding process(es) and techniques to be used
- Base metal specification(s)
- Shielding/Backing gas and flow rates
- Electrical characteristics (Amps, Volts, Polarity, etc.)
- Joint configuration
- Method of cleaning and back gouging
- Pre- or Post-weld heat treating

3.1.6 The SME shall coordinate test coupon preparation and notify Quality Assurance prior to the test initiation.

3.1.7 The actual values of all essential variables and supplementary essential variables (when required) shall be recorded during welding of the test coupon.

3.1.8 The preliminary WPS may be altered by the SME as needed to produce a satisfactory weldment. Changes shall be appropriately documented.

3.1.9 The SME shall direct the preparation and testing of the test specimens from the test coupon. If required, services for mechanical tests or non-destructive examinations shall be procured from qualified agencies in accordance with approved CHBWV procedures.

3.1.10 Test results shall be discussed with the welder, the applicable supervisor, and the QA representative by the SME.

3.1.11 Tests that meet the requirements of the applicable code will result in the preparation and issuance of a new or revised WPS/BPS and PQR by the SME.

A. The WPS/BPS and the PQR shall be recorded on the appropriate CHBWV forms.

3.2 Identification System

3.2.1 Each WPS/BPS and PQR shall be uniquely identified using the alpha numeric system described in this section.

3.2.2 The first character shall identify the process or combination of processes. Table 1 lists the applicable processes and their identifying characters.

TABLE 1

IDENTIFYING CHARACTER	PROCESS
S	SMAW (Shielded Metal Arc Welding)
T	GTAW (Gas Tungsten Arc Welding)
M	GMAW (Gas Metal Arc Welding)
F	FCAW (Flux Cored Arc Welding)
B	BRAZING

3.2.3 The second and third characters shall be separated by a hyphen, which identifies the base materials to be joined (e.g., ASME Section IX P number 8 for stainless steel). The fourth character, when present, shall be a two digit number assigned sequentially for a given process/base metal as needed.

3.2.4 The revision level of the WPS shall be numerically assigned at the time of preparation by the SME.

3.2.5 As an example of this system, T 43-8 01, Revision 1, would be interpreted as follows:

1st Char	2nd Char	3rd Char	4th Char	Rev.
T	43	8	01	Rev. 1
GTAW	P-43 (NICKEL)	P-8 (STAINLESS)	2ND P-43/P8 GTAW PROCEDURE ISSUED	first revision

3.2.6 An existing WPS/BPS may contain a 'W' prefix which coincide with the applicable PQR(s).

SECTION 4 - TECHNIQUE AND WORKMANSHIP

4.1 Technique

4.1.1 All CHBWV welding shall be performed in accordance with site safety requirements. Appropriate protective equipment shall be worn during welding and burning operations. Refer to ANSI Z49.1and Safety for selection criteria and options.

4.1.2 All welding requires an Industrial Work Permit (IWP) and a Hot Work Permit (HWP) prior to start of work. A task specific Job Safety Analysis (JSA) may also be utilized as necessary. Hazard analysis and screening will be performed by the Cognizant Engineer and/or Maintenance Supervisor prior to start of work.

4.1.3 All welding equipment shall be maintained in good operating condition.

4.1.4 The size and length of welds shall be designated through design requirements, detail drawings, or work instructions.

4.1.5 Welding shall not be done when the base metal temperature is lower than 50 degrees F, when surfaces are wet or exposed to rain, snow, or high wind velocities. Preheating shall be performed to bring the weld joint area above 50°F or the minimum preheat temperature specified on the WPS.

4.1.6 The following minimum preheat temperatures shall be utilized for preheating carbon steel materials. When joining materials of varying thicknesses, the preheat temperature shall correspond to the thicker material being joined. Preheats shall be maintained during welding.

Thickness:	Minimum Preheat Temperature
>1-1/2" thru 2-1/2" incl.	150 degrees F
> 2-1/2"	225 degrees F

4.1.7 Generally, post-weld heat treatments do not apply to WVDP work. If needed for specific application, a welding procedure that specifies the stress relief heat treatment to be used will be developed by the SME.

4.1.8 Interpass temperature for nonferrous materials shall not exceed 350 degrees F when measured 3" from either side of the weld.

4.1.9 Weld deposited overlay or buttering shall use an appropriate WPS for the selected process and base material.

4.1.10 Backing rings or consumable inserts may be used when required through work documents and approved by the SME and Cognizant System Engineer prior to work. Specific systems may restrict their use due to contamination control purposes.

4.1.11 For full penetration joints welded from both sides, the root shall be back gouged or ground to sound metal prior to welding the second side.

4.1.12 Intermediate weld passes shall be sufficiently cleaned prior to welding subsequent passes.

4.1.13 If required, the SME or cognizant engineer will prepare additional welding information in conjunction with the welding procedure and denoted on the work document. The direction of progression, sequencing, size considerations, heating, distortion control, etc. may be addressed to enable the welder to satisfactorily complete the required weld.

4.1.14 Welding may be performed by CHBWV certified welders at the direction of the Maintenance Supervisor in accordance with WVDP-485, "Work Control" provided it is Low Risk Routine Work and all the following criteria are met:

- Scope of work is non-process,
- Scope of work is non-code,
- Work is non-safety related,
- Work is non-environmentally impacting, and
- Work is Quality Level N per WVDP-111 and Q-List (WVDP-204)

4.2 Workmanship

4.2.1 Weld-o-lets, thread-o-lets, and soc-o-lets shall be prepared with a root opening of 3/32" minimum and tack welded to maintain alignment and gap. The root pass shall consist of a full penetration groove weld and finished with a cover fillet weld.

4.2.2 Fit-up and alignment of socket welds shall be accomplished as follows: fit the pipe entirely into fitting; lightly scribe a line on the pipe 1 inch above the fitting shoulder; withdraw the pipe 1/16" to 1/8" using the scribed line as a reference point; tack weld a minimum of three (3) places. The welder shall check for pullback prior to welding.

4.2.3 Butt weld end preparation shall be specified on the design drawings, or sketches.

A. For pipe, when the joint is fit up concentrically, a uniform mismatch of 1/16" is allowable.

B. For circumferential butt welds the maximum root gap shall be maximum of 5/32".

C. Should tolerances on diameter, wall thickness, out-of-roundness, or other mismatch result in inside diameter variations that do not meet these limits, the inside diameter can be counterbored or taper-ground to produce a bore within these limits.

D. Counterboring/taper-grinding shall not infringe on the minimum wall thickness of the pipe.

E. The counterbore length shall be a minimum of twice the wall thickness of the thinner member. In parts of unequal thickness, the thicker wall shall be tapered to at least a 3:1 transition or as required on the design drawing.

F. For joining pipe and components with unequal wall thickness, the joint fit-up and permitted off-set (OD) shall be per the applicable code.

4.2.4 Cold spring shall not be used to align joints. Care shall be taken at tie-ins to equipment, to preclude any undue stresses at these joints.

4.2.5 Purging and Shielding Gases

A. Backing, shielding and trailing gases if used, shall be specified on the applicable WPS.

B. Welding grade gases shall be used.

C. Where purging is required, the purge envelope shall not exceed 2% oxygen content.

D. This percentage can be verified with a oxygen meter, or by purging at least 6 volume changes of the volume needed to be purged. Caution shall be used if high flow rate is used for purging as gasses may mix or entrain air instead of creating an inert envelope.

E. Purge envelopes shall be as small as reasonably possible.

NOTE *Soluble paper purge dams can only be used if the line is subsequently flushed with water.*

F. Where purging requires the use of purge dams, such as water soluble paper, they shall be approved by the cognizant system engineer and SME prior to use.

G. Purge dams shall be located outside the heat affected area to prevent damage to the purge device and contamination of the components being welded.

H. Purge gas shall be maintained until 3/16" of weld metal thickness is deposited.

I. Internal purge is not required for fillet welds, joints with internal backing rings, double welded joints, or socket welds.

4.2.6 Appropriate cleaning shall be accomplished prior to proceeding with welding.

A. Surfaces and edges to be welded shall be smooth, uniform, and free from fins, tears, cracks, foreign material including scale and other discontinuities.

B. An area extending at least one inch on each side of the weld joint shall be free from foreign material (i.e. - paint, oil, galvanizing) that might prevent proper welding or produce objectionable fumes. When used, cleaning solvents shall be allowed to completely evaporate prior to welding.

CAUTION

Solvents are flammable and require careful planning for proper ventilation. Refer to IWP and/or JSA.

C. Slag and spatter shall be removed from existing weld deposits and brushed clean before successive weld beads are applied.

D. Slag shall be removed from all completed welds. The weld and adjacent base metal shall be cleaned by appropriate methods. Tightly adherent spatter remaining after the cleaning operation is acceptable unless its removal is required for non-destructive testing. Welded joints shall not be painted until after acceptance of inspections/testing.

E. Non-ferrous parts to be joined or repaired by welding shall be degreased by cleaning the weld area with an approved solvent or by mechanical methods.

F. Surfaces that have been thermally cut or gouged shall be ground or machined to sound metal prior to welding.

4.2.7 Pre-heat and interpass temperature shall be monitored by the welder by use of temperature indicating crayons (e.g. Tempilstik) or by contact pyrometers or thermometers. Preheat temperature shall be in accordance with the WPS.

4.2.8 Caulking or slugging of welds is not permitted.

4.2.9 Peening is not allowed unless specifically directed by the SME and the work document.

A. When directed, peening shall be witnessed by the SME or designee per the following criteria.

- The first and last layer of weld shall not be peened.
- Prior to peening, the weld pass shall be carefully cleaned and visually examined. If defects are present, they shall be removed.
- Reference marks may be employed to prevent peening from causing more distortion than caused by welding.
- The peening tool shall have a round nose no less than 1/8" diameter.

4.2.10 Arc strikes are not allowed on process piping or equipment. Inadvertent arc strikes shall be removed per weld repair section 4.4.1.F.

4.2.11 Weld reinforcement shall have a gradual transition to the plane of the base metal. Surfaces of butt welds which are to be ground or machined flush shall be finished so as not to reduce the thickness of the base material more than 1/32".

4.2.12 Undercut shall not exceed 1/32" and shall not encroach on minimum wall thickness. When undercut exceeds these limits, the area shall be reworked.

4.2.13 Final weld contour shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt edges, and valleys to allow clear interpretation of applicable Non-Destructive Examination (NDE) methods.

4.3 <u>Tool Control</u>

4.3.1 To prevent free-iron contamination of non-ferrous base materials, mechanical metal removal shall be performed using new non-ferrous tools or tools previously used only on non-ferrous materials. A tool identification scheme using: blue paint/segregation and/or stainless steel marking/segregation will be utilized.

A. Stainless steel wire brushes shall be used on non ferrous alloys.

B. Jaws of vises used for stainless steel and nickel based alloy work shall be "isolated" to prevent carbon steel contamination.

C. In the material storage area and fabrication area, stainless steel and nickel alloys shall be separated from carbon steel.

4.4 <u>Weld Repairs</u>

4.4.1 When a repair is required for a welded joint that has been rejected because of radiography or ultrasonic testing, the documentation for that repair shall indicate an R-1 for the first repair and R-2 for the second. More than two repairs requires the SME's approval.

A. The types, extent and method of repair examination shall be the same as for the original weld.

B. Weld end prep repairs required because of physical damage due to handling, etc. may require a combination of welding and mechanical methods to be restored.

C. Welded repairs may be made using the same WPS as the original weld or compatible WPS and process.

D. Areas to be repaired shall be excavated to eliminate the defect and prepared as necessary to provide for proper electrode manipulation.

E. The excavated area shall be examined with an appropriate NDE method (PT, MT, or VT) to assure complete defect removal prior to proceeding with repair.

F. Arc strikes on pressure retaining components shall be removed by grinding or blending to the bottom of the depression. The blended area shall be visually free of crater cracks. If the remaining thickness is less than minimum wall, the area shall be repaired by welding.

4.4.2 If a repair (or alteration) is required on an ASME-Stamped vessel, work will be performed in accordance with the National Board Inspection Code, by an authorized repair organization. No work on ASME stamped vessels shall be initiated without the Engineering Manager and SME approval on the work document.

4.4.3 To ensure internal components are not damaged, planning for welding of items such as valves or pumps may provide for disassembly and reassembly of the components to manufacturer's instructions or methods of reducing the amount of heat input to the item.

4.4.4 Temporary Attachments to Pressure Boundaries

A. Attachments which are welded onto the component during the process of manufacturing or installation are permitted, provided the following requirements are met.

- Attachment material is compatible with base material
- The immediate area around the attachment is marked in a suitable manner to identify the area for examination after attachment removal.
- Attachments are not to be removed by hammer blows.
- The area is examined and documented after attachment removal by an appropriate NDE method (PT or MT).

4.5 Acceptance Criteria

4.5.1 Structural steel, pipe supports, hangers, and miscellaneous metals shall be visually examined to meet the acceptance criteria in AWS D1.1 (static), unless otherwise specified.

4.5.2 Piping welding and all attachments welded to the pipe shall be visually examined to the criteria required in ASME B31.3 (normal service) unless otherwise specified.

4.5.3 Lifting devices designated as 'Below the Hook Lift Devices' per DOE-STD-1090, 'Hoisting and Rigging Manual' shall be inspected per AWS D14.1 unless otherwise noted.

4.5.4 Stainless steel structural welding shall be inspected to AWS D1.6 unless otherwise noted.

4.6 In-Process Documentation

The CHBWV Weld Data Sheet (WV-2529) will be used for documenting welding information when such information is required by the governing work document. Weld maps and weld data sheets are generated by the Cognizant Engineer and Quality Assurance. Completed weld maps and form WV-2529 shall be retained within the work document.

4.6.1 After welding on a particular weld joint, the welder will be responsible for applying his/her symbol and the electrode heat number in the blocks provided next to the applicable weld number.

4.6.2 The Quality Assurance Inspector will document their inspections/examinations by initialing and dating the applicable block(s).

ATTACHMENT A
CHBWV WELDING PROCEDURE SPECIFICATIONS
(w/ MAX. BASE METAL GROOVE THICKNESSES)

1.	W TS 1-1	- C.S. GTAW/SMAW, 1 3/4" MAX.
2.	W S 1-1	- C.S. SMAW, 1 ½" Max. (E6010 & E7018)
3.	S1-1-01	- C.S. SMAW 2½" Max.
4.	W TS 8-1	- S.S./C.S. GTAW/SMAW, 1 ½" MAX.
5.	W TS 8-8	- S.S. GTAW/SMAW, 1 ½" MAX.
6.	W T 10H-8	- S.S. GTAW, 3/4" MAX.
7.	W T 23-23	- Aluminum GTAW, ½" MAX.
8.	W T 43-8	- Inconel/S.S. GTAW, 1" MAX.
9.	W T 43-43	- Inconel GTAW, 1" MAX.
10.	W T 51-51	- Titanium GTAW, .560" MAX.
11.	F 1-1	- C.S. FCAW, Unlimited
12.	W F 8-1	- S.S./C.S. FCAW, ½" MAX.
13.	W F 8-8	- S.S. FCAW, ½" MAX.
14.	W M 8-1	- S.S./C.S. GMAW, .275" MAX.
15.	W M 8-8	- S.S. GMAW, .275" MAX.
16.	W B 107-107	- Brazing, .100" MAX.
17.	TS 43-8	- Inconel/S.S. GTAW/SMAW, 1" MAX.
18.	TS 43-43	- Inconel GTAW/SMAW, 1" MAX.

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W TS1-1 | Date: 7-10-96 | Supporting PQR No(s) WT1-1, & WS1-1

Revision No.: 3 | Date: 03/15/12

Welding Process(es): GTAW / SMAW

Types MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material ★ - WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT

(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No. 1 Group No. 1 OR 2 to P-No. 1 Group No. 1 OR 2

Specification type and grade

to Specification type and grade

Chem. Analysis and Mech. Prop.

to Chem. Analysis and Mech. Prop.

Thickness Range:

Base Metal: Groove: 1/16" - 1 3/4" Fillet: ALL

Pipe Dia. Range: Groove: ALL Fillet: ALL

FILLER METALS (QW-404)	GTAW	SMAW
SFA Specification:	SFA 5.18	SFA 5.1
AWS Classification:	ER70S-X	E7018
F-No.:	6	4
A-No.:	1	1
Size of Filler Metal:	1/16", 3/32", 1/8"	3/32", 1/8", 5/32"
Deposited Weld Metal:		
Thickness Range:		
Groove:	3/4" MAX.	1" MAX.
Fillet:	ALL	ALL
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert:	ONLY IF SPECIFIED IN WORK DOCUMENT	

(BACK) WPS No. W TS1-1 Rev. 3

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408): (FOR GTAW PORTION ONLY)
Other: N/A	Gas(es) (Mixture) Flow Rate
PREHEAT (QW-406)	ARGON 99.9% 10 - 25 CFH
Preheat Temp. Min.: 50° F.	
Interpass Temp. Min.: 50° F. Max: 600° F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: N/A ★

ELECTRICAL CHARACTERISTICS (QW-409)	
Current (AC or DC): DIRECT CURRENT	Polarity: SEE BELOW
Amps (Range): SEE BELOW	Volts (Range): SEE BELOW
Tungsten Electrode Size and Type: 1/16", 3/32", 1/8" (SFA 5.12, EWTh-2 or EWLa)	
Mode of Metal Transfer for GMAW: N/A	
Electrode Wire Feed Speed Range: N/A	
TECHNIQUE (QW-410)	
String or Weave Bead: BOTH	
Office or Gas Cup Size: #4 - #10	
Initial and Interpass Cleaning: BURRING, GRINDING, WIRE BRUSH, OR CHEMICALS AS REQUIRED	
Method of Back Gouging: BURRING, GRINDING, OR ARC-GOUGING FOLLOWED BY GRINDING	
Oscillation: N/A	
Contact Tube to Work Distance: N/A	
Multiple or Single Pass (Per Side): EITHER	
Multiple or Single Electrodes: SINGLE	
Travel Speed (Range): 1 - 8 IPM	
Peening: N/A	
Other NO PASS SHALL BE GREATER THAN 3/8" IN THICKNESS	

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ROOT & SUBSEQUENT PASSES	GTAW	ER70S-X	1/16"	STRAIGHT	50 - 90	8 - 17	1 - 8 IPM	NO PULSING
	"	"	3/32"	"	70 - 140	"	"	
	"	"	1/8"	"	90 - 180	"	"	
	SMAW	E7018	3/32"	REVERSE	60 - 110	19 - 28	1 - 12 IPM	
	"	"	1/8"	"	90 - 160	"	"	
	"	"	5/32"	"	140 - 210	"	"	

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W S1-1 | Date: 6-18-96 | Supporting PQR No(s): WS1-1

Revision No.: 3 | Date: 03-15-12

Welding Process(es): SMAW

Types: MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type) ★ -WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT
(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No. 1 Group No. 1 OR 2 to P-No. 1 Group No. 1 OR 2

Specification type and grade

to Specification type and grade

Chem. Analysis and Mech. Prop.

to Chem. Analysis and Mech. Prop.

Thickness Range:

Base Metal: Groove: 3/16" - 1 ½" Fillet: ALL

Pipe Dia. Range: Groove: ALL Fillet: ALL

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.1	SFA 5.1
AWS Classification:	E6010	E7018
F-No.:	3	4
A-No.:	1	1
Size of Filler Metal:	3/32", 1/8"	3/32", 1/8", 5/32"
Deposited Weld Metal Thickness Range:		
Groove:	½" MAX.	1" MAX.
Fillet:	ALL	ALL
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert: N/A		

(BACK) WPS No. W S1-1 Rev. 3

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408)
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50° F.	Shielding: N/A
Interpass Temp. Min.: 50° F. Max: 600° F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: N/A

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DC Polarity: REVERSE

Amps (Range): SEE BELOW Volts (Range): SEE BELOW

Tungsten Electrode Size and Shape: N/A

Mode of Metal Transfer for GMAW: N/A (Pure Tungsten, 2% Thoriated, etc...)

Electrode Wire Feed Speed Range: N/A (Spray arc, short circuiting arc, etc..)

TECHNIQUE (QW-410)

String or Weave Bead: BOTH

Office or Gas Cup Size: N/A

Initial and Interpass Cleaning: BURRING, GRINDING, WIRE BRUSH, OR CHEMICALS AS REQUIRED

Method of Back Gouging: GRINDING, OR ARC-GOUGING FOLLOWED BY GRINDING

Oscillation: MAX. WEAVE BEAD WIDTH SHOULD NOT EXCEED 5X CORE DIAMETER

Contact Tube to Work Distance: N/A

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): 1 - 12 IPM

Peening: N/A

Other NO PASS SHALL BE GREATER THAN 3/8" IN THICKNESS

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
1st (ROOT)	SMAW	E6010	3/32	REVERSE	60 - 90	19 - 22	1 - 12 IPM	
	"	"	1/8	"	75 - 125	21 - 25	"	
SUBSEQUENT LAYERS	SMAW	E7018	3/32	REVERSE	60 - 110	20 - 28	"	
	"	"	1/8	"	90 - 160	"	"	
	"	"	5/32	"	140 - 210	"	"	

WELD PROCEDURE SPECIFICATION (WPS)

Company Name:
CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.:	Date:	Supporting PQR No(s)	
S1-1-01	9-17-01	AWS D1.1 prequalified	N/A

Revision No.:	Date:
1	3-15-12

Welding Process(es):
SMAW

Types (Manual, Automatic, Machine, Semi-Auto):
Manual

JOINTS (QW-402): Details

Joint Design Groove - Partial Penetration and Fillets

Backing (Yes) Yes (No)

Backing material (type)

(Refer to both backing & retainers)

AWS D1.1 Prequalified Joint BTC-P5

X Metal (base metal) ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of the weld groove may be specified.

(At the option of the Mfr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g. for notch toughness procedures, for multiple process procedures, etc....)

*BASE METALS (QW-403)

P-No. 1	Group No. 1 or 2	to P-No. 1	Group No. 1 or 2
OR			
Specification type and grade ASTM A-36 Plate			
to Specification type and grade ASTM A-36 Plate			
OR			
Chem. Analysis and Mech. Prop.: n/a			
to Chem. Analysis and Mech. Prop: n/a			
Thickness Range:			
Base Metal:	Groove: 5/16" to 2-1/2"	Fillet: All	
Pipe Dia. Range:	Groove: n/a	Fillet: n/a	
Other: n/a			

*FILLER METALS (QW-404)		
SFA Specification:	5.1	
AWS Classification:	E7018	
F-No.:	4	
A-No.:	1	
Size of Filler Metal:	1/8", 5/32", 3/16"	
Deposited Weld Metal Range		
Groove:	1/4" to 2-1/4"	
Fillet:	ALL	
Electrode-Flux (Class):	n/a	
Flux Trade Name:	n/a	
Consumable Insert:	n/a	
Other:	n/a	

*Each base metal-filler combination should be recorded individually.

(BACK) WPS No. S1-1-01 Rev. 1

POSITION (QW-405	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: All	Temperature Range: n/a
Weld Progression (Uphill, Downhill): Uphill	Time Range: n/a
Position of Fillet: All	Gas (QW-408): n/a
Other: n/a	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50 ° F (5/16" to 1-1/2") / 150°F (>1-1/2" to 2-1/2")	Shielding: n/a
Interpass Temp. Min.: See Preheat above Max: 500°F	Trailing: n/a
Preheat Maintenance: Continuous	Backing: n/a
	Other: n/a

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DC Polarity: Reverse

Amps (Range): See below Volts (Range): See below

(Amps & volts should be recorded for each electrode size, position, and thickness, etc.... This information may be listed in a tabular form similar to that shown below.)

Tungsten Electrode Size and Type: n/a ~~(Pure Tungsten, 2% Thoriated, etc...)~~

Mode of Metal Transfer for GMAW and FCAW: n/a ~~(Spray arc, short circuiting arc, etc.)~~

Electrode Wire Feed Speed Range: n/a

TECHNIQUE (QW-410)

String or Weave Bead: Both

Orifice or Gas Cup Size. n/a

Initial and Interpass Cleaning (Brushing, Grinding, etc...): Brushing, Grinding

Method of Back Gouging: Grinding

Oscillation: n/a

Contact Tube to Work Distance: n/a

Multiple or Single Pass (Per Side): Multiple

Multiple or Single Electrodes: Single

Travel Speed (Range): See below

Peening: Not allowed on root pass or surface layer passes

Other: No pass shall be greater than 3/8" in thickness

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Other (e.g. Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, Etc.)
		Class	Diameter	Type Polar.	Amp Range			
Root, 2nd pass	SMAW	E7018	1/8"	REVERSE (Typ.)	90-160	19-28	1-12 IPM	NONE (Typ.)
Subsequent layers	SMAW	E7018	5/32"		140-210	19-28	1-12 IPM	
	SMAW	E7018	3/16"		200-290	23-32	1-15 IPM	

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W TS8-1 Date: 7-9-96 Supporting PQR No(s) WT8-1, & WS8-1

Revision No.: 3 Date: 03/15/12

Welding Process(es): GTAW / SMAW

Types: MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type) ★ -WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT
(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No. 8 Group No. 1 & 2 to P-No. 1 Group No. 1 & 2

Specification type and grade

to Specification type and grade

Chem. Analysis and Mech. Prop.:

to Chem. Analysis and Mech. Prop:

Thickness Range:

Base Metal: Groove: 1/16" - 1 ½" Fillet: ALL

Pipe Dia. Range: Groove: ALL Fillet: ALL

FILLER METALS (QW-404)	GTAW	SMAW
SFA Specification:	SFA 5.9	SFA 5.4
AWS Classification:	ER 309-X	E309-X
F-No.:	6	5
A-No.:	8	8
Size of Filler Metal:	1/16", 3/32", 1/8"	3/32", 1/8"
Deposited Weld Metal:		
Thickness Range:		
Groove:	3/4" MAX.	3/4" MAX.
Fillet:	ALL	ALL
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert:	ONLY IF SPECIFIED IN WORK DOCUMENT	

(BACK) WPS No. W TS8-1 Rev. 3

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression: UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408): (FOR GTAW PORTION ONLY)
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50° F.	Shielding: ARGON 99.9% 10 - 25 CFH
Interpass Temp. Min.: 50° F. Max: 350°F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: ARGON 99.9% 5 - 15 CFH
	Other: GAS BACKING NOT REQUIRED WITH BACKING RINGS, OR FILLETS

ELECTRICAL CHARACTERISTICS (QW-409)	
Current (AC or DC): DIRECT CURRENT	Polarity: STRAIGHT / REVERSE
Amps (Range): SEE BELOW	Volts (Range): SEE BELOW
Tungsten Electrode Size and Type: 1/16", 3/32", 1/8" (SFA 5.12, EWTh-2 or EWLa)	
Mode of Metal Transfer for GMAW: N/A	
Electrode Wire Feed Speed Range: N/A	

TECHNIQUE (QW-410)
String or Weave Bead: BOTH
Office or Gas Cup Size: #4 - #10
Initial and Interpass Cleaning: BURRING, GRINDING, WIRE BRUSH, OR CHEMICALS AS REQUIRED
Method of Back Gouging: BURRING, GRINDING, OR ARC-GOUGING FOLLOWED BY GRINDING
Oscillation: N/A
Contact Tube to Work Distance: N/A
Multiple or Single Pass (Per Side): EITHER
Multiple or Single Electrodes: SINGLE
Travel Speed (Range): 1 - 8 IPM
Peening: N/A
Other NO PASS SHALL BE GREATER THAN 1/4" IN THICKNESS

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ROOT & SUBSEQUENT LAYERS	GTAW " "	ER309-X " "	1/16" 3/32" 1/8"	STRAIGHT " "	40 - 70 50 - 100 70 - 140	10 - 20 " "	1 - 8 IPM " "	NO PULSING
	SMAW "	E309-X "	3/32" 1/8"	REVERSE "	50 - 100 70 - 140	10 - 20 "	1 - 12 IPM "	

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W TS8-8 Date: 7-10-96 Supporting PQR No(s) WT8-8, & WS8-8

Revision No.: 3 Date: 03/15/12

Welding Process(es): GTAW / SMAW

Types: MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type) ★ -WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT
(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)							
P-No.	8	Group No.	1 & 2	to P-No.	8	Group No.	1 & 2
Specification type and grade							
to Specification type and grade							
Chem. Analysis and Mech. Prop.							
to Chem. Analysis and Mech. Prop.							
Thickness Range:							
Base Metal:	Groove:	1/16" - 1 ½"			Fillet:	ALL	
Pipe Dia. Range:	Groove:	ALL	Fillet:	ALL			

FILLER METALS (QW-404)	GTAW	SMAW
SFA Specification:	SFA 5.9	SFA 5.4
AWS Classification:	ER 308L	ER 308L
F-No.:	6	5
A-No.:	8	8
Size of Filler Metal:	1/16", 3/32", 1/8"	3/32", 1/8"
Deposited Weld Metal:		
Thickness Range:		
Groove:	3/4" MAX.	3/4" MAX.
Fillet:	ALL	ALL
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert:	ONLY IF SPECIFIED IN WORK DOCUMENT	

(BACK) WPS No. W TS8-8 Rev. 3

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression: UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408): (FOR GTAW PORTION ONLY)
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50° F.	Shielding: ARGON 99.9% 10 - 25 CFH
Interpass Temp. Min.: 50° F. Max: 350°F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: ARGON 99.9% 5 - 15 CFH
	Other: GAS BACKING NOT REQUIRED WITH BACKING RINGS, OR FILLETS

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DIRECT CURRENT Polarity: STRAIGHT / REVERSE

Amps (Range): SEE BELOW Volts (Range): SEE BELOW

Tungsten Electrode Size and Type: 1/16", 3/32", 1/8" (SFA 5.12, EWTh-2 or EWLa)

Mode of Metal Transfer for GMAW: N/A

Electrode Wire Feed Speed Range: N/A

TECHNIQUE (QW-410)

String or Weave Bead: BOTH

Office or Gas Cup Size: #4 - #10

Initial and Interpass Cleaning: BURRING, GRINDING, WIRE BRUSH, OR CHEMICALS AS REQUIRED

Method of Back Gouging: BURRING, GRINDING, OR ARC-GOUGING FOLLOWED BY GRINDING

Oscillation: N/A

Contact Tube to Work Distance: N/A

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): 1 - 8 IPM

Peening: N/A

Other NO PASS SHALL BE GREATER THAN 1/4" IN THICKNESS

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ROOT & SUBSEQUENT	GTAW	ER3XX-X	1/16"	STRAIGHT	40 - 80	10 - 20	1 - 8 IPM	NO PULSING
	"	"	3/32"	"	50 - 100	"	"	
	"	"	1/8"	"	70 - 140	"	"	
	SMAW	E3XX-X	3/32"	REVERSE	50 - 100	10 - 20	1 - 8 IPM	
	"	"	1/8"	"	70 - 140	"	"	

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W T10H-8 | Date: 9-16-98 | Supporting PQR No: WT10H-8

Revision No.: 2 | Date: 03-15-12

Welding Process: GTAW

Types: MANUAL

JOINTS (QW-402):				Details		

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type)★ WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT
(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)							
P-No.	10H	Group No.	N/A	to P-No.	8	Group No.	N/A
Specification type and grade							
to Specification type and grade							
Chem. Analysis and Mech. Prop.							
to Chem. Analysis and Mech. Prop.							
Thickness Range:							
Base Metal:	Groove: 1/16" - 3/4"	Fillet: ALL					
Pipe Dia. Range:	Groove: ALL	Fillet: ALL					

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.9	
AWS Classification:	ER308L	
F-No.:	6	
A-No.:	8	
Size of Filler Metal:	1/16", 3/32", 1/8"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	3/4" MAX.	
Fillet:	ALL	
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert:	ONLY IF SPECIFIED IN WORK DOCUMENT	

(BACK) WPS No. W T10H-8 Rev. 2

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression (Uphill, Downhill): UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 100°F.	Shielding: ARGON 99.9% 10-25 CFH
Interpass Temp. Min.: 100°F. Max: 350°F.	Trailing:
Preheat Maintenance: AS REQUIRED	Backing: ARGON 99.9% 5-15 CFH

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DIRECT CURRENT Polarity: STRAIGHT

Amps (Range): SEE BELOW Volts (Range): SEE BELOW

Tungsten Electrode Size and Type: 1/16", 3/32", 1/8" (SFA 5.12, EWLa OR EWTh-2)

Mode of Metal Transfer for GMAW: N/A

Electrode Wire Feed Speed Range: N/A

TECHNIQUE (QW-410)

String or Weave Bead: STRING

Office or Gas Cup Size: #4 - #10

Initial and Interpass Cleaning: BURRING, GRINDING, S.S. WIRE BRUSH, OR CHEMICALS

AS REQUIRED

Method of Back Gouging: BURRING, GRINDING, OR ARC GOUGING FOLLOWED BY GRINDING

Oscillation: N/A

Contact Tube to Work Distance: N/A

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): 1 - 10 IPM

Peening: N/A

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	GTAW	ER308L	1/16" 3/32" 1/8"	STRAIGHT	40-80 50-100 70-140	10-20 " "	1-10 IPM " "	NO PULSING

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W T23-23 | Date: 7-8-96 | Supporting PQR No: WT23-23 (3812)

Revision No.: 2 | Date: 03-15-12

Welding Process: GTAW

Types: MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type) ★ -WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT

(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)		
P-No. 23 Group No. N/A to P-No. 23		Group No. N/A
Specification type and grade		
to Specification type and grade		
Chem. Analysis and Mech. Prop.:		
to Chem. Analysis and Mech. Prop:		
Thickness Range:		
Base Metal: Groove: 1/16" - ½"		Fillet: ALL
Pipe Dia. Range: Groove: ALL Fillet: ALL		
FILLER METALS (QW-404)		
SFA Specification:	SFA 5.10	
AWS Classification:	ER 4043	
F-No.:	23	
A-No.:	N/A	
Size of Filler Metal:	1/16", 3/32", 1/8"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	½" MAX.	
Fillet:	ALL	
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert:	ONLY IF SPECIFIED IN WORK DOCUMENT	

(BACK) WPS No.W T23-23 Rev. 2

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression (Uphill, Downhill): UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50° F.	Shielding: ARGON 99.9% 10 - 25 CFH
Interpass Temp. Min.: 50° F.Max: 350°F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: N/A ★
	Other: ★ - ONLY WHEN SPECIFIED IN WORK DOCUMENT

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): ALTERNATING CURRENT Polarity: N/A

Amps (Range): SEE BELOW Volts (Range): SEE BELOW

Tungsten Electrode Size and Type: 1/16", 3/32", 1/8" (SFA 5.12, EWP, or EWZr) w/ A ROUNDED POINT

Mode of Metal Transfer for GMAW: N/A

Electrode Wire Feed Speed Range: N/A

TECHNIQUE (QW-410)

String or Weave Bead: BOTH

Office or Gas Cup Size: #4 - #10

Initial and Interpass Cleaning: BURRING, S.S. WIRE BRUSH, OR CHEMICALS AS REQUIRED

Method of Back Gouging: BURRING, OR GRINDING FOLLOWED BY S.S. WIRE BRUSHING

Oscillation: N/A

Contact Tube to Work Distance: N/A

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): 1 - 10 IPM

Peening: N/A

Other NO PASS SHALL BE GREATER THAN 1/4" IN THICKNESS. RECOMMENDED EQUIPMENT: HIGH-FREQUENCY, REMOTE CONTROL. PROCEDURE DERIVED FROM WESTINGHOUSE NCD PENSACOLA.

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	GTAW	ER4043	1/16" 3/32" 1/8"	AC " "	40 - 90 60 - 120 90 - 160	N/A	1 - 10 IPM " "	NO PULSING

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W T43-8 | Date: 6-25-96 | Supporting PQR No(s) WT43-8, WT43-8 01

Revision No.: 3 | Date: 03/15/12

Welding Process: GTAW

Types: MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type) ★ -WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT (Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No. 43 Group No. N/A to P-No. 8 Group No. 1 & 2

Specification type and grade

to Specification type and grade

Chem. Analysis and Mech. Prop.:

to Chem. Analysis and Mech. Prop:

Thickness Range:

Base Metal: Groove: 1/16" - 1" Fillet: ALL

Pipe Dia. Range: Groove: ALL Fillet: ALL

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.14	
AWS Classification: †	UNS #N06052	
F-No.:	43	
A-No.:	N/A PER QW-404.5	
Size of Filler Metal:	1/16", 3/32", 1/8"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	1" MAX.	
Fillet:	ALL	
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert:	ONLY IF SPECIFIED IN WORK DOCUMENT	
† -A DIFFERENT CLASSIFICATION WITHIN "F-43" MAY BE USED IF SPECIFIED IN WORK DOCUMENT.		

(BACK) WPS No.W T43-8 Rev. 3

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50° F.	Shielding: ARGON 99.9% 10 - 25 CFH
Interpass Temp. Min.: 50° FMax: 350°F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: ARGON 99.9% 5 - 15 CFH
	Other: GAS BACKING NOT REQUIRED WITH BACKING RINGS, OR FILLETS

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DIRECT CURRENT Polarity: STRAIGHT

Amps (Range): SEE BELOW Volts (Range): SEE BELOW

Tungsten Electrode Size and Type: 1/16", 3/32", 1/8" (SFA 5.12, EWTh-2 or EWLa)

Mode of Metal Transfer for GMAW: N/A

Electrode Wire Feed Speed Range: N/A

TECHNIQUE (QW-410)

String or Weave Bead: BOTH

Office or Gas Cup Size: #4 - #10

Initial and Interpass Cleaning: BURRING, GRINDING, WIRE BRUSH, OR CHEMICALS AS REQUIRED. GRINDING WHEELS SHALL BE OF THE ALUMINUM OXIDE TYPE.

Method of Back Gouging: BURRING, GRINDING, OR ARC-GOUGING FOLLOWED BY GRINDING (SEE CLEANING NOTE ABOVE)

Oscillation: N/A

Contact Tube to Work Distance: N/A

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): 1 - 8 IPM

Peening: N/A

Other NO PASS SHALL BE GREATER THAN 1/4" IN THICKNESS

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	GTAW	★ " "	1/16" 3/32" 1/8"	STRAIGHT " "	40 - 70 50 - 100 70 - 140	10 - 20 " "	1 - 8 IPM " "	NO PULSING ★ -UNS #N06052

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W T43-43 | Date: 6-24-96 | Supporting PQR No(s) WT43-43

Revision No.: 3 | Date: 03-15-12

Welding Process: GTAW

Types: MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type) ★ -WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT (Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)			
P-No. 43	Group No. N/A	to P-No. 43	Group No. N/A
Specification type and grade			
to Specification type and grade			
Chem. Analysis and Mech. Prop.:			
to Chem. Analysis and Mech. Prop:			
Thickness Range:			
Base Metal:	Groove: 1/16" - 1"		Fillet: ALL
Pipe Dia. Range:	Groove: ALL		Fillet: ALL

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.14	
AWS Classification:	UNS #N06052	
F-No.:	43	
A-No.:	N/A PER QW-404.5	
Size of Filler Metal:	1/16", 3/32", 1/8"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	1" MAX.	
Fillet:	ALL	
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert:	ONLY IF SPECIFIED IN WORK DOCUMENT	

(BACK) WPS No.W T43-43 Rev. 3

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50° F.	Shielding: ARGON 99.9% 10 - 25 CFH
Interpass Temp. Min.: 50° F. Max: 350°F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: ARGON 99.9% 5 - 15 CFH
	Other: GAS BACKING NOT REQUIRED WITH BACKING RINGS, OR FILLETS

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DIRECT CURRENT — Polarity: STRAIGHT

Amps (Range): SEE BELOW — Volts (Range): SEE BELOW

Tungsten Electrode Size and Type: 1/16", 3/32", 1/8" (SFA 5.12, EWTh-2 or EWLa)

Mode of Metal Transfer for GMAW: N/A

Electrode Wire Feed Speed Range: N/A

TECHNIQUE (QW-410)

String or Weave Bead: BOTH

Office or Gas Cup Size: #4 - #10

Initial and Interpass Cleaning: BURRING, GRINDING, WIRE BRUSH, OR CHEMICALS AS REQUIRED. GRINDING WHEELS SHALL BE OF THE ALUMINUM OXIDE TYPE.

Method of Back Gouging: BURRING, GRINDING, OR ARC-GOUGING FOLLOWED BY GRINDING (SEE CLEANING NOTE ABOVE)

Oscillation: N/A

Contact Tube to Work Distance: N/A

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): 1 - 8 IPM

Peening: N/A

Other NO PASS SHALL BE GREATER THAN 1/4" IN THICKNESS

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	GTAW	INCO 52	1/16"	STRAIGHT	40 - 70	10 - 20	1 - 8 IPM	NO PULSING
		"	3/32"	"	50 - 100	"	"	★ -UNS
		"	1/8"	"	70 - 140	"	"	#N06052

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W T51-51 Date: 6-27-96 Supporting PQR No: WT51-51 (410)

Revision No.: 3 Date: 03/15/12

Welding Process: GTAW

Types: MANUAL

JOINTS (QW-402): Details

Joint Design: GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type) ★ -WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT

(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No. 51 Group No. N/A to P-No. 51 Group No. N/A

Specification type and grade

to Specification type and grade

Chem. Analysis and Mech. Prop.:

to Chem. Analysis and Mech. Prop.:

Thickness Range:

Base Metal: Groove: 1/16" - .560" Fillet: ALL

Pipe Dia. Range: Groove: ALL Fillet: ALL

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.16	
AWS Classification:	ERTi-1	
F-No.:	51	
A-No.:	N/A PER QW-404.5	
Size of Filler Metal:	1/16", 3/32"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	.560" MAX.	
Fillet:	ALL	
Electrode-Flux (Class): N/A		
Flux Trade Name: N/A		
Consumable Insert: N/A		
Other: CLEAN GLOVES SHOULD BE WORN WHEN HANDLING MATERIAL.		

(BACK) WPS No. W T51-51 Rev. 3

Position of Groove: ALL	Temperature Range: N/A
Weld Progression: UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 70° F.	Shielding: ARGON 99.9% 10 - 25 CFH
Interpass Temp. Min.: 70° F. Max: 350°F.	Trailing: ARGON 99.9% 20 - 35 CFH
Preheat Maintenance: AS REQUIRED	Backing: ARGON 99.9% 10 - 25 CFH
	Other: GAS BACKING NOT REQUIRED WITH BACKING RINGS, OR FILLETS

ELECTRICAL CHARACTERISTICS (QW-409)
Current (AC or DC): DIRECT CURRENT Polarity: STRAIGHT
Amps (Range): SEE BELOW Volts (Range): SEE BELOW
Tungsten Electrode Size and Type: 1/16", 3/32", 1/8" (SFA 5.12, EWTh-2 or EWLa)
Mode of Metal Transfer for GMAW: N/A
Electrode Wire Feed Speed Range: N/A
TECHNIQUE (QW-410)
String or Weave Bead: STRING
Office or Gas Cup Size: #8 - #12 (GAS LENS TYPE)
Initial and Interpass Cleaning: CLEANLINESS IS IMPERATIVE. BURRING, GRINDING, S.S. WIRE BRUSH, OR CHEMICALS (NON-CHLORINATED) AS REQUIRED. GRINDING WHEELS SHALL BE OF THE ALUMINUM OXIDE TYPE.
Method of Back Gouging: BURRING, GRINDING (SEE CLEANING NOTE ABOVE)
Oscillation: N/A
Contact Tube to Work Distance: N/A
Multiple or Single Pass (Per Side): EITHER
Multiple or Single Electrodes: SINGLE
Travel Speed (Range): 1 - 10 IPM
Peening: N/A
Other: EQUIPMENT SHOULD INCLUDE HIGH-FREQUENCY REMOTE; WELD AND H.A.Z. TO REMAIN IN INERT ATMOSPHERE UNTIL <600° F.; WHEN "DIPPING" THE FILLER, KEEP THE WIRE'S TIP IN THE SHIELDING GAS; IF WELD BEAD HAS OTHER THAN A SILVERY METALLIC APPEARANCE, EVALUATION WILL BE REQUIRED. PROCEDURE DERIVED FROM WESTINGHOUSE ENERGY DIVISION/PCI SERVICES.

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	GTAW	ERTi-1	1/16"	STRAIGHT	70 - 100	10 - 20	1 - 10 IPM	NO PULSING
		"	3/32"	"	80 - 150	"	"	
		"	1/8"	"	110 - 170	"	"	

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name:
CHM2HILL B&W West Valley, LLC.

Welding Procedure Specification No.:	Date:	Supporting PQR No(s)
F 1-1	03/25/98	AWS Pre-qualified

Revision No.: 2 | Date: 3-15-12

Welding Process(es):
FCAW

Types (Manual, Automatic, Machine, Semi-Auto):
Semi-Automatic

JOINTS (QW-402): | Details

Joint Design All pre-qualified joints per AWS D1.1-96

Backing (Yes) X (No) X

Backing material (type) When used, compatible w/ base material
(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of the weld groove may be specified.

(At the option of the Mfr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g. for notch toughness procedures, for multiple process procedures, etc....)

*BASE METALS (QW-403)			
P-No.	Group No.	to P-No.	Group No.
OR			
Specification type and grade (Pre-qualified base metals from Table 3.1, Groups I or II of AWS D1.1-96)			
to Specification type and grade (Pre-qualified base metals from Table 3.1, Groups I or II of AWS D1.1-96)			
OR			
Chem. Analysis and Mech. Prop.:			
to Chem. Analysis and Mech. Prop:			
Thickness Range:			
Base Metal:	Groove: 1/8" - Unlimited	Fillet: ALL	
Pipe Dia. Range:	Groove: N/A	Fillet: N/A	
Other:			

*FILLER METALS (QW-404)		
SFA Specification:	A5.20	
AWS Classification:	E71T-8	
F-No..	6	
A-No.:	1	
Size of Filler Metal:	.035" - 5/64"	
Deposited Weld Metal Range		
Groove:	1/8" - Unlimited	
Fillet:	Unlimited	
Electrode-Flux (Class):	N/A	
Flux Trade Name:	N/A	
Consumable Insert:	N/A	
Other:	NOT TO BE USED ON PROCESS PIPING	

*Each base metal-filler combination should be recorded individually.

(BACK) WPS No. F 1-1 Rev. 2

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression (Uphill, Downhill): UP	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408): N/A
Other:	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50 DEGREES	Shielding: N/A
Interpass Temp. Min.: 50 DEGREES Max: 600 DEGREES	Trailing: N/A
Preheat Maintenance: DURING WELDING	Backing: N/A
	Other: N/A

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DC Polarity: STRAIGHT

Amps (Range): SEE BELOW Volts (Range): SEE BELOW

(Amps & volts should be recorded for each electrode size, position, and thickness, etc.. This information may be listed in a tabular form similar to that shown below.)

Tungsten Electrode Size and Type: N/A

~~(Pure Tungsten, 2% Thoriated, etc...)~~

Mode of Metal Transfer for GMAW and FCAW: SPRAY

~~(Spray arc, short circuiting arc, etc.)~~

Electrode Wire Feed Speed Range: SEE BELOW

TECHNIQUE (QW-410)

String or Weave Bead: STRINGER

Orifice or Gas Cup Size:

Initial and Interpass Cleaning (Brushing, Grinding, etc...): WIRE BRUSHING OR GRINDING, AS REQUIRED

Method of Back Gouging: GRINDING

Oscillation: MINIMAL

Contact Tube to Work Distance: 3/8" - 1", DEPENDING ON WIRE DIAMETER

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): SEE BELOW

Peening: N/A

Other

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Other (e.g. Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, Etc.)
		Class	Diameter	Type Polar.	Amp. Range			
ALL	FCAW	E71T-8	.035"	DCEN	60 - 140	14 - 19	5 - 12 IPM	NO PULSING
	"	"	.068"	"	110 - 280	16 - 22	7 - 16 IPM	
	"	"	5/64"	"	180 - 320	18 - 24	8 - 18 IPM	

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W F8-1 | Date: 5-12-99 | Supporting PQR No: WF 8-1

Revision No.: 2 | Date: 3-15-12

Welding Process: FCAW

Types: SEMI - AUTOMATIC

JOINTS (QW-402): | Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type)★ WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT

(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No. 8	Group No. N/A	to P-No. 1	Group No. N/A
Specification type and grade			
to Specification type and grade			
Chem. Analysis and Mech. Prop.			
to Chem. Analysis and Mech. Prop.			
Thickness Range:			
Base Metal:	Groove: 1/16" - ½"	Fillet: ALL	
Pipe Dia. Range:	Groove: ALL	Fillet: ALL	

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.22	
AWS Classification:	E309LT	
F-No.:	6	
A-No.:	N/A	
Size of Filler Metal:	.035"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	½" MAX.	
Fillet:	ALL	
Electrode-Flux (Class):N/A		
Flux Trade Name:N/A		
Consumable Insert:N/A		

(BACK) WPS No. W F 8-1 Rev. 2

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression: UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50°F.	Shielding: ARGON / CO2 75 / 25 30-50 CFH
Interpass Temp. Min.: 50°F. Max: 350°F.	Trailing:
Preheat Maintenance: AS REQUIRED	Backing:

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DIRECT CURRENT Polarity: REVERSE

Amps (Range): SEE BELOW Volts (Range): SEE BELOW

Tungsten Electrode Size and Type: N/A

Mode of Metal Transfer for GMAW and FCAW: SPRAY

Electrode Wire Feed Speed Range: 350 - 550 IPM

TECHNIQUE (QW-410)

String or Weave Bead: STRING

Office or Gas Cup Size: ½" - 3/4"

Initial and Interpass Cleaning: BURRING, GRINDING, S.S. WIRE BRUSH, OR CHEMICALS

AS REQUIRED

Method of Back Gouging: BURRING, GRINDING, OR ARC GOUGING FOLLOWED BY GRINDING

Oscillation: N/A

Contact Tube to Work Distance: ½"

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): 6 - 14 IPM

Peening: N/A

Other CONSULT MFR's. RECOMMENDATIONS FOR CORRELATION BETWEEN DIFFERENT WIRE FEED, AMPERAGE AND VOLTAGE

SETTINGS

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	FCAW	E309LT	.035"	REVERSE	80-150	23-31	6-14 IPM	NO PULSING

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W F8-8 | Date: 5-12-99 | Supporting PQR No: WF 8-8

Revision No.: 2 | Date: 3-15-12

Welding Process: FCAW

Types: SEMI - AUTOMATIC

JOINTS (QW-402): | Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type)★ WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT

(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No.	8	Group No.	N/A	to P-No.	8	Group No.	N/A

Specification type and grade

to Specification type and grade

Chem. Analysis and Mech. Prop.:

to Chem. Analysis and Mech. Prop:

Thickness Range:

Base Metal:	Groove:	1/16" - ½"	Fillet:	ALL
Pipe Dia. Range:	Groove:	ALL	Fillet:	ALL

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.22	
AWS Classification:	E308LT	
F-No.:	6	
A-No.:	N/A	
Size of Filler Metal:	.035"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	½" MAX.	
Fillet:	ALL	
Electrode-Flux (Class):N/A		
Flux Trade Name:N/A		
Consumable Insert:N/A		

(BACK) WPS No. W F 8-8 Rev. 2

POSITION (QW 405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression: UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50°F.	Shielding: ARGON / CO2 75 / 25 35-50 CFH
Interpass Temp. Min.: 50°F. Max: 350°F.	Trailing:
Preheat Maintenance: AS REQUIRED	Backing:

ELECTRICAL CHARACTERISTICS (QW-409)	
Current (AC or DC): DIRECT CURRENT	Polarity: REVERSE
Amps (Range): SEE BELOW	Volts (Range): SEE BELOW
Tungsten Electrode Size and Type: N/A	
Mode of Metal Transfer for GMAW and FCAW: SPRAY	
Electrode Wire Feed Speed Range: 180 - 550 IPM	

TECHNIQUE (QW-410)
String or Weave Bead: STRING
Office or Gas Cup Size: ½" - 3/4"
Initial and Interpass Cleaning BURRING, GRINDING, S.S. WIRE BRUSH, OR CHEMICALS
AS REQUIRED
Method of Back Gouging: BURRING, GRINDING, OR ARC GOUGING FOLLOWED BY GRINDING
Oscillation: N/A
Contact Tube to Work Distance: ½"
Multiple or Single Pass (Per Side): EITHER
Multiple or Single Electrodes: SINGLE
Travel Speed (Range): 6 - 14 IPM
Peening: N/A

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	FCAW	E308LT	.035"	REVERSE	80-150	23 31	6-14 IPM	NO PULSING

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W M8-1 | Date: | Supporting PQR No: WM 8-1

Revision No.: 2 | Date: 3-15-12

Welding Process: GMAW

Types: SEMI - AUTOMATIC

JOINTS (QW-402): | Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type)★ WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT (Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No. 8	Group No. N/A	to P-No. 1	Group No. N/A
Specification type and grade			
to Specification type and grade			
Chem. Analysis and Mech. Prop.:			
to Chem. Analysis and Mech. Prop.:			
Thickness Range:			
Base Metal:	Groove: 1/16" - .275"	Fillet: ALL	
Pipe Dia. Range:	Groove: Not to be used	Fillet: Not to be used	

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.9	
AWS Classification:	ER309LSi	
F-No.:	6	
A-No.:	N/A	
Size of Filler Metal:	.030"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	.275" MAX.	
Fillet:	ALL	
Electrode-Flux (Class):N/A		
Flux Trade Name:N/A		
Consumable Insert:N/A		

(BACK) WPS No. W M 8-1 Rev. 2

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression: UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50°F.	Shielding: He/Ar/CO2 90/7.5/2.5 25-45 CFH
Interpass Temp. Min.: 50°F. Max: 350°F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: N/A

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DIRECT CURRENT — Polarity: REVERSE

Amps (Range): SEE BELOW — Volts (Range): SEE BELOW

Tungsten Electrode Size and Type: N/A

Mode of Metal Transfer for GMAW: SHORT-CIRCUIT

Electrode Wire Feed Speed Range: 156 - 312 IPM

TECHNIQUE (QW-410)

String or Weave Bead: STRING

Office or Gas Cup Size: ½" - 3/4"

Initial and Interpass Cleaning BURRING, GRINDING, S.S. WIRE BRUSH, OR CHEMICALS

AS REQUIRED

Method of Back Gouging: BURRING, GRINDING, OR ARC GOUGING FOLLOWED BY GRINDING

Oscillation: N/A

Contact Tube to Work Distance: 3/8"

Multiple or Single Pass (Per Side): EITHER

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): 6 - 14 IPM

Peening: N/A

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	GMAW	ER309LSi	.030"	REVERSE	40-120	15-21	6-14 IPM	NO PULSING

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: W M8-8 | Date: 06-04-99 | Supporting PQR No: WM 8-8

Revision No.: 2 | Date: 3-15-12

Welding Process: GMAW

Types: SEMI - AUTOMATIC

JOINTS (QW-402): · Details

Joint Design GROOVES OR FILLETS

Backing (Yes) ★ (No) X

Backing material (type)★ WHEN USED, BACKING MATERIAL SHALL BE AS SPECIFIED IN WORK DOCUMENT

(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

BASE METALS (QW-403)

P-No. 8 Group No. N/A to P-No. 8 Group No. N/A

Specification type and grade

to Specification type and grade

Chem. Analysis and Mech. Prop.:

to Chem. Analysis and Mech. Prop:

Thickness Range:

Base Metal: Groove: 1/16" - .275" Fillet: ALL

Pipe Dia. Range: Groove: Not to be used Fillet: Not to be used

FILLER METALS (QW-404)		
SFA Specification:	SFA 5.9	
AWS Classification:	ER308LSi	
F-No.:	6	
A-No.:	N/A	
Size of Filler Metal:	.030"	
Deposited Weld Metal:		
Thickness Range:		
Groove:	.275" MAX.	
Fillet:	ALL	
Electrode-Flux (Class):N/A		
Flux Trade Name:N/A		
Consumable Insert:N/A		

(BACK) WPS No.W M 8-8 Rev. 2

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression: UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408):
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50°F.	Shielding: He/Ar/CO2 90/7.5/2.5 25-45 CFH
Interpass Temp. Min.: 50°F. Max: 350°F.	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: N/A

ELECTRICAL CHARACTERISTICS (QW-409)
Current (AC or DC): DIRECT CURRENT Polarity: REVERSE
Amps (Range): SEE BELOW Volts (Range): SEE BELOW
Tungsten Electrode Size and Type: N/A
Mode of Metal Transfer for GMAW: SHORT-CIRCUIT
Electrode Wire Feed Speed Range: 156 - 312 IPM
TECHNIQUE (QW-410)
String or Weave Bead: STRING
Office or Gas Cup Size: ½" - 3/4"
Initial and Interpass Cleaning: BURRING, GRINDING, S.S. WIRE BRUSH, OR CHEMICALS
AS REQUIRED
Method of Back Gouging: BURRING, GRINDING, OR ARC GOUGING FOLLOWED BY GRINDING
Oscillation: N/A
Contact Tube to Work Distance: ½"
Multiple or Single Pass (Per Side): EITHER
Multiple or Single Electrodes: SINGLE
Travel Speed (Range): 6 - 14 IPM
Peening: N/A

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Remarks/ Comments
		Class	Diameter	Type Polar.	Amp. Range			
ALL	GMAW	ER308LSi	.030"	REVERSE	40-120	15-21	6-14 IPM	NO PULSING

BRAZING PROCEDURE SPECIFICATIONS (BPS)

Company Name CHM2HILL B&W West Valley, LLC

BPS No. W B107-107 Date 06/27/96 Supporting PQR No. WB107-107

Revisions 1 5-16-11

2 3-15-12

Brazing Process(es) Torch Type(s) Manual
(Manual, mechanical torch, etc.)

JOINTS (QB-408) **Details**

Type of Joint(s) Lap/Socket

Joint Clearance Range .002" - .005"

Lap Length Range .250" - 1.170"

BASE METALS (QB-402) P-No. 107 to P-No. 107 Spec. type and grade to spec. type and grade **OR** Chem. analysis and mech. prop. to chem. analysis and mech. prop. Thickness Range .025" - .100" Tube/Pipe Diam. Range All Other	**BRAZING FLUX OR ATMOSPHERE (QB-406)** Flux Trade Name or Composition N/A Atmosphere for Furnace Brazing N/A [name or trade designation of the fuel used or the name or trade designation of the gas compressing the atmosphere (hydrogen, Ammo-Gas, etc.) and a statement regarding the designed character of the furnace atmosphere, e.g., whether it is reducing, decarburizing, inert, etc.]
FILLER METALS (QB-403) F-No. 103 Other ASME Spec. No. A5.8 Other AWS Class No. BCUP-5 Other Size or Shape of Filler Metal 1/16", 3/32", 1/8" Other	**FLOW POSITION (QB-407)** Flow Position(s) Horizontal & Vertical Down Method of Applying Filler Metal Face Feed (face feeding, preplaced rings, shims, spray deposit, cladding, etc.) Other
BRAZING TEMPERATURE (QB-404) Temperature Range* N/A Other *Not applicable for torch brazing	**POSTBRAZE HEAT TREATMENT (QB-409)** Type and temperature of aging or stabilizing thermal treatment after brazing N/A
	TECHNIQUE (QB-410) Method of Precleaning Emery Cloth Method of Postbrazing Cleaning Emery Cloth, Wire Brush Type of Flame Neutral Torch Tip Size #1 - #10 Other

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No. TS 43-8 Date: 9/10/99 Supporting PQR No(s) TS43/8-M

Revision No.: 1 Date: 3/15/12

Welding Process(es): GTAW/SMAW

Types (Manual, Automatic, Machine, Semi-Auto): MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) (No) X

Backing material (type) N/A

(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of the weld groove may be specified.

(At the option of the Mfr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g. for notch toughness procedures, for multiple process procedures, etc....)

*BASE METALS (QW-403)

P-No. P43 Group No. N/A to P-No. P8 Group No. 1 & 2

OR

Specification type and grade N/A

to Specification type and grade N/A

OR

Chem. Analysis and Mech Prop.: N/A

to Chem. Analysis and Mech Prop: N/A

Thickness Range. N/A

Base Metal: Groove 3/16" TO 1" Fillet: ALL

Pipe Dia. Range: Groove: ALL Fillet: ALL

Other: N/A

*FILLER METALS (QW-404)	GTAW	SMAW
SFA Specification:	SFA 5.14	SFA 5.11
AWS Classification.	ERNiCrXX-X	ENiCrXX-X
F-No.:	43	43
A-No.:	9	9
Size of Filler Metal:	1/16", 3/32"	3/32", 1/8", 5/32"
Deposited Weld Metal Range		
Groove:	3/8" MAX.	5/8" MAX
Fillet:	ALL	ALL
Electrode-Flux (Class)	N/A	N/A
Flux Trade Name:	N/A	N/A
Consumable Insert.	N/A	N/A
Other:	N/A	N/A

*Each base metal-filler combination should be recorded individually

(BACK) WPS No. TS 43-8 Rev. 1

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression (Uphill, Downhill). UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408): (FOR GTAW ONLY)
Other: N/A	Percent Composition
PREHEAT (QW-406)	Gas(es) (Mixture) Flow Rate
Preheat Temp. Min.: 50° F	Shielding: ARGON 99.9% 15-30 CFH
Interpass Temp. Min.: 50° F Max: 350° F	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: ARGON 99.9% 5-15 CFH
	Other: GAS BACKING IS N/A FOR BACKING RINGS AND FILLETS

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DC Polarity: GTAW: STRAIGHT SMAW: REVERSE

Amps (Range): SEE BELOW Volts (Range): SEE BELOW

(Amps & volts should be recorded for each electrode size, position, and thickness, etc.... This information may be listed in a tabular form similar to that shown below.)

Tungsten Electrode Size and Type: 3/32" (SFA 5.12, EWTh-2, EWLa)

Mode of Metal Transfer for GMAW and FCAW: N/A (Pure Tungsten, 2% Thoriated, etc...)

Electrode Wire Feed Speed Range: (Spray arc, short circuiting arc, etc..)

TECHNIQUE (QW-410)

String or Weave Bead: BOTH

Orifice or Gas Cup Size: #4 - #10

Initial and Interpass Cleaning: BRUSHING, GRINDING, BURRING OR CHEMICAL AS REQUIRED

Method of Back Gouging: BURRING, GRINDING OR AIR-ARC FOLLOWED BY GRINDING

Oscillation: N/A

Contact Tube to Work Distance: N/A

Multiple or Single Pass (Per Side):

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): SEE BELOW

Peening: NONE

Other NO PASS SHALL BE GREATER THAN 3/16 IN. THICKNESS

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Other (e.g. Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, Etc.)
		Class	Diameter	Type Polar.	Amp. Range			
ROOT AND SUBSEQUENT LAYERS	GTAW	ERNiCrXX-X	1/16" 3/32"	(-) (-)	70 - 120 70 - 150	10 - 20 10 - 20	1-8 IPM 1-8 IPM	NO PULSING (TYP.)
	SMAW	ENiCrXX-X	3/32" 1/8" 5/32"	(+) (+) (+)	70 - 130 80 - 130 90 - 140	20 - 28 20 - 28 20 - 28	3-10 IPM 3-10 IPM 3-10 IPM	

WELDING PROCEDURE SPECIFICATION (WPS)

Company Name: CHM2HILL B&W West Valley, LLC

Welding Procedure Specification No.: TS 43-43 Date: 9/10/99 Supporting PQR No(s) TS43/43-M

Revision No.: 1 Date 3-15-12

Welding Process(es): GTAW/SMAW

Types (Manual, Automatic, Machine, Semi-Auto): MANUAL

JOINTS (QW-402): Details

Joint Design GROOVES OR FILLETS

Backing (Yes) (No) X

Backing material (type) N/A

(Refer to both backing & retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of the weld groove may be specified.

(At the option of the Mfr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g. for notch toughness procedures, for multiple process procedures, etc....)

*BASE METALS (QW-403)			
P-No. P43	Group No. N/A	to P-No. P43	Group No. N/A
OR			
Specification type and grade N/A			
to Specification type and grade N/A			
OR			
Chem. Analysis and Mech. Prop.: N/A			
to Chem. Analysis and Mech. Prop: N/A			
Thickness Range: N/A			
Base Metal:	Groove: 3/16" TO 1"	Fillet: ALL	
Pipe Dia. Range:	Groove: ALL	Fillet: ALL	
Other: N/A			

*FILLER METALS (QW-404)	GTAW	SMAW
SFA Specification:	SFA 5.14	SFA 5.11
AWS Classification:	ERNiCrXX-X	ENiCrXX-X
F-No.:	43	43
A-No.:	9	9
Size of Filler Metal:	1/16", 3/32"	3/32", 1/8", 5/32"
Deposited Weld Metal Range		
Groove.	3/8" MAX	5/8" MAX
Fillet:	ALL	ALL
Electrode-Flux (Class):	N/A	N/A
Flux Trade Name:	N/A	N/A
Consumable Insert.	N/A	N/A
Other:	N/A	N/A

*Each base metal-filler combination should be recorded individually

(BACK) WPS No. TS 43-43 Rev. 1

POSITION (QW-405)	POSTWELD HEAT TREATMENT (QW-407)
Position of Groove: ALL	Temperature Range: N/A
Weld Progression (Uphill, Downhill): UPHILL	Time Range: N/A
Position of Fillet: ALL	Gas (QW-408): (FOR GTAW ONLY)
Other: N/A	Percent Composition
PREHEAT (QW-406)	(Gases) (Mixture) Flow Rate
Preheat Temp. Min.: 50° F	Shielding: ARGON 99.9% 15-30 CFH
Interpass Temp. Min.: 50° F Max: 350° F	Trailing: N/A
Preheat Maintenance: AS REQUIRED	Backing: ARGON 99.9% 5-15 CFH
	Other: GAS BACKING IS N/A FOR BACKING RINGS AND FILLETS

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DC — Polarity: GTAW: STRAIGHT SMAW: REVERSE

Amps (Range): SEE BELOW — Volts (Range): SEE BELOW

(Amps & volts should be recorded for each electrode size, position, and thickness, etc.... This information may be listed in a tabular form similar to that shown below.)

Tungsten Electrode Size and Type: 3/32" (SFA 5.12, EWTh-2, EWLa)

Mode of Metal Transfer for GMAW: N/A (Pure Tungsten, 2% Thoriated, etc...)

Electrode Wire Feed Speed Range: N/A (Spray arc, short circuiting arc, etc..)

TECHNIQUE (QW-410)

String or Weave Bead: BOTH

Orifice or Gas Cup Size: #4 - #10

Initial and Interpass Cleaning: BRUSHING, GRINDING, BURRING OR CHEMICAL AS REQUIRED

Method of Back Gouging: BURRING, GRINDING OR AIR-ARC FOLLOWED BY GRINDING

Oscillation: N/A

Contact Tube to Work Distance: N/A

Multiple or Single Pass (Per Side):

Multiple or Single Electrodes: SINGLE

Travel Speed (Range): SEE BELOW

Peening: NONE

Other NO PASS SHALL BE GREATER THAN 3/16 IN. THICKNESS

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Other (e.g. Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, Etc.)
		Class	Diameter	Type Polar.	Amp. Range			
ROOT AND SUBSEQUENT LAYERS	GTAW	ERNiCrXX-X	1/16" 3/32"	(-) (-)	70 - 120 70 - 150	10 - 20 10 - 20	1-8 IPM 1-8 IPM	NO PULSING (TYP.)
	SMAW	ENiCrXX-X	3/32" 1/8" 5/32"	(+) (+) (+)	70 - 130 80 - 130 90 - 140	20 - 28 20 - 28 20 - 28	3-10 IPM 3-10 IPM 3-10 IPM	

WVDP RECORD OF REVISION

Rev. No.	Description of Changes	Revision On Page(s)	Dated
0	Original Issue	All	08/23/99
FC1	Section A - added TS43-8 and TS43-43 to Form WV-1888;	32	11/17/99
	Attachment A - added TS43-8 and TS43-43;	34	
	Added WPS TS43-8 (front)(Form WV-4161);	69	
	Added WPS TS43-8 (back) " " ;	70	
	Added WPS TS43-43 (front) " " ;	71	
	Added WPS TS43-43 (back) " " .	72	
FC2	Note deleted after 4.1.1;	11	01/21/00
	4.2.11 - changed reference section to 4.4.1[F];	15	
	4.6 - added wording from deleted Note (p. 11);	17	
	Updated Form WV-1888	32	
FC3	1.2.7, 1.2.8, 1.9 - Deleted reference to WV-119.	3, 5	08/09/00
FC4	Added Weld Filler Material Control Sections from SOP 00-32 No departments are affected by this change	3-7,27,28,29 31,33,38,39	10/19/01
FC5	Update Form WV-1888 to new revision number 4	31	11/06/01
1	**NEW-TYPE REVISION INCORPORATION OF FIELD CHANGES**	**ALL**	**11/19/01**
2	General Revision. This change was made to update the procedure per a periodic review. Changes include removing forms, updating personnel and department titles, removing unnecessary information, updating forms WV-1888, WV-4161 and WV-2526 and reformatting the procedure per DCIP-100. Qualified welders and engineering are affected by this change.	ALL	10/06/03
3	Updated cognizant manager	Cover	02/06/07
	Corrected typo in 1.5.5	4	
	Added reference to ANSI Z49.1 in 1.9, 4.1.1	6, 9	
	Changed WO/WR to Work document on WV-1888	15	
	Safety and certified welders are affected by this change		

WVDP RECORD OF REVISION CONTINUATION FORM

Rev. No.	Description of Changes	Revision On Page(s)	Dated
4	Major revision. Changed WVNSCO to WVES. Added W as prefix to WPS's to match existing PQR's. Clarified WPS weld progression to Uphill. Deleted CSWE. Added warehouse 'stock' requirements for filler material. Removed form WV-1888 from manual. Deleted WPS T17/4-8 and T17/4-17/4. Added JSA and hazard analysis requirements. Engineering, Infrastructure, QA and Safety are affected by this change.	All	06/29/11
5	General Revision - document revision to address CHBWV Transition Team Blue Sheet & Terminology Replacement Matrix comments. Updated company logo & name, department names, etc., throughout. All Weld Procedures were revised (3-15-12) due to company name change. Changed WE to SME throughout and added DDWO/Craft (mechanic) to filler material control. Updated forms and templates utilized to meet current ASME IX.(2011a). Forms WV-2526 and WV-4161 changed to templates. Added sect 1.7. Engineering, QA, and Infrastructure are affected by this change.	All	07/11/12

SelentK

Document Name: Reference 8-10.pdf

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WVMP SAR Reference 8-12

Certified Test Reports 2004

RECEIVING INSPECTION & MATERIAL VALIDATION—STEEL PLATE

1.Receiving Information :

Purchased by : ATF   Supplier . ISG   P.O.No. 53634

Line Item No. 3   AT&F Job NO. 40945   AT&F Heat Code NA

Receiver No. 7583   Date Rec'd. 6/18/04   Quantity Rec'd. 1

2.Dimensional Inspection :

Thickness : 6   6   6   6

(4 corners)

Width : 153   Length : 155

3. Material Marking or Stamping

Record the following information from Plate Stamping :   (example)

ISG	Plate Manufacturer	(BLP)
SA-516-70 MT	Material Spec and Type or Grade (G, MT, LTV if applicable)	(SA516-70 G MT LTV)
U2395	Plate Heat Number	(402T6511)
2	Plate Slab Number	(1)
	UT Number (if applicable)	(UT SA435)

4. Remarks : (e.g. shipping damage, other stamping or noted nonconformance)

Plate conforms to the attached P.O. requirements and the attached Material Test Reports match the Plate Markings.

Inspected by : [signature] Date 6/24/04   X Accept __ Reject

Validated by : [signature] Date 7-9-04   X Accept __ Reject

Code No.____ QDR S/N______

Material Identification & Verification

(performed at time of fit-up)

1. Item Information :

Mfg. Serial #__________ AT&F Job No.__________ DWG./ Item #__________ Rev.No.___

2. Permanent Stamping Information : (Center of Plate edge 6" from weld or as req'd.)

__________ Plate Manufacturer

__________ Material Spec and Type or Grade (G, MT, LTV if applicable)

__________ Plate Heat No.

__________ Plate Slab No.

__________ UT Number (if applicable)

Mfg. Ser. No. __________ Manufacturers Serial Number

Plate verified to be same as receipt inspected, plate edges visually inspected for laminations and permanent stamping inspected per attached AT&F validated Material Test Report (s)

Verified by :__________ Date ______ Q/C Review :__________ Date ______

AI-Review : __________ Date ______

SP110-2F1 Rev. 1 4/11/02

ISG PLATE INC. TEST CERTIFICATE

SHIP TO:
AMERICAN TANK & FABR. CO.
12314 ELMWOOD AVE.
DOOR #11
CLEVELAND OH 44111

PAGE NO: 01 OF 02
FILE NO: 0325-01-05
MILL ORDER NO: 10291-002
MELT NO: U2395 ✓
SLAB NO: 2
DATE: 06/16/04

SOLD TO:
AMERICAN TANK & FAB. CO.
12314 ELMWOOD AVE.
CLEVELAND OH 44111

SEND TO:
TEST REPORT WITH SHIPMENT

FOR BOL # 44024

PLATE DIMENSIONS / DESCRIPTION

TOTAL QTY	GAUGE	WIDTH	LENGTH	DESCRIPTION	PIECE WEIGHT
	6"	153"	155"	RECTANGLE	40353#

CUSTOMER INFORMATION

CUSTOMER PO: 53634

SPECIFICATION(S)

THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS AND SPECIFICATION(S).

ASTM A516 YR 90 GR 70
ASME SA516 2001 EDITION GRADE 70
MATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH
ISO 9001 ABS-QE CERT. NO. 30130

CHEMICAL COMPOSITION

	C	MN	P	S	CU	SI	NI	CR	MO
MELT:U2395	.24	.93	.008	.009	.25	.19	.12	.07	.05

	V	TI	AL	CB
MELT:U2395	.002	.002	.022	.001

MANUFACTURE

MCQUAID-EHN GRAIN SIZE PER E112 - 7-8

MEETS THE REQUIREMENTS
ASME SA 516-70 2001 edition
JR 7-9-04 pg 1 of 2

HEAT TREAT CONDITION

MATL OR TEST	HEAT TREAT DESCRIPTION	NOM TEMP	HOLD MINS	COOL MTHD
PL/TEST	NORMALIZE	1650F	181	AIR COOL

PO# 53634

TENSILE PROPERTIES

40945-000

SLAB NO.	LOC	DIR	STRENGTH PSI X 100	STRENGTH PSI X 100	GAGE LGTH	%
2	BOT.	TRANS.	423	766	2.00"	24.0

WE HEREBY CERTIFY THAT THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

MEETS THE REQUIREMENTS

ASME SA516-70 2001 edition

7-9-09 pg 2 of 2

40945-0000

ISG PLATE INC. T E S T C E R T I F I C A T E

FILE NO: 0325-01-05
MILL ORDER NO: 10291-002
MELT NO: U2395
SLAB NO: 2
DATE: 06/16/04

G E N E R A L I N F O R M A T I O N

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
MERCURY OR MERCURY COMPOUNDS ARE NOT USED
IN THE MANUFACTURE OF ISG PRODUCTS.

40945-0000

RECEIVING INSPECTION & MATERIAL VALIDATION—STEEL PLATE

1.Receiving Information :

Purchased by : ATF Supplier ISG P.O.No. 53634

Line Item No. 3 AT&F Job NO. 40945 AT&F Heat Code N/A

Receiver No. 7615 Date Rec'd 6/23/04 Quantity Rec'd 1

2.Dimensional Inspection :

Thickness : 6 6 6 6

(4 corners)

Width : 153 Length : 155

3. Material Marking or Stamping

Record the following information from Plate Stamping : (example)

ISG	Plate Manufacturer	(BLP)
SA516-70 MT	Material Spec and Type or Grade (G, MT, LTV if applicable)	(SA516-70 G MT LTV)
42395	Plate Heat Number	(402T6511)
3	Plate Slab Number	(1)
	UT Number (if applicable)	(UT SA435)

4. Remarks : (e.g. shipping damage, other stamping or noted nonconformance)

Plate conforms to the attached P.O. requirements and the attached Material Test Reports match the Plate Markings.

Inspected by : [signature] Date 6/24/04 X Accept __ Reject

Validated by : [signature] Date 7-9-04 X Accept __ Reject

Code No.____ QDR S/N______

Material Identification & Verification
(performed at time of fit-up)

1. Item Information :

Mfg. Serial #__________ AT&F Job No.__________ DWG./ Item #__________ Rev.No.___

2. Permanent Stamping Information : (Center of Plate edge 6" from weld or as req'd.)

__________ Plate Manufacturer

__________ Material Spec and Type or Grade (G, MT, LTV if applicable)

__________ Plate Heat No.

__________ Plate Slab No.

__________ UT Number (if applicable)

Mfg. Ser. No. __________ Manufacturers Serial Number

Plate verified to be same as receipt inspected, plate edges visually inspected for laminations and permanent stamping inspected per attached AT&F validated Material Test Report (s)

Verified by :__________ Date ______ Q/C Review :__________ Date ______

AI-Review : __________ Date ______

SP110-2F1 Rev. 1 4/11/02

ISG PLATE INC. T E S T C E R T I F I C A T E

SHIP TO:
AMERICAN TANK & FABR. CO.
12314 ELMWOOD AVE.
DOOR #11
CLEVELAND OH 44111

PAGE NO: 01 OF 02
FILE NO: 0325-01-05
MILL ORDER NO: 10291-002
MELT NO: U2395✓
SLAB NO: 3
DATE: 06/16/04

SOLD TO:
AMERICAN TANK & FAB. CO.
12314 ELMWOOD AVE.
CLEVELAND OH 44111

SEND TO:
TEST REPORT WITH SHIPMENT

FOR BOL # 44027

P L A T E D I M E N S I O N S / D E S C R I P T I O N

TOTAL QTY	GAUGE	WIDTH	LENGTH	DESCRIPTION	PIECE WEIGHT
	6"	153"	155"	RECTANGLE	40353#

C U S T O M E R I N F O R M A T I O N

CUSTOMER PO: 53634

S P E C I F I C A T I O N (S)

THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS AND SPECIFICATION(S).

ASTM A516 YR 90 GR 70
ASME SA516 2001 EDITION GRADE 70
MATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH
ISO 9001 ABS-QE CERT. NO. 30130

C H E M I C A L C O M P O S I T I O N

	C	MN	P	S	CU	SI	NI	CR	MO
MELT:U2395	.24	.93	.008	.009	.25	.19	.12	.07	.05

	V	TI	AL	CB
MELT:U2395	.002	.002	.022	.001

MEETS THE REQUIREMENTS ✓
ASME SA516-70 2001 Edition
J R 7-4-04 pg 1 of 2

P.O. 53634

M A N U F A C T U R E

MCQUAID-EHN GRAIN SIZE PER E112 - 7-8

H E A T T R E A T C O N D I T I O N

MATL OR TEST	HEAT TREAT DESCRIPTION	NOM TEMP	HOLD MINS	COOL MTHD
PL/TEST	NORMALIZE	1650F	241	AIR COOL

40945-0000

T E N S I L E P R O P E R T I E S

SLAB NO.	LOC	DIR	STRENGTH PSI X 100	STRENGTH PSI X 100	GAGE LGTH	%
3	BOT.	TRANS.	423	763	2.00"	25.0

WE HEREBY CERTIFY THAT THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

40945-0000

MEETS THE REQUIREMENTS ✓

~~Meets of~~ ASME SA516-70 2001 ed.

J R 9-9-04. 2002

ISG PLATE INC.   T E S T   C E R T I F I C A T E

FILE NO: 0325-01-05
MILL ORDER NO: 10291-002
MELT NO: U2395
SLAB NO: 3
DATE: 06/16/04

G E N E R A L   I N F O R M A T I O N

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
MERCURY OR MERCURY COMPOUNDS ARE NOT USED
IN THE MANUFACTURE OF ISG PRODUCTS.

40945-0000

RECEIVING INSPECTION & MATERIAL VALIDATION—STEEL PLATE

1. Receiving Information :

Purchased by : ATF. Supplier ISG P.O.No. 53634

Line Item No. 2 AT&F Job NO. 40945 AT&F Heat Code UA

Receiver No. 7582 Date Rec'd. 6/18/04 Quantity Rec'd. 1

2. Dimensional Inspection :

Thickness : 6 6 6 6
(4 corners)

Width : 154 Length : 153

3. Material Marking or Stamping

Record the following information from Plate Stamping : (example)

ISG	Plate Manufacturer	(BLP)
SA516-70 MT	Material Spec and Type or Grade ("G, MT, LTY if applicable)	(SA516-70-G MT LTV)
U2465	Plate Heat Number	(402T6511)
2	Plate Slab Number	(1)
______	UT Number (if applicable)	(UT SA435)

4. Remarks : (e.g. shipping damage, other stamping or noted nonconformance)

Plate conforms to the attached P.O. requirements and the attached Material Test Reports match the Plate Markings.

Inspected by : [signature] Date 6/24/04 X Accept __ Reject

Validated by [signature] Date 7-9-04 X Accept __ Reject

Code No.____ QDR S/N______

Material Identification & Verification
(performed at time of fit-up)

1. Item Information :

Mfg. Serial #__________ AT&F Job No.__________ DWG./ Item #__________ Rev.No.___

2. Permanent Stamping Information : (Center of Plate edge 6" from weld or as req'd.)

__________ Plate Manufacturer

__________ Material Spec and Type or Grade (G, MT, LTV if applicable)

__________ Plate Heat No.

__________ Plate Slab No.

__________ UT Number (if applicable)

Mfg. Ser. No. __________ Manufacturers Serial Number

Plate verified to be same as receipt inspected, plate edges visually inspected for laminations and permanent stamping inspected per attached AT&F validated Material Test Report (s)

Verified by :__________ Date ______ Q/C Review :__________ Date ______

AI-Review : __________ Date ______

SP110-2F1 Rev. 1 4/11/02

ISO PLATE INC. T E S T C E R T I F I C A T E

SHIP TO:
AMERICAN TANK & FABR. CO.
12314 ELMWOOD AVE.
DOOR #11
CLEVELAND OH 44111

PAGE NO: 01 OF 02
FILE NO: 0325-01-05
MILL ORDER NO: 10291-001
MELT NO: U2465✓
SLAB NO: 2
DATE: 06/16/04

SOLD TO:
AMERICAN TANK & FAB. CO.
12314 ELMWOOD AVE.
CLEVELAND OH 44111

SEND TO:
TEST REPORT WITH SHIPMENT

FOR BOL # 44025

P L A T E D I M E N S I O N S / D E S C R I P T I O N

TOTAL QTY	GAUGE	WIDTH	LENGTH	DESCRIPTION	PIECE WEIGHT
	6" ✓	154"	153"	RECTANGLE	40093#

C U S T O M E R I N F O R M A T I O N

CUSTOMER PO: 53634

S P E C I F I C A T I O N (S)

THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS AND SPECIFICATION(S).

ASTM A516 YR 90 GR 70
ASME SA516 2001 EDITION GRADE 70
MATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH
ISO 9001 ABS-QE CERT. NO. 30130

C H E M I C A L C O M P O S I T I O N

	C	MN	P	S	CU	SI	NI	CR	MO
MELT:U2465	.23	.95	.010	.011	.26	.19	.11	.10	.03

	V	TI	AL	CB
MELT:U2465	.002	.001	.029	.001

M A N U F A C T U R E

MCQUAID-EHN GRAIN SIZE PER E112 - 7-8

MEETS THE REQUIREMENTS ✓
ASME SA516-70 2001 edition
[signature] 7-9-04 pg 1 of 2
40945-000

H E A T T R E A T C O N D I T I O N

MATL OR TEST	HEAT TREAT DESCRIPTION	NOM TEMP	HOLD MINS	COOL MTHD
PL/TEST	NORMALIZE	1650F	180	AIR COOL

PO# 53634

T E N S I L E P R O P E R T I E S

SLAB NO.	LOC	DIR	YIELD STRENGTH PSI X 100	TENSILE STRENGTH PSI X 100	ELONGATION GAGE LGTH	%
2	BOT.	TRANS.	423	781	2.00"	23.0

WE HEREBY CERTIFY THAT THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

40945-0000

MEETS THE REQUIREMENTS

ASME SA 516-70 - 2001 Sul/ch2

7-9-04 pg 2 of 2

ISG PLATE

T E S T   C E R T I F I C A T E

PAGE NO: 02 OF 02
FILE NO: 0325-01-05
MILL ORDER NO: 10291-001
MELT NO: U2465
SLAB NO: 2
DATE: 06/16/04

G E N E R A L   I N F O R M A T I O N

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
MERCURY OR MERCURY COMPOUNDS ARE NOT USED
IN THE MANUFACTURE OF ISG PRODUCTS.

40945-0000

ISG PLATE .　　　　T E S T　C E R T I F I C A T E

FILE NO: 0325-01-05
MILL ORDER NO: 10291-001
MELT NO: U2465
SLAB NO: 2
DATE: 06/16/04

NERAL INFORMATION

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
MERCURY OR MERCURY COMPOUNDS ARE NOT USED
IN THE MANUFACTURE OF ISG PRODUCTS.

40945-0000

SLAB NO.	LOC	DIR	YIELD STRENGTH PSI X 100	TENSILE STRENGTH PSI X 100	ELONGATION GAGE LGTH	%
2 ✓	BOT.	TRANS.	423	781	2.00"	23.0

WE HEREBY CERTIFY THAT THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

40945-0000

MEETS THE REQUIREMENTS ✓

ASME SA 516-70 - 2001 Sub 'n'

7-9-04 pg 2 of 2

ISG PLATE

T E S T   C E R T I F I C A T E

PAGE NO: 02 OF 02
FILE NO: 0325-01-05
MILL ORDER NO: 10291-001
MELT NO: U2465
SLAB NO: 2
DATE: 06/16/04

G E N E R A L   I N F O R M A T I O N

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
MERCURY OR MERCURY COMPOUNDS ARE NOT USED
IN THE MANUFACTURE OF ISG PRODUCTS.

40945-0000

RECEIVING INSPECTION & MATERIAL VALIDATION—STEEL PLATE

1.Receiving Information :
Purchased by : ATF Supplier ISG P.O.No. 53634
Line Item No. 2 AT&F Job NO. 40945 AT&F Heat Code NA
Receiver No. 7616 Date Rec'd. 6/23/04 Quantity Rec'd. 1

2.Dimensional Inspection :
Thickness : 6 6 6 6
(4 corners)
Width : 154 Length : 153

3. Material Marking or Stamping
Record the following information from Plate Stamping : (example)

ISG	Plate Manufacturer	(BLP)
SA516-70 MT	Material Spec and Type or Grade (G, MT, LTV if applicable)	(SA516-70 G MT LTV)
U2465	Plate Heat Number	(402T6511)
1	Plate Slab Number	(1)
	UT Number (if applicable)	(UT SA435)

4. Remarks : (e.g. shipping damage, other stamping or noted nonconformance) Plate has twist out of flat

Plate conforms to the attached P.O. requirements and the attached Material Test Reports match the Plate Markings.
Inspected by : [signature] Date 6/24/04 ~~Accept~~ ✓ Reject Plate with A-20
Validated by : [signature] Date 7-9-04 X Accept __ Reject Flatness tolerance. [initials] 7-9-04
Code No.____ QDR S/N____

Material Identification & Verification
(performed at time of fit-up)

1. Item Information :
Mfg. Serial #__________ AT&F Job No.__________ DWG./Item #__________ Rev.No.___

3.. Permanent Stamping Information : (Center of Plate edge 6" from weld or as req'd.)

__________ Plate Manufacturer

__________ Material Spec and Type or Grade (G, MT, LTV if applicable)

__________ Plate Heat No.

__________ Plate Slab No.

__________ UT Number (if applicable)

Mfg. Ser. No. __________ Manufacturers Serial Number

Plate verified to be same as receipt inspected, plate edges visually inspected for laminations and permanent stamping inspected per attached AT&F validated Material Test Report (s)

Verified by :__________ Date ______ Q/C Review :__________ Date ______

AI-Review : __________ Date ______

ISG PLATE INC. T E S T C E R T I F I C A T E

SHIP TO:
AMERICAN TANK & FABR. CO.
12314 ELMWOOD AVE.
DOOR #11
CLEVELAND OH 44111

PAGE NO: 01 OF 02
FILE NO: 0325-01-05
MILL ORDER NO: 10291-001
MELT NO: U2465
SLAB NO: 1
DATE: 06/21/04

SOLD TO:
AMERICAN TANK & FAB. CO.
12314 ELMWOOD AVE.
CLEVELAND OH 44111

SEND TO:
TEST REPORT WITH SHIPMENT

FOR BOL # 44482

P L A T E D I M E N S I O N S / D E S C R I P T I O N

TOTAL QTY	GAUGE	WIDTH	LENGTH	DESCRIPTION	PIECE WEIGHT
	6"	154"	153"	RECTANGLE	40093#

C U S T O M E R I N F O R M A T I O N

CUSTOMER PO: 53634

S P E C I F I C A T I O N (S)

THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS AND SPECIFICATION(S).

ASTM A516 YR 90 GR 70
ASME SA516 2001 EDITION GRADE 70
MATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH
ISO 9001 ABS-QE CERT. NO. 30130

C H E M I C A L C O M P O S I T I O N

	C	MN	P	S	CU	SI	NI	CR	MO
MELT:U2465	.23	.95	.010	.011	.26	.19	.11	.10	.03

	V	TI	AL	CB
MELT:U2465	.002	.001	.029	.001

M A N U F A C T U R E

MCQUAID-EHN GRAIN SIZE PER E112 - 7-8

40945-0000

MEETS THE REQUIREMENTS ✓
ASME SA516-70 2001 Edition
7-8-04 PS 1 of 2

H E A T T R E A T C O N D I T I O N

MATL OR TEST	HEAT TREAT DESCRIPTION	NOM TEMP	HOLD MINS	COOL MTHD
PL/TEST	NORMALIZE	1650F	180	AIR COOL

PO# 53634

T E N S I L E P R O P E R T I E S

SLAB NO.	LOC	DIR	YIELD STRENGTH PSI X 100	TENSILE STRENGTH PSI X 100	ELONGATION GAGE LGTH	%
1	BOT.	TRANS.	385	758	2.00"	27.0

WE HEREBY CERTIFY THAT THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

MEETS THE REQUIREMENTS ✓
ASME SA 516-70 2001 Edition
7-9-04 pg 2 of 2

40945-0000

ISG PLATE INC.   T E S T   C E R T I F I C A T E

FILE NO: 0325-01-05
MILL ORDER NO: 10291-001
MELT NO: U2465
SLAB NO: 1
DATE: 06/21/04

G E N E R A L   I N F O R M A T I O N

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
MERCURY OR MERCURY COMPOUNDS ARE NOT USED
IN THE MANUFACTURE OF ISG PRODUCTS.

40945-0000

ISG PLATE INC. T E S T   C E R T I F I C A T E

SHIP TO:
AMERICAN TANK & FABR. CO.
12314 ELMWOOD AVE.
DOOR #11
CLEVELAND OH 44111

PAGE NO: 01 OF 02
FILE NO: 0325-01-
MILL ORDER NO: 10291-00
MELT NO: U2395
SLAB NO: 1A
DATE: 07/16/

SOLD TO:
AMERICAN TANK & FAB. CO.
12314 ELMWOOD AVE.
CLEVELAND OH 44111

SEND TO:
AMERICAN TANK & FABR. CO.
12314 ELMWOOD AVENUE
ATTN: WAREHOUSE DEPT.
CLEVELAND, OH 44111

03

P L A T E   D I M E N S I O N S / D E S C R I P T I O N

TOTAL QTY	GAUGE	WIDTH	LENGTH	DESCRIPTION	PIECE WEIGHT
1	4"	151"	162"	RECTANGLE	27750#

C U S T O M E R   I N F O R M A T I O N

CUSTOMER PO: 53634

S P E C I F I C A T I O N (S)

THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHAS
ORDER REQUIREMENTS AND SPECIFICATION(S).

ASTM A516 YR 90 GR 70
ASME SA516 2001 EDITION GRADE 70
MATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH
ISO 9001 ABS-QE CERT. NO. 30130

C H E M I C A L   C O M P O S I T I O N

	C	MN	P	S	CU	SI	NI	CR	M
MELT:U2395	.24	.93	.008	.009	.25	.19	.12	.07	.

	V	TI	AL	CB
MELT:U2395	.002	.002	.022	.001

M A N U F A C T U R E

MCQUAID-EHN GRAIN SIZE PER E112 - 7-8

H E A T   T R E A T   C O N D I T I O N

MATL OR TEST	HEAT TREAT DESCRIPTION	NOM TEMP	HOLD MINS	COOL MTHD
PL/TEST	NORMALIZE	1650F	134	AIR COOL

T E N S I L E   P R O P E R T I E S

SLAB NO.	LOC	DIR	YIELD STRENGTH PSI X 100	TENSILE STRENGTH PSI X 100	ELONGATION GAGE LGTH	%
1A	BOT.	TRANS.	443	790	2.00"	26.0

WE HEREBY CERTIFY THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

ISG PLATE INC. T E S T C E R T I F I C A T E

FILE NO: 0325-01-(
MILL ORDER NO: 10291-00:
MELT NO: U2395
SLAB NO: 1A
DATE: 07/16/04

G E N E R A L I N F O R M A T I O N

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
MERCURY OR MERCURY COMPOUNDS ARE NOT USED
IN THE MANUFACTURE OF ISG PRODUCTS.

B/L #46938 CUSTOMER'S TRUCK

WE HEREBY CERTIFY THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

ISG PLATE INC. T E S T   C E R T I F I C A T E

SHIP TO:
AMERICAN TANK & FABR. CO.
12314 ELMWOOD AVE.
DOOR #11
CLEVELAND OH 44111

PAGE NO: 01 OF 02
FILE NO: 0325-01-05
MILL ORDER NO: 10291-003
MELT NO: U2395
SLAB NO: 1B
DATE: 07/21/04

SOLD TO:
AMERICAN TANK & FAB. CO.
12314 ELMWOOD AVE.
CLEVELAND OH 44111

SEND TO:
AMERICAN TANK & FABR. CO.
12314 ELMWOOD AVENUE
ATTN: WAREHOUSE DEPT.
CLEVELAND, OH 44111

03-C

P L A T E   D I M E N S I O N S   /   D E S C R I P T I O N

TOTAL QTY	GAUGE	WIDTH	LENGTH	DESCRIPTION	PIECE WEIGHT
1	4"	151"	162"	RECTANGLE	27750#

C U S T O M E R   I N F O R M A T I O N

CUSTOMER PO: 53634

S P E C I F I C A T I O N (S)

THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS AND SPECIFICATION(S).

ASTM A516 YR 90 GR 70
ASME SA516 2001 EDITION GRADE 70
MATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH ISO 9001 ABS-QE CERT. NO. 30130

C H E M I C A L   C O M P O S I T I O N

	C	MN	P	S	CU	SI	NI	CR	MO
MELT:U2395	.24	.93	.008	.009	.25	.19	.12	.07	.05

	V	TI	AL	CB
MELT:U2395	.002	.002	.022	.001

M A N U F A C T U R E

MCQUAID-EHN GRAIN SIZE PER E112 - 7-8

H E A T   T R E A T   C O N D I T I O N

MATL OR TEST	HEAT TREAT DESCRIPTION	NOM TEMP	HOLD MINS	COOL MTHD
PL/TEST	NORMALIZE	1650F	133	AIR COOL

T E N S I L E   P R O P E R T I E S

SLAB NO.	LOC	DIR	YIELD STRENGTH PSI X 100	TENSILE STRENGTH PSI X 100	ELONGATION GAGE LGTH	%
1B	BOT.	TRANS.	426	787	2.00"	27.0

WE HEREBY CERTIFY THE ABOVE INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

ISG PLATE INC. T E S T C E R T I F I C A T E

FILE NO: 0325-01-05
MILL ORDER NO: 10291-003
MELT NO: U2395
SLAB NO: 1B
DATE: 07/21/04

G E N E R A L I N F O R M A T I O N

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
MERCURY OR MERCURY COMPOUNDS ARE NOT USED
IN THE MANUFACTURE OF ISG PRODUCTS.

B/L #47375 CUSTOMER'S TRUCK

WE HEREBY CERTIFY THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

PAGE	1
CERT. #:	00422400

steel warehouse

2722 West Tucker Drive
South Bend, In 46624-1377

P.O. Box 1377
(574) 236-5100

CERTIFICATE OF ANALYSIS AND TESTS

FOR: AM. TANK & FAB CO.
12314 ELMWOOD AVE.
CLEVELAND OH 44111
DOOR 6

DATE: 09/15/04
YOUR P/O NUMBER 54275 ✓
SHIPPER NUMBER 00652848
OUR INVOICE NUMBER
OUR SALES ORDER 00646710

DESCRIPTION OF MATERIAL AND SPECIFICATIONS

1. HRTPHS 0001 11 0.1120 55.0000 X 372.0000 ✓ TCGXL

HEAT # 60515 NAFTA Y BUNDLE # 004035352B

CHEMICAL ANALYSIS

HEAT #	C ✓	MN ✓	P ✓	S ✓	SI ✓	AL	CB	V ✓
1. 60515 ✓	.050	0.800	.012	.002	.020	.020	.001	.056
	CR ✓	CU ✓	MO ✓	NI ✓	NIT	TI	B	
	0.040	0.070	.010	0.030	.0140	.001	.0000	

MECHANICAL PROPERTIES

BUNDLE # NAF	YIELD ✓	TENSILE ✓	ELONGATION % IN 2 IN. ✓	D		MISC
1. 004035352B Y	67500 psi	76150 psi	30	L		
				T		

S/N TCGXL
P.O. 54275

Meets The Requirements Of
ASTM A 572-50 TYPE 2 04A
BK 9/20/04

BOUGHT TO STOCK

THIS MATERIAL IS IN ACCORDANCE WITH AND CONFORMS TO
A572 -00 GR50 ✓

We hereby certify that the foregoing data is a true copy of the data furnished us by our supplier or resulting from tests performed in a recognized laboratory or our laboratory.

By ______________________
Authorized Agent

FORM # SW-17 REV 1-99

United States Steel Corporation
Gary Works
Gary, IN 46402

Metallurgical Test Report

ORDER: UE51304-01
LOAD: T02438
PO NBR: 051170-00

PART:
INVOICE: 154-198163 SHIP DATE: 01/30/02
00 OH

SOLD TO:

THE AMERICAN TANK&FABRICATING CO
12314 ELMWOOD AVE
CLEVELAND OH 44111-5991

SHIP TO:

THE AMERICAN TANK&FABRICATING CO
12314 ELMWOOD AVE NW
DOOR #5
CLEVELAND OH 44111-5991

SERIAL (HEAT: M27525 I/C: 53W2) STEEL TYPE = CAST REDUCTION RATIO = 11.9 TO 1
84071B00 1.0" X 75.0" X 257.0" 5466LBS 1PC

SPEC: PLATE HIGH STRENGTH LOW ALLOY USS SIXTY-N ASTM A633 REV A 01-JAN-2000 GR E APPROVED STRUCTURAL QUALITY NORMALIZED PLATE

INSP: 01 MILL INSPECTION PRELIMINARY T/R TO ACCOMPANY SHIPPING PAPERS ALSO T/R TO INDICATE NO MERCURY CONTENT UPON SHIPMENT FAX T/R TO ATTN: GREG MAZUR AT 216-252-4871 RA/SN ALSO RA/LT CERTIFY THAT ALL MELTING AND MANUFACTURING TOOK PLACE IN THE USA. ,

HEAT M27525 MELTED AND MANUFACTURED IN THE USA. FINE GRAIN
C=.20 MN=1.37 P=.016 S=.008 SI=.21 CU=.30 NI=.15 CR=.13 MO=.05 AL=.027 N=.01 V=.09 CB=.001

TRANSVERSE	YIELD:	63.0	KSI	TENSILE:	84.0	KSI	2" % ELONGATION: 50.0
		63000	PSI		84000	PSI	8" % ELONGATION: 25.0

PRODUCT AND TEST SPECIMENS WERE NORMALIZED AT 1660 DEG F. FOR 00 HR 56 MIN. COOLING COMPLETED IN STILL AIR.

** END OF TEST RESULT DATA **

TEST RESULTS WERE CONDUCTED AND RECORDED IN ACCORDANCE WITH TEST METHODS ACCREDITED BY A2LA.

THIS PRODUCT WAS MANUFACTURED IN ACCORDANCE WITH THE QUALITY MANAGEMENT SYSTEM WHICH COMPLIES WITH ISO 9002:1994.

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MANUFACTURED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS REQUIREMENTS IN SUCH RESPECT.
PREP. BY THE OFFICE OF D.M. BORMET, MANAGER, Q.A. BY: Ruben Fontaney DATE: 2-1-02

*0900 C F 3 0 0 0277450007A BKM 3 1 0

USS®

** LOAD TALLY **

PLATES

PICKUP(S)	Purchase Order Date	Purchase Order No.
32694,	11/19/01	051170-00

FROM

U. S. STEEL CORP.

GARY WORKS
GARY, INDIANA 46402

Invoice No.	U.S. Steel Order No.	Page
198163	UE51304	01

Subject to Section 7 of conditions of Bill of Lading in N.M.F.C. and U.F.C. No recourse clause is exercised.
USS Corp. - Consignor

Shipper's No. 154T02438-01

CHARGE 0277450 SHIP TO 007

SOLD TO

THE AMERICAN TANK&FABRICATING CO
12314 ELMWOOD AVE
CLEVELAND OH 44111-5991

SHIP TO

THE AMERICAN TANK&FABRICATING CO
12314 ELMWOOD AVE NW
DOOR #5
CLEVELAND OH 44111-5991

Date Shipped	From	Route / Carrier	
01/30/02	GARY, INDIANA	CAR CAP. 000 CAR TYPE CUSTOMER TRUCK FOR HIRE	9999998
Ship Mode	**Minimum Weight**		**PPD / COL.**
CTH	404	00 OH	COL

IF YOU USE A SHIPPER REFERENCE NBR FOR PYMT, USE 154T02438-01

ORDER ITEM		HEAT ING CUT PC		PLATE#	GAUGE	WIDTH	LENGTH	WEIGHT
ORDERED SIZE		1.0000	75.0000	257.0000				

SPEC: USS SIXTY-N ASTM A633 REV A 01-JAN-2000 GR E APPROVED STRUCTURAL
CUST: PT#A633E-1.0000-W--
PT#: A633E-1.0000-W- ✓
MARK: STAMP USS HT# SLAB# MT IN 1 PLACE
STEN CUST ORD# & USS EA PLT
STENCIL SIXTY-N STEEL A633 GR E
PACK: OR 1 PC - KEEP SIZES SEP
LOAD: FLATBED TRK - SHEET LIFTER UNLDG - BLOCK - COVER W/TARP
20000 LB ABSOLUTE MAX
B/L COVER WITH TARP

ORDER ITEM		HEAT ING CUT PC		PLATE#	GAUGE	WIDTH	LENGTH	WEIGHT
		BDHBD		METRIC	25.40MM	1905.00MM	6527.80MM	2479KG
UE51304	01	M27525 53 W2	1	084071A00	1.000	75.00	257.00	5466#
		BDHCY		METRIC	25.40MM	1905.00MM	6527.80MM	2479KG
UE51304	01	M27525 53 W2	1	084071B00	1.000	75.00	257.00	5466#

Per Controller - Gary Works USS Corp. - Shipper ____________________ Agent

Permanent Post Office Address of Shipper:
600 Grant Street, Pittsburgh, PA 15219-4776

Per ____________________

(MORE)

Bethlehem
Bethlehem Lukens Plate

TEST CERTIFICATE

FILE NO: 482-01-01
DATE: 07/23/99
MILL ORDER NO: 46292-005

CUSTOMER P.O.: J.C.R. 2765
DESCRIPTION:
1 - RECTANGLE 4 -X- 120 -X- 240
03-C

SOLD TO:	SEND TO:	SHIP TO:
WARREN FABRICATING CORPORATION P.O. BOX 1032	WARREN FABRICATING CORPORATION P.O. BOX 1032	WARREN FABRICATING HUBBARD SIDE (OLD GATX) WEST END
WARREN OH 44482	WARREN OH 44482	HUBBARD OH 44452

THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS AND SPECIFICATION(S):

ASTM A36 YR 96 ASME SA36 YR 98

MATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH ISO 9002 ABS-QE CERT. NO. 30130

MELT/SLAB	CHEMICAL ANALYSIS															PRACTICES
	C	MN	P	S	CU	SI	NI	CR	MO	V	TI	B	AL	CB		
R2476	.16	.89	.014	.012	.29	.20	.20	.16	.06	.001			.032	.001		

TENSILES					CHARPY V IMPACTS				OTHER TESTS PERFORMED
TYPE	YLD (PSI	TENS X 100)	% ELONG 2"	% R.A.	TYPE	TEMP	MILS LATERAL EXPANSION	% SHEAR	
5X	453	703	27.0						BBWJQ

INFORMATION

WEIGHT PER PIECE = 32671 LBS. 14850 KG.
ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
CUSTOMER ITEM NO. 006
B/L #61146 NORL 2904

The American Tank & Fabricating Co.
MEETS THE REQUIREMENTS OF
ASTM A36-97a
REVIEWED BY: PJC DATE 3/14/00

HEAT TREAT CYCLES - MATL. OR TESTS - DEG							
MATL.	TEST	NOM TEMP	MIN TEMP	MAX TEMP	HOLD MINS.	COOL METHOD	E TE

HEAT TREAT CYCLES - TESTS ONLY - DEG						
START END TEMP	NOM TEMP	MIN TEMP	MAX TEMP	HOLD MINS.	HEAT RATE MAX	CC RA M.

WE HEREBY CERTIFY THE ABOVE INFORMATION IS CORRECT: Quality Assurance Laboratory

Elinore Zaplitny

EV. F1-99)

BETHLEHEM STEEL CORPORATION
QUALITY and PRACTICE DEVELOPMENT
REPORT OF TESTS AND ANALYSES

ETHLEHEM LUKENS PLATE DIVISION

IPMENT NO.	DATE SHIPPED	CAR OR VEHICLE NO.		
803-06934	3-23-00	NS	BN 614279	PAGE 1

SOLD

SERIAL NUMBER	PAT. NO.	HEAT NUMBER	NO. PCS.	THICKNESS INCHES	WIDTH OR DIA. INCHES	LENGTH INCHES	WEIGHT POUNDS	YIELD POINT PSI	TENSILE STRENGTH PSI	ELONG. IN	ELONG. %	RED. %
PRODUCED UNDER A CERTIFIED QMS COMPLYING WITH ISO 9002 ABS-QE CERT. #30477												
QUALITY STEEL MELTED & MANUFACTURED IN THE U. S. A.												
PLATES - ASTM A516-90 GR 70 PVQ, ASME SA516 GR 70 PVQ 1998 EDITION												
MFST - LIFT MAX 15 TON-SIZES & GAUGES SEP UNLDG OH-MAGNET-CHAIN-SLING												
CO# J.C.R. 2887 GH 365-0653												
YIELD STRENGTH @ .5% E.U.L.												
S 62195		823L71250	1	1.5	120	240	12252	44200	79500	2	23	
S 62196		823L71250	1	1.5	120	240	12252	46300	79500	2	29	
PLATES - ASTM A 36-96, ASME SA36 1998 EDITION												
MFST - LIFT MAX 15 TON-SIZES & GAUGES SEP UNLDG OH-MAGNET-CHAIN-SLING												
CO# J.C.R. 2886 GH 365-0654												
		813L70150	1	1	120	480	16335	40400	64200	8	30	
		823L70120	2	1	120	480	32670	40000 41900	66400 67400	8 8	28 26	
		823L70130	1	1	120	480	16335	41400	67600	8	27	

Q—QUENCH TEMPERATURE T—TEMPER TEMPERATURE N—NORMALIZE TEMPERATURE

BDAYZ

SERIAL NUMBER	PAT. NO.	HEAT NUMBER	HARD	BEND	THICKNESS INCHES	TYPE	SIZE	DIR.	TEST TEMP. F	CHARPY IMPACT ENERGY FT. LBS. 1	2	3	SHEAR (%) 1	2	3	LAT. EXP. MILS 1	2	3

The American Tank & Fabricating Co.
MEETS THE REQUIREMENTS OF
ASTM A516-70 99A
REVIEWED BY: J Deml DATE 8-28-01

HEAT NUMBER	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Ti	Al	B	Cb	N	McQUAID GRAIN SIZE
823L71250	.24	1.10	.012	.007	.253	.019	.01	.03	.005	.002		.036		.002		
813L70150	.14	1.06	.017	.006	.208	.009	.01	.03	.005	.003				.002		
823L70120	.16	1.08	.015	.012	.232	.014	.01	.04	.005	.002				.002		
823L70130	.16	1.09	.015	.012	.224	.010	.01	.04	.005	.004				.002		

I CERTIFY THAT THE ABOVE RESULTS ARE A TRUE AND CORRECT COPY OF ACTUAL RESULTS CONTAINED IN RECORDS MAINTAINED BY BETHLEHEM AND ARE IN FULL COMPLIANCE WITH THE REQUIREMENTS OF THE SPECIFICATION CITED ABOVE. THIS TEST REPORT CANNOT BE ALTERED AND MUST BE TRANSMITTED INTACT WITH ANY SUBSEQUENT THIRD PARTY TEST REPORTS, IF REQUIRED.

SUPV. QUALITY and PRACTICE DEVELOPMENT D. A. ELWOOD PER WNK

United States Steel Corporation
Gary Works
Gary, IN 46402

PRELIMINARY TEST REPORT
CONFIRMING TEST REPORT WILL BE MAILED

ORDER: UE55784-06 PART:
LOAD: T13642 INVOICE: 154 241121 SHIP DATE: 12/05/02
NBR: 52060 VEH ID: 130A OH 38097

SOLD TO:	SHIP TO:
THE AMERICAN TANK&FABRICATING CO 12314 ELMWOOD AVE CLEVELAND OH 44111-5991	THE AMERICAN TANK&FABRICATING CO 12314 ELMWOOD AVE DOOR #11 CLEVELAND OH 44111-5991

SERIAL HEAT: Y49461 I/C: 54W2 STEEL TYPE = CAST REDUCTION RATIO = 4.0 TO 1
X9108A00 3.0" X 93.0" X 330.0" 1 PC 26111.00 LBS

SPEC: PLATE HIGH STRENGTH LOW ALLOY USS SIXTY-N ASTM A633 01-JAN-2001 GR E APPROVED STRUCTURAL QUALITY NORMALIZED PLATE LCVN IMPACT TEST HEAT LOT FREQ. H LCVN 20 FT-LBS AVG @ +0 F LCVN 15 FT-LBS MIN @ +0 F

INSP: 01 MILL INSPECTION TEST REPORT TO INDICATE NO MERCURY CONTENT AND REPORT CB RA/SN ALSO RA/LT CERTIFY THAT ALL MELTING AND MANUFACTURING TOOK PLACE IN THE USA. ,

HEAT Y49461 MELTED AND MANUFACTURED IN THE USA. FINE GRAIN
C=.18 MN=1.33 P=.015 S=.007 SI=.22 CU=.28 NI=.13 CR=.12 MO=.05 AL=.027 N=.010 V=.11 CB=.001

TRANSVERSE YIELD: 61.0 KSI TENSILE: 85.0 KSI 2" % ELONGATION: 23.0
61000 PSI 85000 PSI
TRANSVERSE YIELD: 63.0 KSI TENSILE: 87.0 KSI 2" % ELONGATION: 32.0
63000 PSI 87000 PSI

LONGITUDINAL FL SIZE CHARPY IMPACT V-NOTCH +000 DEG F FT LBS/ 067-074-074
-18 DEG C AVG IMPACT STRENGTH +72 FT LBS
LONGITUDINAL FL SIZE CHARPY IMPACT V-NOTCH +000 DEG F FT LBS/ 098-074-088
-18 DEG C AVG IMPACT STRENGTH +87 FT LBS

PRODUCT AND TEST SPECIMENS WERE NORMALIZED AT 1660 DEG F. FOR 02 HR 48 MIN. COOLING COMPLETED IN STILL AIR.

MERCURY OR MERCURY BEARING COMPOUNDS ARE NOT USED IN THE MANUFACTURE OF THIS MATERIAL.
** END OF TEST RESULT DATA **

TEST RESULTS WERE CONDUCTED AND RECORDED IN ACCORDANCE WITH TEST METHODS ACCREDITED BY A2LA.

THIS PRODUCT WAS MANUFACTURED IN ACCORDANCE WITH THE QUALITY MANAGEMENT SYSTEM WHICH COMPLIES WITH ISO 9002:1994.

RDSUB

The American Tank & Fabricating Co.
MEETS THE REQUIREMENTS OF
ASTM A633 Grade E 00400 ASTM 633-01
REVIEWED BY: [signature] DATE 12-12-02

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MANUFACTURED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS REQUIREMENTS IN SUCH RESPECT.
PREP. BY THE OFFICE OF D.M. BORMET, MGR, PLATE TECH BY: DATE:

*1515 PCNF NNN 0 0 0 0277450002A BKW 0 1 0

U.S. Steel Corporation Metallurgical Test Report

Gary Works
Gary, IN 46402

Heat Treat Number M47470 Grade A516-70 Size 3.0

ORDER: UE55761-01 PART:
LOAD: H04202 INVOICE: 154-239192 SHIP DATE: 11/20/02
PO NBR: JCR-3497 VEH ID: EJE 006257 H4202
SOLD TO: SHIP TO:

SERIAL HEAT: M47470 I/C: 55W1 STEEL TYPE = CAST REDUCTION RATIO = 4.0 TO 1
C9170A00 3.0" X 96.0" X 360.0" 1 PC 29404.00 LBS

SPEC: PLATE CARBON ASME SA 516 01-JUL-2001 2001 EDITION 2002 ADDENDA GR 70 APPROVED ASTM A516 01-JAN-2001 GR 70 APPROVED PVQ NORMALIZED PLATE KILLED FINE GRAIN MILL EDGE

INSP: 01 MILL INSPECTION RA/SN ALSO RA/LT CERTIFY THAT ALL MELTING AND MANUFACTURING TOOK PLACE IN THE USA. ,

HEAT M47470 MELTED AND MANUFACTURED IN THE USA. FINE GRAIN
C=.26 MN=0.99 P=.017 S=.010 SI=.22 CU=.02 NI=.02 CR=.04 MO=.01 AL=.025 V=.001 TI=.001 CB=.001

TRANSVERSE	*YIELD:	44.0	KSI	TENSILE:	77.0	KSI	2" % ELONGATION: 29.0
		44000	PSI		77000	PSI	

TENSILE TEST WAS TAKEN ON INGOT/CUT: 55W 1

PRODUCT AND TEST SPECIMENS WERE NORMALIZED AT 1660 DEG F. FOR 02 HR 48 MIN. COOLING COMPLETED IN STILL AIR.

* - YIELD STRENGTH @ 0.5% E.U.L.
** END OF TEST RESULT DATA **

TEST RESULTS WERE CONDUCTED AND RECORDED IN ACCORDANCE WITH TEST METHODS ACCREDITED BY A2LA.
THIS REPORT SHALL NOT BE REPRODUCED OR ALTERED WITHOUT THE PRIOR WRITTEN APPROVAL OF UNITED STATES STEEL.
THIS PRODUCT WAS MANUFACTURED IN ACCORDANCE WITH THE QUALITY MANAGEMENT SYSTEM WHICH COMPLIES WITH ISO 9002:1994.

BDWUX

The American Tank & Fabricating Co.
MEETS THE REQUIREMENTS OF
ASTM A516-70, 03a
REVIEWED BY: B Kennedy DATE 7/17/03

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MANUFACTURED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS REQUIREMENTS IN SUCH RESPECT.
PREP. BY THE OFFICE OF D.M. BORMET, MGR, PLATE TECH BY: DATE: 11/22/02

IPSCO Steel Inc.

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412

T[redacted]ertificate

Form TC1: Revision 1: Date 3[redacted]000

Customer P.O. No.: 106761	Mill Order No.: 41-046195-13	Shipping Manifest: 205387
Product Description: ASTM A36(01)/A709(01A)36/ASME SA36(01ED) AASHTO M270(01)36	Ship Date: 31 Oct 03 Cert Date: 31 Oct 03	Cert No: 224975
Size: 2.000 X 96.00 X 240.0 (IN)		

Tested Pieces			Tensiles					Charpy Impact Tests												
Heat Id	Piece Id	Piece Dimensions	YS (PSI)	UTS (PSI)	Elong % of 2in	8in	Bend Test	Average Hardness	Absorbed Energy 1	2	3	Avg	% Shear 1	2	3	Avg	Test Temp	Test Dir	Test Size	DWTT
B3J624	B34	1.995 X 96.96	42000	75000	25															
B3J624	B35	1.995 X 96.96	44000	76000	27															
A3J225	E09	1.995 X 96.87	42000	76000	33															

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N
B3J624	.19	1.03	.015	.008	.26	.035	.24	.11	.11	.02	.003	.002	.029	.0003	.0063
A3J225	.19	1.02	.015	.002	.29	.033	.29	.12	.15	.03	.004	.003	.027	.0003	.0068

100 % MELTED AND MANUFACTURED IN THE USA. MTR.DIN50049/EN10204 PAR 3.1B

MERCURY HAS NOT BEEN USED IN THE DIRECT MANUFACTURING OF THIS MATERIAL

B3J624 B36 PIECES: 2, WEIGHT: 26968 A3J225 E09 PIECES: 1, WEIGHT: 13442

The American Tank & Fabricating Co.
MEETS THE REQUIREMENTS OF
ASTM A-36, 03a
REVIEWED BY: [signature] DATE 12/22/03

Cust Part #:

WE HEREBY CERTIFY THAT THIS MATERIAL WAS TESTED IN ACCORDANCE WITH THE APPROPRIATE SPECIFICATION

P. A. CROZIER
Q.A. METALLURGIST

FASTENAL®

INDUSTRIAL & CONSTRUCTION SUPPLIES

Certificate of Compliance

Attn: Greg Morgan
6 pages

Sold To:

AMERICAN TANK AND FABRICATING CO

Purchase Order: 54338

Job:

Invoice Date: 9/20/04

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

10 PCS 2"-4.5x6.25 SHCS A193 B7 SUPPLIED UNDER OUR TRACE NUMBER mdoh2184 AND UNDER PART NUMBER 10971-01550

38 PCS 1"-8X2 ASTM A193 B7 HEAVY HEX BOLT , DOMESTIC SUPPLIED UNDER OUR TRACE NUMBER ic021254 AND UNDER PART NUMBER 0155550

38 PCS 1" A325 Plain F436 Dom Structural Flat Washer SUPPLIED UNDER OUR TRACE NUMBER sy031642 AND UNDER PART NUMBER 0133548

This is to certify that the above document is true and accurate to the best of my knowledge.

This document was printed on 9/20/04 and was current at that time.
Please check current revision date of 12-15-03 to avoid using obsolete copies.

Fastenal Account Representative

Cardinal Fastener Test Certification

Reported:9/22/2004

Certification No.:	20428	Shop Order#:	225206
Order No.:	106880 1	Heat No.:	HT# 11610780
Customer PO:	MDOH2184	Grade:	B7 SHCS
		Thread Class:	2A
Customer No.:	000000032106	Shipped Qty:	10
Customer:	FASTENAL MIDDLEBURG HTS, OH	Heat Treat Spec:	
Address:	17851 ENGLE ROAD MIDDLEBURG HTS, OH 44130	Supplier:	
		Finish Spec.:	
		Supplier:	
Manufacturer:	Cardinal Fastener & Specialty Co.,	Item description:	2 - 4.5 x 6-1/4 B7 SHCS
Address:	5185 Richmond Road Bedford Heights, Ohio 44146	Headmark:	Socket Head Capscrew
Laboratory:	Cardinal Fastener & Specialty Co.,		
Address:	5185 Richmond Road Bedford Heights, Ohio 44146		
Notes:			

Test No.: 28745 Order No.: 221728 0 Test Date: 5/25/2004 Test Disposition: PASS

Specification: MET_A574(5/8"TO3">=3D) -98 SPECIMEN MACHINED Test Facility: CFS

Tech. Name: DFD Tech. Title: LT LotSize(pcs/lbs): 244

Notes: Tensile Test Per ASTM F606 Sample Size: 1

Hardness Per ASTM E18

Accept Per. ASTM A574 Para.8.1& 12.3.2 Carb/Decarb

Inspection (min. - max.) units	Disposition	Sample Values:
HARDNESS (37, 45) Rc	PASS	40
TENSILE (170000, 999999) PSI	PASS	182000
YIELD (153000, 999999) PSI	PASS	170000
ELONGATION% (8, 999) %	PASS	14
REDUCTION OF AREA (0, 999) %	PASS	49

Test No.: 27554 Order No.: 11610780 0 Test Date: 2/5/2004 Test Disposition: PASS

Specification: CHEM_GRADE 4140 Test Facility: CHAPARREL

Tech. Name: T HARRINGTON Tech. Title: QA LotSize(pcs/lbs): 18737

Notes: MACRO ETCH RESULTS: S1 R1 C1 Sample Size: 1

Inspection (min. - max.) units	Disposition	Sample Values:
CARBON (0, 999) %	PASS	0.4
MANGANESE (0, 999) %	PASS	0.93
PHOSPHORUS (0, 999) %	PASS	0.011
SULFUR (0, 999) %	PASS	0.014

SILICON (0, 999) %	PASS	0.26
COPPER (0, 999) %	PASS	0.28
NICKEL (0, 999) %	PASS	0.08
CHROMIUM (0, 999) %	PASS	0.98
MOLYBDENUM (0, 999) %	PASS	0.197
ALUMINUM (0, 999) %	PASS	0.033
VANADIUM (0, 999) %	PASS	0.03

Cert No: 20428

ALL MANUFACTURING AND MATERIAL PROCESSES IN THIS PRODUCT HAVE OCCURED WITHIN THE U.S.A. IN COMPLIANCE WITH THE BUY AMERICA PROVISIONS OF THE SURFACE TRANSPORTATION ACT OF 1982

All data represented on this report relates only to the item(s) tested, which have been sampled in order to represent the processed lot identified in the description.

Information and data in the report is correct and reliable to the best of our knowledge; however, results are not guaranteed and no responsibility is assumed.

All items furnished on the above referenced Purchase Order are in full conformance with all Purchase Order and Specification Requirements. Test values, either provided by our supplier or generated in Cardinal's Laboratory, represent actual attributes of the items furnished and the test results are in full compliance with all applicable specification and order requirements. All manufacturing, testing, sampling and inspections have been performed in accordance with Cardinal's Quality Assurance Program. All applicable tests are in accordance with the Quality Control Manual dated 4/24/98. The product was manufactured and supplied free from mercury contamination. This document may only be reproduced unaltered and only for the purpose of certifying the same or lesser quality of the product specified herein. Reproduction or alteration of this document for any other purpose is prohibited.

(Approval)

Q.A.
(Title)

9/22/2004
(Date Approved)

CARDINAL FASTENER & SPECIALTY CO., INC. / 5185 RICHMOND RD. BEDFORD HEIGHTS, OHIO 44146 / 216-831-3661

83031642
-013356

STAMPING THE FUTURE

WROUGHT WASHER MFG., INC.

September 8, 2003

Certification of Compliance

118553
JESSUP WAREHOUSE
1225 MID-VALLEY DRIVE
JESSUP, PA 18434

Wrought Washer Ordr/Lot Number
432774

Heat Number	Chemical Analysis C	Mn	P	S	Si
40313120	.340	.770	.009	.002	.200

Purchase Order Number	Part Description	Date Shipped	Quantity Shipped
JESSUP STOCK	1" S MARK HT	09/05/2003	12,000

We hereby certify that the subject parts conform to the requirements of the applicable specification indicated for the subject parts and are in complete conformance to F436-93. We hereby certify that the subject parts were hardened to RC 38-45.

We hereby certify that all statutory requirements as to American Production and Labor Standards and all conditions of purchase applicable to the transaction have been complied with and that the subject parts were melted and manufactured in the U.S.A.

Truly yours,
Wrought Washer Mfg., Inc.

David Zupancic
Q.C. Manager

Sworn and subscribed before me on September 8, 2003
My commission expires June 5, 2005

(030) SMARK, HT, F436
W/W INTERNAL USE : 43352508/108/017318/62404

Steel Dynamics, Inc.
4500 County Road 59
Butler, IN 46721 USA
Telephone (260) 868-8000
Fax (260) 868-8855

CHEMICAL/PHYSICAL CERTIFICATION

SDI Steel Dynamics, Inc.

SHIP TO	SOLD TO
HS Processing-Butler 4460 CR 59 Butler, IN 46721 United States Butler RECEIVING 868-0080 868-9977	Heidtman Steel - Erie 640 Lavoy Road Erie, MI 48133 United States Greg Goad CR,CRG & HRG Purchas 1-734-848-2915 868-0893

Customer #	Part #	Po #	Order #	Line Item #	Coil #	Heat #	Coil Weight (lbs)
11	16118	AP 18856	67714	1	B576573	40313120	46,520

Width (in)	Gauge (in)	Length(ft)	Material Specification	Product Description
48.50	0.125	2,027	SAE 1025	Prime Hot Rolled Band

Ladle Chemical Analysis %

C	Mn	P	S	Si	Al	Cu	Ni	Cr	Mo	Sn	N	V	Nb	Ti	B	Ca
0.24	0.77	0.009	0.002	0.20	0.03	0.09	0.04	0.04	0.01	0.005	0.006	0.00	0.00	0.00	0.000	0.002

Mechanical Properties

Yield Strength (PSI)	Tensile Strength (PSI)	Percent Elongation	Rockwell Result	
56,110	87,139	23.0	94	Tail Sample

62404

"Made & Mfg in the USA"

Melted, thin-slab cast, and rolled by proud Americans in Butler, Indiana, USA.
Shipped from Butler, IN, United States.
All tests were performed according to applicable standards and are correct as contained in the records of the company.
Quality Assurance ___

NOVA MACHINE PRODUCTS CORPORATION

18001 Sheldon Road
Middleburg Heights, OH
44130

216 267 3200
Fax 216 433 1640

MATERIAL TEST REPORT #0000029383 Page: 1

Date: 11/02/02

PO #: IC021254
Rel :

FASTENAL COMPANY
5851 GUION ROAD

INDIANAPOLIS, IN 46254

SO #: 0000080927
Line #: 38
Qty: 80 EA
Lot #: 0040011844
Heat #: US Y06420
Drwg: (80/BOX)

CL./STOCK: 0155550

DESC: 1"-8 UNC 2A x 2" HEAVY HEX SCREW

MATERIAL SPECIFICATIONS: ASTM A-193('01) Gr.B7

HEAT SPECIFICATIONS:
Quenched & tempered per the material specification, minimum tempering temperature: 1100 F

APPLICABLE SPECIFICATIONS:
ANSI/ASME B1.1 ANSI/ASME B18.2.1

QUALITY SPECIFICATIONS:
Domestic manufactured; This is a commercial grade item;

CHEMICAL TEST:
C .40 MN .92 P .012 S .005 SI .21 CU .02 NI .03 CR 1.01
MO .225 AL .034

MECHANICAL TEST:
TENSIL 134000PSI YIELD 115400PSI ELONG 21.4 REDUCT 61.7
HARD RC 29.2
MACRO ETCH: ACCEPTABLE

PROGRAM STATEMENT:
Nova Machine Products Corporation certifies that the material, parts, components, or services supplied on this purchase order have been processed in accordance with, and therefore meet or exceed the quality requirements established by the references or specifications in this order. Maintained mercury free by Nova.

I certify that these results are a true and correct copy of records prepared and maintained by Nova Machine Products Corporation in compliance with the requirements of the purchase order and specifications cited.

Processed per ISO-9001('94)/ISO-9002, Certificate QQC 211. Fastener products received from Nova are FQA compliant.

Your salesperson is Beau Laslo
Please call day or night if you have any questions or comments.

Sheila Galaday, Quality Control

CERTIFIED TEST REPORT

DYSON CORP.
DOMESTIC NUT

53 Freedom Road
Painesville, OH 44077

440-946-3500
440-352-2700 fax

DYSON ORDER#	CUSTOMER ORDER#	ITEM NUMBER	QUANTITY SHIPPED	DATE SHIPPED
C 70701	MDOH2160	4 of 4	32 pc	8/26/04

CUSTOMER
Fastenal Company
17851 Englowood Drive
Middleburg Heights, OH 44130
USA

PRODUCT DESCRIPTION
1.50" (bolt diameter) flat washer, Plain

SPECIFICATIONS
ASTM-F436 Type 1

DRAWING

STARTING MATERIAL	DIA	GRADE	QTY	LOT CODE	HEAT NO.	ORIGINAL MILL
Flat Washer	1.500	F436	32	JEI	22469001	Sabre Steel

The product listed above was manufactured, tested, sampled, and inspected in accordance with the specification, purchase order, and any supplementary requirements and was found to meet those requirements unless otherwise noted.
1. The steel was melted and manufactured in the USA and the product was manufactured and tested in the USA.

MEETS REQ'TS OF:
ASTM F436, TYPE
PC 9/24/04

PO# 054265
ITEM #1
P. 1 of 4

Attachments:
Mill/Supplier Test Reports

Deborah A. Smith
Q.A. Admin. Assistant
8/26/04

TECHNICAL STAMPING TSI EST. 1991

TECHNICAL STAMPING, INC.

50600 E RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051
PH(586)948-3285 / FX(586)948-3286

CERTS OK
MAY 2 7 2003

MATERIAL CERTIFICATION

CODE JEI

CUSTOMER	CUSTOMER ORDER NUMBER	DATE
ZIEGLER'S BOLT & NUT HOUSE	146288	5/23/03

PART NUMBER	LOT NUMBER	QUANTITY
1-1/2" F436	0301-717	15,000

STEEL GRADE	HEAT	C	MN	P	S	SI	AL	[illegible]
	22469001 ✓	.29	1.34	✓ .011	✓ .001	.034	.027	REL.

SPECIFICATION		ACTUAL	GAUGE
O.D	2.969 - 3.031	2.997 - 3.000	CALIPER
I.D	1.625 - 1.656	1.639 - 1.641	CALIPER, PIN GAUGE
THICKNESS	.136 - .177	.138 - .140	MICROMETER
FLATNESS	MAX .010	.002	CALIPER
STEEL		SEE CERT	
HEAT TREAT		SEE CERT	
PLATING			
OTHER			

WE HEARBY CERTIFY THAT THE SUBJECT PARTS CONFORM TO THE REQUIREMENTS OF THE APPLICABLE SPECIFICATIONS INDICATED FOR THE SUBJECT PARTS AND ARE IN COMPLETE CONFORMANCE TO ASTM F436 HARDENED TO RC 38-45. THE MATERIAL WAS MELTED DOMESTICALLY. THE SUBJECT PARTS WERE MANUFACTURED DOMESTICALLY IN CHESTERFIELD TWP., MI U.S.A.

MEETS REQ'TS OF:
CHEMISTRY OF ASTM F-436-04, TYPE 1
PC 9/24/04

Robin Vaughn
AUTHORIZED SIGNATURE

JUNE M. SAXTON
Notary Public, Macomb County, MI
My Commission Expires Mar. 11, 2008

June M Saxton
5-23-03

PO# 054265
ITEM #1
P. 2 of 4

NOTARY PUBLIC

Qlty.3008 Rev. 1 11-28-01

Q.A. REVIEWED
DJ
DATE 12/23/03
DYSON

2833

WORK ORDER-CERTIFICATION

Alpha Steel Treating Inc.
32969 GLENDALE AVENUE
LIVONIA, MICHIGAN 48150-1613
PHONE (734) 523-1030
FAX (734) 523-1039

QS 9000 REGISTERED
ISO 9002 REGISTERED
ACCREDITED MECHANICAL 0220-01

CODE JEI

1/14/03

CUSTOMER SHIPPER	DATE RECEIVED	Q NUMBER	WORK ORDER
1449	1/14/03		0089753/001

SOLD TO	SHIP TO
TECHNICAL STAMPING 50600 E. RUSSELL SCHMIDT CHESTERFIELD TWP MI	TECHNICAL STAMPING 50600 E. RUSSELL SCHMIDT CHESTERFIELD TWP MI

PART NUMBER	DESCRIPTION
F0112	2.99ID x 1.64ID x .140Th FLAT WASHER

LOT NUMBER	HEAT NUMBER	ORDER WEIGHT	ORDER QUANTITY
0301-717		9059 7545	6

QUALITY CONTROL	QUALITY CONTROL CODES
Hold for Q.C.	PMF10/16/2002 JDP

PROCESS DESCRIPTION	REV. # & DATE	MATERIAL	GRADE/CLASS
Harden Temper ASTM F436		1035	

HEAT TREAT SPECIFICATIONS

HARDNER TEMP	BELT SPEED	CARBON PROBE	QUENCH MEDIUM	LOADER SETTING	MMI RECIPE	RUN TIME	PROD. RATE	TIME/BI
875	18.0	.50	130-140	01 4000 #/HR	1861	1.68	26.9	23.1

CORE SPEC	MEAN	SURFACE SPEC	WASHER SPEC	CASE SPEC
HRC 39.00-43.00 Hold 38.00-45.00	41.00	15N 77.0-83.0		

CONTAINER INFORMATION

Desc - 6 BIN
Cnts - 083 535 201 413 555 847

Q.A. REVIEWED
DATE 1/23/03
DYSON

SPECIAL INSTRUCTIONS

Run Samples - KC FB 43-42 Temp 750 FCE 3
MMI S/36 INSP 220

CHECK HARDNESS ON FLAT AFTER BUFF

OPERATORS MUST SIGN ROUTING TAGS!!!!!!!!

QUENCH TEMP NOT TO EXCEED 160xF MAINTAIN 130-160xF

PO#05426
ITEM #1
P. 3 of 4

NO MINIMUM TEMPERING TEMP.
OPERATOR SIGN OFF
HARDNER OPE______ DRAW OPE 249

CERTIFIED COPY

MEETS REQ'TS OF:
MECHANICAL PROPERTIES OF ASTM F436-04, TYPE 1
PC 9/24/04

STAGING/LOADING INSPECTION: FURNACE OPERATOR #1 110	FURNACE OPERATOR #2 220
BINS FREE OF GREEN PARTS: FURNACE OPERATOR 220	OPERATOR INSPECTOR 249
SOLUBLE OIL / DRY	TEMPERING TEMPERATURE 760

THIS TWO SIDED DOCUMENT MUST BE REPRODUCED IN WHOLE

2833

CERTIFICATE OF CONFORMANCE

SABRE STEEL INC.
23680 RESEARCH DRIVE
FARMINGTON HILL, MI 48335
248-615-0500

DATE: 1/03/03

CODE JET

SOLD TO: TECHNICAL STAMPING
50600 E. RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051

SHIP TO: TECHNICAL STAMPING
50600 RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051

Cust P/O# 7003 Part# F0112 Sales Ord 007389
Work Ord 016100

SIZE: .136 MIN X 3.20 X COIL

GRADE:

DATE SHPPD: 1/03/03 B/L# 060787

Wt. Shipped 16585

CHEMICAL ANALYSIS

Heat Number 22469001

C : .29 ✓ Mn: 1.34 P : .011 S : .001 ✓
Si: .034 Al: .027

PHYSICAL PROPERTIES

Chemistry: C1027

Q.A. REVIEWED
DATE 12/23/03
DYSON

MADE AND MELTED IN THE USA

MEETS REQ'TS OF:
CHEMISTRY OF ASTM F436-04, TYPE 1
PC 9/24/04

PO# 054265
ITEM #1
P. 4 OF 4

WE HEREBY CERTIFY THE ABOVE FIGURES ARE ACCURATELY STATED, MEET YOUR MATERIAL REQUIREMENTS AND ARE TRACEABLE IN OUR RECORDS BACK TO THE PRODUCER AND/OR AN ACCREDITED TEST LABORATORY.

QUALITY ASSURANCE MANAGER

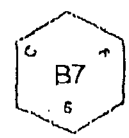
Attn: GREG MAZUR

Cardinal Fastener Test Certification

(216) - 252 - 4871
(440) 243 - 6072

Reported:9/27/2004

Certification No.:	20489	Shop Order#:	00224750
Order No.:	106803 1	Heat No.:	300187
Customer PO:	MDOH2157	Grade:	B7 Heavy hex bolt
Customer No.:	000000032106	Thread Class:	2A
Customer:	FASTENAL MIDDLEBURG HTS, OH	Shipped Qty:	32
Address:	17851 ENGLE ROAD	Heat Treat Spec:	
	MIDDLEBURG HTS, OH 44130	Supplier:	
		Finish Spec.:	
		Supplier:	
Manufacturer:	Cardinal Fastener & Specialty Co.,	Item description:	1 1/2 - 6 x 8: B7 ✓
Address:	5185 Richmond Road	Headmark:	Heavy Hex Bolt
	Bedford Heights, Ohio 44146		
Laboratory:	Cardinal Fastener & Specialty Co.,		
Address:	5185 Richmond Road		
	Bedford Heights, Ohio 44146		



Notes:

Test No.: 28982 Order No.: 221531 0 Test Date: 6/18/2004 Test Disposition: PASS

Specification: MET_A193(1/2"TO1 3/4">=3D) -99 Test Facility: CFS

Tech. Name: DFD Tech. Title: LT LotSize(pcs/lbs): 557

Notes: Wedge Test Per ASTM A370 Sample Size: 1

Hardness Per ASTM E18

1100 Deg. Min Temper

Wedge Angle 10 Degrees

Inspection (min. - max.) units	Disposition	Sample Values:
HARDNESS (0, 35) Rc	PASS	33 ✓
TENSILE (125000, 999999) PSI	PASS	153566

Test No.: 28983 Order No.: 221531 0 Test Date: 6/18/2004 Test Disposition: PASS

Specification: MET_A193(1/2"TO2">=3D) -99 Specimen Test Facility: CFS

Tech. Name: DFD Tech. Title: LT LotSize(pcs/lbs): 557

Notes: Tensile Test Per ASTM A370 Sample Size: 1

1100 Deg. Min Temper ✓

Inspection (min. - max.) units	Disposition	Sample Values:
TENSILE (125000, 999999) PSI	PASS	152000 ✓
YIELD (105000, 999999) PSI	PASS	140200 ✓
ELONGATION% (16, 999) %	PASS	16 ✓
REDUCTION IN AREA (50, 999) %	PASS	52 ✓

MEETS REQ'TS OF:
ASTM A193-01b, GRADE B7 ✓
PC 4/28/04

PO #054625
ITEM #2
P. 1 OF 2

CARDINAL FASTENER & SPECIALTY CO., INC. / 5185 RICHMOND RD. BEDFORD HEIGHTS, OHIO 44146 / 216-831-3651

Test No.: 27569	Order No.:	300187 0	Test Date:	2/6/2004	Test Disposition: PASS
Specification: CHEM_GRADE 4140 HR				Test Facility:	ALTON STEEL INC
Tech. Name: R CAULEY		Tech. Title:	QA	LotSize(pcs/lbs):	35186
Notes: MACRO ETCH RESULTS: S2 R3 C2				Sample Size:	1

Inspection (min. - max.) units	Disposition	Sample Values:
CARBON (0, 999) %	PASS	0.41 ✓
MANGANESE (0, 999) %	PASS	0.79 ✓
PHOSPHORUS (0, 999) %	PASS	0.015 ✓
SULFUR (0, 999) %	PASS	0.025 ✓
SILICON (0, 999) %	PASS	0.027 ✓
COPPER (0, 999) %	PASS	0.22
NICKEL (0, 999) %	PASS	0.074
CHROMIUM (0, 999) %	PASS	0.939 ✓
MOLYBDENUM (0, 999) %	PASS	0.18 ✓
ALUMINUM (0, 999) %	PASS	0.004
VANADIUM (0, 999) %	PASS	0.036

Cert No: 20488

ALL MANUFACTURING AND MATERIAL PROCESSES IN THIS PRODUCT HAVE OCCURED WITHIN THE U.S.A. IN COMPLIANCE WITH THE BUY AMERICA PROVISIONS OF THE SURFACE TRANSPORTATION ACT OF 1982

All data represented on this report relates only to the item(s) tested, which have been sampled in order to represent the processed lot identified in the description.

Information and data in the report is correct and reliable to the best of our knowledge; however, results are not guaranteed and no responsibility is assumed.

All items furnished on the above referenced Purchase Order are in full conformance with all Purchase Order and Specification Requirements. Test values, either provided by our supplier or generated in Cardinal's Laboratory, represent actual attributes of the items furnished and the test results are in full compliance with all applicable specification and order requirements. All manufacturing, testing, sampling and inspections have been performed in accordance with Cardinal's Quality Assurance Program. All applicable tests are in accordance with the Quality Control Manual dated 4/24/98. The product was manufactured and supplied free from mercury contamination. This document may only be reproduced unaltered and only for the purpose of certifying the same or lesser quality of the product specified herein. Reproduction or alteration of this document for any other purpose is prohibited.

Denise L Mueller
(Approval)

Q.A.
(Title)

9/27/2004
(Date Approved)

MEETS REQ'TS OF: ✓
ASTM A-193-01b, GRADE B7
PC 9/28/04

PO #054625
ITEM #2
P. 2 OF 2

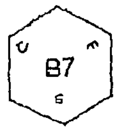
CARDINAL FASTENER & SPECIALTY CO., INC. / 5185 RICHMOND RD. BEDFORD HEIGHTS, OHIO 44146 / 216-831-3651

Attn: Wally Danko

Cardinal Fastener Test Certification

Reported: 10/20/2004

Certification No.:	20634	Shop Order#:	00226086
Order No.:	107489 1	Heat No.:	300187
Customer PO:	MDOH2236	Grade:	A193 b7
		Thread Class:	2a
Customer No.:	000000032108	Shipped Qty:	7
Customer:	FASTENAL MIDDLEBURG HTS, OH	Heat Treat Spec:	
Address:	17851 ENGLE ROAD MIDDLEBURG HTS, OH 44130	Supplier:	
		Finish Spec.:	
		Supplier:	
Manufacturer:	Cardinal Fastener & Specialty Co.,	Item description:	1 1/2 - 6 x 8: B7
Address:	5185 Richmond Road Bedford Heights, Ohio 44146	Headmark:	Heavy Hex Bolt
Laboratory:	Cardinal Fastener & Specialty Co.,		
Address:	5185 Richmond Road Bedford Heights, Ohio 44146		
Notes:			



Test No.: 28982 Order No.: 221531 0 Test Date: 6/18/2004 Test Disposition: PASS
Specification: MET_A193(1/2"TO1 3/4">=3D) -99 Test Facility: CFS
Tech. Name: DFD Tech. Title: LT LotSize(pcs/lbs): 557
Notes: Wedge Test Per ASTM A370 Sample Size: 1
Hardness Per ASTM E18
1100 Deg. Min Temper
Wedge Angle 10 Degrees

Inspection (min. - max.) units	Disposition	Sample Values:
HARDNESS (0, 35) Rc	PASS	33
TENSILE (125000, 999999) PSI	PASS	183566

Test No.: 28983 Order No.: 221531 0 Test Date: 6/18/2004 Test Disposition: PASS
Specification: MET_A193(1/2"TO2">=3D) -99 Specimen Test Facility: CFS
Tech. Name: DFD Tech. Title: LT LotSize(pcs/lbs): 557
Notes: Tensile Test Per ASTM A370 Sample Size: 1

1100 Deg. Min Temper

Inspection (min. - max.) units	Disposition	Sample Values:
TENSILE (125000, 999999) PSI	PASS	152000
YIELD (105000, 999999) PSI	PASS	140200
ELONGATION% (16, 999) %	PASS	16
REDUCTION IN AREA (50, 999) %	PASS	52

CARDINAL FASTENER & SPECIALTY CO., INC / 5185 RICHMOND RD. BEDFORD HEIGHTS, OHIO 44146 / 216.831.3681

AR 23-A

Test No.:	27669	Order No.:	300187 0	Test Date:	2/6/2004	Test Disposition:	PASS
Specification:	CHEM_GRADE 4140 HR					Test Facility:	ALTON STEEL INC
Tech. Name:	R CAULEY	Tech. Title:	QA			LotSize(pcs/lbs):	35184
Notes:	MACRO ETCH RESULTS: S2 R3 C2					Sample Size:	1

Inspection (min. - max.) units	Disposition	Sample Values:
CARBON (0, 999) %	PASS	0.41
MANGANESE (0, 999) %	PASS	0.79
PHOSPHORUS (0, 999) %	PASS	0.015
SULFUR (0, 999) %	PASS	0.025
SILICON (0, 999) %	PASS	0.027
COPPER (0, 999) %	PASS	0.22
NICKEL (0, 999) %	PASS	0.074
CHROMIUM (0, 999) %	PASS	0.939
MOLYBDENUM (0, 999) %	PASS	0.18
ALUMINUM (0, 999) %	PASS	0.004
VANADIUM (0, 999) %	PASS	0.038

Cert No: 20654

ALL MANUFACTURING AND MATERIAL PROCESSES IN THIS PRODUCT HAVE OCCURED WITHIN THE U.S.A. IN COMPLIANCE WITH THE BUY AMERICA PROVISIONS OF THE SURFACE TRANSPORTATION ACT OF 1982

All data represented on this report relates only to the item(s) tested, which have been sampled in order to represent the processed lot identified in the description.

Information and data in the report is correct and reliable to the best of our knowledge; however, results are not guaranteed and no responsibility is assumed.

All items furnished on the above referenced Purchase Order are in full conformance with all Purchase Order and Specification Requirements. Test values, either provided by our supplier or generated in Cardinal's Laboratory, represent actual attributes of the items furnished and the test results are in full compliance with all applicable specification and order requirements. All manufacturing, testing, sampling and inspections have been performed in accordance with Cardinal's Quality Assurance Program. All applicable tests are in accordance with the Quality Control Manual dated 4/24/98. The product was manufactured and supplied free from mercury contamination. This document may only be reproduced unaltered and only for the purpose of certifying the same or lesser quality of the product specified herein. Reproduction or alteration of this document for any other purpose is prohibited.

Denise L Merka
(Approval)

Q.A.
(Title)

10/20/2004
(Date Approved)

NOVA MACHINE PRODUCTS CORPORATION

18001 Sheldon Road
Middleburg Heights, OH
44130

216 267 3200
Fax 216 433 1640

MATERIAL TEST REPORT #0000029387 Page: 1

Date: 10/20/04

PO #: IC021254
Rel :
SO #: 0000080927
Line #: 42
Qty: 150 EA
Lot #: 0040012015
Heat #: US Y06420
Drwg: (50/BOX)

FASTENAL COMPANY
5851 GUION ROAD

INDIANAPOLIS, IN 46254

CL./STOCK: 0155558

DESC: 1"-8 UNC 2A x 4" HEAVY HEX SCREW

MATERIAL SPECIFICATIONS: ASTM A-193('01) Gr.B7
HEAT SPECIFICATIONS:
Quenched & tempered per the material specification, minimum tempering temperature: 1100 F

APPLICABLE SPECIFICATIONS:
ANSI/ASME B1.1 ANSI/ASME B18.2.1

QUALITY SPECIFICATIONS:
Domestic manufactured; This is a commercial grade item;

CHEMICAL TEST:
C .40 MN .92 P .012 S .005 SI .21 CU .02 NI .03 CR 1.01
MO .225 AL .034

MECHANICAL TEST:
TENSIL 135800PSI YIELD 116600PSI ELONG 21.4 REDUCT 59.1
HARD RC 30.5
MACRO ETCH: ACCEPTABLE

PROGRAM STATEMENT:
Nova Machine Products Corporation certifies that the material, parts, components or services supplied on this purchase order have been processed in accordance with, and therefore meet or exceed the quality requirements established by the references or specifications in this order. Maintained mercury free by Nova.

I certify that these results are a true and correct copy of records prepared and maintained by Nova Machine Products Corporation in compliance with the requirements of the purchase order and specifications cited.

Processed per ISO-9001('94)/ISO-9002, Certificate GQC 211. Fastener products received from Nova are FQA compliant.

Your salesperson is Beau Laslo
Please call day or night if you have any questions or comments.

SM Galaday QC
Sheila Galaday G, Quality Control

AR 23A

NOVA MACHINE PRODUCTS CORPORATION

18001 Sheldon Road
Middleburg Heights, OH
44130

216 267 3200
Fax 216 433 1640

CERT. OF COMPLIANCE/CONFORMANCE #0000029387 Page: 1

Date: 10/20/04

FASTENAL COMPANY
5851 GUION ROAD

INDIANAPOLIS, IN 46254

CL./STOCK:0155558

PO #: IC021254
Rel :
SO #: 0000080927
Line #: 42
Qty: 150 EA
Lot #: 0040012015
Heat #: US Y06420
Drwg: (50/BOX)

DESC: 1"-8 UNC 2A x 4" HEAVY HEX SCREW

MATERIAL SPECIFICATIONS: ASTM A-193('01) Gr.B7
HEAT SPECIFICATIONS:
Quenched & tempered per the material specification, minimum tempering temperature: 1100 F

APPLICABLE SPECIFICATIONS:
ANSI/ASME B1.1 ANSI/ASME B18.2.1

QUALITY SPECIFICATIONS:
Domestic manufactured; This is a commercial grade item;

PROGRAM STATEMENT:
Nova Machine Products Corporation certifies that the material, parts, components or services supplied on this purchase order have been processed in accordance with, and therefore meet or exceed the quality requirements established by the references or specifications in this order. Maintained mercury free by Nova.

I certify that these results are a true and correct copy of records prepared and maintained by Nova Machine Products Corporation in compliance with the requirements of the purchase order and specifications cited.

Processed per ISO-9001('94)/ISO-9002, Certificate GQC 211. Fastener products received from Nova are FQA compliant.

Your salesperson is Beau Laslo
Please call day or night if you have any questions or comments.

SM Galaday QC
Sheila Galaday G, Quality Control

Bethlehem
ethlehem Lukens Plate

TEST CERTIFICATE

CUSTOMER P.O.: J.C.R.2663
DESCRIPTION :
1 – RECTANGLE 2.5 -X- 96 -X- 480

FILE NO. 8462-01-01
DATE: 02/04/99
MILL ORDER NO: 33510-006

OLD TO: | SEND TO: | 03-C SHIP TO:
WAR
COR
P.O

WAR ... 44452

MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS AND SPECIFICATION(S):

STM A516 GR 70 YR 90   ASME SA516 GR 70 YR 96A

ATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH ISO 9002 ABS-QE CERT. NO. 30130

MELT/SLAB	C	MN	P	S	CU	SI	NI	CR	MO	V	TI	B	CB				PRACTICES
028 /5																	GS 7-8
R1028	.23	.97	.011	.009	.22	.21	.14	.14	.07	.002			.001				

TENSILES / CHARPY V IMPACTS

YLD (PSI	TENS X 100)	% ELONG 2"	% R.A.	TYPE	TEMP				MILS LATERAL EXPANSION			% SHEAR		
490	746	30.0												

OTHER TESTS PERFORMED

INFORMATION

GHT PER PIECE = 32671 LBS. 14850 KG.
241132 BVRY 5402

The American Tank & Fabricating Co.
MEETS THE REQUIREMENTS OF
ASME SA 516 Gr. 70 (1998 ed., 1999 add.)
FASRF
REVIEWED BY: PJC DATE 5/8/00

HEAT TREAT CYCLES - MATL. OR TESTS - DEG FAHR.

MATL.	TEST	NOM TEMP	MIN TEMP	MAX TEMP	HOLD MINS.	COOL METHOD	END TEMP
X	X	1650			0082	AC	

HEAT TREAT CYCLES - TESTS ONLY - DEG FAHR.

START END TEMP	NOM TEMP	MIN TEMP	MAX TEMP	HOLD MINS.	HEAT RATE MAX	COOL RATE MAX

HEREBY CERTIFY ... ABOVE INFORMATION IS CORRECT:
I NO. 2221...9...

Quality Assura... Laboratory
Coatesville ...20

Elinore Zaplitny
SUPERVISOR - TEST REPORTING

U. S. STEEL GROUP
A division of USX Corporation
01.000.0772 (REV. 8/91)

Metallurgical Test Report

USS, USX, USX are trademarks of USX Corp.

REQ. JOB CONTRACT NO.	P.O. DATE	PURCHASE ORDER NO.		
	11/21/97	01-74317		
	SHIPPERS NO.		MILL ORDER NO.	INVOICE NO.
	T04917	04 28 98	UM55692	151-185488
	VEHICLE NUMBER 28		IL	37967

VENDOR
GARY WORKS
GARY, INDIANA 46402

** MELTED AND MANUFACTURED IN THE USA **

SOLD TO
A M CASTLE & CO
3400 NORTH WOLF ROAD
FRANKLIN PARK IL 60131-1319

SHIP TO
A M CASTLE & CO
3400 NORTH WOLF ROAD
DAY #4
FRANKLIN PARK IL

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MFGD., SAMPLED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS REQUIREMENTS IN SUCH RESPECT.

PREPARED BY THE OFFICE OF:
S.C.PARK GEN.MGR. Q.A.

5-1-98

PART NO: PT#I.A.C.26136-- ** NAFTA CERTIFIED AS NORTH AMERICAN DOMESTIC **

SPEC. & INSP.
PLATE CARBON ASTM A516-*90 GRADE 70 ASME SA516-*1995 EDITION, 96
ADDENDA, DECEMBER 31,1996 GRADE 70 A M CASTLE AND CO SPEC
K02700-67 REV 5 DATED 8/2/96 PRESSURE VESSEL QUALITY NORMALIZE
REST FLATNESS TOL 1/2 STD
INSP:01 MILL RA/SR ALSO RA/LT CERTIFIED T/R WITH LOAD ANALYSIS MERCURY
FREE STATEMENT REQUIRED

ITEM NO.	MATERIAL DESCRIPTION			QUANTITY	WEIGHT	HEAT NO.	TEST OR PIECE IDENTITY	YIELD PT.	TENSILE STR.	ELONGATION %		% RED. OF AREA	BEND
	THICKNESS OR SECTION	WIDTH OR OD	LENGTH					KSI	KSI	IN 8"	IN 2"		
03	5.0000	96.0000	240"	01	39205	Y55720	34W 1						
	STEEL-TYPE = INGOT												
							34W 1 *	47.0	78.0		25.0		

PRODUCT & TEST SPECIMENS WERE NORMALIZED AT 1660 DEG.F.
FOR 0192 MINUTES.COOLING COMPLETED IN STILL AIR.
END OF DATA

CASTLE METALS - FP
DATE REC'D 5/4/98
REC'D FROM
APPROVED BY

*YIELD STRENGTH @ 0.5% E.U.L.

THIS REPORT SHALL NOT BE REPRODUCED WITHOUT THE PRIOR WRITTEN APPROVAL OF THE USX CORPORATION.

HEAT NO.	TYPE	C	MN	P	S	SI	CU	NI	CR	MO	SN	AL	N	V	B	TI	CB	CO	
Y55720	HEAT	25	095	011	009	22	02	02	05	01		029		001			001		FINE GRAIN
END OF DATA																			

ALL TEST RESULTS WERE CONDUCTED AND RECORDED IN ACCORDANCE WITH TEST METHODS ACCREDITED BY A2LA

MATRIX DECIMAL POSITIONS FOR ELEMENTS ARE INDICATED BY THE LEFT MARGIN, VERTICAL DOTTED LINE OR DECIMAL POINT.

...oUP
...sX Corporation
...40772 (REV.8/97)

Metallurgical Test Report

USS, USX, ... are trademarks of USX Corp.

P.O. DATE	PURCHASE ORDER NO.		
11/21/97	01-74317		
SHIPPERS NO.		MILL ORDER NO.	INVOICE NO.
704917 04 28 98		UM85692	154-486488
VEHICLE NUMBER 28		IL	37967

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MFGD., SAMPLED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS REQUIREMENTS IN SUCH RESPECT. Meo

PREPARED BY THE OFFICE OF:
A.C.PAPE GEN.MGR, Q.A.

VENDOR: GARY WORKS
GARY, INDIANA 46402

** MELTED AND MANUFACTURED IN THE USA **

SOLD TO: A M CASTLE & CO
3400 NORTH WOLF ROAD
FRANKLIN PARK IL 60131-1319

SHIP TO: A M CASTLE & CO
3400 NORTH WOLF ROAD
BAY #4
FRANKLIN PARK IL

PART NO: PT*L.A.C.26136-- ** NAFTA CERTIFIED AS NORTH AMERICAN DOMESTIC ** 5-1-98

SPEC. & INSP.: PLATE CARBON ASTM A516-*90 GRADE 70 ASME SA516-*1995 EDITION, 96 ADDENDA, DECEMBER 31,1996 GRADE 70 A M CASTLE AND CO SPEC K02700-67 REV 5 DATED 6/2/96 PRESSURE VESSEL QUALITY NORMALIZE REST FLATNESS TOL 1/2 STD
INSP:01 MILL RA/SM ALSO RA/LT CERTIFIED T/R WITH LOAD ANALYSIS MERCURY FREE STATEMENT REQUIRED

ITEM NO.	MATERIAL DESCRIPTION: THICKNESS OR SECTION	WIDTH DIA OR LB. WT.	LENGTH	QUANTITY	WEIGHT	HEAT NO.	TEST OR PIECE IDENTITY	YIELD PT.	TENSILE STR.	ELONGATION % IN 8"	ELONGATION % IN 2"	% RED. OF AREA	BEND
	MERCURY OR MERCURY BEARING COMPOUNDS ARE NOT USED IN THE MANUFACTURE OF THIS MATERIAL.												
	END OF DATA												

HEAT NO.	TYPE	C	MN	P	S	SI	CU	NI	CR	MO	SN	AL	N	V	B	TI	CB	CO
END OF DATA																		

ALL TEST RESULTS WERE CONDUCTED AND RECORDED IN ACCORDANCE WITH TEST METHODS ACCREDITED BY A2LA
MATRIX DECIMAL POSITIONS FOR ELEMENTS ARE INDICATED BY THE LEFT MARGIN, VERTICAL DOTTED LINE OR DECIMAL POINT.

09/15/2004 From: AMERICAN ALLOY STEEL To: AMERICAN TANK & FABRICATING
P.O.# :054337-00 S.O.# :37811-NY AA PL#:8024766
Item :1 (1 PC) 3" X 96" X 60" :
:ISG HEAT# U0624 ALREADY APPROVED

ISG PLATE INC. TEST CERTIFICATE

SHIP TO:
AMERICAN ALLOY STEEL INC
C/O B & R MARINE SVS
PORT OF GREATER BATON ROUGE
TRACK #791
PORT ALLEN LA 70767

PAGE NO: 01 OF 02
FILE NO: 0284-01-20
MILL ORDER NO: 85476-001
MELT NO: U0624
SLAB NO: 4
DATE: 04/09/04

SOLD TO:
AMERICAN ALLOY STEEL, INC
P. O. BOX 40469
HOUSTON TX 77240-0469

SEND TO:
AMERICAN ALLOY STEEL, INC
P. O. BOX 40469
ATTN: HOMER GARZA
HOUSTON, TX 77240-0469

02-C

P L A T E D I M E N S I O N S / D E S C R I P T I O N

TOTAL QTY	GAUGE	WIDTH	LENGTH	DESCRIPTION	PIECE WEIGHT
1	3"	96"	480"	RECTANGLE	39205#

C U S T O M E R I N F O R M A T I O N

CUSTOMER PO: 57082-LA

S P E C I F I C A T I O N (S)

THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS AND SPECIFICATION(S).

API 2H-8TH-EDITION YR 99 GR 50 S1 S3 S4
SUPPL. PARA. S5 & SUPPL. PARA. S12
SPEC MOD FOR PHYSICALS
SPEC MOD FOR CARBON
ASME SA537 99 CLASS 1 MODIFIED TO .04 MAX CB,
ABS PART 2-SECT-1 00 GRS EH36/DH36, ASTM A633
95 GR C AND MIL-S-22698C GR DH36
MATERIAL PRODUCED UNDER A CERTIFIED QUALITY MGMT SYSTEM COMPLYING WITH ISO 9001 ABS-QE CERT. NO. 30130

Certified a true copy of the original, retained in our file.
AMERICAN ALLOY STEEL, INC.
DG 5/3/04

C H E M I C A L C O M P O S I T I O N

	C	MN	P	S	CU	SI	NI	CR	MO
MELT:U0624	.14	1.53	.008	.002	.14	.37	.09	.10	.03

	V	TI	B	AL	CB	CA	N	CEF
MELT:U0624	.001	.004	.0004	.041	.031	.002	.0077	.44

CARBON EQUIVALENT FORMULA (CEF)
CEF = C + (MN * .1667) + ((CR + MO + V) * .2000) + ((CU + NI) * .0667)

M A N U F A C T U R E

FINELINE - VACUUM DEGASSED - FINE GRAIN PRACTICE

AMERICAN BUREAU OF SHIPPING ABS PHILADELPHIA

H E A T T R E A T C O N D I T I O N

MATL OR TEST	HEAT TREAT DESCRIPTION	NOM TEMP	HOLD MINS	COOL MTHD
PL/TEST	NORMALIZE	1650F	106	AIR COOL

PA514374

36809

AMERICAN ALLOY PLATE # 8024766

WE HEREBY CERTIFY THE ABOVE INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

MEETS THE REQUIREMENTS
ASTM A 633 Grade E pg 1 of 2
9-22-04

po# 54337-
so# 40945-00

From: AMERICAN ALLOY STEEL   To: AMERICAN TANK & FABRICATING
P.O.# :054337-00   S.O.# :37811-NY   AA PL#:8024766
Item :1 (1 PC) 3" X 96" X 60"
:ISG HEAT# U0624 ALREADY APPROVED

ISG PLATE INC.   T E S T   C E R T I F I C A T E

PAGE NO: 02 OF 02
FILE NO: 0284-01-20
MILL ORDER NO: 85476-001
MELT NO: U0624
SLAB NO: 4
DATE: 04/09/04

T E N S I L E   P R O P E R T I E S

SLAB NO.	LOC	DIR	YIELD STRENGTH PSI X 100	TENSILE STRENGTH PSI X 100	ELONGATION GAGE LGTH	%	%R.A.
4	BOT.	THRU GA.	—	—	—		71.0
4	TOP	THRU GA.					69.0
4	BOT.	TRANS.	559	807	2.00"	30.0	

CHARPY V-NOTCH IMPACT RESULTS

SLAB	LOC	DIR	TEMP	SIZE	FT. LBS.
4	BOT.	TRANS.	-40F	FULL	90 133 135

D R O P   W E I G H T   T E S T I N G

LOC	DIR	SIZE	DEPTH	TEMP	RSLT	TEMP	RSLT
BOT.	LONG.	P3	SURF	-30F	NB	-30F	NB

G E N E R A L   I N F O R M A T I O N

ALL STEEL HAS BEEN MELTED AND MANUFACTURED IN THE U.S.A.
A.B.S. Q.A. CERTIFICATE 00-QA1415-X.
MATERIAL HAS BEEN VACUUM DEGASSED AND CALCIUM TREATED
FOR SULFIDE SHAPE CONTROL.
FINELINE MOD FOR SULPHUR
TEST CERTS. ARE PREPARED IN ACCORD. WITH PROCEDURES
OUTLINED IN DIN 50049 3.1.B/EN 10204 3.1.B.

B/L# 36809 UP 262082
PCM = .25

Certified a true copy of the
original, retained in our file.
AMERICAN ALLOY STEEL, INC.

MEETS THE REQUIREMENTS
ASTM A 633 Grade E pg 2 of 2
J R 9-22-04

PO# 54337
SO# 40945-00

WE HEREBY CERTIFY THE ABOVE
INFORMATION IS CORRECT:

QUALITY ASSURANCE LABORATORY
COATESVILLE, PA 19320

Elinore Zaplitny
SUPERVISOR - TEST REPORTING
ELINORE ZAPLITNY

WVMP SAR Reference 8-13

Supplier Surveillance Reports SR-13-078 (10/31/2013) and SR-13-085 (11/06/2013), CH2M Hill-B&W West Valley, LLC, West Valley, New York, 2013.

SUPPLIER SURVEILLANCE REPORT

No: SR - 13 - 078

PAGE 1 OF 1

PO No (Suppl.): Ch-001821	COG. ENGR. Neil Armknecht	SPEC. No. (Rev.): N/A

SURV. DATE: 10/31/2013

SUPPLIER SURVEYED: GeoScience Group, Inc. 86 Gunville Rd. Lancaster, NY 14086

ORIGINAL

PERSON(S) CONTACTED:

Mick Honeck, Geo-Science Group, Inc. Project Executive
Linda Michalczak, CHBWV Project Manager
Kenneth Koleff, QISI Field Test Specialist
Ernie Kihl, QISI Field Test Specialist
Neil Armknecht, Cognizant Engineer
Dan Sullivan, DOE-WVDP

SURVEILLANCE OBJECTIVES: (Reference & Describe applicable compliance/performance criteria)

Witness grout/foam mixing to ensure the following:

1. Verify wet density of grout in accordance with ASTM C-138. (Req'd 68-72 PCF)
2. Observe casting of test cylinders per PO Scope of Work and ASTM C495/C495M
3. Verify calibration of equipment used for density measurement.
4. Verify that qualified field test personnel are present (Ernie Kihl) as approved on 9/17/13.

COPY

SUMMARY (RESULTS/COMMENTS): [X] Satisfactory [ ] Unsatisfactory [ ] Indeterminate

1. Liquid Concentrate (foaming agent) was added to the cement drum for timed intervals (i.e. 50 sec.) to determine the best grout mix design based on the wet density measurement. Four trucks were brought onsite to grout the melter. Density measurements were witnessed for the first three, results are listed below:

   a. Truck #1 reached a wet density of 71.6 PCF, additional tests verified stability of grout mix.

   b. Truck #2 reached a wet density of 71.2 PCF which also stayed consistent.

   c. Truck #3 reached a wet density of 70.4 PCF

   SATISFACTORY

2. Test cylinders (20 – 3" X 6" and 2 – 6" X 12") were cast from the grout in truck #1, and 8 from the remaining three trucks. Cylinders were stored in a cure box awaiting delivery to the QISI-ApplusRTD, test facility.

   SATISFACTORY

3. Calibration of the equipment used for wet density measurement and calculation (i.e. bucket #QC0032 and scale #3771) was verified and found to be up-to-date (the test bucket was recalibrated on 10/25/2013).

   SATISFACTORY

4. The field testing was performed by Ernie Kihl of QISI, ApplusRTD with assistance from Ken Koleff, also of QISI. Documentation of his qualification(s) were submitted and approved by CHBWV. **SATISFACTORY**

The weight of the melter at this point was calculated at 357,000 lbs.

Hold Point Release No: N/A SNR No. N/A Issue Report No. N/A

Linda M. Lund / Linda M. Lund — 10/31/2013

Quality Assurance Representative — Date

cc: QADCC; QAM; Procurement & Contracts; Cognizant Engineer Neil Armknecht MS- PL-6; QA PO File

SUPPLIER SURVEILLANCE REPORT

No: SR - 13 - 085

PO No (Suppl.): Ch-001821	COG. ENGR. Neil Armknecht	SPEC. No. (Rev.): N/A

SURV. DATE: 11/04/2013	SUPPLIER SURVEYED: GeoScience Group, Inc. 86 Gunville Rd. Lancaster, NY 14086

PERSON(S) CONTACTED:

Mick Honeck, Geo-Science Group, Inc. Project Executive
Linda Michalczak, CHBWV Project Manager
Dan Sullivan, DOE-WVDP
Mason Smith, QISI Field Test Specialist
Neil Armknecht, Cognizant Engineer

SURVEILLANCE OBJECTIVES: (Reference & Describe applicable compliance/performance criteria)

Witness grout/foam mixing to ensure the following:

1. Verify wet density of grout in accordance with ASTM C-138. (Req'd 68-72 PCF)
2. Observe casting of test cylinders per PO Scope of Work and ASTM C495/C495M
3. Verify calibration of equipment used for density measurement.
4. Verify that qualified field test personnel are present.

COPY

SUMMARY (RESULTS/COMMENTS): [X] Satisfactory [ ] Unsatisfactory [ ] Indeterminate

1. Liquid Concentrate (foaming agent) was added to the cement drum for timed intervals (i.e. 50 sec.). Foamed cement was tested from each truck to verify the ASTM C-138 required wet density measurement (68-72 PCF). Four trucks were brought onsite to complete the project of grouting the melter. Density measurements were witnessed for all four, results are listed below:

   a. Truck #1 reached a wet density of 70.80 PCF, additional test of the concrete/foam mix taken from the sample spout after pumping into the melter for 5 minutes showed 84.15 PCF. The operation was ceased and the truck sent away.
   b. Truck #2 reached a wet density of 68.75 PCF. ***At this time, the unofficial weight was recorded at 370,025 #***
   c. Truck #3 reached a wet density of 69.3 PCF.
   d. Truck #4 reached a wet density of 70.12 PCF.

   SATISFACTORY

2. Test cylinders (20 - 3" X 6" and 2 - 6" X 12") were cast from the grout in truck #1, and 8 from the remaining three trucks. Cylinders were stored in a cure box awaiting delivery to the QISI-ApplusRTD. test facility. See photos #2 & #3-Attachment A. **SATISFACTORY**

3. Calibration of the equipment used for wet density measurement and calculation (i.e. bucket #Q416 and scale #3153) was verified and found to be up-to-date (test bucket was calibrated on 10/16/2013, scale calibrated 1/22/2013).

   SATISFACTORY

4. The field testing was performed by Mason Smith of QISI, ApplusRTD (Certification –Attachment B).

   SATISFACTORY

The weight of the melter at this point was calculated at 381,539 lbs. (see Attachment C)

Safety observation: Spoils containers for runoff and rinsate were available and hazard marking was visible. (See photo #1)

Hold Point Release No: N/A SNR No. N/A Issue Report No. N/A

Linda M. Lund / *Linda M. Lund* — 11/06/2013

Quality Assurance Representative — Date

cc:	QADCC	QAM	Procurement & Contracts
	Cognizant Engineer Neil Armknecht	MS- PL-6	QA PO File

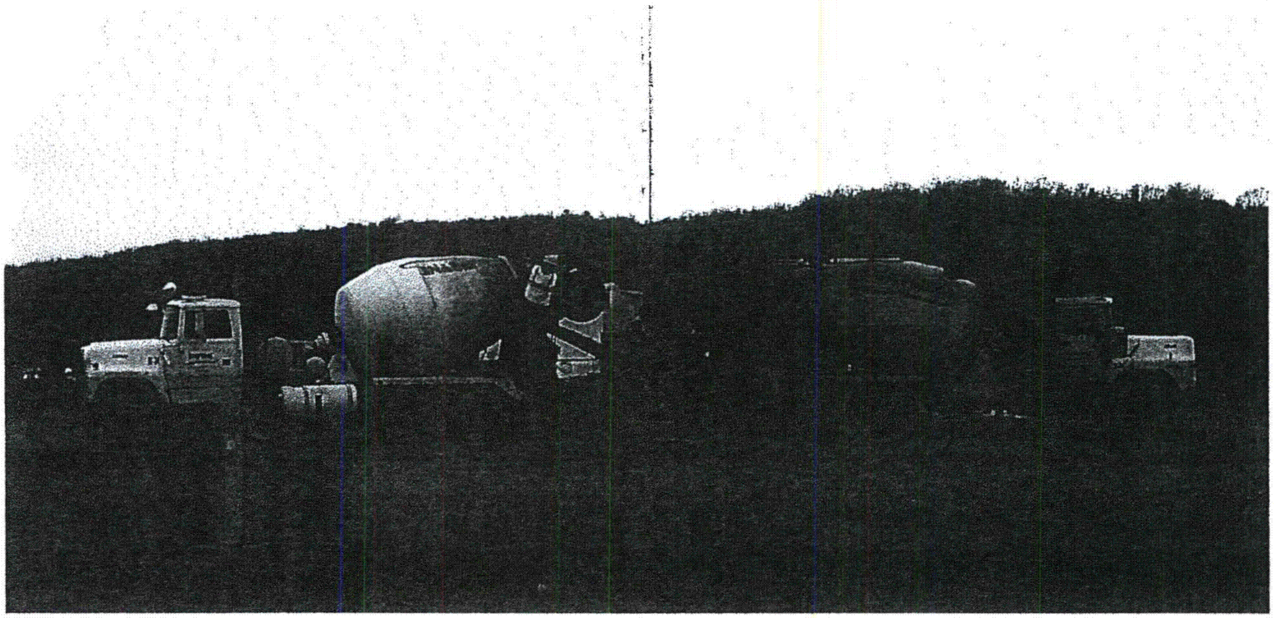


Photo 1 – excess foamed cement and water runoff was collected in labeled catch basins

Photo 2 – casting cylinders

Photo 3 – due to inclement weather, cylinders were placed in cure boxes

SR-13-085
Attachment B
Pg 3 of 4

AMERICAN CONCRETE INSTITUTE

This is to certify that

MASON P SMITH

has demonstrated knowledge and ability by successfully completing the ACI Certification requirements and is hereby recognized as an

ACI Concrete Field Testing Technician - Grade I

Certified Date: 08/10/2013 **Expires:** 08/10/2018

Examiner of Record: Donald E Borkowski

ACI Managing Director of Certification

The Authenticity of this certification can be verified at www.ACICertification.org/verify

Melter Container TC-474 Weight

Melter package was weighed using four Enerpac RSC-1002 hydraulic cylinders.

Each cylinder has an effective area of 19.63 square inches.

Individual cylinder pressures (per calibrated gauges) as follow:

Cylinder 1 = 5000 psi

Cylinder 2 = 4850 psi

Cylinder 3 = 4800 psi

Cylinder 4 = 4950 psi

Total = 19600 psi

Mult. by effective area of cylinder = 19.63 in sq

Therefore = 384,748 lbs current weight

Calculated weight of lift lug = 790.98 lbs., mult four lugs = 3163.92 lbs

Weight of 1" – 8UNC x 4" Bolt with washer = 1.25 lbs mult 36 bolts = 45 lbs

Therefore = 384,748 lbs

- 3,163.92 lbs
- 45 lbs

Total for package = 381,539 lbs

WVMP SAR Reference 8-14

Grout Compressive Strength Test Reports, ASTM C-1019, Ticket Numbers 522, 523, 524, 526, 544, 546, and 547, Quality Inspection Services, Inc., Buffalo, New York, December 9, 2013.

Applus® RTD

Quality Inspection Services, Inc.

GROUT COMPRESSIVE STRENGTH TEST REPORT
(ASTM C-1019)

Project: West Valley Cellular Grout

Client: Geo Science

Contractor: N/A

Project No.: 1101-13-CIV-0073 Set No.: WVWP-8

Supplier: N/A

Cylinder Compression Machine Q #: 3964 Cal. due date: 01/21/14

Mix Data: Grout Ticket No.: 522

Date Molded: 10/31/13 Date Received: 11/04/13

Condition Received: Good # of Cylinders in Set: 22

Cubic Yards Placed: 6 Truck No: M24

Placement Location: First lift in Melter Box

Specimens Cast By: E. Kihl Unit Wt. (ASTM C138): 71.6

Batch Time: 9:31 AM Cylinder Cast Time: 10:45 AM

Concrete Temperature (C-1064): 65°F Air Temperature: 56°F

Slump (C-143): N/A Air Content (C-173 / C-231): N/A

Strength Specific. @ 28 Days: 1000 PSI Water Added On Site: N/A

Remarks: Stable Air Foam added prior to pumping

COMPRESSIVE STRENGTH DATA

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
193	11-07-13	7	7.16	7850	1100
194	11-07-13	7	7.21	12400	1720
195	11-07-13	7	7.16	11750	1640
196	11-07-13	7	7.21	9400	1300
197	11-14-13	14	7.16	9120	1270
198	11-14-13	14	7.16	8890	1240
199	11-14-13	14	7.16	9630	1340
200	11-14-13	14	7.12	8990	1260
201	11-21-13	21	7.07	7740	1090
202	11-21-13	21	7.07	7940	1120
203	11-21-13	21	7.07	9350	1320
204	11-21-13	21	7.12	8960	1260
205	11-28-13	28	7.12	9970	1400
206	11-28-13	28	7.07	9860	1390
207	11-28-13	28	7.07	9910	1400
208	11-28-13	28	7.12	10030	1410

Applus® RTD

Q I S I

Quality Inspection Services, Inc.

GROUT COMPRESSIVE STRENGTH TEST REPORT
(ASTM C-1019)

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
209	1-23-14	56			
210	1-23-14	56			
211	1-23-14	56			
212	1-23-14	56			
213	UW	28			63.8
214	UW	28			64.5

12/9/13

Respectively Submitted,
Quality Inspection Services, Inc.

Date

For Job Satisfaction - Think Quality

Form TP 1.8-2
Rev. 1

Applus® RTD

Quality Inspection Services, Inc.

GROUT COMPRESSIVE STRENGTH TEST REPORT (ASTM C-1019)

Project: West Valley Cellular Grout

Client: Geo Science

Contractor: N/A

Project No.: 1101-13-CIV-0073 Set No.: WVWP-9

Supplier: Wayne Concrete

Cylinder Compression Machine Q #: 3964 Cal. due date: 01/21/14

Mix Data: Grout Ticket No.: 523

Date Molded: 10/31/13 Date Received: 11/04/13

Condition Received: Good # of Cylinders in Set: 8

Cubic Yards Placed: 6 Truck No: M56

Placement Location: First lift in Melter Box

Specimens Cast By: E. Kihl Unit Wt. (ASTM C138): 71.2

Batch Time: 10:58 AM Cylinder Cast Time: 12:10 PM

Concrete Temperature (C-1064): 67°F Air Temperature: 56°F

Slump (C-143): N/A Air Content (C-173 / C-231): N/A

Strength Specific. @ 28 Days: 1000 PSI Water Added On Site: N/A

Remarks: Stable Air Foam added prior to pumping

COMPRESSIVE STRENGTH DATA

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
215	11-14-13	14	7.16	6870	960
216	11-14-13	14	7.12	6710	940
217	11-14-13	14	7.12	6690	940
218	11-14-13	14	7.16	6760	940
219	11-28-13	28	7.12	7180	1010
220	11-28-13	28	7.12	7230	1020
221	11-28-13	28	7.07	7610	1080
222	11-28-13	28	7.12	8060	1130

[signature] 12/9/13

Respectively Submitted,
Quality Inspection Services, Inc. *Date*

For Job Satisfaction - Think Quality

Form TP 1.8-2

Applus® RTD

Quality Inspection Services, Inc.

GROUT COMPRESSIVE STRENGTH TEST REPORT (ASTM C-1019)

Project: West Valley Cellular Grout

Client: Geo Science

Contractor: N/A

Project No.: 1101-13-CIV-0073 Set No.: WVWP-10

Supplier: Wayne Concrete

Cylinder Compression Machine Q #: 3964 Cal. due date: 01/21/14

Mix Data: Grout Ticket No.: 524

Date Molded: 10/31/13 Date Received: 11/04/13

Condition Received: Good # of Cylinders in Set: 8

Cubic Yards Placed: 6 Truck No: M44

Placement Location: First lift in Melter Box

Specimens Cast By: E. Kihl Unit Wt. (ASTM C138): 70.4

Batch Time: 11:51 AM Cylinder Cast Time: 1:00 PM

Concrete Temperature (C-1064): 64°F Air Temperature: 56°F

Slump (C-143): N/A Air Content (C-173 / C-231): N/A

Strength Specific. @ 28 Days: 1000 PSI Water Added On Site: N/A

Remarks: Stable Air Foam added prior to pumping

COMPRESSIVE STRENGTH DATA

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
223	11-14-13	14	7.16	19010	2660
224	11-14-13	14	7.12	16900	2370
225	11-14-13	14	7.21	24370	3380
226	11-14-13	14	7.16	20960	2930
227	11-28-13	28	7.12	26420	3710
228	11-28-13	28	7.12	23800	3340
229	11-28-13	28	7.07	24120	3410
230	11-28-13	28	7.06	30380	4240

[signature] 12/9/13

Respectively Submitted *Date*

Quality Inspection Services, Inc.

For Job Satisfaction - Think Quality

Form TP 1.8-2

Applus® RTD

Quality Inspection Services, Inc.

GROUT COMPRESSIVE STRENGTH TEST REPORT (ASTM C-1019)

Project: West Valley Cellular Grout

Client: Geo Science

Contractor: N/A

Project No.: 1101-13-CIV-0073 Set No.: WVWP-11

Supplier: Wayne Concrete

Cylinder Compression Machine Q #: 3964 Cal. due date: 01/21/14

Mix Data: Grout Ticket No.: 526

Date Molded: 10/31/13 Date Received: 11/04/13

Condition Received: Good # of Cylinders in Set: 8

Cubic Yards Placed: 6 Truck No: M24

Placement Location: First lift in Melter Box

Specimens Cast By: E. Kihl Unit Wt. (ASTM C138): 68.0

Batch Time: 12:55 PM Cylinder Cast Time: 1:50 PM

Concrete Temperature (C-1064): 67°F Air Temperature: 56°F

Slump (C-143): N/A Air Content (C-173 / C-231): N/A

Strength Specific. @ 28 Days: 1000 PSI Water Added On Site: N/A

Remarks: Stable Air Foam added prior to pumping

COMPRESSIVE STRENGTH DATA

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
231	11-14-13	14	7.12	18240	2560
232	11-14-13	14	7.12	26570	3730
233	11-14-13	14	7.16	31980	4470
234	11-14-13	14	7.16	29980	4190
235	11-28-13	28	7.12	29680	4170
236	11-28-13	28	7.07	29780	4210
237	11-28-13	28	7.02	24750	3530
238	11-28-13	28	7.07	29580	4180

[signature] 12/9/13

Respectively Submitted, Date
Quality Inspection Services, Inc.

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Quality Inspection Services, Inc.

GROUT COMPRESSIVE STRENGTH TEST REPORT (ASTM C-1019)

Project: West Valley Cellular Grout

Client: Geo Science

Contractor: N/A

Project No.: 1101-13-CIV-0073 Set No.: WVWP-12

Supplier: Wayne Concrete

Cylinder Compression Machine Q #: 3964 Cal. due date: 01/21/14

Mix Data: Grout Ticket No.: 544

Date Molded: 11/04/13 Date Received: 11/07/13

Condition Received: Good # of Cylinders in Set: 22

Cubic Yards Placed: 6 Truck No: M53

Placement Location: Second lift in Melter Box

Specimens Cast By: M. Smith Unit Wt. (ASTM C138): 68.8

Batch Time: 12:49 PM Cylinder Cast Time: 1:15 PM

Concrete Temperature (C-1064): 64°F Air Temperature: 31°F

Slump (C-143): N/A Air Content (C-173 / C-231): N/A

Strength Specific. @ 28 Days: 1000 PSI Water Added On Site: N/A

Remarks: Stable Air Foam added prior to pumping

COMPRESSIVE STRENGTH DATA

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
239	11-11-13	7	7.16	8000	1120
240	11-11-13	7	7.12	7100	1000
241	11-11-13	7	7.12	7850	1100
242	11-11-13	7	7.16	7400	1030
243	11-18-13	14	7.07	8650	1220
244	11-18-13	14	7.12	7680	1080
245	11-18-13	14	7.12	9300	1310
246	11-18-13	14	7.12	7700	1080
247	11-25-13	21	7.07	7990	1130
248	11-25-13	21	7.07	8800	1240
249	11-25-13	21	7.12	9100	1280
250	11-25-13	21	7.12	9350	1310
251	12-02-13	28	7.16	10790	1510
252	12-02-13	28	7.21	10250	1420
253	12-02-13	28	7.21	12370	1720
254	12-02-13	28	7.21	11240	1560

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GROUT COMPRESSIVE STRENGTH TEST REPORT (ASTM C-1019)

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
255	12-30-13	56			
256	12-30-13	56			
257	12-30-13	56			
258	12-30-13	56			
259	UW	28			62.6
260	UW	28			64.1

12/31/13

Respectively Submitted,
Quality Inspection Services, Inc.

Date

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Form TP 1.8-2
Rev. 1

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Quality Inspection Services, Inc.

GROUT COMPRESSIVE STRENGTH TEST REPORT (ASTM C-1019)

Project: West Valley Cellular Grout

Client: Geo Science

Contractor: N/A

Project No.: 1101-13-CIV-0073 Set No.: WVWP-13

Supplier: Wayne Concrete

Cylinder Compression Machine Q #: 3964 Cal. due date: 01/21/14

Mix Data: Grout Ticket No.: 546

Date Molded: 11/04/13 Date Received: 11/07/13

Condition Received: Good # of Cylinders in Set: 8

Cubic Yards Placed: 6 Truck No: M24

Placement Location: Second lift in Melter Box

Specimens Cast By: M. Smith Unit Wt. (ASTM C138): 69.3

Batch Time: 1:25 PM Cylinder Cast Time: 2:00 PM

Concrete Temperature (C-1064): 65°F Air Temperature: 31°F

Slump (C-143): N/A Air Content (C-173 / C-231): N/A

Strength Specific. @ 28 Days: 1000 PSI Water Added On Site: N/A

Remarks: Stable Air Foam added prior to pumping

COMPRESSIVE STRENGTH DATA

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
261	11-18-13	14	7.12	16350	2300
262	11-18-13	14	7.12	10550	1480
263	11-18-13	14	7.12	13400	1880
264	11-18-13	14	7.12	12850	1800
265	12-02-13	28	7.16	13290	1860
266	12-02-13	28	7.12	14160	1990
267	12-02-13	28	7.16	11090	1550
268	12-02-13	28	7.21	17110	2370

[signature] 12/9/13

Respectively Submitted, Date

Quality Inspection Services, Inc.

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Quality Inspection Services, Inc.

GROUT COMPRESSIVE STRENGTH TEST REPORT (ASTM C-1019)

Project: West Valley Cellular Grout

Client: Geo Science

Contractor: N/A

Project No.: 1101-13-CIV-0073 Set No.: WVWP-14

Supplier: Wayne Concrete

Cylinder Compression Machine Q #: 3964 Cal. due date: 01/21/14

Mix Data: Grout Ticket No.: 547

Date Molded: 11/04/13 Date Received: 11/07/13

Condition Received: Good # of Cylinders in Set: 8

Cubic Yards Placed: 6 Truck No: M44

Placement Location: Second lift in Melter Box

Specimens Cast By: M. Smith Unit Wt. (ASTM C138): 70.1

Batch Time: 3:14 PM Cylinder Cast Time: 3:40 PM

Concrete Temperature (C-1064): 63°F Air Temperature: 31°F

Slump (C-143): N/A Air Content (C-173 / C-231): N/A

Strength Specific. @ 28 Days: 1000 PSI Water Added On Site: N/A

Remarks: Stable Air Foam added prior to pumping

COMPRESSIVE STRENGTH DATA

Laboratory #	Date Tested	Age (Days)	Cross Sectional Area (in^2)	Maximum Load (lbs)	Compressive Strength (PSI)
269	11-18-13	14	7.16	9850	1380
270	11-18-13	14	7.12	9750	1370
271	11-18-13	14	7.16	10150	1420
272	11-18-13	14	7.07	13900	1970
273	12-02-13	28	7.12	11210	1570
274	12-02-13	28	7.16	10030	1400
275	12-02-13	28	7.16	12690	1770
276	12-02-13	28	7.21	13360	1850

12/9/13

Respectively Submitted, *Date*

Quality Inspection Services, Inc.

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Form TP 1.8-2

WVMP SAR Reference 8-15

West Valley Melter Package (WVMP) — Comparison of AWS D1.1, Structural Welding Code and ASME Section III, Subsection ND Welding Requirements, SRNL-L4430-2015-00001, D.N. Maxwell, SRNL Material Science and Technology. March 2015

Date: 3/27/2015

To: J.L. England
Program Manager, Packaging Technology
R&D Engineering

From: D.N. Maxwell
SRNL/MS&T, Material Science and Technology

West Valley Melter Package (WVMP) – Comparison of AWS D1.1, Structural Welding Code and ASME Section III, Subsection ND Welding Requirements

The WVMP is fabricated of low alloy carbon steel materials joined by using the welding processes of flux core arc welding (FCAW), gas tungsten arc welding (GTAW), shielded metal arc welding (SMAW), and submerged arc welding (SAW). Requirements for use of these welding processes, fabrication, and all welding performed on this melter package were in accordance with the American Welding Society (AWS) D1.1 Structural Welding Code – Steel, 1998 Edition (AWS D1.1).

The melter package was manufactured by American Tank and Fabricating of Cleveland, Ohio.

Prior to use, the melter package is required to meet or provide an equivalent level of safety to NUREG/CR -3019, UCRL-53044, RM, *Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials* (NUREG/CR-3019), Category II containment related welds. This criterion is based on the requirements of the American Society of Mechanical Engineers (ASME) Section III, Division 1, Subsection ND, 2004 Edition (ASME Section III ND).

The following entails a comparison of the welding requirements set forth by the specified code and standards based on review of the WVMP welding documentation package[1].

[1] Welding Documentation Package included - WMG Inc, West Valley Melter Container drawings 4005-DW-001, pages 1 thru 8, weld records, weld map, MT & VT reports, CMTR's, load test, welder qualifications, WPS's & PQRs, and NDE qualifications.

WELDING REQUIREMENTS			
NUREG/CR-3019 – *Containment Related Welds*, Category I; ASME Section III, Sub. ND	**Fabrication Recorded Attributes/Code of Record – AWS D1.1, 1998 Edition**	**Equivalency**	**Differences Identified**
Base Materials – *ND-2000 (except ND-2300 and ND-4100)* NUREG/CR-3019 and ASME Subsection ND require fracture toughness testing. ND-2121(a) - Pressure retaining material shall conform to the requirements of one of the specifications for materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1…..	Base materials approved for use – A36, A572 grade 50/60 (sub. A633 E/C), A516 grade 70 – Thickness (1/8" 1/2", 1", 2", 4" 6")	Base materials approved by ASME and AWS, same SA (ASME specification designation) and ASTM specifications as applicable.	No fracture toughness documentation is contained in the welding documentation package for base or weld material except for ASTM A633 Grade E (3" x 93" x 330"). A633 was an allowable substitution for A572 Grade 60 material. Reference drawing 4005-DW-001, Revision 4, Sheet 1 of 8, General Note 13. .
ND 2121(e) – "Welding and brazing materials used in manufacture of items shall comply with an SFA specification in Section II, Part C, except as otherwise permitted in Section IX, and shall also comply with the applicable requirements of this Article.	Welding materials approved for use – E71T-1 (spec. A5.20), ER70S-3 (spec. A5.18), E81T1-A1M (spec. A5.29), E7018 (spec. A5.1), and EA1 (spec. A5.23). Each material met the applicable AWS A5.X specification.	SFA Specifications (ASME) required in Section III, ND, are identical to that listed in AWS A5.X Specifications.	Reference *Welding Materials,* ND-2400
ND2531 - Plates shall be examined in accordance with the requirements of the material specification.	Visual examination performed on base material prior to welding.	Plates were examined prior to welding.	No purchase order specification available. Therefore, plate examination requirements unknown. However, receipt inspection records document that MT examination was performed on the SA/A516 6" thick material.

Welding Materials – *ND-2400* NUREG/CR-3019 and ASME Subsection ND require fracture toughness testing. ASME Section III, Subsection ND requires filler material testing for tensile and chemistry. ND-2440 - Suitable storage and handling of electrodes, flux, and other welding material shall be maintained. Precautions shall be taken to minimize absorption of moisture by fluxes and cored, fabricated, and coated electrodes.	Welding Materials Used – E71T-1 (spec. A5.20), ER70S-3 (spec. A5.18), E81T1-A1M (spec. A5.29), E7018 (spec. A5.1), and EA1 (spec. A5.23) Section 5.3 establishes in detail the storage and handling requirements for welding consumables and electrodes.	Although fracture toughness, chemical, and tensile test results are not available through CMTRs, the filler material used in the FCAW, SMAW and SAW process met these requirements through due process by the manufacturer in order to meet the applicable AWS A5.X Specification as specified in the welding procedure specification (WPS). Storage and handling requirements of welding materials are equivalent.	The filler material certified material test reports (CMTRs) verifying fracture toughness, tensile, and chemistry are not available. None
Joint Design/Fabrication – *ND-4200/4400* ASME Section III, Subsection ND requires full penetration butt welds for Category A, B, C, and D weld joints except for Category D branch connections. Partial penetration welds are allowed for branch connections. ASME Section IX approved welding processes. Welding preparation and welding profile requirements.	Weld Joint/Welds - Complete/partial joint penetration v-groove, fillet and plug welds meet AWS prequalified joint design. Welding Processes – FCAW, GTAW, SMAW, and SAW Welding preparation and welding profile requirements.	The WVMP full penetration welds are the ones associated with the lifting lugs, railcar securement lugs, and sacrificial shock absorbers and do not allow radiographic examination due to joint geometry. Welding processes used (FCAW, GTAW, SMAW, and SAW) are approved for use by ASME Section IX. Weld joint preparation, groove type, weld type, and welding profiles used in the fabrication.	Partial penetration welds are not allowed for corner joints. None None

Heat Treatment – *ND-4600* ASME Section III, Subsection ND requires heat treatment for the thickness and material used. PWHT exemptions are allowed when specific preheats are performed (250° F min. and an intermediate post weld soak at 300° F min. for 2hr. for material over 3" thick).	AWS requires heat treatment when specified contractually. Preheat requirements are 225° F minimum for material thickness equal to or greater than 2 1/2" for the base material used.	Both codes require preheat.	WPSs used are prequalified to meet the AWS D1.1 requirements for minimum preheat (225° F) and PWHT in accordance with the Purchase Order. Preheat requirements below the minimum specified to meet Section III, Subsection ND. Purchase Order and documentation recording of any PWHT are not available.
Qualification Procedure/Personnel – *ND-4300* ASME Section III, Subsection ND requires qualification to be performed in accordance with ASME Section IX and additional requirements specified in ND-4300.	Welding Procedure Specifications – Prequalified and qualified in accordance with AWS requirements. AWS allows the use of welder qualifications performed in accordance with other standards at the Engineers' discretion. "**Engineer -** "Engineer" shall be defined as a duly designated individual who acts for, and in behalf of, the Owner on all matters within the scope of the code."	The essential and nonessential variables and mechanical testing of the AWS prequalified and qualified WPSs are equivalent to ASME Section IX and ASME Section III, Subsection ND requirements. The welder performance qualifications were performed in accordance with ASME Section IX.	Welding Procedure Specifications are required to be qualified in accordance with ASME Section IX which requires acceptable mechanical testing of prescribed welded coupons by the fabricator. Prequalified welding procedure specifications are not allowed.

Examination – *ND-5000* ASME Section III, Subsection ND requires radiography on full penetration welds.	Weld Inspections – All welds are required to receive a Visual examination (VT).		Radiographic examination not conducive to the joint geometry of the full penetration welds (the lifting lugs, railcar securement lugs, and sacrificial shock absorbers).
ASME Section III, Subsection ND requires NDE (MT) examination on partial penetration and fillet welds.	Reports indicate that all structural welds received a VT and magnetic particle (MT) examination.	Full penetration, partial penetration, and fillet welds received MT examination.	No significant differences.
ASME Section III, Subsection ND requires NDE personnel certification in accordance with SNT-TC-1A.	Weld Inspection Personnel – NDE certification in accordance SNT-TC-1A and visual examination performed by certified weld inspectors (CWI).	Documents contained in the welding documentation package are showing NDE certification to SNT-TC-1A and CWI. This includes eye examination, training, and testing reports.	None

Conclusion

To achieve code compliance or to claim equivalency all aspects, (material, design, fabrication and installation, examination, and testing requirements) of the governing code must be met.

As revealed in the welding requirements chart, differences exist with ASME Section III, Subsection ND mandatory requirements as compared to similar AWS D1.1 requirements, which are only implemented at the discretion of the Engineer[2] and/or purchase specification.

Review of the WVMP welding documentation package revealed the following differences[3]:

- Base metal fracture toughness requirements,
- Filler material – Certified Material Test Report (fracture toughness requirements, chemistry and tensile results),
- Use of prequalified welding procedure specifications,
- Partial penetration groove weld approval for specified joint designs,
- Heat treat requirements both preheat and postweld heat treatment.

This comparison does not conclude any inadequacies with the AWS D1.1, Structural Welding Code. Both the AWS D1.1 and the ASME Section III design codes establish welding requirements (material certification, weld joint design, fabrication requirements, procedure/personnel qualification, pre-heat/postweld heat treat requirements, weld examination, and weld examination personnel certification) that collectively produce a sound weld capable of functioning at the design level of safety.

Therefore, use of the AWS D1.1 Structural Welding Code – Steel could be used as an acceptable alternative providing the level of safety needed for a containment/transportation package.

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[2] **"Engineer** - "Engineer" shall be defined as a duly designated individual who acts for, and in behalf of, the Owner on all matters within the scope of the code."

[3] Resolution of these differences is addressed in report SARWVMP-01, *Safety Analysis Report for the West Valley Melter Package,* Revision 1, Docket Number 71-9797.