NOV 16 1998

SANDIA REPORT

SAND98-2389
Unlimited Release
Printed November 1998

Review & Approval Desk (1)
For DOE/OSTI

Department 15102
MS 0619

RECEIVED

NOV 27 1998

OSTI

H1616 Shipping Container Radiographic Inspection Report

D. Gregory Tipton

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of
Energy under Contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Prices available from (615) 576-8401, FTS 626-8401

Available to the public from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161

NTIS price codes
Printed copy: A03
Microfiche copy: A01

DISCLAIMER

**Portions of this document may be illegible
electronic image products. Images are
produced from the best available original
document.**

SAND98-2389
Unlimited Release
Printed November 1998

H1616 SHIPPING CONTAINER RADIOGRAPHIC INSPECTION REPORT

D. Gregory Tipton
WMD Container Systems
Sandia National Laboratories
P.O Box 5800
Albuquerque, NM 87185-0483

Abstract

The H1616 shipping container is a certified type B(U) packaging used by the Department of Energy (DOE) to ship tritium in support of defense programs. During the 1997 recertification of the container, DOE became concerned about the possible cracking of the polyurethane foam in the overpacks of the 2300 containers currently in service. In response, Sandia National Laboratories (SNL) initiated a radiographic inspection program to determine if cracking of the foam was occurring in the H1616 overpacks. SNL developed the radiographic technique for inspecting the foam and contracted the Savannah River Site's Tritium Engineering division to inspect a representative sample of overpacks in service. This report details the development process and the results of all of the radiography performed both at SNL and Savannah River.

Table of Contents

Table of Contents	4
List of Tables	4
List of Figures	5
1.0 Introduction	7
2.0 Initial Radiography	8
2.1 Inspection Set-Up & Parameters	9
2.2 Inspection Results	11
3.0 Supplemental Compliance Test Unit Radiography	15
3.1 Inspection Set-Up & Parameters	15
3.2 Inspection Results	16
4.0 Final Process Prove-In	19
4.1 Inspection Set-Up & Parameters	19
4.2 Inspection Results	20
5.0 Radiographic Inspection at Savannah River	23
5.1 Inspection Set-Up & Parameters	23
5.2 Inspection Results	25
6.0 Evaluation of Results & Conclusions	33
7.0 References	35
8.0 Distribution	36

List of Tables

Table 1. Parameters Used for Initial Inspections	11
Table 2. List of Initial Overpacks Inspected	11
Table 3. Summary of SCTU Inspections	16
Table 4. List of Overpacks Radiographed	20
Table 5. Overpack Selection Criteria	23
Table 6. Parameters Used for Inspections at Savannah River	24
Table 7. List of Overpacks Radiographed	26
Table 8. Number of Overpacks Inspected per Use Group	26
Table 9. Summary of Overpacks with Additional Radiographic Indications	28

List of Figures

Figure 1. The H1616 Shipping Container.	7
Figure 2. Cross-Section of the H1616 Overpack	9
Figure 3. Set-up to Image the Overpack Walls.	10
Figure 4. Set-up for Imaging the Bottom of the Overpack.	10
Figure 5. Typical Side-Wall Radiograph (Unit 21023)	12
Figure 6. Typical Bottom Radiograph (Unit 13955)	13
Figure 7. A Side-Wall Radiograph of Unit 2002 Showing a Crack in the Foam	14
Figure 8. Set-up for Imaging the Side-Wall Foam Between Drop Tests	15
Figure 9. Sections of SCTU-1 After the Drop and Puncture Tests.	17
Figure 10. Side-Wall Radiograph of SCTU-1 After the 30-foot Drop Test.	18
Figure 11. Set-up for Imaging the Bottom of the Overpack.	19
Figure 12. Close-up of Bottom Crack (Unit 13955).	20
Figure 13. Bottom Images of Unit 13955 at 0 and 90-degrees.	21
Figure 14. Side-Wall Radiograph of Unit 13955 Showing a Vertical Indication.	22
Figure 15. Set-up to Image Overpack Walls.	24
Figure 16. Set-up for Imaging the Bottom of the Overpack.	25
Figure 17. Typical Bottom Radiograph (Unit 13520)	27
Figure 18. Side-Wall Radiograph of Overpack 12126	29
Figure 19. Side-Wall Radiograph of Overpack 13336	30
Figure 20. Side-Wall Radiograph of Overpack 13517	31
Figure 21. Side-Wall Radiograph of Overpack 14051	32
Figure 22. Close-up Showing Porosity of Foam.	33

1.0 Introduction

The H1616 shipping container is a type B(U) packaging used by the Department of Energy (DOE) to ship tritium in support of defense programs. The packaging consists of a foam filled stainless steel drum, or overpack, which houses a removable stainless steel containment vessel. The purpose of the overpack is to protect the containment vessel during shipment from both impact and fire environments [1]. Figure 1 shows a disassembled view of the H1616.

Figure 1. The H1616 Shipping Container

During the 1997 recertification of the H1616 design, the DOE asked about cracking in the polyurethane foam which fills the overpack [2]. This concern arose from cracking that occurred during the manufacturing of similar foam filled overpacks. The question was; do the H1616 overpacks have cracks in the foam either from the manufacturing process or from heavy use, and if so what effect would such cracks have on the performance of the container?

The foam cracking observed in the other overpacks resulted from differential thermal expansion of the foam and the stainless steel liner encasing the foam. Polyurethane foam has about an order of magnitude greater coefficient of thermal expansion than stainless steel. The foam is poured into the stainless steel drum at an elevated temperature and left to cure. As the foam cures, the entire overpack cools and the foam tries to shrink faster than the liner leaving residual stresses in the foam. In the overpacks similar to the H1616, this stress was sufficient to crack the foam either during curing or as a result of rough handling (shocks or impact which could initiate cracks to relieve the stress).

Sandia National Laboratories (SNL) gained experience using radiography to inspect for foam cracks with these similar foam filled overpacks. Using this experience SNL decided to radiograph a representative portion of the H1616 overpacks in service to determine if cracks are present. SNL accomplished this in four steps. First, five overpacks on hand at SNL were radiographed to prove the ability to see cracks with radiography and to alleviate immediate DOE concerns. Based on this data, a specification was developed (SS708378) to standardize the inspection process [3]. Second, four full production units used for recertification accident testing were radiographed at SNL. Third, ten more full production units from Savannah River were radiographed at SNL to finalize the specification SS708378. Finally, SNL qualified the radiography process at Savannah River to SS708378, and 125 overpacks were inspected. This number represents an acceptable quality level (AQL) of 0.1 per ANSI/ASQC Z1.4 based on normal sampling of the approximately 2300 overpacks in service [4].

The results of all of the radiography performed showed that cracking due to the manufacturing process is not a concern in the H1616. Nearly all of the overpacks radiographed showed a linear indication at the bottom of the overpack. This indication was determined to be an interface between two foam pours (the foam was added to the overpack in two stages). No signs of cracking due to differential thermal expansion were evident. Several overpacks did show other indications of unknown origin. These indications were all different and shown not to be visual defects on the stainless steel drum or liner. In addition, inspection of the foam in the units drop tested showed very little cracking after 44 ft/sec impacts. This is contrary to what was expected and indicates that cracking due to rough handling is also not a concern.

2.0 Initial Radiography

In April of 1997, SNL radiographed five overpacks to get an initial idea of whether or not cracks could be seen in the foam with both film and real-time radiography. In addition, the results helped to alleviate immediate DOE concerns with cracking of the foam. The five overpacks radiographed were on hand at SNL. Three of the overpacks were training units which were identical to the real production units. The other two were production units kept at SNL after production.

During this time both film and real-time radiography were tried on several of the units. For the real-time radiography the container was placed between the source and the detector. This produced an image through both walls of the container. It appeared that it would be better if the source could be put inside of the container so inspection could be made of just one wall. To do this, fixturing would have had to been made to hold the source inside the overpack with a table to rotate the overpack around the source. It was decided to use a film technique instead to save time and money.

All five of the overpacks were radiographed using a film technique and showed no cracks in the foam. Two holes were drilled vertically through the side wall of one of the overpacks (trainer 2002) and new radiographs were taken. Both holes (1/4 and 1/2-inch diameter) showed up on the radiographs. The same unit was then crushed radially to create cracks in the foam. The unit was radiographed again and the newly created cracks were imaged. The fact that the two holes and the

induced cracks could be seen proved that the technique used to inspect the overpacks could detect the minimum flaw size of interest.

2.1 Inspection Set-up & Parameters

A film technique was decided upon for inspection of the overpacks. All of the foam in the overpacks needed to be inspected for cracks. To do this separate set-ups were used to inspect the side walls of the overpack and the bottom. Figure 2 shows a cross-section of the H1616 overpack. Noted in the figure are what will be referred to in this report as the side-wall foam and the bottom foam.

Figure 2. Cross-Section of the H1616 Overpack

Figure 3 shows the set-up for imaging the foam in the side walls. Film was placed on the inside of the overpack with the source a distance away. Ten shots were taken to inspect the entire circumference of the overpack. The film used for these ten shots was 7" x 17" Kodak AA Lead Pack.

Figure 3. Set-up to Image the Overpack Walls

Larger film was used to inspect the foam in the bottom of the overpack. Figure 4 shows the set-up used to inspect the bottom. The film was placed underneath the container with the source located above the container. Just one of these shots was taken for each container inspected. The film used was 14" x 17" Kodak AA Lead Pack.

Figure 4. Set-up for Imaging the Bottom of the Overpack

Table 1 shows the parameters used for inspecting the overpacks. These parameters were developed during this initial phase of the radiography and were used as guidance for all subsequent radiography performed at SNL and Savannah River.

Table 1: Parameters Used for Initial Inspections

Parameter	Value
Type of Film	Kodak AA Lead Pack
Source-to-Film Distance	6 feet
Location of Film	Sides: Inside overpack, against near wall Bottom: Outside, against drum bottom
X-ray Peak Voltage	Sides: 80 KeV Bottom: 100 KeV
Machine Current	15 mA
Exposure Time	1 minute
Number of Shots	Sides: 10 Bottom: 1

2.2 Inspection Results

Table 2 summarizes the initial inspections. Listed are the serial numbers of the overpacks, type of overpack, and the number of shots taken for each overpack. Overpack number 2002 was inspected three separate times.

Table 2: List of Initial Overpacks Inspected

Serial Number	Overpack Type	Images Taken
2002	Trainer	10 side wall
2002 (post-drilling)	Trainer	10 side wall
2002 (post-crush)	Trainer	10 side wall, 1 bottom
2003	Trainer	10 side wall, 1 bottom
2005	Trainer	10 side wall, 1 bottom
21023	Production	10 side wall, 1 bottom
22006	Production	10 side wall, 1 bottom

Figures 5 and 6 show a typical side-wall and bottom shot respectively. No cracks are apparent in either image. The numbers in Figure 5 were placed around the container circumference to mark the relative position of the image with respect to the overpack. Note that the resolution in the radiograph was enough to image the stitching in the ceramic blanket.

Figure 5. Typical Side-Wall Radiograph (Unit 21023)

Figure 6. Typical Bottom Radiograph (Unit 13955)

Figure 7 shows a side-wall image of overpack number 2002 after drilling and crushing to produce voids/cracks. An induced radial crack can be seen in the image. Figure 7 shows that the technique used to radiograph these five units is adequate to reveal cracks of the size that would exceed the overpack fabrication specification, SS393246 [5].

All five overpacks (with the exception of 2002 post drill and crush) showed no cracking in the foam. These five initial units gave an indication that cracks due to the manufacturing process were not as prevalent as in the other similar overpack designs. Further, no cracking occurred as a result of drilling into the overpack which indicates that there was little or no residual stress in the foam. Stress relief rate in polyurethane foam is dependent on the foam density. The higher the density the more time it takes for the stress to subside due to viscoelastic effects. The foam in the H1616 container is approximately 16.5 lb/ft^3 as opposed to the other overpacks which contained 25 to 30 lb/ft^3 foam.

Furthermore, overpack 2002 had been noticeably damaged at some point prior to arriving at SNL. The top edge of the overpack was dented in one place indicating that it had possibly been dropped. As stated previously, no cracks in the foam were evident on the first set of radiographs. This suggests that cracking of the foam will not occur as a result of rough handling.

Figure 7. A Side-Wall Radiograph of Unit 2002 Showing a Crack in the Foam

The parameters used to perform this initial radiography and listed in Table 1 were translated into a requirements document (SNL specification SS708378). These requirements were used by the Savannah River site for their inspection of 125 overpacks (see Section 5 page 23). In addition to these parameters, SS708378 documents such things as overpack selection and the number of overpacks to be radiographed.

3.0 Supplemental Compliance Test Unit Radiography

As part of the 1997 recertification of the H1616 design, SNL performed accident testing of four production containers from the Savannah River Site [1,6]. It was decided to radiograph some of these units before and after each test in an attempt to establish the amount of foam cracking induced by an impact.

The four units were designated supplemental compliance test units (SCTU) and were labeled SCTU-1, SCTU-2, SCTU-3, and SCTU-4. All four containers were radiographed prior to assembly in the same fashion as the initial five overpacks discussed previously. Then SCTU-1 was radiographed after the 30-foot drop test. The unit was not disassembled for this inspection requiring a slightly different technique. After the subsequent puncture test, SCTU-1 was disassembled and fully radiographed. Then SCTU-1 was sectioned to inspect the foam visually for comparison with the radiographs.

3.1 Inspection Set-up & Parameters

Prior to the accident testing, SCTU-1, SCTU-2, SCTU-3, and SCTU-4 were radiographed using the same technique used for the initial five overpacks discussed in Section 2 with the exception of the bottom shot. Only the ten side-wall images were taken because this is the area of foam most likely to receive damage during the impact tests. The radiographic parameters used for these inspections were the same as used previously (listed in Table 1).

A thirty-foot drop test was performed on SCTU-1. After this test the unit was radiographed to inspect the foam for cracks expected to occur as a result of the test. The unit could not be disassembled so as not to invalidate the subsequent tests. Thus, a different technique was used to inspect the foam. Figure 8 shows the technique used. Four shots were taken 90-degrees apart. The film used for these shots was Kodak AA Lead Pack.

Figure 8. Set-up for Imaging the Side-Wall Foam Between Drop Tests

After the drop and puncture testing was complete, SCTU-1 was disassembled and the side-wall foam was radiographed. Again, only the ten side-wall shots were taken. The other test units were subjected to a 30-minute pool-fire test instead of being radiographed.

3.2 Inspection Results

Table 3 summarizes the inspections performed on the supplemental compliance test units. As can be seen from the table, only SCTU-1 was radiographed after the 30-foot drop test and the puncture test. The original plan was to radiograph each unit after each drop and puncture test. However, the post-drop radiographs of SCTU-1 did not appear to show any cracking in the foam. Many cracks were expected in the foam in the area deformed by the impact. None were apparent on the radiographs and it was decided that the technique used was not appropriate for the type of cracking expected. It was decided to not radiograph any other units between tests, but to disassemble SCTU-1 and radiograph it (using the proven technique of the initial five units) instead of subjecting it to a pool-fire test with the other three.

Table 3: Summary of SCTU Inspections

Unit Number	Overpack Type	Images Taken
SCTU-1	H1616-1 Production Unit	10 side wall
SCTU-1 (post-drop)	H1616-1 Production Unit	4 side wall (assembled)
SCTU-1 (post-punch)	H1616-1 Production Unit	10 side wall
SCTU-2	H1616-1 Production Unit	10 side wall
SCTU-3	H1616-1 Production Unit	10 side wall
SCTU-4	H1616-1 Production Unit	10 side wall

None of the pre-test radiographs of SCTU-1, SCTU-2, SCTU-3, or SCTU-4 showed cracks in the foam. This gave further support for the belief that cracking was not occurring in the H1616 overpacks. Indications in the post-drop radiographs were not interpreted as cracks in the foam (upon sectioning SCTU-1 this was shown not to be the case). Even, the radiographs taken of SCTU-1 after disassembly seemed to show no cracking of the foam. These results were contrary to what was expected.

After sectioning the overpack, it was apparent that the foam cracked very little as a result of the drop and puncture tests. However, two cracks were present in the foam. These cracks can be seen in Figure 9.

After SCTU-1 was sectioned, it was apparent that the indications in the post-drop radiographs were cracks in the foam. Figure 10 shows one of the post-drop radiographs revealing the cracking seen in SCTU-1.

Figure 9. Sections of SCTU-1 After the Drop and Puncture Tests

The bottom crack on SCTU-1 was in the bottom foam and could not be seen in the side-wall radiographs pre or post-test. If a bottom shot was taken, this crack probably would not have been picked up. The bottom shot used on the initial five units was oriented to image radial cracks not one oriented along the liner. Thus, subsequent overpacks were radiographed with a different technique to image the bottom foam (see Section 4 page 19).

The little amount of foam cracking seen after the drop tests was a surprise. The small crack at the top of SCTU-1 (noted in Figure 9) probably was the only crack resulting from the testing (the large bottom crack will be discussed in the following sections). Deformation of the stainless steel drum and compression of the ceramic fiber appear to account for most of the energy absorption during the drop tests. This was also apparent on overpack 2002 (one of the initial five units radio-

Figure 10. Side-Wall Radiograph of SCTU-1 After the 30-foot Drop Test

graphed) which was visually damaged from some kind of impact. This suggests that rough handling will have little or no impact on the foam, and that it would take an impact more severe than 44 ft/sec to crack the foam sufficiently to affect the function of the overpack.

4.0 Final Process Prove-In

Based on the results of the radiography of the supplemental compliance test units, it was decided to radiograph several more production overpacks from Savannah River to refine the technique and finalize the specification (SS708378) for use at Savannah River. It was believed that the bottom crack found on SCTU-1 was due to the manufacturing process and not the drop tests. If this was the case, most if not all of the production overpacks would have this crack following the contour of the liner.

In March of 1998, ten more H1616 overpacks were radiographed at SNL. The only difference with this inspection from the previous ones was that two additional shots were taken to look for the bottom crack apparent in SCTU-1. All but one of the overpacks inspected had this bottom crack supporting the idea that this crack was a result of the manufacturing process and not the drop tests. The shots using the old technique for inspecting the bottom foam showed no evidence of cracks. As a result, specification SS708378 was modified to require the new technique for inspecting the bottom foam instead of the method used to inspect the previous units.

4.1 Inspection Set-up & Parameters

The same technique used to inspect the initial five overpacks (Figures 3 and 4 and Table 1) was used to inspect the ten production overpacks from Savannah River. In addition, two more shots were taken of the bottom foam to inspect for the crack seen in SCTU-1. Figure 11 shows the set-up used to make these shots. Two images were taken 90-degrees apart. The film used for these shots was Kodak AA Lead Pack.

Figure 11. Set-up for Imaging the Bottom of the Overpack

4.2 Inspection Results

Table 4 lists the overpacks radiographed as part of this inspection. All of the overpacks were production units from Savannah River. Thirteen shots were taken for each overpack. All ten of the overpacks were visually inspected for damage. No damage was detected.

Table 4: List of Overpacks Radiographed

11052	14042
13889	14118
13955	14184
13965	14451
14005	14496

Overpack number 11052 was the only one that did not appear to have the bottom crack as seen on SCTU-1. All of the others had the crack following the entire contour about 1/4-inch away from the liner. Both bottom shots taken 90-degrees apart showed the same crack indicating that the crack follows the entire circumference of the overpack liner. Figures 12 and 13 show both of these bottom shots taken for unit 13955.

Figure 12. Close up of Bottom Crack (Unit 13955)

Figure 13. Bottom Images of Unit 13955 at 0 and 90-degrees

In addition, unit 13955 showed a very thin vertical crack in the side-wall foam. The overpack was visually inspected for a scratch that could cause such an indication on the film but none was found. It is possible that this indication is a scratch on the inside of the drum or liner which could not be seen visually. Figure 14 shows this vertical indication in unit 13955.

Figure 14. Side-Wall Radiograph of Unit 13955 Showing a Vertical Indication

Based on the results of these inspections, the specification to be used by Savannah River (SS708378) was changed. The side shot used to image the crack in the bottom of the foam on these ten units was substituted for the bottom shot used on the original five overpacks.

5.0 Radiographic Inspection at Savannah River

The Savannah River site's Tritium Engineering division is responsible for all maintenance activities for the H1616 shipping container. After the inspections at SNL were complete, SNL contracted Savannah River to radiograph a representative sample of the H1616 overpacks in service. The Tritium Engineering division contracts all of their radiography work to Raytheon. Specification SS708378 was developed for Savannah River and Raytheon to follow in performing the inspections.

Raytheon developed a procedure based on SS708378 and performed inspections of several overpacks in service at Savannah [7]. In addition, SNL supplied the crushed overpack from the initial inspections at SNL (overpack number 2002) for Raytheon to develop their process. Both the procedure and the process were reviewed by SNL prior to start-up of the inspections at Savannah [8,9].

In addition to defining the radiographic parameters, SS708378 specified requirements for selecting the overpacks to be inspected, handling the overpacks, marking the radiographic film, and the inspection criteria. One hundred and twenty five overpacks were inspected at Savannah River per the specification. Each overpack was selected based on its number of uses. Specification SS708378 specified certain numbers of overpacks with varying numbers of uses to be inspected to insure that the overpacks inspected were representative of the entire population of overpacks in service. The selection criteria can be seen in Table 5. Prior to issuing the specification, SNL reviewed all of the use data for all of the H1616 overpacks and developed the use groups and picked the number of overpacks to be inspected from each group.

Table 5: Overpack Selection Criteria*

Number of Uses	0 - 6	7 - 13	14 - 20	21 - 27	≥ 28
Number of Overpacks to be Inspected	16	30	44	30	5

* As called out in SS708378.

An inspection sheet was filled out for each overpack inspected. Once all 125 overpacks were inspected, SNL reviewed the inspection sheets and reviewed several of the radiographs. All of the radiographs were reviewed by Raytheon, and SNL reviewed the ones showing indications. All of the overpacks radiographed showed the bottom crack as seen on many of the units radiographed at Sandia. In addition, several of the overpacks had indications in the side wall radiographs.

5.1 Inspection Set-up & Parameters

As stated previously the radiographic technique was changed to look for the bottom crack seen on many of the containers radiographed at SNL. In accordance, the specification SS708378 was updated and some of the parameters were changed at the request of Savannah River. Table 6 lists

the suggested parameters called out in SS708378 and used by Savannah River. These parameters were used as a guide for developing a process with sufficient resolution.

Table 6: Parameters Used for Inspections at Savannah River

Parameter	Value
Type of Film	Kodak AA Lead Pack or approved alternate
Film Size	Sides: 7 x 17 inch Bottom: 14 x 17 inch
Source-to-Film Distance	6 feet
X-ray Peak Voltage	Sides: 80 KeV Bottom: 100 KeV
Machine Current	15 mA
Exposure Time	1 minute for Kodak AA film
Number of Shots	Sides: 10 shots (every 36°)
Radiographic Density	1.8 - 3.5

Figure 15 shows the set-up for imaging the foam in the side walls of the overpack. This set-up is the same as was used for all of the previous inspections at SNL except two overpacks were exposed at the same time.

Figure 15. Set-up to Image Overpack Walls

Figure 16 shows the set-up for imaging the foam in the bottom of the overpack. This technique was used to look for the bottom crack seen previously. However, larger film was used than that used at SNL to get a more complete image of the bottom foam. Two overpacks were exposed at the same time.

Figure 16. Set-up for Imaging the Bottom of the Overpack

5.2 Inspection Results

Table 7 lists the overpacks radiographed at Savannah River. Savannah River documented which overpacks were radiographed with the corresponding number of uses in an Information Engineering Release (IER) number 980007SR [10]. A total of 125 overpacks were inspected. An inspection report was filled out for each overpack inspected [11]. These reports are kept on file at Savannah River and at SNL.

Table 8 lists the number of overpacks radiographed from each use group as specified in SS708378. As can be seen from comparison of Table 5 and Table 8, the number inspected in each use group varies from the number called for in SS708378. The specification does allow for deviation but not as much as occurred. During the inspections, SNL was informed of the possible deviation from the specification, and SNL determined this to be acceptable. The variation from SS708378 was due to the way in which Savannah River picked the overpacks to be inspected. Overpacks were randomly selected from the overpacks on hand and *in use* at Savannah River. A large number of overpacks are in inactive storage. Thus, the overpacks radiographed do represent the overpacks in use at Savannah River and generally fall into the use groups with 7 or more uses. The overpacks that fell into the 0 to 6 usages group were for the most part from the overpacks in inactive storage. SNL specifically requested that some overpacks from inactive storage be inspected to include containers with no usage.

Table 7: List of Overpacks Radiographed*

11104	11129	13231	13837	14297	11042	13740	14670
13146	11166	13386	13840	14315	11096	13784	14673
14347	11187	13414	13874	14338	11134	13922	14682
13728	11217	13421	13900	14370	11184	14014	14693
14051	11307	13468	13927	14381	11237	14068	14717
13034	12042	13503	14000	14400	12081	14100	21105
13336	12093	13520	14020	14402	13090	14139	21106
13363	12096	13585	14069	14475	13147	14214	21107
13475	12126	13624	14101	14478	13220	14302	21108
13499	13003	13628	14143	14504	13253	14432	21109
13809	13024	13634	14144	14543	13296	14435	21110
13822	13046	13711	14181	14575	13345	14452	21111
14284	13047	13725	14197	14618	13395	14474	21114
21030	13089	13791	14201	14678	13500	14499	
22082	13159	13811	14243	14701	13517	14546	
11003	13192	13813	14281	14704	13613	14656	

* Information compiled from IER 980007SR.

Table 8: Number of Overpacks Inspected per Use Group*

Number of Uses	0 - 6	7 - 13	14 - 20	21 - 27	≥ 28
Number of Overpacks Inspected	20	44	33	19	9

* Information compiled from IER 980007SR.

All of the overpacks radiographed showed a bottom crack similar to the ones seen on units inspected at SNL.* The fact that all of these units had this crack and that all but one of the process prove-in units had this crack supports the idea that this is something due to the manufacturing process and not something occurring during use. The source of this crack will be discussed in detail in Section 6 (page 33). Figure 17 shows a typical bottom foam radiograph in which the bottom crack is evident.

Figure 17. Typical Bottom Radiograph (Unit 13520)

In addition to the bottom crack seen on all of the overpacks, 7 of the units showed other indications. Table 9 summarizes these additional indications. Two of these overpacks had indications in the seam weld. Though these are of interest, the indications did not have anything to do with cracking in the foam.

* The Raytheon inspection reports identified two containers that did not have this bottom crack. However, SNL review showed that such indications were present in these two overpacks. The radiographs showed densification in this area as opposed to a void like the other radiographs, thus the indications were not noted as a crack on the inspection reports.

Table 9: Summary of Overpacks with Additional Radiographic Indications

Overpack	Number of Uses	Side-Wall Indications
12126	7	Gouge-like indication: ~ 2.5" L
13336	11	1 linear indication: ~ 3" L, 0.030" W
13517	27	Linear indications in seam weld
13520	15	1 linear indication: length of radiograph
14051	9	5 linear indications: ~ 1" L, 0.020" W
14656	9	Linear indication in seam weld
21030	3	Scar indication

Overpack 21030 showed a horizontal linear indication near the bottom of the radiograph. This indication looked more like a scratch on the inside of the drum or liner instead of a crack in the foam. Visible scratches on the drum or liner were detected on the radiographs of some of the other overpacks inspected. These scratches appeared as thin, sharply defined lines on the radiograph. The indication on the side-wall radiograph of 21030 was very similar to those due to visible scratches. No scratches were visible on the outside of the overpack or liner.

Overpack 12126 had a horizontal indication in one of the side-wall radiographs. This indication was about 2 1/2-inches long and about 1/4-inch wide. Savannah River's inspection report calls this a gouge-like indication because it looks like a gouge in the overpack or liner. However, no such indentations are evident on the overpack. The radiograph in question can be seen in Figure 18.

Figure 18. Side-Wall Radiograph of Overpack 12126

Overpacks 13336 and 13520 had a similar linear indication on one of the side-wall radiographs. On both overpacks this indication was behind the identification plate. The side-wall radiograph of overpack 13336 can be seen in Figure 19. The indication shown in the figure is approximately 3-inches long and 0.030-inch wide. The indication on overpack 13520 was very similar except it runs the length of the radiograph and is slightly wider at the bottom than at the top.

Figure 19. Side-Wall Radiograph of Overpack 13336

Overpacks 13517 and 14656 both had linear indications in the seam weld. Figure 20 shows the radiograph in question for overpack 13517. The indication was about 1/4-inch in length and appeared at an overlap in the seam weld. The indication on overpack 14656 was at the top roll on the overpack and was about 2-inches in length. Neither of these indications in the seam weld could be seen visually.

Figure 20. Side-Wall Radiograph of Overpack 13517

Overpack 14051 had several indications on one side-wall radiograph. Figure 21 shows the radiograph in question. All of the indications are short and curved and in approximately the same area on the overpack. These indications are possibly scratches on the inside of the liner or the drum or folds in the ceramic fiber blanket. No scratches were seen visually on the outside of the drum or liner.

Figure 21. Side-Wall Radiograph of Overpack 14051

6.0 Evaluation of Results & Conclusions

The bottom cracks seen on SCTU-1, most of the units radiographed at SNL, and all of the units radiographed at Savannah River are a result of the manufacturing process. In fact, it is not really a crack. SNL contacted General Plastics, the foam manufacturer, to discuss this feature in the overpacks. General Plastics indicated that the foam was added to the drum in two steps. In the first step, foam was added through the center hole in the bottom of the overpack where it flowed over the liner and into the side walls. This foam was allowed to cure, then the remainder of the overpack was filled with foam. This process produced an interface between the cured foam of the first pour and the second pour. This interface is what can be seen in the radiographs and visually in the sections of SCTU-1. In addition, the foam at this interface is very porous unlike the undisturbed foam in the rest of the overpack. This porosity can be seen in Figure 22. Such porosity is expected to occur at a foam interface.

Figure 22. Close-up Showing Porosity of Foam

Close inspection of the radiographs also reveals this porosity as can be seen in Figure 12 (page 20). One side of the interface is sharply defined. The other is hazy as a result of the porosity.

General Plastics also indicated that cracking from differential thermal expansion should not have occurred in the H1616 because of the low density of the foam. SNL agrees with this conclusion supported by three things. One, no cracks were propagated in unit 2002 by drilling into the overpack indicating that there is little residual stress in the foam. Two, no obvious stress relieving noises were noted during manufacturing of the overpacks. Such noises were evident during manufacturing of similar overpacks which did crack as a result of differential thermal expansion. Three, no common indications of such cracks can be seen in any of the radiographs. All of the indications seem to be the result of mechanical damage and not cracks in the foam.

Based on the above results, foam cracking from differential thermal expansion is not a concern for the H1616 overpack. Likewise, cracking from use does not seem to be problem. The lack of cracking on SCTU-1 after the drop tests shows the resilience of the H1616 foam during impacts.

In addition, the crushed overpack (number 2002) was notably damaged, and no cracks were imaged in the damaged area. This trainer overpack was damaged to the point that it would have been removed from service during routine physical inspections. Thus, a system is in place to remove overpacks from service if that overpack has been damaged enough to crack the foam.

With the exception of the two overpacks with indications in the seam welds, the indications found on five of the overpacks inspected at Savannah River are possibly the result of damage to the components prior to assembly. Several of the indications appear more like scratches on the stainless steel drum or liner. The other indications could possibly be in the foam or even in the ceramic fiber blanket. Destructive examinations of the overpacks should reveal the nature of the indications. In any event, there is no common type of indication among all of the radiographs indicating that the marks are from some sort of damage either during or after fabrication. Damage from use is expected in this type of application, and physical inspections of the overpack are required before every shipment.

The indications in the seam welds on two of the overpacks radiographed at Savannah River are of no concern. The stainless steel material used in the H1616 design is highly ductile which arrests crack propagation. In addition, the same supplier produced the drums for four other SNL overpack designs. Out of all the testing performed on the H1616 and these other overpacks, SNL has never had a failure of this seam weld from this supplier. The vendor's process was qualified to assure an acceptable weld was achieved each time. These two overpacks were produced by this qualified process and are considered acceptable for use.

The five other overpacks will be sent to SNL for evaluation to determine the nature of the indications. The only common feature on all of the overpacks was the foam interface at the bottom of the liner which was determined not to be a crack. Nothing else appears to be common in the overpacks. Such a common feature would indicate that foam cracking during manufacturing was occurring or that normal use of the container produces unexpected cracking of the foam. Neither appears to be the case. The indications that are seen appear to be the miscellaneous type of marks that would occur from normal manufacturing processes and repeated use and are not of concern.

7.0 References

- [1] D. G. Tipton, "Safety Analysis Report for the Type B(U) AL-SX (H1616) Reservoir Packages," SAND91-2205 Revised, Sandia National Laboratories, June 1998.
- [2] "Safety Evaluation Report for the H1616 Package," U.S. Department of Energy, Albuquerque Operations Office, Nuclear Explosive Safety Division, Revision 2, October 1997.
- [3] "Periodic Inspection, H1616 Overpack," SS708378, Sandia National Laboratories, Issue C, July 1997.
- [4] "Sampling Procedures and Tables for Inspection by Attributes," ANSI/ASQC Z1.4, American National Standard.
- [5] "Foaming and Fabrication, H1616 Overpack and Insert Cover," SS393246, Sandia National Laboratories, Issue D, November 1991.
- [6] R. E. Glass, "H1616 Supplemental Compliance Test Report," SAND98-1086, Sandia National Laboratories, May 1998.
- [7] "Radiographic Examination of the H1616 Overpack," NDE-002-3, Savannah River Site Raytheon Engineers & Constructors Quality Control Procedure, 1998.
- [8] "Engineering Evaluation Release," EER 980716SA, Sandia National Laboratories, 1998.
- [9] "Qualification Evaluation Release," QER 980717SA, Sandia National Laboratories, 1998.
- [10] "Information Engineering Release," IER 980007SR, Savannah River Site, 1998.
- [11] "H1616 Radiographic Inspection Report," ASR 18-336, Raytheon Engineers & Constructors Savannah River Site, 1998.

8.0 Distribution

2	Steven M. Nunley U.S. Department of Energy Weapons Surety Division Albuquerque, NM 87185		
1	B. Lynn Bulfinch U.S. Department of Energy Savannah River Operations Office Aiken, SC 29801		
2	Glenn A. Mathues Westinghouse Savannah River Company Aiken, SC 29801 Attn: G.A. Mathues, Bld 234-H		
1	MS0429	J. H. Stichman	2100
1	MS0483	T. D. Hernandez	2165
5	MS0483	D. G. Tipton	2165
1	MS0483	R. E. Glass	2165
1	MS0483	R. S. Pacheco	2165
1	MS0483	D. J. Giersch	2165
1	MS9006	D. J. Bohrer	2200
1	MS9035	R. D. Monson	2265
1	MS1213	D. L. Mangan	5314
1	MS0555	J. D. Murray	9133
1	MS0555	C. S. Holmes	9133
1	MS9018	Central Technical Files	8940-2
2	MS0899	Technical Library	4916
1	MS0619	Review & Approval Desk For DOE/OSTI	15102