Century Industries

Safety Analysis Report for the Century Industries Versa-Pac Shipping Container

Application for License Docket No. 71-09342

Revision 6 January 24, 2012

Designed and Submitted By:

Century Industries
Bristol, Virginia

Safety Analysis Report for the	**Docket No. 71-09342**	**Submitted By:**
Century Industries Versa-Pac	**TAC No. L24365**	**Century Industries**
Shipping Containers	**Revision 6 January 24, 2012**	**Bristol, Virginia**

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for
Century Industries
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Bristol, Virginia

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General Glossary of Terms and Acronyms

Annually	Once every year
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society of Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
Versa-Pac	A shipping container for the transport of Type AF radioactive materials.
CFR	U.S. Code of Federal Regulations
Containment Boundary	The components of the packaging intended to retain the radioactive material during transport.
CSI	The criticality safety index as define by the dimensionless number (rounded up to the next tenth) assigned to and placed on the label of a fissile material package, to designate the degree of control of accumulated packages containing fissile material during transport.
Decay Heat	The heat resulting from radioactive decay.
Enrichment	The percentage (by weight) of U^{235} contained in the radioactive material.
FEA	Finite Element Analysis
H/X Ratio	The water-hydrogen to fissile atom ratio
(H+C)/X Ratio	The ratio of the sum of water-hydrogen atoms and the carbon atoms to the fissile atoms.
HAC	Hypothetical Accident Conditions as defined by 10 CFR 71.73.
Heterogeneous	The form of fissile material is such that discrete particles exist and the moderator material is distributed around the particles.
HEU	Highly-enriched uranium
Homogenous	The form of the fissile material is such that the moderator is mixed uniformly with it.
Hydrogenous	Containing hydrogen atoms.
ID	Inner diameter
IH	Inside Height
Insolation	Heat input by solar radiation as defined by 10 CFR 71.71.
Internal moderator	The presence of hydrogenous material in the payload vessel and mixed with the payload.
Interspersed Moderator	The presence of hydrogenous material between packages and in the payload vessel, but not mixed with the payload.
Moderation Control	Control of materials containing hydrogen.
NCT	Normal Conditions of Transport as defined by 10 CFR 71.71.
NIST	National Institute of Standards and Technology

Nominal	The design value or dimension without application of the allowable variation or tolerance.
Non-hydrogenous	Does not contain hydrogen atoms.
NRC	The U.S. Regulatory Commission
OD	Outer diameter
Package	The packaging together with its radioactive contents as presented for transport.
Packaging	The assembly of components necessary to ensure compliance with the packaging requirements of 10 CFR 71.
Plastic	A thermosetting or thermoplastic polymer
Poly	Polyethylene
Pre-packaging	Materials, not supplied as part of the Versa-Pac shipping container and not a part of the radioactive payload, that are used to limit the movement of radioactive material within the payload vessel.
RQ	Regulated Quantity
RTV	Silicone Rubber Compound
Specific Activity	The radioactivity of a radionuclide per unit mass.
Type A Package	Package used to transport a quantity of material where the aggregate radioactivity content does not exceed the Normal Form A_2 value listed in 10 CFR 71.
Type B Package	Package used to transport more than Type A quantity of material.
UC	Uranium Carbides
UH	Uranium Hydrites
U-Metal	Uranium Metal
UNX	All forms of uranyl nitrate in crystalline or solution form, including uranyl nitrate hexahydrate, uranyl nitrate dihydrate, uranyl nitrate trihydrate and uranyl nitrate solution.
UO_2	Uranium Dioxide
Uranium Compound	Any compound of uranium containing any combination of elements, referred to also as U_xO_y.
User	The person or entity shipping radioactive material in the package.
U_xO_y	Uranium compounds. Although the designation shows X atoms of uranium and Y atoms of oxygen, this designation is meant to represent any compound of uranium containing any combination of elements.

SECTION ONE
GENERAL INFORMATION

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List of Tables and Figures

SAFETY ANALYSIS REPORT
FOR MODEL VERSA-PAC
SHIPPING CONTAINER
(Revision 6, December 2011)

Submitted By:
Century Industries
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Designed and Written By:
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1 GENERAL INFORMATION

This Safety Analysis Report for the Versa-Pac Shipping Container is submitted in support of the Century Industries request for approval of the subject shipping container and issuance of a Type A Fissile Material Certificate of Compliance for the container in compliance with the requirements of 10 CFR 71 and IAEA Regulations for the Safe Transport of Radioactive Material, No. TS-R-1, 1996 Edition. This Safety Analysis Report for Packaging (SARP) has been prepared in accordance with U.S. Regulatory Commission (NRC), Regulatory Guide 7.9 Proposed Revision 2, March 2005.

1.1 Introduction

The Versa-Pac Shipping Containers employ an innovative design concept (Patent Pending) in combination with the familiar drum exterior packaging to provide enhanced structural protection to the payloads previously transported per 49 CFR 173.417(a)(6) during Hypothetical Accident Conditions (HAC). The Versa-Pac shipping containers, model numbers VP-55 and VP-110, have been designed to transport Type A Fissile Materials containing less than or equal to 350 grams of U-235 and has been evaluated to transport many of the products currently being transported in older shipping containers. The package has been designed and constructed so that it is acceptable under 71.43(g) for transport in non-exclusive and exclusive means of transport.

The package system includes an outer set of drum closure seals and an inner secondary flat gasket seal. The payload containment area of the 55 gallon version has an inside diameter of 15 inches and is 25-7/8 inches in length; while the 110 gallon version has an inside diameter of 21 inches and is 29-3/4 inches in length. The package has two distinct areas of insulation for thermal and impact protection.

The Criticality Safety Index (CSI) is 1.0.

1.2 Package Description

1.2.1 Packaging

Engineering Drawings are provided in Appendix 1.3.1. General notes pertaining to fabrication are provided in Appendix 1.3.2. An illustration of the packaging configuration is provided in Figure 1-1. Packaging markings are shown on the drawings provided in Appendix 1.3.1 with General Notes shown in Appendix 1.3.2.

The exterior skin of the Versa-Pac Shipping Container consists of at a minimum, a UN1A2/X400/S for the 55-gallon drum version with a 16 gauge body, bottom and cover. The drums use a 12 gauge bolted closure ring, standard carbon steel lugs, 5/8" diameter, ASTM A307 bolts and nuts, and a closed-cell EPDM gasket. The overall outer dimensions of the 55 gallon package are 23-1/16" OD x 34-3/4" in height to the top of the outer drum bolt ring. The drum cover is reinforced by a 10 gauge thick 22-3/8" OD x 18-3/8" ID plate, and four ½" bolts are provided to lend additional strength to the drum closure ring.

The 110 gallon version utilizes at a minimum a UN/1A2/Y400/S with 16 gauge body, bottom and cover. The drums use a 12 gauge bolted closure ring, standard carbon steel lugs, 5/8" diameter ASTM A307 bolts and nuts, and a closed-cell EPDM gasket. The overall outer dimensions for the 110 gallon package are 30-7/16" OD x 42-3/4" in height to the top of the outer drum bolt ring. The drum cover is reinforced by a 10 gauge thick 29-3/4" OD x 27-1/4" ID plate and eight ½" bolts are provided to lend additional strength to the drum closure ring.

Both drums are further strengthened with vertical stiffeners fabricated from 1-1/4" carbon steel square tubing, two inner liners of rolled 16 gauge carbon steel insulated by ceramic fiber blanket encase the vertical tubing, and a ¼" carbon steel reinforcing plate on the bottom.

The package's interior is completely insulated with the appropriate layers of ceramic fiber blanket around the containment area with 6 pcf rigid polyurethane foam disk on the top and on the bottom to complete the insulation of the package. Specifications for the insulation are provided in Appendix 1.3.3 and 1.3.4 for the blanket and polyurethane, respectively. The primary function of both insulations is to provide thermal protection. Although the rigid polyurethane provides some impact protection, the frame of the packaging performs the majority of the required impact protection.

A ½" thick fiberglass ring is used as a thermal break at the payload cavity flange. The thermal break is sandwiched between the steel components, with twelve 1/2 inch bolts providing the connection between the structural members through the fiberglass and effectively limits the flow of heat to the payload cavity through the steel flange components. There are no moving parts to the thermal break, and its functionality is maintained as long as it separates the steel components FB from FK (See Drawings in Appendix 1.3.1). A specification for the fiberglass material is provided in Appendix 1.3.5.

The containment boundary of the package is defined as the payload vessel with its associated welds, payload vessel high temperature heat resistant silicone coated fiberglass gasket, payload vessel blind flanges, and reinforcing ring.

The payload vessel is comprised of a 10 gauge carbon steel sheet for the body and bottom. The upper end of the vessel is fitted with a ¼" inner carbon steel flange ring with a ½" thick carbon steel blind flange. The vessel has three circumferential welds (two at the flange, one at the base) and one longitudinal weld. A 1/8" high temperature heat resistant silicone coated fiberglass

gasket is used between the steel flange ring and blind flange. The payload vessel blind flange is secured with twelve ½" bolts. There are no penetrations, valves or venting devices used within the containment boundary.

The Versa-Pac meets the General Requirements for all packages as specified in 10CFR71.43.

1.2.1.1 Gross Weights

The gross weights of the Versa-Pac Shipping Container are provided in Table 1-1.

1.2.1.2 Materials of Construction

The materials of construction of the Versa-Pac are provided in Tables 1-2 and 1-3 for the 55-gallon and 110-gallon versions, respectively.

1.2.1.3 Outer and Inner Protrusions

There is one outer protrusion on the Versa-Pac consisting of carbon steel fitting which contains a 1" plastic plug on the side of the package. The plug is designed to melt and allow venting of any gases that might develop in the event of a fire. The protrusion extends less than ½" from the side-wall of the outer drum and does not impede the stacking or handling of the shipping container. There are no inner protrusions on the Versa-Pac Shipping Container.

1.2.1.4 Lifting and Tie-Down Devices

The Versa-Pac shipping container may be handled by normal industry standards for the safe movement of drums; such equipment might include specifically designed devices, forklifts, pallet jacks or other methods as determined by the User. However, the Versa-Pac package does not utilize any specific device or attachment for lifting. Additionally, there are no specific provisions for tie down of the package.

1.2.1.5 Shielding

Neutron and gamma shields are not required for the Versa-Pac payloads.

1.2.1.6 Pressure Relief Systems

There are no pressure relief systems other than the four – ¼" holes, closed with vinyl push plugs on the inner liner between the insulation and containment and one in the top cavity area used to vent gases that might be produced in the event of a fire. No special heat transfer mechanisms are provided or required.

1.2.1.7 Containment Features

There are three individual points of closure employed by the Versa-Pac Shipping Container. The payload ½ inch thick closure plate provides a fastening and seal using twelve ½" bolts and a 1/8" thick silicone coated fiberglass gasket. A second closure is provided at the outer drum lid. The drum lid is secured using ½" bolts and is sealed with a 3/8" thick silicone rubber flat gasket. A standard drum ring, its EPDM gasket, and a 5/8" tensioning bolt provide the final closure. A 1/8" hole is drilled in the end of the tensioning bolt for use with a security seal.

The primary containment boundary of the Versa-Pac Shipping Container is defined as the inner containment body, containment end plate, inner flange ring, silicone coated fiberglass gasket, ½" blind flange, ½" bolts, washers and insert holders. Figure 1-1 further illustrates these components by text description enclosed within a text box.

1.2.1.8 Package Markings

Package marking are shown in Appendix 1.3.1 and 1.3.2.

1.2.2 Contents

All materials must be in solid form with no freestanding liquids; density is not limited. These material quantities may not exceed 350 grams U-235 in any non-pyrophoric form, enriched up to 100 Wt.%. Materials that may be shipped in the Versa-Pac include uranium oxides (U_yO_x), uranium metal (U-metal), uranyl nitrate crystals (UNX), and other uranium compounds (e.g., Uranyl Fluorides and Uranyl Carbonates) enriched up to 100 Wt.% U-235. The uranium compounds may also contain carbon or graphite (e.g., UC, U_2C_3 and UC_2). UNX may be in the form of uranyl nitrate hexahydrate, trihydrate or dihydrate, and must be in solid form. The payload may be in homogeneous (powder or crystalline) or non-homogeneous form. Table 1-5 identifies the limits for U-234 and U-236 as applied to the Versa-Pac Shipping Container. The A_2 values are used as stated in 10 CFR 71 and are applied to the package since the payload is limited to normal form material.

The package is evaluated assuming optimum moderation using a bounding high-density polyethylene plastic (Density = 0.98 g/cc) and supports packaging applications containing both carbon (e.g., graphite, paraffin, and polyethylene) and hydrogen based materials (e.g., water paraffin, and polyethylene). Non-fissile chemical impurities do not increase the reactivity of the system; therefore, they may be present in any quantity. The payload may be enriched in U-235 to 100 Wt.%. Because the payload decay is essentially zero (approximately 11.4 W, *Section 3.4.2*); thus, there are no radiolytic decay products.

The payload material may be pre-packaged in hydrogenous or non-hydrogenous containers within the payload vessel. Hydrogenous pre-packaging materials may include polyethylene, polypropylene, and PVC. PTFE or Teflon® pre-packaging material is also allowed. Metallic pre-packaging materials such as aluminum, stainless and carbon steel are allowed. Table 1-4 provides a listing of typical packaging materials used to pack the Versa-Pac Shipping Container.

Package contents are typically shipped in an axial array to fill the payload cavity. A fire proof perlite like packing material is often used as dunnage to fill the voids between the cans and inner vessel wall. The Versa-Pac design allows for the use of two neoprene pads, a 1/8 inch bottom pad, and a 3/8 inch top pad. The pads serve the purpose of protecting the inner containment shell during repeated use. The use of these pads is optional for packages not intended for reuse.

No materials, excluding the minimum steel wall thickness of the package, are used as neutron absorbers or moderators.

The maximum payload capacity for the 55-gallon version is 250 pounds. The maximum payload capacity for the 110-gallon version is 260 pounds.

1.2.3 Special Requirements for Plutonium

The Versa-Pac Shipping Container is not approved for the transport of Plutonium above minimum detectable quantities.

1.2.4 Operational Features

The Versa-Pac Shipping Container provides for two individual closures and seals to secure the payload within the inner containment area. Connections and closures are accomplished using bolt and gasket seals.

There are no operationally complex features of the Versa-Pac Shipping Container. All operational features are readily apparent from an inspection of the drawings provided in Appendix 1.3.1, *Packaging General Arrangement Drawings*. Operation procedures and instructions for loading, unloading, and preparing an empty Versa-Pac Shipping Container for transport are provided in Chapter 7.0, *Operating Procedures*.

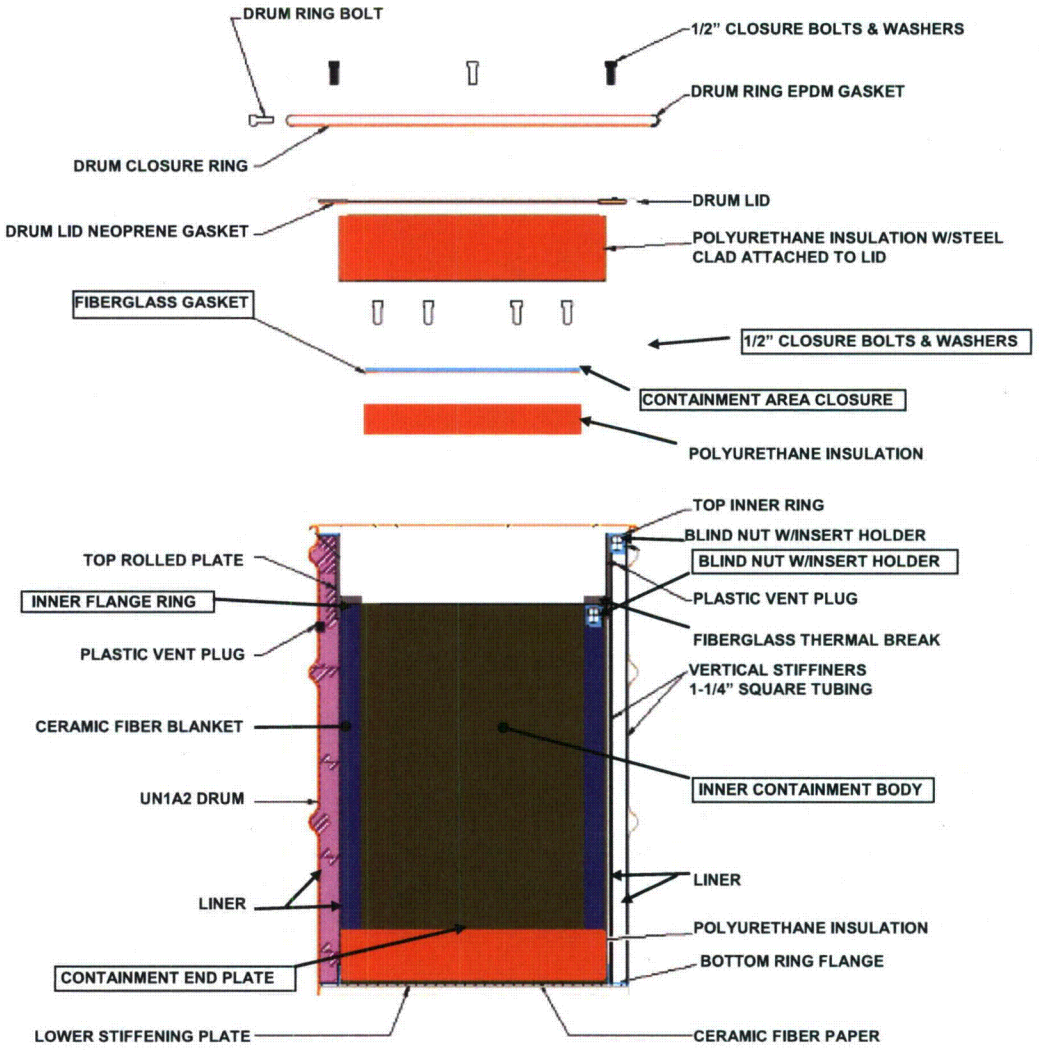


Figure 1-1: Versa-Pac Component Illustration

(Containment boundary components, as indicated in Section 1.2.1.7, are described in text boxes)

1.3 Appendices

1.3.1 Versa-Pac Shipping Container Drawings, Century Industries Drawing No.

VP-55-LD-1 & -2, VP-110-LD-1 & -2

1.3.2 General Notes

1.3.3 SOP 6.11 – UF-1 Polyurethane Closed Cell Foam Specification for Century Products

1.3.4 SOP 6.12 – CFI-1 Ceramic Fiber Insulation Specification for Century Products

1.3.5 SOP 6.13 – Structural Fiberglass Component Specification for Century Products

Table 1-1: Versa-Pac Shipping Container Gross Weights

55 Gallon Version – Model No. VP-55

Component	Weight (kg)	Weight (lb.)
Versa-Pac Shipping Container	178	390
Maximum Payload	114	250
Maximum Gross Weight of Loaded Package	291	**640**

110 Gallon Version – Model No. VP-110

Component	Weight (kg)	Weight (lb.)
Versa-Pac Shipping Container	321	705
Maximum Payload	119	260
Maximum Gross Weight of Loaded Package	439	**965**

Table 1-2: 55 Gallon Versa-Pac Materials of Construction

Item	Material	Specification
55-Gallon Drum	16 Gauge, Carbon Steel	UN1A2/X400/S Design Minimum
Closure Ring	12 Gauge, Carbon Steel	UN1A2/X400/S
Drum Bolt	Carbon Steel	ASTM A307
Drum Gasket	EPDM Closed Cell	Certificate of Compliance
Inner Flat Gasket	Silicone Rubber Coated Fiberglass	Certificate of Compliance
Top Flange Gasket	Silicone Sponge Rubber	AMS-3195, Commercial ZZR 765, MILR 46089
Inner Flat Pads	Neoprene Sponge Rubber	ASTM D105668SCE41, ASTM 1056002C1
Inner Pads	Neoprene Rubber	ASTM D-2000, SAE J200 MIL R-33065
Sheet Materials	Carbon Steel	ASTM A1011
Plate Materials	Carbon Steel	ASTM A36
Angle	Carbon Steel	ASTM A36
Square Tubing	Carbon Steel	ASTM A500
Square Bar	Carbon Steel	AISI C1018
Thread Inserts	Carbon Steel	Fastenal-EZ LOK Part No.60158 or equivalent
All Other Closure Bolts	Carbon Steel – Zinc Plated	ASTM SAE J429 Grade 5
Lock Washers	Carbon Steel – Zinc Plated	Clad
Insulation	Polyurethane Foam	Century SOP 6.11
Insulation	Ceramic Fiber Blanket/Paper	Century SOP 6.12
Thermal Break	Fiberglass Band/Rings	Century SOP 6.13
Nameplate	Stainless Steel	ASTM 300 Series
Paint	Industrial Primer (Inside Surfaces)	Industrial Grade (Minimum)
Paint	Enamel Touch Up	Industrial Grade (Minimum)

Table 1-3: 110 Gallon Versa-Pac Materials of Construction

Item	Material	Specification
110-Gallon Drum	16 Gauge, Carbon Steel	UN1A2/Y409/S Design Minimum
Closure Ring	12 Gauge, Carbon Steel	UN1A2/X400/S
Drum Bolt	Carbon Steel	ASTM A307
Drum Gasket	EPDM Closed Cell	Certificate of Compliance
Inner Flat Gasket	Silicone Rubber Coated Fiberglass	Certificate of Compliance
Top Flange Gasket	Silicone Sponge Rubber	AMS-3195, Commercial ZZR 765, MILR 46089
Inner Flat Pads	Neoprene Sponge Rubber	ASTM D105668SCE41, ASTM 1056002C1
Inner Pads	Neoprene Rubber	ASTM D-2000, SAE J200 MIL R-33065
Sheet Materials	Carbon Steel	ASTM A1011
Plate Materials	Carbon Steel	ASTM A36
Angle	Carbon Steel	ASTM A36
Square Tubing	Carbon Steel	ASTM A500
Square Bar	Carbon Steel	AISI C1018
Thread Inserts	Carbon Steel	Fastenal-EZ LOK Part No.60158 or equivalent
All Other Closure Bolts	Carbon Steel – Zinc Plated	ASTM SAE J429 Grade 5
Lock Washers	Carbon Steel – Zinc Plated	Clad
Insulation	Polyurethane Foam	Century SOP 6.11
Insulation	Ceramic Fiber Blanket/Paper	Century SOP 6.12
Thermal Break	Fiberglass Band/Rings	Century SOP 6.13
Nameplate	Stainless Steel	ASTM 300 Series
Paint	Industrial Primer (Inside Surfaces)	Industrial Grade (Minimum)
Paint	Enamel Touch Up	Industrial Grade (Minimum)

Table 1-4: Melting Points for Typical Packaging Materials for use within the Versa-Pac

Material	Melting Point		Notes
	(°F)	(°C)	
Carbon Steel	2500	1371	
Aluminum	1220	660	
PTFE	621	327	High Density Plastic
LDPE	240	116	Low Density Plastic

Note for Table 1-4:

1. "Physical Constants for Investigators", http://www.tcforensic.com.au/docs/article10.html, by Tony Cafe, Reproduced from "Firepoint" magazine - Journal of Australian Fire Investigators
2. "Fuels and Chemicals - Auto Ignition Temperatures", http://www.engineeringtoolbox.com/fuels-ignition-temperatures-d_171.html

Note: All other materials used for packaging within the Versa-Pac shall be individually evaluated by the user to establish acceptance to the requirements.

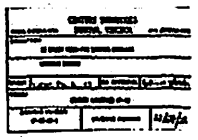
Table 1-5: Summary of Uranium Isotope Limits for U-234 and U-236

Uranium Isotope	A_2	Ci/g	Package Gram Limit (1)
U-234 (2)	2.4	6.2×10^{-3}	387
U-234 (3)	5.4×10^{-1}	6.2×10^{-3}	87
U-234 (4)	1.6×10^{-1}	6.2×10^{-3}	25
U-236 (2)	Unlimited	6.5×10^{-5}	Unlimited
U-236 (3)	5.4×10^{-1}	6.5×10^{-5}	87
U-236 (4)	1.6×10^{-1}	6.5×10^{-5}	25

1. The mixture A_2 value is calculated per 10CFR71 by the user. The payload radionuclide inventory including U-234 and U-236 shall be less than the calculated mixture A_2 value.
2. These values apply only to compounds of uranium that take the chemical for of UF_6, UO_2F_2, and $UO_2(NO_3)_2$ in both normal and accident conditions of transport.
3. These values apply only to compounds of uranium that take the chemical for of UO_3, UF_4, UCl_4 and hexavalent compounds in both normal and accident conditions of transport.
4. These values apply to all compounds of uranium other than those specified in (2) and (3) of this table.

Appendix 1.3.1
Versa-Pac Shipping Container Licensing Drawings
(4 Sheets)

Figure Withheld Under 10 CFR 2.390



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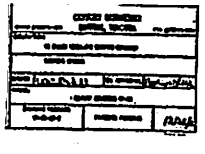


Figure Withheld Under 10 CFR 2.390

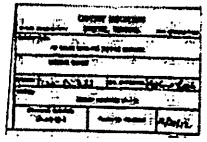
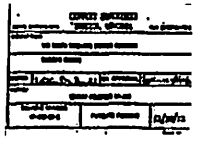


Figure Withheld Under 10 CFR 2.390



Appendix 1.3.2 - General Notes

1. Paint all carbon steel surfaces with (2 mils.) of industrial primer in accordance with manufacturer's specifications. The drum exterior surface is to be painted with enamel top coat in accordance with the drum manufacturers' specification, touchup with spray enamel.
2. Placard as required.
3. Welding procedures and personnel shall be qualified in accordance with AWS D1.1 and AWS D1.3 as applicable.
4. NDT Personnel shall be qualified in accordance with ASNT-TC-1A. Visual personnel may be certified in addition or in lieu of ASNT-TC-1A as an AWS CWI or CAWI.
5. Nameplates shall be attached after painting by spot welding and paint retouched.
6. General shop tolerances of ± 1/8" apply unless noted. Material tolerances are as required under the appropriate specification.
7. Equivalent components must be approved by engineering and submitted to the NRC for approval.
8. This package shall be manufactured under a Quality Assurance Program that meets the program requirements as outlined in 10 CFR 71. Quality Assurance shall perform visual and magnetic particle inspection through the use of hold points on the Fabrication Control Records for individual packages at pre-determined points to insure that the package is produced according to specifications.
9. The nameplate shall be a minimum of 6" x 6" x 22 gauge stainless steel, ASTM A240, 300 Series. The letters shall be at least ½" high as follows:

   MFG. By: Century Industries, USA

   S/N: ----------

   Century Versa-Pac VP-(55 or 110)

   Type AF

   Tare Wgt: ------ LB

   ------KG

   Max. Gross Wgt: ----- LB

   KG
10. Gaskets and Plugs shall be installed using the appropriate material as described in Standard Operating Procedures.

11. Ceramic fiber paper/blanket/boards and polyurethane foam products shall be in accordance with Century SOPs.

12. Certifications, test reports and QA records shall be stored and maintained as required by Century Industries' Quality Assurance Program.

13. Stenciling shall be in contrasting color and be a minimum of 1" in height unless noted and shall include at a minimum the following information:

Design ID Number:	USA/----/AF Type A (2" Letters)
Model Number:	Century Versa-Pac VP-(55 or 110)
Owners Name:	----------
Owners Address:	City, State, and/or Country
	RQ, Radioactive Material, Type A
	Package, Fissile Non-Special Form

(Additional stenciling of the package is at the discretion of the customer. RQ may not be required since it is dependent on the payload contents.)

Appendix 1.3.3

Century Industries
Bristol, Virginia

Procedure Type: Standard Operating Procedure
Procedure No: SOP 6.11
Description: UF-1 Polyurethane Closed Cell Foam Specification for Century Products

This page is a record of revisions to this procedure. Each time a revision is made, only the revised pages are reissued. Remarks indicate a brief description of the revision and are not a part of the procedure.

REVISION	DATE	AFFECTED PAGE (S)	REMARKS
0	01/01/04	ALL	Original
1	04/11/05	ALL	Update for Panels
2	01/02/09	ALL	General Update
3	01/01/10	6	Adjustment to Paragraphs 7.2.1 & 7.2.2
4	08/06/10	3	Corrected ASTM Specification
5	10/28/10	3,4,5,6,7	General Update
6	12/29/11	ALL	General Update

APPROVALS

6	Heather N. Lith	William M. Hall	William M. Hall
REV	QA MANAGER	PRESIDENT	PRODUCTION MGR

1.0 PURPOSE

1.1 The purpose of this procedure is to describe the methods of installing UF-1 polyurethane foam in Century Industries products.

2.0 SCOPE

2.1 The scope of this specification shall cover material requirements of the installation of closed cell urethane foam with a density range of 5.0 to 11.0 pounds per cubic foot (PCF) for all shipping containers manufactured by Century Industries.

3.0 ELEMENTAL COMPOUNDS

3.1 The closed cell urethane foam shall have the following elemental percentages, each with a tolerance of ± 10%.

Hydrogen	6.7%
Carbon	61.7%
Oxygen	26.1%
Nitrogen	5.2%
Other	0.3%

4.0 BASIC PHYSICAL PROPERTIES

4.1 Density

Density measurements of test samples shall be performed in accordance with ASTM D-1622. Density measurement of the urethane foam as installed will be by simple calculation of the foam weight divided by the package cavity volume during the normal production runs.

4.2 Compressive Strength

Compressive strength shall be tested in accordance with ASTM D-1621, Compressive Properties of Rigid Cellular Plastics or ASTM D695, Compressive Properties of Rigid Plastics. Density of the foam shall range between 5.0 and 11.0 PCF, with the compressive strength range between 80 and 300 PSI dependant upon the foam strength required by the product specifications.

4.3 Thermal Conductivity

Thermal conductivity shall meet the requirements of and be performed in accordance with ASTM C518. Based upon previous test results the thermal conductivity of the foam K Factor = 4.05 Btu-in/ (h-sq ft-°F).

4.4 Flame Retardancy

Testing for flame retardancy shall be performed in accordance with ASTM E84 and meet the minimum requirements.

4.5 Water Absorption

Testing for Water Absorption shall be in accordance with ASTM C209.

4.6 Chloride Content

Leachable chloride content shall be less than 200 ppm.

5.0 Storage Requirements

Urethane foam resins and urethane foam and other raw materials and processing chemicals should be stored at room temperature.

6.0 Operating Procedure

6.1 Raw Materials

6.1.1 The urethane foam will be a two component, rigid polyurethane system that produces hard foam with a nominal, free rinse core density of 5 to 11 pcf. The system should be a water blown foam formula with a polymeric MDI as the "A" component.

6.1.2 The flame retardant should be either a carbon intumescent or mono-penta-erythritol based material.

6.2 Foam In Place Procedure

6.2.1 Calculate the amount of foam required for volume and add 10%.

6.2.2 Weigh container to be foamed – Record reading.

6.2.3 Weigh raw materials for a 7 ± 2% flame retardant formulation.

6.2.4 Temperature adjustment of container prior to foaming shall be made by means of indirect heat, such as space heaters or

other methods of radiant heat. The container temperature shall be between 70-110°F. Additional information can be found by referring to the manufacturer's literature.

6.2.5 Pre-mix flame retardant and Part A of urethane system in container that will hold all of the components.

6.2.6 Add Part R and mix.

6.2.7 Pour into container cavity.

6.2.8 Watch foam rise for any abnormalities.

6.2.9 When the rise is complete, allow foam to cure before cutting. Curing temperature shall be between 50-100°F.

6.2.10 Trim excess foam from container.

6.2.11 Weigh foamed container.

6.2.12 Calculate density of the foam in the container based on container void volume and net weight of the foam installed.

6.3 Mold Fabrication Foam Procedure

6.3.1 This procedure is used for foaming molds, blocks or buns of material to be cut to a particular finished component part to be used in the final container.

6.3.2 Calculate the amount of foam required for the mold.

6.3.3 Temperature adjustment of the mold prior to foaming shall be made by means of indirect heat, such as space heaters or other methods of radiant heat. The mold temperature shall be between 70-110°F. Additional information, if needed, can be found by referring to the manufacturer's literature.

6.3.4 Weigh out the raw materials.

6.3.5 Pre-mix flame retardant and Part A of the urethane system in a container that will hold all components.

6.3.6 Add Part R and mix.

6.3.7 Pour evenly into mold.

6.3.8 Watch for abnormalities.

6.3.9 Once the rise is complete, record total rise height.

6.3.10 Curing temperature shall be between 50-100°F. Once the foam has cured, cut the foam to the specified shape.

6.3.11 As required, take sample and calculate pcf.

6.3.12 A specific bun number (Pour No.) is assigned to the bun and spray painted on the top.

6.3 Mold Fabrication Foam Procedure – Cutting

6.4.1 Cutting: After curing, each bun will be cut on the wire saw to the required foam component shape per the instructions and drawings provided. Each individual component shape will have a unique letter identification assigned to it.

6.4.2 Each component shape that is cut will be segregated by the Bun Number and the Component Shape ID.

6.4.3 A sample of left over foam from each bun will be collected and labeled for pcf calculation.

7.0 Quality Assurance

7.1 Production

Prior to production of each product utilizing the closed cell urethane foam, Quality Assurance shall establish the correct weight of the foam materials required to produce the correct density.

7.2 Records

7.2.1 Foam in Place

A foaming record must be completed for each foam installation in each individual package and it shall become a part of the final QA record. This record shall include as a minimum: foam components, weight of the container before and after the foaming and trimming, and have proper QA verifications.

The foam fabricator shall supply records from the resin manufacturer for each urethane resin batch. They shall also supply from an independent laboratory, results to verify that the leachable chloride content taken from foam samples of each resin batch, meet the leachable chloride content requirement of less than 200 ppm.

7.2.2 Foam Panels

A foaming record must be completed for each foam panel bun produced and it shall become a part of the final QA record. This record shall include as a minimum: foam components, weight of raw materials charged, the dimensions of the foamed bun, and have proper QA verifications.

The density of the representative foam panel material from each bun shall be calculated and recorded in the Panel Foam Density Record.

The foam fabricator shall supply records from the resin manufacturer for each urethane resin batch. They shall also supply from an independent laboratory, results to verify that the leachable chloride content taken from foam samples of each resin batch, meet the leachable chloride content requirement of less than 200 ppm.

8.0 Attachments

8.1 Century Industries UF-1 Production Foam Record

8.2 Century Industries UF-1 Panel Foam Density Record

Attachment 8.1

Century Industries UF-1 Production Foam Record

Date: _____ Time: _____ Pour/Bun No: _____

Mold Room Temperature: _____ Type of Pour: In-Place _____ Mold ____

Chemical	LBS	Grams	Lot/Batch Number
"A" System			
"R" System			
Flame Retardant			
Total			

Foam in Place Density Data

Containers Empty Weight	
Trimmed Foam Container Weight	
Volume of Container Cavity Foamed	
Density of Container Foam	

Mold Foam Density **Expected PCF:** _____

Mold size in Inches	
Height of Foam in Mold	
Weight of Foam Charge	
Density of Foam Component	

Foaming Information

	Plan	Actual
Start Temp. – Resin "A"		
Start Temp. – Resin "R"		
Mixer RPM		
Mixer Type		
Chem. Mix Time in Sec.		
Cream Time in Sec.		
Foam Time in Sec.		
Tack Free Time in Sec.		
Foam Height in Mold(IN.)		

Person Responsible for Formulation: _____

Person Responsible for Production: _____

QA Review By: _____ Date: _____

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Attachment 8.2

Century Industries UF-1 Panel Foam Density Record

Bun Number	Calculated Density	Comments

Person Responsible for Calculations: _____

QA Review By: _____ Date: _____

Appendix
1.3.4

Century Industries
Bristol, Virginia

Procedure Type: Standard Operating Procedure
Procedure No: SOP 6.12
Description: CFI-1 Ceramic Fiber Insulation Specification for Century Products

This page is a record of revisions to this procedure. Each time a revision is made, only the revised pages are reissued. Remarks indicate a brief description of the revision and are not a part of the procedure.

REVISION	DATE	AFFECTED PAGE (S)	REMARKS
0	01/01/04	ALL	Original
1	07/03/08	2	Density and Thickness
2	06/15/09	2	Addition of Higher Density Materials
3	12/12/09	2, 3 & 4	Adjustment to Text and Record Adjustment
4	12/29/11	ALL	General Update

APPROVALS

4	Heather Smith	Will-Ph. Ard	Will-Ph. Ard
REV	QA MANAGER	PRESIDENT	PRODUCTION MGR

1.0 PURPOSE

1.1 The purpose of this procedure is to describe the ceramic fiber materials used in Century Industries products

2.0 SCOPE

2.1 The scope of this specification shall cover material requirements for the installation of both ceramic fiber paper and blanket insulation products in Century Industries products.

3.0 BASIC PHYSICAL PROPERTIES

3.1 Paper

Density = 4 pcf, compressed

Thickness = 1/8 in.

Thermal Conductivity, Btu-in./hr.-ft^{2}-°F (ASTM C 201):

4 pcf (Mean Temp. @ 2,000°F) = 1.58

3.2 Blanket

Density = 6 & 8 lb/ft^{3}

Thickness = 0.5 to 2 in.

Thermal Conductivity, Btu-in./hr.-ft^{2}-°F (ASTM C 201):

6 pcf (Mean Temp. @ 2,000°F) = 2.83

8 pcf (Mean Temp. @ 2,000°F) = 2.34

4.0 Storage Requirements

4.1 Store the Ceramic Fiber paper and blanket insulation in an area with relatively low humidity at ambient temperature.

5.0 Quality Assurance

5.1 Production

Quality Assurance shall verify that the density and thickness of the ceramic fiber insulation is correct when received and prior to installation.

5.2 Records

A ceramic fiber insulation record must be completed for each individual package and it shall become a part of the final QA record. This record shall include as a minimum: verification of density and thickness and serial number of the package(s) in which the insulation was installed.

6.0 Attachments

6.1 Century Industries CFI-1 Ceramic Fiber Installation Record

Attachment 6.1

Century Industries CFI-1
Ceramic Fiber Installation Record

Ceramic Fiber Paper

Package Serial Number(s)	Density	Thickness	Manufacturer/Product	Lot/Batch No.

Ceramic Fiber Blanket

Package Serial Number(s)	Density	Thickness	Manufacturer/Product	Lot/Batch No.

Production Signature: _____ Date: _____

QA Signature: _____ Date: _____

Appendix 1.3.5

Century Industries
Bristol, Virginia

Procedure Type: Standard Operating Procedure
Procedure No: SOP 6.13
Description: Structural Fiberglass Component Specification for Century Products

This page is a record of revisions to this procedure. Each time a revision is made, only the revised pages are reissued. Remarks indicate a brief description of the revision and are not a part of the procedure.

REVISION	DATE	AFFECTED PAGE (S)	REMARKS
0	11/10/08	ALL	Original
1	12/12/09	4, Paragraph 4.1	Storage Requirement Completion
2	12/29/11	ALL	General Update

APPROVALS

2	Heather N. Tuttle	William A. Hall	William A. Hall
REV	QA MANAGER	PRESIDENT	PRODUCTION MGR

Century Industries

Procedure Type	Procedure No.	Description
Standard Operating Procedures	SOP 6.13 Rev. 2	Structural Fiberglass Component Specification for Century Products

1.0 PURPOSE

1.1 The purpose of this procedure is to describe the structural fiberglass component materials used in Century Industries products.

2.0 SCOPE

2.1 The scope of this specification shall cover material requirements for the structural fiberglass components utilized in Century Industries products.

3.0 BASIC PHYSICAL PROPERTIES

3.1

Property	Value	ASTM Test
Mechanical		
Tensile Stress, LW	30,000 psi	D638
Tensile Stress, CW	7,000 psi	D638
Compressive Stress, LW	30,000 psi	D695
Compressive Stress, CW	15,000 psi	D695
Flexural Stress, LW	30,000 psi	D790
Flexural Stress, CW	10,000 psi	D790
Modulus of Elasticity[1]	2.6×10^6 psi	Full Section
Modulus of Elasticity >4"[1]	2.5×10^6 psi	Full Section
Physical		
Barcol Hardness	45	D2583
24 Hour Water Absorption	0.6% Maximum	D570
Density	.062 - .070 lbs/in^3	D792
Thermal Conductivity	4-BTU-in/ft^2/hr/$^\circ$F	C177
Electrical		
Arc Resistance, LW	120 Seconds	D495
Flammability		
Tunnel Test	25 Maximum	E84
Flammability	Self Extinguishing	D635

LW – Lengthwise
CW – Crosswise

Note:

1. This value is to be determined from full section simple beam bending of structural shapes.
2. All test requirements are minimum ultimate coupon properties of structural shapes per the referenced ASTM Specification, unless otherwise noted.

3.2 Description of Tests

Tensile Strength (ASTM D638)

The tensile strength is determined by pulling ends of a test specimen until failure.

Compressive Strength (ASTM D695)

The ultimate compressive strength of a material is a force required to rupture the test specimen when a load is applied such that the specimen is crushed.

Flexural Properties (ASTM D790)

The flexural strength is determined by placing a test specimen between two supports and applying a load to the center.

Thermal Conductivity (C177)

This test establishes the criteria for the laboratory measurement of the steady-state heat flux through flat, homogeneous specimens when the surface is in contact with solid, parallel boundaries held at constant temperature using a guarded hot plate apparatus.

Arc Resistance (ASTM D495)

This test is performed by placing two probes on a test specimen at a distance of ¼". A high voltage, low current, arc is passed between the probes with a specified on/off cycle for the arc. The time taken for the arc to completely burn a path through the composite is measured.

Tunnel Test (ASTM E84)

In the 25 foot tunnel test, a smoke generation value and the rate of flame spread are determined.

Flammability (ASTM D635)

The specimen is held horizontally with one end subjected to a flame for 30 seconds.

4.0 Storage Requirements

4.1 All fiberglass products shall be stored in a dry area at ambient temperatures. Fiberglass products may be stored either vertically or horizontally and should be properly supported to reduce the possibility of damage.

5.0 Quality Assurance

5.1 Production

Quality Assurance shall verify that the materials are free from damage and that the certificate of compliance for the product is correct and that it meets the requirements of this procedure when received and prior to installation.

5.2 Records

A Certificate of Compliance from the manufacturer must be reviewed for compliance with this procedure and it shall become a part of the final QA record.

SECTION TWO

STRUCTURAL EVALUATION

Table of Contents

List of Tables and Figures

2 STRUCTURAL EVALUATION

2.1 Description of Structural Design

2.1.1 Discussion

The Versa-Pac is a packaging designed for the shipment of radioactive materials containing less than or equal to 350 grams U-235, including uranium oxides (U_yO_x), uranium metal (U-metal), uranyl nitrate crystals (UNX), and other uranium compounds (e.g., Uranyl Fluorides and Uranyl Carbonates) enriched up to 100 Wt% U-235. The material may be pre-packaged in plastic, metal or Teflon containers.

The 55-gallon Versa-Pac consists of a 15" inner diameter by 25-7/8" inner height (IH) containment area centered within an insulated 55-gallon drum. Drawings of the 55-gallon version Versa-Pac are provided in Appendix 1.3.1. The Versa-Pac design utilizes standard shop dimensions, tolerances and structural materials as outlined in the drawings in Appendix 1.3.1 and the General Note Sheet in Appendix 1.3.2. An illustration of the packaging is provided in Figure 1-1.

The overall nominal dimensions of the 55-gallon package are 23-1/16" Outside Diameter (OD) x 34-3/4" in height to the top of the outer drum bolt ring. The containment area is protected with a gasketed inner containment lid that is closed with twelve ½" bolts. A polyurethane insulation plug is encapsulated in 16-gauge carbon steel welded onto the drum lid (see Appendix 1.3.3). The gasketed drum lid is closed with four ½" bolts and a standard drum ring. A gasket at the drum lid's stiffening ring provides an additional barrier against water in-leakage.

The 55-gallon drum is strengthened with four longitudinal stiffeners fabricated from 1-1/4" carbon steel square tubing equally spaced around the circumference of the drum. A 16-gauge outer liner and a 16ga inner liner provide additional insulated radial stiffness to the drum. The volume between the inner liner and the 10-gauge containment body is filled with ceramic fiber insulation (see Appendix 1.3.4).

The 110-gallon Versa-Pac consists of a 21" Inside Diameter (ID) x 32-3/4" Inside Height (IH) containment area centered within an insulated 110-gallon drum. Drawings of the 110-gallon version Versa-Pac are provided in Appendix 1.3.1. The Versa-Pac design utilizes standard shop dimensions, tolerances and structural materials as outlined in the drawings in Appendix 1.3.1 and the General Note Sheet in Appendix 1.3.2. An illustration of the packaging is provided in Figure 1-1.

The overall nominal dimensions of the 110-gallon package are 30-7/16" Outside Diameter (OD) x 42-3/4" in height to the top of the outer drum bolt ring. The containment area is protected with a gasketed inner containment lid that is closed with twelve ½" bolts. A polyurethane insulation plug is encapsulated in 16-gauge carbon steel welded onto the drum lid (see Appendix 1.3.3). The gasketed drum lid is closed with eight ½" bolts and a standard drum ring. A gasket at the drum lid's stiffening ring provides an additional barrier against water in-leakage.

The 110-gallon drum is strengthened with eight longitudinal stiffeners fabricated from 1-1/4" carbon steel square tubing equally spaced around the circumference of the drum. A 16ga outer liner and a 16ga inner liner provide additional insulated radial stiffness to the drum. The volume between the inner liner and the 10-gauge containment body is filled with ceramic fiber insulation (see Appendix 1.3.4).

The Versa-Pac design does not include lifting or tie down devices. Handling is accomplished using a standard drum handling equipment and/or a forklift. Shielding and pressure relief devices are not required for the Versa-Pac payloads. Plastic plugs, located on the inner liner and the acetate plug located on the exterior of the package are designed to vent any combustion products generated by the insulation under Hypothetical Accident Conditions. The containment boundary is the containment area, the containment area blind flange and containment flat gasket seal. The containment area is attached to the structural components of the Versa-Pac using 12 equally spaced ½" bolts thru a ¼" connection ring, a ½" thick fiberglass thermal break connected to the structural frame. Bolts are torqued and the bolt/nut connection spot welded to prevent potential loss of the connection.

Performance of the package to the required regulations and design criteria is demonstrated through the analytical evaluations and prototype testing discussed in the remainder of this section. The package performs as required to the applicable regulations, assuring safe transport of the payload. Table 2-1 provides a summary of the evaluations performed and their results.

2.1.2 Design Criteria

The Versa-Pac was designed to meet all of the performance requirements of 10CFR71 for fissile materials. The Versa-Pac is manufactured under a quality assurance program that meets the requirements of 10CFR71, Subpart H. All welding is conducted by qualified personnel in accordance with AWS D1.1. All inspections are conducted by personnel qualified under ASNT-TC-1A and/or for visual inspection certified as an AWS certified welding inspector or assistant.

The containment boundary is defined as the containment area, its seal and blind flange. The structural design criteria for the packaging under the Normal condition are:

- The packaging is maintained within the allowable temperature, pressure and stress ranges as stated in each Section and Table 2-1;
- 55 Gallon Version - The package outer diameter and the height are essentially maintained at their nominal as-built dimensions;
- 110 Gallon Version - The package outer diameter and the height are essentially maintained at their nominal as-built dimensions;
- Positive closure is maintained during transport;
- Moderators are evaluated inside the payload vessel (criticality control requirement);
- Chemical and Galvanic reactions do not impair the function of the packaging within its 10-year design lifetime;

- The package is stackable and meets the applicable regulations; and
- Performance and design of the packaging meets other minimum regulatory requirements for licensure.

The design criteria under Hypothetical Accident Conditions are:

- The packaging is maintained within the allowable temperature, pressure and stress ranges as stated in each Section and Table 2-1;
- 55-Gallon Version - The average OD of the packaging is maintained greater than 21.1" and the minimum height of the packaging is maintained greater than 33.6" under all conditions (criticality control requirement);
- 110-Gallon Version - The average OD of the packaging is maintained greater than 28.5"and the minimum height of the packaging is maintained greater than 41.8" under all conditions (criticality control requirement);

Table 2-1 provides a summary of the structural evaluation, design criteria, and results of the evaluation.

2.1.3 Weights and Centers of Gravity

The weight of each component of the Versa-Pac is provided Table 1-1. The center of gravity of an empty 55-gallon packaging is located 20.2" from the absolute base of the package along a vertical axis in the geometric center of the package. The center of gravity of a loaded package will shift downward by 1.3". The center of gravity of an empty 110-gallon package is located at 17.5".

2.1.4 Identification of Codes and Standards for Package Design

The Versa-Pac is a Type A fissile package, based on the maximum U-235 payload of 350 grams enriched up to 100wt%.

The Versa-Pac Shipping Container was designed to meet the requirements of 10 CFR 71 and IAEA Safety Standards Series – Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised) No. TS-R-1.

Fabrication and the assembly of the Versa-Pac Shipping Container will be conducted in accordance with Century Industries Quality Assurance Program and normal shop Standard Operating Procedures. Welding shall be conduct by qualified personnel and procedures in accordance with AWS D1.1.

Testing and inspection of the Versa-Pac Shipping Containers will be conducted in accordance with Standard Operating Procedures in compliance with the appropriate code, such as ASNT, ASME and AWS.

Maintenance and use of the Versa-Pac Shipping Container shall be conducted in accordance with Section 7.0, Operating Procedures and Section 8.0, Acceptance Tests and Maintenance Program and the Certificate of Compliance.

2.2 Materials

2.2.1 Mechanical Properties of Materials

The mechanical material properties used to evaluate the Versa-Pac performance are provided in Table 2-2. The thermal material properties used to evaluate the Versa-Pac performance are provided in Table 3.5.1-3.

2.2.2 Chemical, Galvanic Reactions and Other Reactions

Appendix 2.12.1 contains information concerning the compatibility of the materials used to fabricate the Versa-Pac. This information demonstrates that the combined materials of construction do not experience significant material loss due to galvanic reactions.

There are two combinations of Versa-Pac materials of construction with a potential to react galvanically. The first combination is steel, primer, ceramic fiber insulation, and polyurethane foam insulation. The second combination is steel and the payload. Other packages have successfully used this combination of materials without galvanic reactions and have done accelerated corrosion tests to support the combined use.

All of the insulation materials used in the construction of the Versa-Pac container are low in chloride content. The fiber insulation used has been tested for its corrosive action on steel with acceptable results (see Appendix 2.12.1). Therefore, the first combination of materials is acceptable for use.

The payload material is pre-packaged to limit contact with the containment area. Therefore, a galvanic reaction with the payload is not considered credible. However, pre-shipment and maintenance inspections would identify any corrosion due to contact with the payload well before the structural integrity of the containment area would be compromised.

Additionally, the contents and plastic pre-packaging materials do not produce significant amounts of hydrogen gas by radiolysis, as the available decay to support the reaction is essentially zero (less than 11.4 W). The Versa-Pac is not a sealed system as the RTV (Silicone Rubber Compound) coated fibrous sleeve allows gas venting without passage of solids.

Therefore, interactions among contents, packaging materials of construction and packing material satisfy the requirements of 10 CFR 71.43(d).

2.2.3 Effects of Radiation on Materials

The radiation produced by the authorized payloads is very low. The packaging materials used (steel, rigid polyurethane insulation products, ceramic fiber insulation products, silicone rubber, fluorocarbon) do not undergo significant changes in properties or performance due to their exposure to the authorized payloads.

2.3 Fabrication and Examination

2.3.1 Fabrication

The Versa-Pac Shipping Container is fabricated using Century Industries Standard

Operating Procedures, Fabrication Control Records, which document each step of the fabrication process (i.e., cutting of material, fitting, welding and other special processes) and becomes a part of the permanent Quality Assurance Record for the package. All welding is conducted in accordance with approved procedures, which are in compliance with the applicable code such as AWS D1.1. All insulation materials are installed in accordance with Century Industries SOP 6.11, 6.12, and 6.13 as referenced in Appendices 1.3.3, 1.3.4, and 1.3.5.

A typical fabrication sequence for the Versa-Pac Shipping Container begins with the cutting and forming of the individual components which is carried out thru the use of a Route Sheet system which provides the preparation group the details for all items. These items are inspected and once approved, released for production to begin the process of manufacturing the Versa-Pac.

The Fabrication Control Record (FCR) provides sequenced steps for the manufacturing of the Versa-Pac. These individual sequences give the quality assurance and production departments the instructions, standard operating procedures, welding procedures and inspection hold points for proper fabrication of the package.

Each sequence must be completed in order and the FCR step signed and dated by the individual responsible for that work, prior to moving to the next sequence. The FCR allows for QA or the customer to insert additional hold points at any location in the production process.

2.3.2 Examination

All non-destructive examinations methods utilized in the fabrication of the Versa-Pac Shipping Container, are conducted in accordance with Century Industries, Standard Operating Procedures, which are in accordance with appropriate codes, such as ASME and AWS D1.1 and/or 1.3 and applicable engineering specifications. Section 8 of this report specifies the requirements for fabrication acceptance and maintenance examinations of this package.

2.4 General Requirements for All Packages

2.4.1 Minimum Package Size

The smallest overall dimension of the 55 gallon version of the Versa-Pac is 22-1/2 inches in diameter and the smallest overall dimension of the 110 gallon version of the Versa-Pac is 30-7/16 inches in diameter. The Versa-Pac thereby complies with the minimum package size requirement of 10 CFR 71.43(a) which states that the smallest overall dimension of a package may not be less that 4 inches.

2.4.2 Tamper-Indicating Feature

The Versa-Pac utilizes the outer drum ring closure bolt for installation of tamper indicating devices, typically individually numbered seals.

2.4.3 Positive Closure

The primary containment is close by use of a gasketed ½" thick blind flange with 12 carbon steel clad ½"bolts, flat washers and lock washers. The outer opening of the Versa-Pac is closed utilizing a reinforced insulated drum cover initially bolted through a gasketed surface with

4 carbon steel clad ½" bolts and flat washers on the 55 gallon version and 8 bolts on the 110 gallon version. In addition the standard 12-gauge drum closure ring with a 5/8" bolt. All closure bolts are torqued at 60 ft.-lbs.

2.5 Lifting and Tie-down Devices

2.5.1 Lifting Devices

The Versa-Pac shipping container may be handled by normal industry standards for the safe movement of drums; such equipment might include specifically designed devices, forklifts, pallet jacks or other methods as determined by the user. However, the Versa-Pac package does not utilize any specific device or attachment for lifting.

2.5.2 Tie-down Devices

There are no specific provisions for tie-down of the Versa-Pac Shipping Container.

2.6 Normal Conditions of Transport

The Versa-Pac meets the standards specified by 10CFR71 when subjected to the conditions and tests required. The effectiveness of the package is maintained throughout all normal conditions of transport.

Evaluation by Test

Full-scale prototypes of both versions of the Versa-Pac Shipping Container were first tested in accordance with the (Structural) requirements specified by 10 CFR 71.71, Normal Conditions of Transport, and 10 CFR71.73, Hypothetical Accident Conditions, in July 2008. For package certification, additional NCT and HAC test series were conducted during the months of February and March of 2009 and the results are reported in Appendix 2.12.2. Additional testing including a shallow angle series of the 55 gallon in September, 2009 and NCT penetration and stacking test in December of 2009.

The packages used for the test series were fabricated as specified by the packaging drawings provided in Appendix 1.3.1.

Evaluation by Analysis

The drop test angles for the mechanical performance test series described in Appendix 2.12.2 were previously evaluated to determine the worst-case damage using finite element analyses in combination with a preliminary mechanical performance test series involving the Champion Type B package. The results of these analyses suggested that the crush tests would be most damaging to the package. The most damaging condition was observed in the subsequent testing of the Champion package. The calculations and test orientations for the Champion package are directly applicable to the Versa-Pac package due to the similarity of the package design. The most damaging configuration was further demonstrated through a preliminary series of tests conducted on both Versa-Pac package design versions during July 2008. Crush tests were conducted to impact the package side in the vicinity of the containment closure, main body below the containment closure and between vertical stiffeners, and the top of the package. A

final series of tests with the 110-gallon package version produced similar results. A complete description of the latter tests is provided in Appendix 2.12.2.

2.6.1 Heat

2.6.1.1 Summary of Pressures and Temperatures

The peak payload temperature of the packaging is 144°F (49°C), under Normal Conditions of Transport (see Section 3.4). The material properties of the packaging remain essentially nominal at this temperature. At the steady state, the temperature of the contents cannot be hotter than the exterior of the packaging, since there is no appreciable decay heat associated with the contents. Therefore, the maximum average temperature of the contents is less than 144°F (61°C). This is well below the maximum allowable temperature of 500°F (defined in Section 3.4) for the contents. At the maximum temperature of the payload, the bounding maximum pressure developed is 9.8 psig, well below the maximum allowable for the containment boundary (15 psig). Although the internal pressure of a filled package is normally atmospheric, the internal pressure of the containment may range from 0 to 9.8 psig (24.5 psia). However, since the Versa-Pac is not a sealed system, the maximum normal operating pressure is near atmospheric pressure.

2.6.1.2 Differential Thermal Expansion

The Versa-Pac is basically constructed of steel and insulation components. Due to its relatively high thermal conductivity and the relative uniformity of the heat application, the steel components do not independently develop significant stresses due to differential thermal expansion.

The blanket insulation used is compressible, and therefore is not damaged by thermal expansion effects.

The linear thermal expansion coefficient of the rigid foam insulation is approximately four times that of the steel; therefore it is possible that the foam insulation expands more than the steel shell. If the entire volume of the foam increases in temperature from 72°F to the peak steady state surface temperature of 144°F, the average maximum linear differential thermal expansion of the foam is about 1/16". However, due to the cyclic loading of the insulation, the actual volume of foam at 144°F is limited to less than 15% of the total foam volume and a more realistic estimate of the expansion is about 1/240". These very small expansion lengths are absorbed by the microstructure of the foam at the steel surface and by the allowable tolerances on the parts themselves. Therefore, no significant stresses are generated as a result of differential thermal expansion.

2.6.1.3 Thermal Stress Calculations

Due to the decoupled design of the packaging, thermal stresses generated by the packaging are negligible.

2.6.1.4 Comparison with Allowable Stresses

Not applicable.

2.6.2 Cold

At an ambient temperature of -40^{0}F with no insolation and zero decay heat generated by the contents, the package attains a uniform temperature of -40^{0}F. At this temperature, the foam insulation compression strength and compressive modulus are increased. The increased foam (top and bottom of the package) strength and modulus result in a stiffer package response under drop conditions, and therefore more of the load is transferred to the containment boundary on impact. Also, the carbon steel components may be brittle below -20^{0}F. Performance testing of the package was completed at low temperature, demonstrating that the packaging performs as required under cold conditions.

No observable differences in damage were noted by comparison of prototype testing of the package at normal ambient temperatures (see *Evaluation by Test*, Section 2.6) to the performance testing conducted at low temperatures. Therefore, low temperature effects have little impact on the Versa-Pac package performance.

2.6.3 Reduced External Pressure

Although the internal pressure of a filled package is nominally atmospheric, the internal pressure of the containment may range from 0 to 2.0 psig (16.7 psia) for the normal condition. In the worst case, a reduced external pressure of 3.5 psia results in a net internal pressure of 13.2 psia or a net external pressure of 3.5 psia. These pressures are within the design internal and external pressure (25 psig) of the containment.

2.6.4 Increased External Pressure

Although the internal pressure of a filled payload canister is nominally atmospheric, the internal pressure of the sealed canister may range from 0 to 2.0 psig (16.7 psia) for the normal condition. In the worst case, an increased external pressure of 20 psia results in a net external pressure of 20 psia or a net external pressure of 3.3 psia. These pressures are within the design internal and external pressure (25 psig) of the containment.

2.6.5 Vibration

Vibration incident to transport does not produce settling, compaction or a loss of structural cohesion for any of the materials used in the packaging. Vibrational compaction of the payload does not impact the performance of the packaging, since the criticality evaluation (see Section 6) applies a variable payload density up to the theoretical limit to evaluate the optimum condition. Vibration testing conducted on the outer drum during the performance design qualification test as set forth in 49 CFR 178.608 were successfully performed with past experience indicating no failure to the drum ring closure. In addition, the Versa-Pac includes an additional bolted closure thru the top lid attached to the internal structure. This bolted closure utilizes ½" bolts and locking washers that are torqued to a prescribed rating of 60 ft/lbs. to prevent the loss of the bolts during transportation. Thus, normal vibration incident to transport does not impact the performance of the Versa-Pac.

2.6.6 Water Spray

A one-hour water spray simulating rainfall at a rate of 2 in/hr has no effect on the Versa-Pac, as the outer vessel is designed to withstand exterior pressure loads much higher than those applied by the water spray.

The Versa-Pac utilizes multiple seals to prevent the loss or dispersal of its contents. Because it is clear that the water spray test has no effect on the package or contents, it was not conducted during the performance test sequence.

2.6.7 Free Drop

Per regulatory requirement, the package must maintain its integrity and effectiveness when subjected to a free drop from a height of 4 feet (1.2 meters) onto a flat, essentially unyielding horizontal surface. Although the damage from a 4-foot free drop results in some local deformation of the transport unit, the deformation is well within the allowable specified for criticality safety, and structural stability. Three different drop orientations were conducted and the results of all five normal condition performance tests of the Versa-Pac are provided in Appendix 2.12.2.

2.6.8 Corner Drop

This test is not applicable to the Versa-Pac packaging, as its weight exceeds the specified maximum of 220 lb.

2.6.9 Compression

The primary load bearing members of the Versa-Pac are the steel 55 or 110-gallon drum shell, the vertical stiffeners, and the inner liner. These components, when assembled as a unit, can be analyzed as an axial member in compression. Assuming the metal thickness is 0.036" and 0.05" for the drum and inner liner, respectively, and using 1-1/4" x 1-1/4" x 0.12" for conservatism (the actual thicknesses are 0.06", 0.0598", and 0.135" respectively), the load-bearing cross-sectional area is approximated as:

$$\pi(22.5")(0.036") + \pi(19.25")(0.05") + 4(1.25"^2 - 1.01"^2) = 7.738 \text{ in}^2$$

Five times the weight of the package is: (5) (965 lb) = 4,825 lb

The compressive stress on the steel members is:

$$4{,}825 \text{ lb} / 7.738 \text{ in}^2 = 623 \text{ psi}$$

The margin of safety against compressive failure is:

$$\text{M.S.} = (36{,}000/623) - 1 = 56.7.$$

Empty Package – Five times the weight of the package is: (5) (390 lb) = 1,950 lb

The compressive stress on the steel members is: 1,950 lb /7.738 in^2 – 252 psi

The margin of safety against compressive failure is: M.S. = (36,000/252) – 1 = 141.85.

The structural members of the Versa-Pac are comprised of a variety of thicknesses of steel components, although when combined thru the process of manufacturing act in conjunction with one another to produce an exceptionally strong unit. To further demonstrate that the Versa-Pac meets the requirements set forth in 10 CFR 71.71(c)(9) the Versa-Pac was subjected to a load greater than 5 times the weight of the package for a period of 24 hours without any damage. The 55-gallon version was tested and the results provide in Appendix 2.12.5 NCT Versa-Pac Test Report for Compression and Penetration.

Conclusion

Based upon the calculations providing a large margin of safety against compressive failure and the physical testing performed using the previously tested 55 gallon version described above and reported in Appendix 2.12.5 NCT Versa-Pac Test Report for Compression and Penetration, the Versa-Pac meets and exceeds the requirements specified in 10 CFR 71.

2.6.10 Penetration

Impact from a 13-pound rod as described in 10CFR71 does not penetrate the steel shell of the Versa-Pac.

The Versa-Pac shipping container was subject the penetration described under 10 CFR 71.71(10) for penetration using a 1.25 inch diameter steel bar weighing 13.2 pounds and dropped from a height of 40 inches (1 Meter) onto several different areas of the test package considered to be the weakest parts of the package without measurable damage at the impact point. These results are supplied in Appendix 2.12.5 NCT Versa-Pac Test Report for Compression and Penetration.

2.7 Hypothetical Accident Conditions (HAC)

The Versa-Pac meets the standards specified by 10CFR71 when subjected to the conditions and tests required. Analytical techniques were used to determine the test orientations producing the maximum damage. Representative prototypes were constructed and tested on two separate occasions using both package design variations (55-gallon and 110-gallon) to demonstrate that the package performs as required to transport the payload. A detailed report of the tests performed is provided in Appendix 2.12.2.

The compliance testing demonstrated:

- The Versa-Pac provides sufficient thermal protection to prevent the internal temperature of the payload container from exceeding the maximum design temperature of the containment boundary ($500^{O}F$) during and following HAC;
- The average OD of the package, and the required package height is maintained under HAC (specified in Section 6) is maintained under all conditions; and
- Containment of the payload is maintained.

Therefore, the Versa-Pac provides adequate protection to the payload during HAC as defined by 10CFR71.73.

2.7.1 Free Drop

The full-scale representatives of the 110 gallon Versa-Pac containing a simulated payload were subjected to a variety of sequenced drops, punctures, shallow angle drops and crush test, specified by 10CFR71.73 and outlined in the test plan and report in Appendix 2.12.3. The same prototype was used for each test sequence in succession, with no repairs between the tests. The test prototypes were fabricated to the drawings and specifications provided in Appendix 2.12.2.

All drop tests were performed on the same 70 ton pad which is 10' x 10' x 10' deep reinforced with a grid of ¾" re-bar spaced on 12 "center and capped with an 8' x 10' x 1" thick steel plate which is embedded to the surface of the concrete and secured to it with fourteen 1-1/2" diameter x 16' long bolts. A quick release mechanism was used to release the prototypes from the drop height without imparting rotational or translational motion to the prototype. For the puncture drop, a puncture ram was welded to the test pad. The ram is a 6" diameter by 18" long right circular cylinder, fabricated from mild steel and welded to the pad reinforcement plate. The solid steel plate used for the dynamic crush test weighs 500 kg and is 1m by 1m in cross section. The tests were video taped and photographed, and post-drop damage measurements were recorded after each drop.

In order to determine the worst-case initial temperature conditions for the drop tests, the performance characteristics of the primary Versa-Pac fabrication materials were evaluated. The primary structural and sealing materials include carbon steel, polyurethane foam, and silicone rubber. Because carbon steel may exhibit brittle failure mechanisms at temperatures below 0°F and the other materials are essentially unaffected over the design temperature range, the initial condition temperature selected is –20°F. For consistency with the minimum design operating temperature specified by international regulations, the impact testing initial ambient condition selected is –40°F.

The payload utilized for the drop test series consisted of a 30-gallon drum that was filled with approximately 226 lb of different size gravel with an additional 1 to 1-1/2 lbs. of loose play sand which was placed on the top of the 30 gallon drum, combining for a test payload of 260 lbs. The blind flange was secured by tightening the bolts to an initial torque of 40 ft-lbs. The decay heat generated by the contents is negligible; therefore, heat generated by the contents was not simulated. The Versa-Pac was then subjected to an ambient air temperature of approximately -40°F for 12 hours. Upon removal from the conditioning chamber, the exterior skin of the shipping package recorded a temperature of -28°F at time of transport to the test pad.

2.7.1.1 End Drop

After cooling, test package serial number 10552 was positioned with the top end of the package positioned over the test pad at an angle of 0 degrees so as to impact the container directly onto the top surface of the package. This drop series is intended to test the top closure of the package and the internal containment closure components.

Test Record Number – TS-001-1

Test Number 1A – NCT 4' Top End Drop

The initial drop was made from a height of 4' onto the target pad, and the external damage was recorded and documented with both video and still photography. As result of the impact no visible damage was accumulated. All welds, closures and bolts remained intact. The package was not opened after the Normal Condition Drop, but was prepared for the 30' HAC Drop.

Test Number 1B – HAC 30' Top End Drop

Following the Normal Conditions Drop, the package was positioned for the HAC 30' drop onto the same surface and orientation of 0 degrees. Post drop inspection documented that the overall height of the package was reduced by 1/4 inch and that the diameter was increased by 1/6 inch. An area measuring a total of 2 and 3/8 inches long at the bolt closure was crumpled in slightly. All welds, closures and blots remained in tact. The package was not opened, but was set aside for use in the puncture test listed in Test Record TS-001-1 Number 1C.

2.7.1.2 Side Drop

After cooling, test package number 10551 was positioned in a level horizontal position over the test pad. This drop series was designed to test the impact on the bolt closure of the package on its side, along with inner containment closure when exposed to the impact.

Test Record Number – TS-001-2

Test Number 2A – NCT Horizontal Side Drop

The initial drop was made from a height of 4' onto the target pad, and the external damage was recorded and documented with both video and still photography. The result of the impact to the exterior surface of the package was that the closure bolt was pushed into the package side wall approximately 5/8 inch. No reduction in height or diameter occurred. All welds, closures and bolts remained in tact.

Test Record Number – 2B – HAC 30' Horizontal Side Drop

The same test package was positioned for the HAC 30' drop onto the same horizontal surface as the Normal Conditions Drop in an effort to shown accumulated damage in the side drop orientation. Resultant damage from this drop accounted for a buckling around the closure bolt area and on the lid and a decrease in the diameter of I inch in the bolt impact direction. There was no loss of bolts or closure and all welds remained in tact. The package was then subjected to the crush plate drop described below and recorded in TS-001-2 Record Number 3C.

2.7.1.3 Corner Drop

Upon cooling, test package number 10550 was in a position with the center of gravity impact to be through the package bolt closure over the test pad. This drop series was designed to test the impact on the bolted closure of the package through its center of gravity, along with inner containment closure when exposed to the impact.

Test Record Number TS-001-3

Test Number 3A – NCT Center of Gravity Drop

The normal condition drop center of gravity drop from a height of 4' through the bolted closure at an angle of 57 degrees was recorded and documented using both video and still photography. The impact resulted in a deformation on the drum side at the closure bolt with measurements of 1-1/16 inch deep by 2 inches long. All welds, bolts and closures remained in tact.

Test Record 3B – HAC Center of Gravity Drop

The package was repositioned in the same attitude of 57 degrees so as to impact the identical area tested in 3A above over the test pad at a height of 30' form the lowest point of the package. The impact resulted in a depression 11/16 inches deep into the lid and additional side deformation totaling 2-1/2" deep by 20 inches long. All welds, bolts and closure remained intact. The package was then readied for the HAC oblique (Shallow) angle drop described below.

2.7.1.4 Oblique Drop

Using test package number 10550 an oblique drop of 17 degrees was positioned of the test pad so as to initially impact the top closure with the resulting acceleration impact to attack the bottom of the package. This drop was also intended to test the inner containment area closure system.

Test Record Number 3C – HAC Shallow Angle Drop (Slap Test)

The package was positioned over the test pad at 17 degrees from the horizontal position with the lowest point of the package 30' from the target surface. The damage to the package exterior surface produced a tear at the exterior drum side to bottom rim connection point measuring 3/16 inch at its widest point by 7 inches in length. Although this slit in the outer drum occurred, no internal breach of the inner liner occurred, remaining completely sealed from the exterior atmosphere. Additional deformation at the bolted closure affected an area measuring 2-15/16 inches deep with a 1-inch crumple in the lid. The diameter of the package across the top surface only, of the outer drum lid, was reduced in the direction of the impact upon the bolt, by approximately 3 inches, which coincides with the deformation described above. The package was then readied for a puncture test to be described below and listed in Test Record TS-001-3 Number 3D.

2.7.1.5 Summary of Results

The initial drops of this test series provided information showing that the package design was capable of withstanding multiple impacts with only minor damage to the exterior surfaces of the package this point. Complete measurements along with full photographic and written documentation are included in Appendix 2.12.3. Drop test series complete summary of results are noted in 2.7.3.1 below.

2.7.2 Crush

Based upon past history and an attempt to attack the top closure mechanism of the package system, the test package previously used in horizontal drop of Test Record TS-001-2 was positioned on the test pad in a horizontal attitude. The crush plate was placed to impact the package directly on both the closure and top flange areas and also over the bottom edge of the package. The purpose of this test was to test both the internal and exterior closures and surfaces of the test package.

Test Record Number 2C – HAC 30' Crush Plate Side Drop

The crush plate was suspended at an angle of 0 degrees directly over the test package and lifted to a height of 361 inches from the lowest point of the test plate to the top of the test package surface. Upon impact the overall diameter of the package in the direction of the impact was reduced by 2-1/2 inches from its original shape at its maximum point. A gap of ¼ inch by 1-1/4 inch long was documented at the drum lid to drum rim interface. Due to the design of the closure lid a metal-metal interface was visible with no direct opening to the internal structure or seals.

2.7.3 Puncture

Prototypes of both the 55 and 110-gallon versions of the Versa-Pac were subjected to the puncture test in a variety of orientations including side, center bottom, center top and center of gravity through the bolt closure. The most damage to the exterior surface of the package was through the center of gravity onto the closure and by attacking the side between the vertical stiffeners. Based upon this data both areas were punctured during this test series. The packages were lifted to a height of 41 inches above the top of the puncture ram, which was welded to the top surface of the drop test pad.

Test Record Number 1C – HAC 1 Meter Puncture Drop – Horizontal

The suspended package was positioned level and horizontal (1 degree) so that the impact location was between two of the vertical stiffeners and in the middle of package. The test was recorded and documented using video and still photography. The deformation upon measurement was a maximum of 3/8 inch deep. The package sustained no tears as a result of the puncture drop.

Test Record Number 3D – HAC 1 Meter Puncture Drop – CG Over Bolt Closure

The package was positioned with the center of gravity through the bolted closure at an angle of 56 degrees from a height of 41 inches from the lowest point of the package to the top of the puncture ram. The drop test was recorded and documented using both video and still photography. The impact resulted in additional damage on the drum side at the closure bolt with a small separation of ¼ inch by 3 inches long at the drum lid and drum rim interface. The opening was sealed by metal-metal contact between the flange and the drum lid insulation sheet metal cover and the top gasket material, which remained in tact.

2.7.3.1 Summary of Damage

Upon completion of the drop test series all test packages were inspected for damage, the torque of the bolts recorded and internal condition and damage noted.

Test Record Number TS-001-1 – Top End Drops - Package Serial Number 10552

The series of test conducted included a 4-foot top end drop, a 30-foot top end drop and a horizontal side puncture drop. Outer closure bolts recorded a torque of 30 ft-lbs. The outer lid was removed exposing a bulge in the inner containment flange. The bulge in the inner flange allowed sand, which was placed on the top of the payload 30-gallon drum to be forced under the containment gasket. It is believed that the piston action within the inner drum payload provided a secondary impact force upon the primary containment flange thus causing the flange to bulge. Containment flange bolts were torqued prior to removal and recorded at 20 ft-lbs. Gaskets and the internal condition of the package were found to be in good condition with no damage.

Test Record Number TS-001-2 – Horizontal Side & Crush Plate Drops - Package Serial Number 10551

The test article series of drops included a 4-foot horizontal side drop, a30-foot horizontal side drop and a 30-foot crush plate side drop. Although, the outer drum ring was dislodged during previous testing the package remained closed and in place due to the additional top closure bolt design of the Versa-Pac Shipping Container. The outer closure bolts of the top cover were torqued and recorded a reading of 25 ft-lbs. Upon removal of the outer lid inspection revealed a slight interior wall deformation in the upper plug well of the package. There was no loss of contents. The containment flange was in good condition and the bolts recorded a torque of 25 ft-lbs. Gaskets were in good condition. The inner payload drum lid exhibited some buckling from the piston action of the internal payload within the drum. This payload comprised of gravel and sand acted as an additional piston action within the body of the drum. Upon removal of the inner containment payload visual inspection was conducted with no damage shown within the inner containment cavity.

Test Record Number TS-001-3 – Center of Gravity, Shallow Angle & Puncture - Package Serial Number 10550

This series consisted of a 4-foot center of gravity drop, a 30-foot center of gravity drop, a 30-foot shallow angle drop and a center of gravity puncture drop. Upon completion of these drops the test package outer closure bolts were torqued with readings found to be less than 20 ft-lbs. upon removal of the outer lid inspection revealed a deformation of the inner wall at the impact area. A bulge in the inner containment flange was also noted along with some sand from the inner containment area. This again was due to the piston action coming from the internal payload during the impact and corresponding secondary impact from the payload. The gaskets were found to be in good condition. Upon removal of the inner containment payload a visual inspection was conducted with no damage found to the internal cavity.

2.7.3.2 Conclusions

Based upon the information obtained from the series of drops conducted it was determined that the two of the drop series results were unsatisfactory and that additional testing would be conducted. It was determined that three primary causes were responsible for the

bugling of the internal containment flange and the resultant loss of sand from the top of the inner payload. The first being that the flange in itself was under sized at $^{3}/_{16}$ inch thick and secondly, that the thickness of the silicone coated fiberglass gasket used in sealing the containment allowed a flexing at the interface of gasket and flange. The third potential cause was the removal of the gasket pad located between the inner flange and the payload.

In order to correct this condition the flange was increased to a thickness of ½ inch. This would accommodate a greater torque to be applied to the sealing of the inner containment area and provide a much higher strength to support the internal piston action within the payload area. Also the gasket pad would be reinstalled between the payload and the inner flange surface.

After evaluating the three test articles, two were chosen for reuse in an additional round of testing. The packages chosen were in good condition and were able to be resealed after their original series of testing. These package serial numbers were 10551 and 10552.

2.7.3.3 Package Preparation

Both previously drop packages were carefully inspected and measurements of height and diameter recorded on new testing records. The payloads were identical to the original test series, with 1-1/2 pounds of sand place on top of and around the payload as before. The test articles were fitted with new ½ inch thick inner containment flanges with 3/8 inch thick neoprene sponge rubber pads affixed to the inside of the inner flange lid prior to installation. The torque of the inner containment bolts was also increased for a better seal on the 1.8 inch thick silicone rubber coated fiberglass gasket to 60 ft-lbs. The outer container lid was put into place and bolts torqued to 60 ft-lbs.

The test articles were then placed in the cooling chamber for 18 hours prior to the new drop tests.

2.7.3.4 Second Round End Drops

After cooling, test package serial number 10551 was positioned with the top end of the package positioned over the test pad at an angle of 0 degrees so as to impact the container directly onto the top surface of the package. This second round drop test series was intended to test the top closure of the package and the internal containment closure components and to validate that the changes made to the inner containment flange would prove to correct the loss of materials previous found during the original drop testing.

Second Round Test Record Number – TS-001-4

Second Round Test Number 1A – NCT 4' Top End Drop

This drop was made from a height of 4' onto the target pad, and the external damage was recorded and documented with both video and still photography. As result of the impact no visible damage was accumulated. All welds, closures and bolts remained intact. The package was not opened after the Normal Condition Drop, but was prepared for the 30' HAC Drop.

Second Round Test Number 1B – HAC 30' Top End Drop

Following the Normal Conditions Drop, the package was positioned for the HAC 30' drop onto the same surface and orientation of 0 degrees. Post drop inspection documented that

the overall height of the package was reduced by 7/16 inch and that the drop test did not affect the diameter. All welds, closures and blots remained in tact.

Prior to opening the test article the bolt torque of the outer closure was measured and found to be between 20 to 80 ft-lbs. with all bolts in tact. After opening the package photographs were taken and the interior well surfaces inspected with no damage found. The new thicker blind flange remained flat, sealed and no loss of payload contents were found outside the inner containment area. The bolts of the interior containment were torqued and found to be at a torque of 30 to 50 ft-lbs. The gasket and payload were in good condition.

2.7.3.5 Second Round Corner Drop

After cooling, test package number 10552 was in a position with the center of gravity impact to be through the package bolt closure over the test pad. This second round drop series was designed to test the impact on the bolted closure of the package through its center of gravity, along with inner containment closure when exposed to the impact and to verify that the changes made to the test article were sufficient to correct the loss of contents in this previously tested series of drops.

Second Round Test Record Number TS-001-5

Second Round Test Number 3A – NCT Center of Gravity Drop

The normal condition drop center of gravity drop from a height of 4' through the bolted closure at an angle of 57 degrees was recorded and documented using both video and still photography. The impact resulted in a deformation on the closure bolt area with measurements of 1-3/16 inch deep by 21/4 inches long. All welds, bolts and closures remained in tact.

Second Round Test Record 3B – HAC Center of Gravity Drop

The package was repositioned in the same attitude of 57 degrees so as to impact the identical area tested in 3A above over the test pad at a height of 30' form the lowest point of the package. The impact resulted deformation totaling 2-9/16" deep by 20-1/2 inches long. All welds, bolts and closure remained intact. The package was then readied for the HAC oblique (Shallow) angle drop described below.

2.7.3.6 Second Round Oblique Drop

Using test package number 10552 a second oblique drop of 17 degrees was positioned of the test pad so as to impact the top closure with the resulting acceleration impact to attack the bottom of the package. This second round drop was also intended to test the inner containment area closure system and to provide evidence that the changes made to the test article corrected the loss of content problem previously found in the original testing.

Second Round Test Record Number 3C – HAC Shallow Angle Drop (Slap Test)

The package was positioned over the test pad at 17 degrees from the horizontal position with the lowest point of the package 30' from the target surface. The damage to the package exterior surface produced deformation on the initial top closure measuring 2-15/16 inches deep

with a 1 inch crumple in the lid. Secondary impact produced damage measuring 5 inches in length on the bottom rim of the test article. Diameter of the package was reduced in the direction of the impact area through the bolt by approximately 1 inch.

Before opening the outer closure the torque was measured and found to be less than 20 ft-lbs. Photographs were taken and inspection of the inner well area found only minor deformation within the sidewalls of the well area, no other damage was found. The inner flange was flat and sealed with no loss of contents form the internal containment area.

2.7.3.7 Secondary Test Series Conclusion

With the changes made to the inner blind flange closure, increasing the thickness of the flange, increasing the torque of the bolts and reinstalling the containment flange pad the Versa-Pac Shipping Container successfully completed the drop test evaluation series.

2.7.3.8 55 Gallon Shallow Angle (Slap-Down) Drop Test Series - Test Record Number TS-002-1

This series of testing was conducted to provide additional information and verification that the 55 gallon version of the Versa-Pac shipping container would demonstrate the capability to successfully meet the requirements set forth with similar results provided by previously conducted testing of the 110 gallon version when subjected to the affects of both NCT and HAC Shallow Angle Drops. The package contained 254-1/2 pounds of payload consisting of gravel, steel bars (to amplify the secondary piston impact effect) and 1-1/2 pounds of loose sand for a total weight of 644-1/2 pounds. All bolts were torqued to 60 ft/lbs. at closure of the blind flange and top closure lid.

2.7.3.9 Oblique Drop

Using 55 gallon test package number 10553 an oblique drop of 17 degrees was positioned of the test pad so as to initially impact the top closure with the resulting acceleration impact to attack the bottom of the package. This drop was also intended to test the inner containment area closure system. The drop angle of 17 degrees was chosen based upon previous drop history of like packages and drop information found and recorded in NUREG 6818. The puncture drop was chosen after the initial drops to attack the most vulnerable area of the package base upon the damage from the shallow angle NCT and HAC drops to the package.

Test Record Number 1-55-A – NCT Shallow Angle Drop (Slap Test)

The package was positioned over the test pad at 17 degrees from the horizontal position with the lowest point of the package 4' from the target surface. The damage to the package exterior surface produced only minimal damage to the impact side of the test package, with an area 7-1/4" long at the widest points on the top closure end and a impact are 5-3/4" in width at the bottom edge. Minor indentation along the outer drum rolling hoops was also noted. Both flattened areas were approximately ¼" in depth. There was no tearing or opening of the package. The package was then readied for a puncture test to be described below and listed in Test Record TS-001-3 Number 3D.

Test Record Number 1-55-B – HAC Shallow Angle Drop (Slap Test)

The test package was then positioned over the test pad at 17 degrees from the horizontal position with the lowest point of the package 30' from the target surface. Damage to the package consisted of a small ripple in the middle of the outer drum lid with minor flattening of the outer drum rolling hoops. Additional damage to the top closure, initial impact area was noted increasing the length of the area to 11-1/2" long by 3/8" deep and the bottom, secondary impact increasing to 100 long by ¼" deep. The bolt closure ring of the outer drum was pushed into the side wall of the outer drum producing a small tear in the drum sidewall material at the top rolling hoop, but due to the design of the package there was no breach or tearing of the Versa-Pac's inner liner, which is adjacent to the outer drum. The drum closure ring lug was also broken with the impact, but the top closure, remained in tact and secure due to the top closure bolts of the package.

Test Record Number 1-55-C – HAC 1 Meter Puncture Drop – CG Over Bolt Closure

The package was positioned with the center of gravity through the bolted closure at an angle of 56-1/2 degrees from a height of 41 inches from the lowest point of the package to the top of the puncture ram. The drop test was recorded and documented. The impact resulted in additional damage to the outer drum closure ring and lid interface with an impact deformation measuring 8-3/8" in diameter. There was no tearing or opening of the package as a result of the puncture drop.

2.7.3.10 55 Gallon Test Series Conclusion

Based upon the results of the test series the 55 gallon version of the Versa-Pac has demonstrated that it is capable of meeting the requirements set forth in 10 CFR 71 and Century Industries Test Plan TP-002 Revision 0 by retention of the outer closure, no openings, tears or failure that would lead to the loss of material, no open pathway to the insulation materials and no loss of the inner containment payload. The overall diameter of the package thru the impact area was reduced by ½", but remained the same in the opposite direction.

2.7.4 Thermal

A thermal test was not performed on the test prototype in its damaged condition following the drop test sequence. However, the package was analytically evaluated as indicated in Section 3. Based on testing of a similar package (Champion) as presented in Section 3.5.3, the analytically calculated values appear to be conservative.

2.7.4.1 Summary of Pressures and Temperatures

The Versa-Pac was evaluated for HAC using the finite element models described in Appendix 3.5.1 and under the conditions listed in Table 3-2. The maximum temperature recorded at the payload cavity during the fire event was 423°F at the top of payload cavity, just below the polyurethane plug, as shown in Figure 3.1. This temperature is well below the maximum HAC allowable temperature of 500°F. Although the internal pressure of a filled package is nominally atmospheric, the internal pressure of the containment may range from 0 to

9.8 psig (24.5 psia) for the HAC condition. However, since the Versa-Pac is not a sealed system, the maximum normal operating pressure is near atmospheric pressure.

2.7.4.2 Differential Thermal Expansion

As discussed in Section 2.6.1.2, the materials used to fabricate the Versa-Pac and the arrangement of the packaging limit the effects of differential thermal expansion. No significant stresses are generated as a result of differential thermal expansion.

2.7.4.3 Stress Calculations

Due to the decoupled design of the packaging, thermal stresses generated by the packaging are negligible.

2.7.5 Immersion – Fissile Material

Moderator inleakage to the most reactive credible extent is assumed for the Versa-Pac and evaluated in Section 6.0. Thus, the fissile material immersion test is not required.

2.7.6 Immersion – All Packages

Regulations require that an undamaged package be capable of sustaining a hydraulic pressure of 50 feet of water. As indicated in Appendix 2.12.3, a similar damaged prototype was placed in an immersion chamber at 23 psig for 15 minutes. As expected, due to the reinforcements within the drum, no further damage was noted.

2.7.7 Deep Water Immersion Test

This section is not applicable to the Versa-Pac Shipping Container.

2.7.8 Summary of Damage

The series of drop tests (3 initial series and 2 second round series a total of 5 in all) completed were performed for the worst-case package orientations, worst-case initial packaging temperature, and with a maximum payload on board. The test article was slightly too moderately deformed at the impact sites. Due to impact from testing only minor changes in the diameter were found with measured diameter changing primarily at the impact points only. The worst case of oval conditions at impact points were measured major and minor diameters at 31.625" and 28.5", respectively following the center of gravity and shallow angle drops in Test Series TS-001-3. The majority of test article diameters remained constant through out the test series. The maximum overall height of a deformed package was 42-1/4" and the minimum height was 41-5/8". All bolts remained in tact during all test series with the exception of the loss drum ring in test number 2C Crush Plate Drop, although the closure ring was lost there was no opening of the test article due to the design of the Versa-Pac and its top bolts. The impact of the puncture test conducted produce only minor damage with indentations of ¼" and 3/8". One exterior drum surface tear occurred at the bottom of the drum rim upon impact, during the secondary impact of the initial shallow angle drop 3C, but due to the inner liner design of the Vera-Pac, with a sealed steel liner directly adjacent to the drum skin no breach of the container occurred. A small gap

from the impact in test number 2C at the lid to drum rim interface was sealed with a metal to metal contact of the lid steel insulation cover and the top side wall and gasket.

The second series of tests conducted to confirm that the changes made to the inner containment blind flange and seal validated that the increase in thickness of the blind flange, the increase in torque and the addition of the neoprene sponge rubber pad attached to the inside of the flange corrected the loss of payload contents that occurred in the original test series. With the changes no tears, no broken welds, no openings and no broken bolts were found. The inner flange remained flat and sealed as required.

The 55 gallon drop test series produced expected damage to the impact areas with no loose of containment and no damage that would lead to loss of materials. It provided additional information supporting evidence based upon physical testing that the 110 gallon version binds the smaller 55 gallon version of the Versa-Pac shipping container system.

There was no damage or shift to the inner containment area during any of the five separate test series.

The results of the test series demonstrate that the packaging is maintained within the allowable temperature, pressure and stress ranges. The average OD of the packaging is maintained greater than 21.5" and the minimum height of the packaging is maintained greater than 34" under all conditions as required for criticality control. There is no breach of the containment area and thus no loss or dispersal of radioactive contents. Thus, the packaging is acceptable for use.

2.8 Accident Conditions For Air Transport of Plutonium

This Section is not applicable to the Versa-Pac Shipping Container.

2.9 Accident Conditions For Fissile Material Packages For Air Transport

This section is not applicable to the Versa-Pac Shipping Container.

2.10 Special Form

Special form material as defined in 10CFR71 is not applicable to the Versa-Pac.

2.11 Fuel Rods

This section is not applicable to the Versa-Pac.

2.12 List of Appendices

Table 2.1 Evaluation Results

Table 2.2 Mechanical Properties of Materials

2.12.1 MACTEC Report on Material Compatibility

2.12.2 Century Industries Performance Test Report for the Versa-Pac

2.12.3 Excerpted from Safety Analysis Report for the Century Champion Type B Package Immersion Test

2.12.4 Century Industries Performance Test Report for the 55 Gallon Versa-Pac (Shallow Angle Drops)

Table 2-1 Evaluation Results

Evaluation	Evaluation Result	Evaluation Criteria	Minimum Factor of Safety (FS)[1] or Design Margin (DM)[2]
Minimum package size	Versa-Pac is 24" x 35"	10CFR71.43(a)	N/A Package is acceptable
Tamperproof feature	One per package, Closure Ring Bolt	10CFR71.43(b)	N/A Package is acceptable
Positive Closure	110 Gallon Versa-Pac uses 20 bolts to secure the packaging & the 55 Gallon Versa-Pac uses 16	10CFR71.43(c)	N/A Package is acceptable
Chemical & Galvanic reactions	The materials do not react chemically and galvanic reactions are acceptable over the packaging life	10CFR71.43(d)	N/A Package is acceptable
Lifting	N/A	10CFR71.45(a)	N/A Package is acceptable
Tie down	N/A	10CFR71.45(b)(1)	N/A Package is acceptable
Differential thermal expansion	Foam maximum expansion ~0.004" Stress developed ~ 0 psi in both foam and steel components	Yield strength	FS $\rightarrow \infty$
Thermal Stress	N/A Package uses a de-coupled design that minimizes thermal stresses	Steel yield strength Foam compressive strength	FS $\rightarrow \infty$
Cold	Packaging temperature = -40°F	Minimum allowable, -40°F	FS = 1.0
Reduced External Pressure	Effective pressure differential = 16.7 psia internal or 3.3 psia external	Containment rated to 15 psig	FS = 1.7
Increased External Pressure	Effective pressure differential = 20 psia external or 3.3 psia external	Containment rated to 15 psig	FS = 1.4
Transport Vibration	No loss of containment, no loss of packaging effectiveness	10CFR71.71(5)	N/A Package is acceptable
Water Spray	No effect on packaging effectiveness	10CFR71.71(6)	N/A Package is acceptable

Table 2-1 Evaluation Results

Evaluation	Evaluation Result	Evaluation Criteria	Minimum Factor of Safety (FS)[1] or Design Margin (DM)[2]
Normal Condition Free Drop	No effect on packaging effectiveness	10CFR71.71(7)	N/A Package is acceptable
Compression	623 psi	10CFR71.71(9) steel yield strength	FS = 25.7
Penetration	No effect on packaging effectiveness	10CFR71.71(9)	N/A Package is acceptable
Hypothetical Accident Condition Free Drop and Puncture Drop	No effect on packaging effectiveness	10CFR71.73(1) and (3)	N/A Package is acceptable
Hypothetical Accident Condition Fire	Maximum payload vessel temperature 423°F	10CFR71.73(4) Maximum allowable payload/seal temperature = 500°F	DM = 131 °F FS = 1.18
Fissile Immersion	No in-leakage	10CFR71.73(5)	N/A
Immersion	No in-leakage	10CFR71.73(6)	N/A

Notes on Table 2-1:

1. The Factor of Safety is defined as the ratio of the allowable to the actual, rounded down the nearest tenth.
2. The Design Margin is defined as the allowable minus the actual.

Table 2-2 Mechanical Properties of Materials[Note 1]

Property/Material	Carbon Steel Plate and Sheet	Carbon Steel Bolts
Density (lb/ft^3)	491 [Note 2]	N/A
Thermal Expansion Coefficient (in/in/F)	[9.22 x 10^{-6}]	N/A
Min Yield Strength (psi x 1,000)	[36]	[81]
Min Tensile Strength (psi x 1,000)	[58]	[105]
Elongation in 2" (%) *Elongation in 4D (%)	[21*]	[14]

Property	Impact Absorbing Foam Insulation
Density (lb/ft^3)	5.0 – 11.0 [Note 3]
Nominal Thermal Expansion Coefficient (in/in/F)	3.4 x 10^{-5} [Note 4]
Compressive Strength (psi)	85 – 300 [Note 3]

Notes on Table 2-2:

1. Information provided in [brackets] is an average or nominal for the material used and is provided for comparison purposes only, as it is not used in any evaluation presented for the packaging.
2. Ross, R. B. Metallic Materials Specification Handbook, 4th Edition, London, Chapman and Hall, 1992.
3. Century Industries SOP 6.11, Versa-Pac Polyurethane Closed Cell Foam Specification for Century Products.
4. General Plastics Last-a-Foam FR-3700 for Crash & Fire Protection of Nuclear Material Shipping Packages, General Plastics Manufacturing Company, Tacoma Washington, 2/99.

Appendix 2.12.1

MACTEC Report on Material Compatibility

MACTEC

May 6, 2004

Mr. Mike Arnold
Centuries Industries
P.O Box 17084
Bristol, Virginia 24209

Subject: **Corrosion of carbon and stainless steel in contact with foam**
MACTEC Project 6230-03-0989

Mactec Engineering and Consulting, Inc. (MACTEC) previously performed chemical analysis of a foam sample. The results of our testing were provided to you in our report dated January 15, 2004.

The results of our testing indicated that the chloride content of the foam sample tested was less than the detection level (25ppm) of the test method and apparatus utilized.

Based on the low chloride content, it is our opinion that significant chloride related corrosion of carbon steel and 316L stainless steel material in contact with this foam is not likely to occur.

We appreciate the opportunity to provide this letter. Please contact us if we can be of further assistance.

Sincerely,
Mactec Engineering and Consulting, Inc.

Lakshman Santanam, P.E.
Principal Engineer

MACTEC Engineering and Consulting
2801 Yorkmont Road, Suite 100 • Charlotte, NC 28208
704-357-8600 • Fax: 704-357-8638

MACTEC Engineering & Consulting, Inc.
2801 YORKMONT ROAD, SUITE 200 • CHARLOTTE, NC 28208
PHONE 704-357-8600 • FAX 704-357-8637

FILE

REPORT OF CHEMICAL ANALYSIS

Client: Century Industries
P.O. Box 17084
Bristol, VA 24209

Attn: Mr. Mike Arnold

Project: General
Office: Charlotte
Lab No.: 6230-03-0989
Page: 1 of 1
Date: January 15, 2004

Client P.O.: PWAS
Material: Reported as Foam Samples
Heat/Lot No.: See Below
Date Tested: Completed December 31, 2004
Procedure: In general accordance with Client's Instructions and ASTM D-1411-99

Test Results (%)

MACTEC Piece No.	pH Value (units)	Chlorides (ppm)	Sulfate (ppm)	Comments
Foam Sample Leachable	4.3	< 25	287	
Foam Sample Total	---	< 25	21,248	

Reviewed By: Lakshman Santanam, P.E.
Principal Engineer

Respectfully Submitted,
MACTEC ENGINEERING & CONSULTING, INC.

Carol J. Pilarczyk, Staff Engineer

Appendix 2.12.2

Century Industries Performance Test Report for the Versa-Pac

(133 Pages)

Note: Paragraph 6.5 has been revised to add missing information regarding the NIST Traceability requirements.

Century Industries Box 17084, Bristol, Virginia 24209
Phone: 423-646-1864
E-mail:CenturyIndWMA@aol.com

Test Report
Performance Evaluation Test Series Of
Century Industries' Model VP-55 & VP-110
Versa-Pac Shipping Container

US NRC Docket Number 71-9342

Test Conducted in Accordance with Test Plan TP-001 Revision 0
And
Test Specification TS-001 Revision 0
Prepared & Conducted By:
Century Industries
William M. Arnold

Prepared By: _____ Date: _____

Table of Contents

1.0 INTRODUCTION

This Report describes the methods and guidelines Century Industries followed for the preparation and testing of the Versa-Pac Shipping Container in accordance with the requirements specified in Century Industries Test Plan TP-001 Revision 0 and Century Industries Test Specification TS-001 Revision 0 (Attachment A and B). The test program was conducted by Century Industries located in Bristol, Virginia between February 25 and March 5, 2009. This report includes the program objective, test procedure, item description, test results, test records (Attachment C) and other applicable documents including photographs of the testing.

2.0 OBJECTIVE

The objective of this test program was to conduct the physical performance evaluation tests for Century Industries VP-55 and VP-110 Versa-Pac Shipping Container designer and manufacturer of the package, in accordance with the normal conditions and hypothetical accident conditions specified in Title 10 Part 71.73 [1], Test Plan TP-001 Revision 0 and Test Specification TS-001 Revision 0.

The test items were identified as Versa-Pac shipping container prototypes and subjected to the following performance tests:

1. Initial visual inspection of the outer and inner container surfaces.

2. Low Temperature Conditioning

3. Drop testing in accordance with 10 CFR 71.71(c)(7), 71.73 (c)(1),(2) & (3), along with NUREG6818, Shallow Angle Drop in a variety of orientations described in Regulatory Guide 7.9

4. Post Test Visual Inspection of the outer and interior container surfaces.

Following each test the physical condition of the shipping container was inspected and the results recorded.

3.0 RESPONSIBILITIES

Century Industries personnel conducted the test program and were responsible for the base analysis of the test articles, the test plan and oversight of the test series. All test personnel completed the Pre-test Readiness Review and associated procedures.

The test series was performed in accordance with the applicable requirements and guidance of Century Industries QA Program QA-1 Revision 1, 10 CFR 71 and this test plan.

The program manager was William M. Arnold, President of Century Industries.
Quality Assurance Coordinator was Heather Little.

4.0 TEST ITEM IDENTIFICATION

Century Industries was responsible for the design, fabrication, inspection, recording the preliminary measurements and the loading of payload and payload containers with multiple size gravels and loose sand.

5.0 TEST ITEM DESCRIPTION

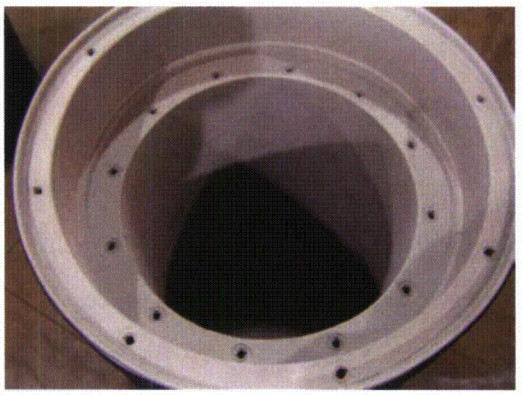
The Versa-Pac Shipping Container is designed for the shipment of Type A radioactive and fissile materials in the form U-metal, oxides, fluorides and nitrate for both product and scrap materials. The fissile payload was design for 350 grams at 100% enrichment and a criticality safety index of 1.5.

The Versa-Pac Shipping Container was designed in two basic versions, a UN1A2 -55 gallon and 110 gallon outer drum with a 16 gauge body, bottom and cover, in addition to the standard 12 gauge closure ring with a 5/8" ASTM A307 bolt, the cover is reinforced and secured using the addition of bolts attached to the internal structure of the package as detailed in the design drawings. The internal structure consists of vertical and horizontal stiffeners at specific points around the package. Outer and inner 16 gauge liners, with an insulating ceramic fiber blanket between the liners complete the primary inner structural components. A secondary barrier of insulation consisting of ceramic fiber blanket; surround the inner containment body. The payload gasket is a woven fiberglass yarn in a flexible substrate, coated with high grade silicone rubber. The gasketed payload containment cavity is made of 10 gauge body and bottom with a ¼" thick top flange to which in the initial series of testing, a 3/16" thick top flange was secure using 12 -1/2" bolts. In the second round of testing the 3/16" thick flange was replaced by a ½ " thick flange and secured by the same number of bolts. The payload cavity is attached to the internal structural components by use of a bolted connection through a fiberglass thermal break between the payload cavity and the structure. Closed cell polyurethane foam is utilized to provide insulation and added impact protection, to both the top and bottom of the Versa-Pac. The top insulation plug is encapsulated in sheet metal welded to the outer drum closure lid. Plastic plugs enclosed within the body of the structure provide a path for venting to the external acetate plug on the exterior of the drum. The cavity is designed to be loaded directly or with the use of an insert to reduce the diameter or with up to a 30 gallon standard drum.

The Versa-Pac was designed in accordance with the requirements of 10 CRF 71 [1] and Century Industries – QA-8, Plan for Manufacture of Versa-Pac Shipping Containers [2].

Pre-Test Photographs 110 and 55 Gallon Versions

110 Gallon - Side View



110 Gallon - Inside View

55 Gallon - Outer Side Top View

55 Gallon - Internal Loaded View

55 Gallon – Blind Flange Bolted

55 Gallon - Top Closure Side View

55 Gallon Version - Side View

6.0 TEST FACILITES & EQUIPMENT

6.1 Environmental Conditioning

Low temperature conditioning of the test articles was conducted before the drop testing was performed in a pre-existing refrigeration chamber. The chamber was cooled by multiple refrigeration units and forced air in the top of the chamber with capability to cool below the required temperatures. Twin door allowed for the packages to be placed into the conditioning chamber by forklift. Temperatures were monitored by the use of calibrated surface thermometers. The packages were transported directly to the drop site in a manner to minimize the time between removal of the shipping container and the drop site.

6.2 Drop Test Pad Facilities

The drop test pad consists of a 70 ton concrete pad made in accordance with IAEA Safety Series No. 37. The pad is 10 feet wide by 10 feet long by 10 feet deep, reinforced with a grid of ¾ inch re-bar spaced on 12 inch centers and capped with a 1 inch thick by 8 feet wide by 10 feet long carbon steel plate, which is embedded into the surface of the concrete and secured by fourteen 1-1/2 inch diameter bolts by 16 inches long.

6.3 Release Device

The release device utilized was capable of releasing the package in a manner that provided a smooth clean drop without imparting any twisting or turning of the package. The device has a safe working load limit of 18,000 pounds. The test articles were lifted into place by use of a crane.

6.4 Orientation and Angles

The orientation if each drop was controlled by the use of nylon fixed straps and adjustable straps used to set the angles required. The orientation of the container was verified using a magnetic protractor attached to the test article surface.

6.5 Measurements and Weights

Drop heights were determined by use of a pre-measured plumb line set by a 100 foot steel tape measure Serial Number 08461846, calibrated by Starett Company and traceable to NIST. The test items tare weights and payload weights were made using a set of floor scales calibrated by Carlton Scales, Kingsport, Tennessee and traceable to NIST.

6.6 Temperature and Wind Speed

Surface and air temperatures were obtained using calibrated surface gauge Serial Number 05548 with a range of -100°F to +160°F and Dickson Temperature Recorder Model SM320 and traceable to NIST. Wind speed was obtained thru the local metro airport service.

6.7 Puncture Device

The puncture device consist of a 6 inch diameter by 22 inches long carbon steel round bar welded to a ¾ inch thick plate, which was then secured to the drop test pad by means of tack welding to the center of the pad.

6.8 Photographic Equipment

Color photographs were taken with a Sony 4.1 Mega pixel digital camera by Century Industries. Video was taken using Sony Digital Handy Cam Mini0DVD DCR-TR-17 and Sony Handy Cam Mini DV DCR-HC20 equipment.

6.9 Crush Plate

The crush test plate is made of A36 carbon steel with measurements of 2-5/8 inches thick by 40-1/4 inches wide by 40-1/4 inches long. The weight of the crush test plate is 1205 pounds. The plate is lifted by up to four ½ thick flat bars welded to each corner of the plate.

7.0 EQUIPMENT AND INSTRUMENT CALIBRATION

All applicable test and measurement equipment were calibrated in accordance with Century Industries Quality Assurance Program. Test and measurement calibration certificates are found in Attachment E. The instrumentation used during testing is listed in Table 1 below.

ITEM	MODEL	S/N	CALIBRATION DUE DATE	COMENTS
Starett 100' Tape Measure	N/A	08461846	November 17, 2009	Used to measure length of plumb bob drop heights
Dickson Temperature Recorder	SM320	09057179	February 01, 2009	Used to calibrate surface thermometer and record air temperature
PTC Instruments Surface Thermometer	330F	05548	April 09, 2009	Used to measure the temperature of the test articles during the conditioning
Floor Scale	0-300 Pound	98530806V1812	February 15, 2009	Used to measure the weight of the payload
Elizabethton Airport	N/A	N/A	N/A	Used to check wind speed
Protractor	N/A	N/A	N/A	Used to measure angles, Calibration not required
4 ' Level	N/A	N/A	N/A	Used as straight edge for measurements
Plumb Bob 30', 4' & 1 Meter Drop height	N/A	N/A	N/A	Used during drop series length determined by calibrated tape

Table 1 – Test Instruments

8.0 ACCEPTANCE CRITERIA

The acceptance criteria for this series of testing was retention of the outer closure, no openings, tears or failure that would lead to loss of materials, no open pathway to the insulation materials and no loss of the inner containment payload.

9.0 TEST PREPARATION AND RESULTS

9.1 Initial Inspection

On February 25, 2009, the visual inspection of the test item was conducted prior to performing any of the physical evaluation tests. During the inspection no damage was found to the exterior or interior surface of the shipping containers. Measurements were taken and recorded on all test articles.

Test Article Serial Number 10550

Location	Pre-Test Measurement	Description
A-C	20-15/16" ID	Inner Container
A-C	31" Ø	Outer Container
A	41-7/8"	Drum Height
A	5-1/16"	Wall – In/Our
A	29-11/16"	Inside Height
A	7-5/16"	Top Rim – Inside Flange
B	41-15/16"	Drum Height
B	7-1/4"	Top Rim – Inside Flange
B	5-1/8"	Wall – In/Out
B-D	20-13/16" ID	Inner Container
B-D	31"Ø	Outer Container
C	29-11/16"	Inside Height
C	5-1/16"	Wall – In/Out
C	42"	Drum Height
C	7-1/4"	Top Rim – Inside Flange
D	29-11/16"	Inside Height
D	42"	Outer Container
D	7-5/16"	Top Rim – Inside Flange
D	5-1/8"	Wall – In/Out

Test Article Serial Number 10551

Location	Pre-Test Measurement	Description
A-C	20-7/8" ID	Inner Container
A-C	31-1/16" Ø	Outer Container
A	41-7/8"	Drum Height
A	5-1/8"	Wall – In/Our
A	29-3/4"	Inside Height
A	7-1/4"	Top Rim – Inside Flange
B	41-7/8"	Drum Height
B	7-3/16"	Top Rim – Inside Flange
B	5-1/8"	Wall – In/Out
B-D	20-7/8" ID	Inner Container
B-D	31"Ø	Outer Container
C	29-3/4"	Inside Height
C	5-1/8"	Wall – In/Out
C	41-7/8"	Drum Height
C	7-3/16"	Top Rim – Inside Flange
D	29-3/4"	Inside Height
D	42"	Outer Container
D	7-3/16"	Top Rim – Inside Flange
D	5-3/16"	Wall – In/Out

Test Article Serial Number 10552

Location	Pre-Test Measurement	Description
A-C	20-7/8" ID	Inner Container
A-C	31-1/16" Ø	Outer Container
A	41-7/8"	Drum Height
A	5-1/8"	Wall – In/Our
A	29-5/8"	Inside Height
A	7-3/16"	Top Rim – Inside Flange
B	41-7/8"	Drum Height
B	7-1/8"	Top Rim – Inside Flange
B	5-3/16"	Wall – In/Out
B-D	20-15/16" ID	Inner Container
B-D	31"Ø	Outer Container
C	29-11/16"	Inside Height
C	5-1/8"	Wall – In/Out
C	41-13/16"	Drum Height
C	7-1/8"	Top Rim – Inside Flange
D	29-5/8"	Inside Height
D	41-15/16"	Outer Container
D	7-3/16"	Top Rim – Inside Flange
D	5"	Wall – In/Out

9.2 Weights and Payload

The package tare weights were recorded on the individual test records. In order to provide the test articles with the most aggressive challenge to the inner payload containment of the Versa-Pac it was decided to use 30 gallon drums to contain the payload contents of multiple size gravel and sand. The materials once place into the drum partially filled the drum container. The payload would provide a secondary piston action within the drum, with an additional piston action occurring from the drum to containment flange impact. 1-1/2 pounds of loose sand was place upon the top of each 30 gallon drum within the containment area in order to provide content material capable of breaching the containment flange seal.

Item/Serial Number	10550	10551	10552
Package Tare Weight	660	662	661
Payload Drum/Gravel and Sand	259.5	260	260.5
Loose Sand Weight	1.5	1.5	1.5
Total	921 lbs.	923.5 lbs.	923 lbs.

9.3 Loading of the Test Item

The 30 gallon drums were closed and the bolt closure ring of each container was torqued to 60 ft/lbs. and lowered into the containment cavity and the loose sand placed onto the top of the drum within the containment cavity. The 1/8" thick silicone coated fiberglass gasket and 3/16" thick containment flange were placed into position and the bolts inserted and hand tightened. The flange bolts were then tightened using an alternating method and torqued to 40 ft/lbs. The top gasket and outer closure, which includes the attached encased polyurethane foam insulation top plug, was installed on each of the test articles and the top outer bolts installed and torqued using the same alternating method to a tension of 40 ft/lbs. The outer drum closure rings were then installed and tightened to a torque of 60 ft/lbs.

30 Gallon Drum Loaded With 260 Pounds of Loose Gravel

1-1/2 Pounds of Sand on Top of Containment Payload

Bolted Inner Blind Flange and Top Gasket

Side View – 110 Gallon Acetate Plug

9.4 Test Article Conditioning

The test articles were placed into the conditioning chamber to achieve the targeted test temperature of -40°F, on the exterior skin of the shipping container test articles. To measure the temperature a calibrated surface thermometer was placed on the surface of the test articles and the side walls of the conditioning chamber and temperatures recorded upon removal of the packages from the chamber for transport to the drop test site. Conditioning was conducted for a period of 16 hours, starting on February 24 at 4:00 PM. At time of transport to the test site test article temperatures were -28°F.

Test Articles in Cooling Chamber

110 Gallon upon Removal from Cooling Chamber

10.0 DROP TEST SEQUENCES

The drop test sequences were chosen based upon engineering calculations, historical drop testing and prototype testing conducted on both the 55 gallon and 110 gallon versions. The original prototype testing results are included in Attachment D. All three test articles were produced in accordance with the fabrication drawings and QA-8, plan for the Manufacture of Versa-Pac Shipping Containers. The test articles were tested in accordance with Century Industries Test Plan TP-001 Revision 0. The original series of drops describe below were conducted on February 25, 2009 and recorded on Century Industries NCT and HAC Test Records for each package.

11.0 TEST PACAKGE SERIAL NUMBER 10552 – TEST RECORD TS-001-1

11.1 Test Number 1A – NCT - 4' Top End Drop

The drop test performance evaluation describe in the Test Plan TP-0001 Revision 0 was performed with the undamaged Versa-Pac Shipping Container. Test Configuration 1A was a 4' free drop vertically onto the top end of the test article at an angle of 0 degrees. The air temperature at the start of this series was 45°F and wind speed was 4 mph. The test article was suspended from a crane by use of a sling connected to the clip that was welded to the center of the bottom of the package and attached to a release mechanism. It was lifted above the test pad in a vertical orientation so that the lowest point of the package was at 4 feet above the top surface of the test pad. The test article was released so that it did not impart rotational motion into the package free fall to the test pad. The container impact on to the test pad surface and produced no noticeable damage to the top of the test article. Both height and diameter were unaffected by the drop. Measurements and photographs were taken showing the extent of the damage.

Top End Drop – 4' Height

Damage from NCT 4' Drop

There were no tears or openings to the drum surface. All bolts remained in tact.

11.2 Test Number 1B – HAC 30' Top End Drop

Configuration 1B was a free drop onto the top end of the previously used test article from test number 1A from a height of 30 feet-1 inch. It was positioned vertically onto the top end of the test article at an angle of 0 degrees. The air temperature at the start of this series was 45°F and wind speed was 4 mph. The test article was suspended from a crane by use of a sling connected to the clip that was welded to the center of the bottom of the package and attached to a release mechanism. It was lifted above the test pad in a vertical orientation so that the lowest point of the package was at 30 feet-2 inch above the top surface of the test pad. The test article was released so that it did not impart rotational motion into the package free fall to the test pad. Measurements and photographs were taken showing the extent of damage.

Top End 30' HAC Drop in Position

Free Fall of HAC 30' Top End Drop

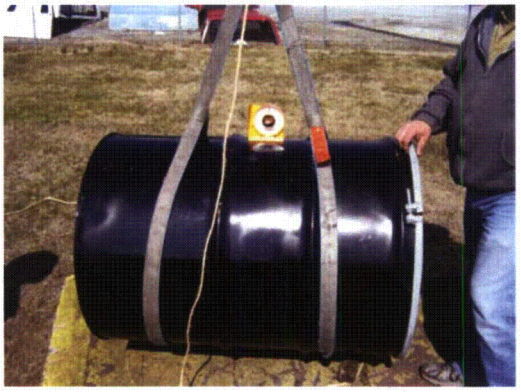
Upon impact to the top end of the package the overall height was reduced by 1/4" inch and the diameter was increased by 1/16 inch. The closure ring and all bolts remained in tact and secure.

Side View – Top End Drop Damage

Close-up – Damage to Closure End

11.3 Test Number 1C – HAC 1 Meter Puncture Drop – Horizontal

Configuration 1C was a puncture drop from a height of 41 inches form the lowest point of the package side to the top of the puncture ram, on the side of the test article at a location directly between two of the vertical stiffeners. The package was positioned level and horizontal (1 degree). This location was chosen to validate that upon impact with the puncture ram that the side wall material of the outer surfaces would not tear and create an opening to the internal components of the package.



Horizontal Side – Puncture Drop

Positioned over the Puncture Ram

Horizontal Puncture Impact onto Ram

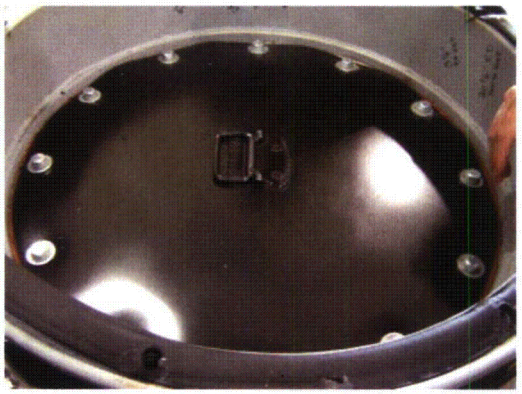
Upon impact a deformation in the side of the test article was measured at a depth of 3/8 inch. There were no tears as a result of the puncture drop. The results were recorded and photographed.

Close-up Damage from Puncture Between the Vertical Stiffeners

Side View – Horizontal Puncture Damage

11.4 Results and Conclusions

As a result of this test series the outer closure bolts recorded a post test torque of 30 ft/lbs. The outer lid was removed exposing a bulge in the inner containment flange. The bulge allowed sand which was placed on the top of the inner containment payload 30 gallon drum to be forced under the containment gasket. The bulge was caused by the impact of the inner payload and the secondary piston impact of the internal payload within the drum itself. Containment flange bolts were torqued prior to removal and recorded at 20 ft/lbs. The gaskets and the internal cavity of the containment were found to be in good condition with no damage. The conclusion of this test series is that corrections were needed to the blind flange seal and closure and that additional testing would be required.



Internal Blind Flange Bulge

Post Test View - Payload

12.0 TEST PACKAGE SERIAL NUMBER 10551 – TEST RECORD TS-001-2

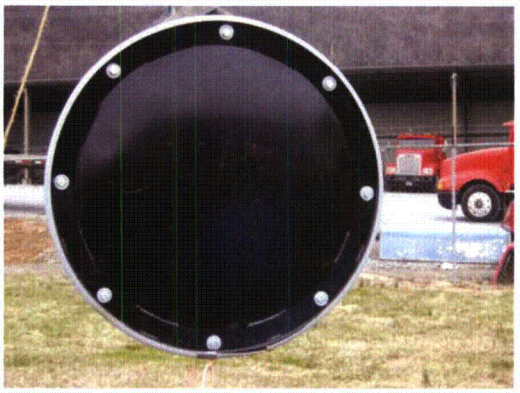
12.1 Test Number 2A – NCT Horizontal Side Drop

After cooling, test configuration 2A was positioned in a level and horizontal orientation of 0 degrees over the test pad at a height of 48 inches from the lowest point of the test article to the surface of the pad. The package was positioned with the use of nylon straps and attached to the release mechanism. The air temperature was 47.5°F with a wind speed of 4 mph. All measurements were previously recorded. The package was released so as not to impart any rotational motion to the test article free fall to the test pad.

Pre-Test Side View 110 Gallon Version

NCT- Horizontal Side Drop – 4' Height

The resultant impact to the exterior surface allowed the bolted closure ring to push into the side wall approximately 5/8 inch deep. There was no reduction in the diameter or height of the package. No bolts were broken and there were no tears or broken welds. Damage was documented and photographed.



Post-Test – End View of Damage

12.2 Test Number 2B – HAC 30' Horizontal Side Drop

The same package was positioned for test configuration 2B for the HAC 30 foot horizontal side drop onto the same surface as the normal conditions drop. This was done in an effort to accumulated damage in this drop orientation. The air temperature was 48°F with a wind speed of 4 mph. The package was lifted to a height of 30 feet–1 inch with the angle of orientation at 0 degrees. The package was release so as not to impart any rotation motion to the test article freefall to the test pad.

The damage from this drop produced a buckle around the closure bolt area and on the lid, along with a decrease in the diameter of 1 inch in the direction of impact through the bolt. There was no loss of bolts or closure and all welds remained in tact. The damage was recorded and photographed.

Post-Test HAC 30' Drop
End View of Damage

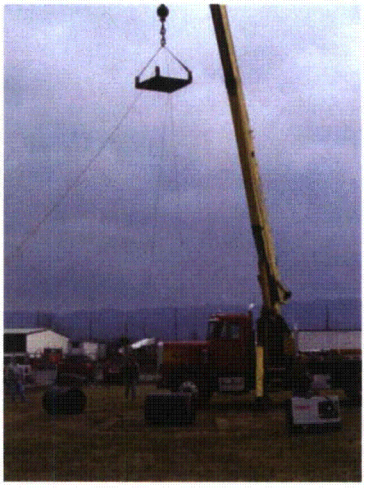
Close-Up HAC 30' Horizontal Side Drop
Damage

Side View – Top End Closure Ring Bolt
30' HAC Horizontal Drop Damage

12.3 Test Number 2C – HAC 30' Crush Plate Side Drop

Test configuration 2C was conducted using the same test article used in test number 2B above. The air temperature was recorded at 49°F and the wind speed was 4 mph. The test package was placed in the horizontal position on the test pad with the crush test plate suspended at an angle of 0 degrees from horizontal directly over the package so as to impact the test article directly on both the closure and top flange areas and also the bottom edge of the package. The package was lifted to a height of 30 feet-1 inch from the lowest point of the crush plate to the top of the horizontally placed test package. It was suspended and attached to the release mechanism by nylon straps. The crush plate was released so as not to impart any rotational motion to the crush plate free fall to the impact point with the test article.

HAC 30' Crush Plate Positioning

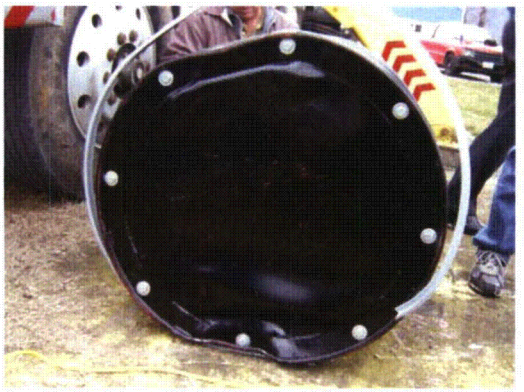


Crush Plate at 30' Height

Crush Plate Impact

Upon impact the overall diameter of the package in the direction of the impact was reduced by a total of 2-1/2" from the original diameter at its maximum point. A gap of ¼ inch by 1-1/4 inch long was documented at the drum to lid interface. However due to the design of the Versa-Pac closure lid the metal to metal interface between the top flange and the encased insulation was visible with no direct opening to the internal structure or seals of the package. The results were recorded and photographed.

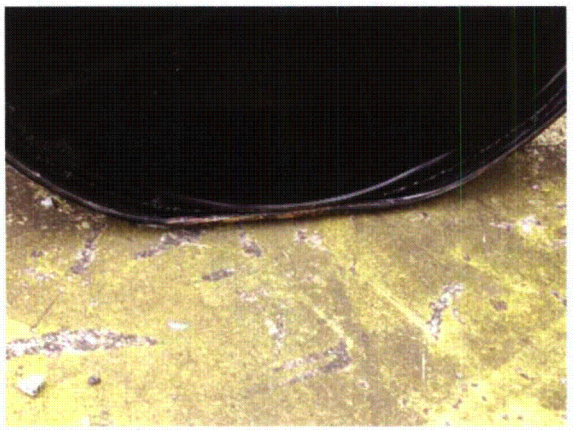
Post Test – Top Closure Lid Intact



End View – Sheared Drum Ring Top Closure In Place and Secure

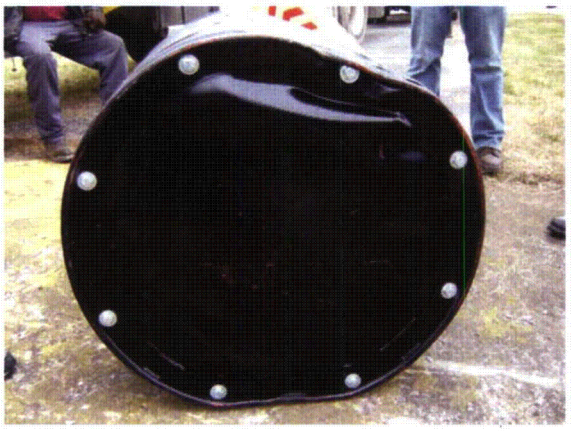
Bottom End Impact Damage

Bottom End View – 30' Crush Plate Damage



End View Bottom End Damage

Close-up Top End Damage ¼" x 1-1/14" Gap – Metal to Metal Seal No Opening



Top End Damage - Post Test View

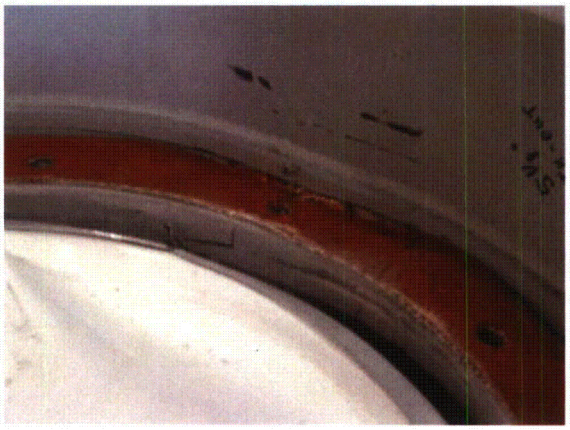
Post Test – Side View Damage

12.4 Results and Conclusions

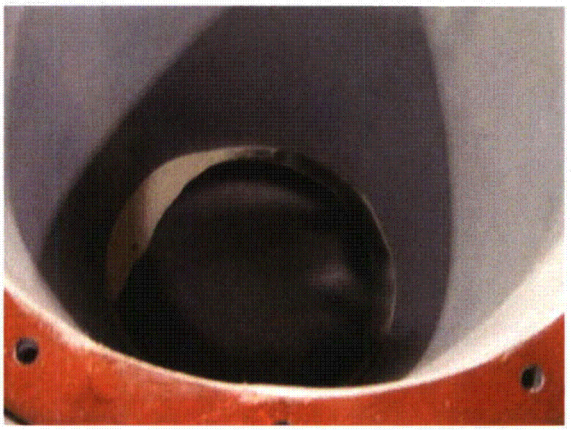
As result of this series of testing the outer closure bolts were torqued prior to removal and found to be at a reading of 25 ft/lbs. Upon removal of the outer closure lid a slight deformation of the inner wall was noted. There was no loss of containment contents found within the inner well area. The inner containment blind flange remained in good condition and sealed. The interior bolts were torqued with readings at 25 ft/lbs. The gaskets were intact with minimal damage. The payload drum did exhibit some crumpling at the lid but all of the payload materials remained within the drum and payload cavity as required. The inner cavity upon inspection showed no visible damage. The results of this series proved to be acceptable.

Post Test – No Loss of Payload Contents

Top Closure Lid – Post Test



Side Wall Deformation View



Post Test View of Containment Cavity

13.0 TEST PACKAGE SERIAL NUMBER 10550 – TEST RECORD TS-001-3

13.1 Test Number 3A – NCT Center of Gravity Drop

In test configuration 3A the test article was cooled and positioned with the center of gravity impact to be through the package bolted closure ring over the test pad at angle of 57 degrees from horizontal. The height of the drop was 4 feet from the lowest point of the package to the test pad surface. The air temperature at the time of the drop was 53°F and the wind speed was 5 mph. The package was attached to the release device and lifted by use of nylon straps to the proper orientation. The package was release so as not to impart any rotational motion to the free fall to the test pad.

Center of gravity 57° - NCT 4' Drop

Pre-Drop NCT 4' Height

The impact resulted in a deformation on the drum side at the closure bolt measuring 1-1/16 inch deep by 2 inches long. The diameter of the test article was decreased by 1/8 inch. All welds, bolts and closures remained in tact with no tearing of the outer structural components.

Post Drop Damage to Top Closure

Side View Center of Gravity NCT Damage

13.2 Test Number 3B – HAC 30' Center of Gravity Top Closure Drop

The test article used in test configuration 3B was previously used in 3A above and was positioned with the center of gravity through the bolted connection at an angle of 56 degrees from horizontal. The package was raised to the drop height of 30 feet-1 inch above the test pad surface from the lowest point of the package. The air temperature was 54.5°F with a wind speed of 5 mph.

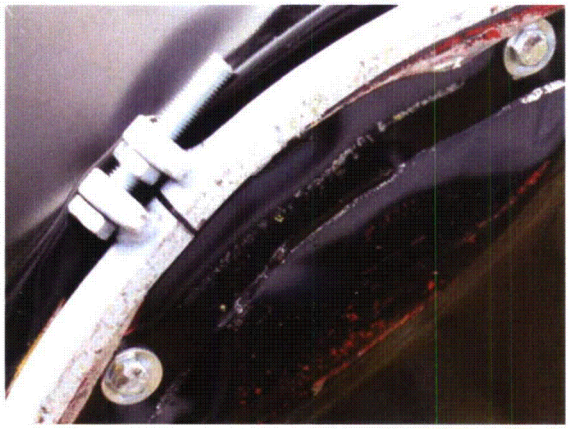
HAC 30' Center of Gravity 57° Position

HAC 30' Impact

The impact resulted in a depression 11/16 inch deep into the lid and caused additional side deformation totaling 2-1/2 inches deep by 20 inches long. All welds, bolts and closures remained intact.

Accumulated Damage – Top Closure

Close-up Post Test Photograph



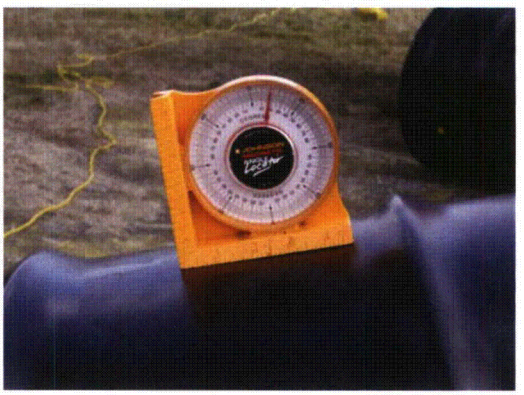
Close-up Damage from Center of Gravity Drop onto Top Closure Ring

Side View – Top End

13.3 Test Number 3C – HAC Shallow Angle Accelerated Drop (Slap Test)

Using the same test article that was utilized in 3B an oblique (Shallow Angle) drop from a height of 30 feet-1 inch and an angle of 17 degrees from horizontal was positioned over the test pad using nylon strap attached to the release mechanism. The height was measured from the lowest point of the package to the test pad surface.

Shallow Angle Accelerated Drop Set-up



17° Angle of HAC Shallow Angle Drop

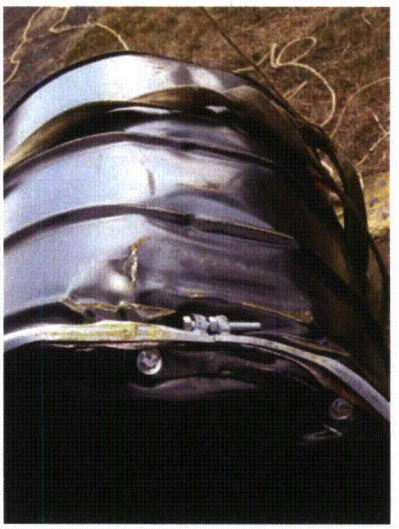
Shallow Angle Drop Impact

The damage to the exterior package surface produced a tear at the exterior drum side to bottom rim connection point measuring 3/16 inch at its widest point by 7 inches in length. Although this slit to the outer drum sheet meet metal occurred, no internal breach of the inner liner occurred and the package remained completely sealed from the exterior atmosphere due to the design of the Vera-Pac with its inner liner directly in contact with the outer drum surface. Additional deformation at the bolted closure ring affected an area measuring 2-15/16 inches deep with a 1 inch crumple in the lid closure. The diameter of the package was reduced in the direction of the impact through the bolt by approximately 3 inches. The test article bolts and seals remained in place. Measurements of the damage were recorded and photographed.

Top End Damage from Shallow Angle Drop

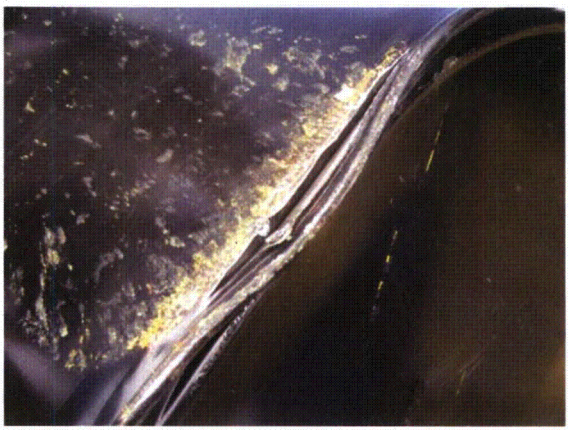
Close-up View Impact Damage

Impact Side – Initial Impact Point View



Long Side View of Damage

Bolted top Closure & Ring Post Test Damage View



Bottom Slit at Drum Rim Showing Inner Metal Re-enforcing Sheet In Place with No Openings

13.4 Test Number 3D – HAC 1 Meter Puncture Drop – Center of Gravity Over Bolted Closure

The test article chosen for test configuration 3D was previously used in the test series above due to the accumulated damage to the exterior surface of the package. Based upon this damage the most detrimental orientation was chosen to be through the center of gravity at the bolted closure ring connection. The package was suspended by use of nylon straps which were attached to the release mechanism at a height of 41 inches measured from the lowest point of the package to the top of the puncture ram. The angle of orientation was 56 degrees from the horizontal position. The air temperature was 56°F and the wind speed was 5 mph. The test package was released so as not to impart rotation motion to the test article free fall to the impact point of the puncture ram.

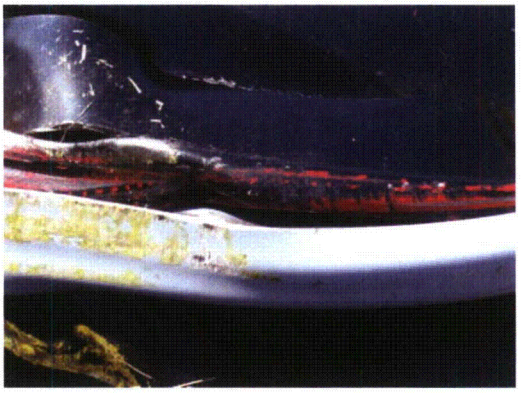
56° Angle for Center of Gravity HAC Puncture Drop

HAC 1 Meter Center of Gravity Puncture Drop Height Position

Free Fall of Center of Gravity Puncture Drop

The impact upon the puncture ram produced additional damage to the side of the drum at the closure bolt with a small opening of ¼ inch by 3 inches long at the drum closure lid and drum rim interface. The opening was again sealed by a metal to metal contact between the flange and the drum lid insulation sheet metal cover and the top flange gasket which remained in tact. All welds, bolts and closures remained in place.

Impact Damage from Puncture Drop

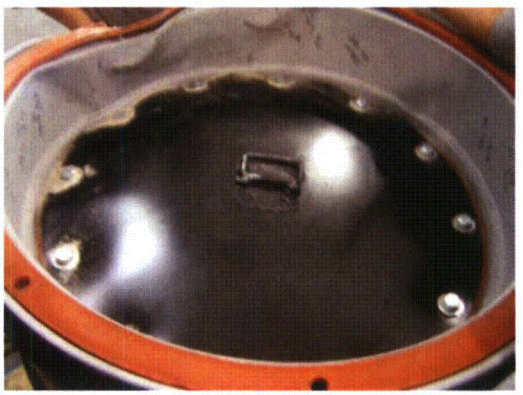


Close-up View of ¼" Wide x 3" Long Gap – Sealed by Metal to Metal Contact and Top Flange Gasket

13.5 Results and Conclusions

As a result of this series of testing the outer closure bolts recorded a torque at less than 20 ft/lbs. Upon removal of the outer closure lid a bulge in the containment blind flange was discovered with some sand from within the containment cavity found. A deformation at the impact point to the inner wall was also recorded. The bolts of the inner containment flange were torqued with a reading of less than 20 ft/lbs recorded. Once the flange and payload had been removed inspection of the inner containment cavity found no visible damage. The inner gaskets were in good condition with only minimal damage to the outer closure gasket.

Damage from Series Testing Drop Total



Bulge in Containment Blind Flange Showing Loose Sand from Containment Cavity

Side Wall Damage and Bulge of Containment Flange

Post Test View of Top Closure Lid

Top View Containment Payload – Post-Test

The conclusion of this test series is that again corrections were needed to the blind flange seal and closure and that additional testing would be required.

14.0 CORRECTIONS AND ADDITIONAL TESTING

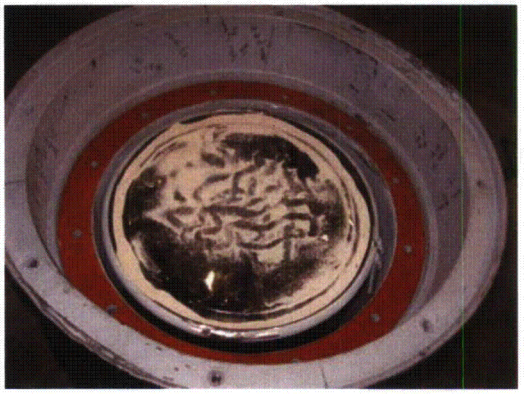
Based upon the information obtained from the series of drops conducted it was determined that due to the unsatisfactory results upon post test inspection that corrections to the internal blind flange closure were required prior to an additional testing. It is believed that the piston action from within the inner payload cavity was the primary cause of the damage to the containment closure. The damage to the flange led to the conclusion that the blind flange thickness of 3/16 inch was insufficient for the force that occurred during the test series and that an increase to ½ inch thick and the reinstallation of the inside flange pad would provide an acceptable condition after the follow up testing was complete. In addition it was decided that the bolt torque for all bolts on the Versa-Pac Shipping Container would 60 ft/lbs to provide a better sealing of the silicone coated fiberglass inner gasket and provide a much higher strength to support the impact of the piston action within the payload area.

After evaluation, two of the previously utilized test articles were found to be in good condition and were able to be resealed for use in the follow up test series. The payloads were identical to the original test series with 1-1/2 pounds of loose sand being placed on top of and around the inner payload as before. The test articles were fitted with new ½ inch thick inner blind flanges with 3/8 inch thick neoprene sponge rubber pads affixed to the inside of the inner flange prior to installation. The torque of inner containment blind flange was increased to 60 ft/lbs. The outer closure lid bolts were also torqued at 60 ft/lbs.

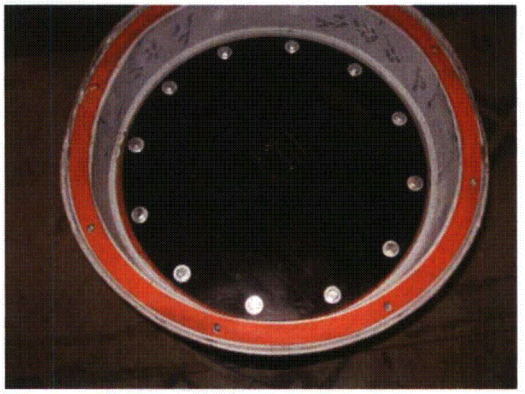
On review of the previous testing which produced unsatisfactory results it was determined that the testing should duplicate those tests. The test articles were then placed into the cooling chamber for a period of 18 hours prior to the new drop tests.

These tests were intended to validate that the corrections made to the design of the inner containment flange would prove to correct the loss of materials and damage to the flange previously found during the original drop testing.

15.0 RE-TEST PACKAGE SERIAL NUMBER 10551 – TEST RECORD TS-001-4



Containment Cavity with Payload With Loose Sand on top of Payload



Inner Containment Blind Flange

Pre-Test – Top Closure of Sealed Test Article

15.1 Re-Test Number 1A – NCT - 4' Top End Drop

On March 05, 2009 the package was removed from the cooling chamber and was transported to the test area. It was positioned with the top end of the package over the test target at an angle of 0 degrees so that the impact of the container would be directly onto the top surface of the package. The height of the test article from the lowest point to the surface of the test target was 4 feet. The air temperature was 58.5 degrees and wind speed of 5 mph. The package was release so that no rotational motion was imparted during the free fall to test pad surface. New package tare weight was increased by 43 ponds with the additional thickness of the inner flange.

Pre-Drop Top End Side View

NCT 4' Top End Drop Position

As a result of the impact no visible damage was found on the exterior surface of the package. All welds, closures and bolts remained intact. The results were recorded and photographed.

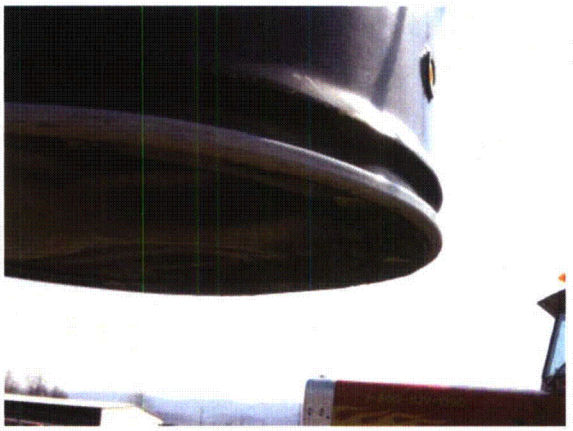
Post-Test Top End Drop Damage

15.2 Re-Test Number 1B – HAC 30' Top End Drop

After the NCT test above the package was positioned for test configuration 1B the HAC 30' drop onto the same surface and orientation of 0 degrees. The air temperature was 58.5°F and the wind speed was 5 mph.

Pre-Drop HAC 30' Top End Drop **30' Height Position Top End Drop**

Post test inspection of the outer surface found that the overall height had been reduced by 7/16 inch and that three of the top bolts had been impacted, but all bolts remained in place and sealed. There was no damage to any welds and no tears were found during the inspection.

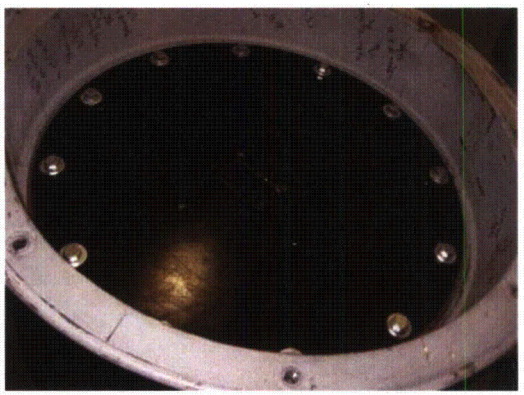


Post Test View of Damage
Total Package Drops – 2 NCT,
3-HAC 30' Drop, 1-wCrush Plate Drop

15.3 Results and Conclusions

Prior to opening of the test package the outer bolts were torqued and readings were found to be between 20 and 80 ft/lbs. with all bolts intact. After opening the test article photographs were taken and the interior well surfaces inspected with no damage found. The new thicker blind flange remained flat, sealed and no loss of the payload contents were found outside the containment cavity. The bolts of the inner blind flange were torqued and found to have readings of between 30 to 50 ft/lbs. The gaskets and payload cavity were in good condition. All post test damage was recorded and photographed.

The conclusion of this series is that the design changes of increasing the flange thickness, increasing the torque requirement and the reinstallation of the flange inside pad were found to be successful.

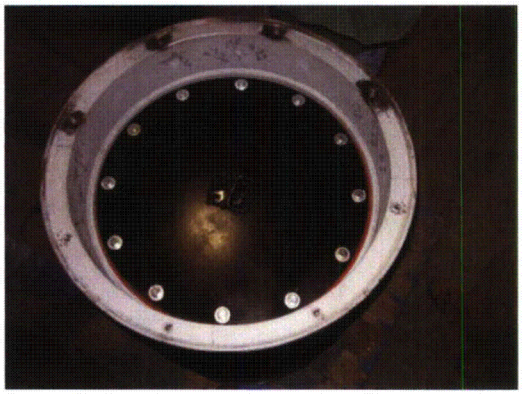


½" Thick Inner Blind Flange Post Test Flat & No Loss of Payload Contents

Payload and Lose Sand Remained within the Containment Cavity

16.0 RE-TEST PACKAGE SERIAL NUMBER 10551 – TEST RECORD TS-001-5

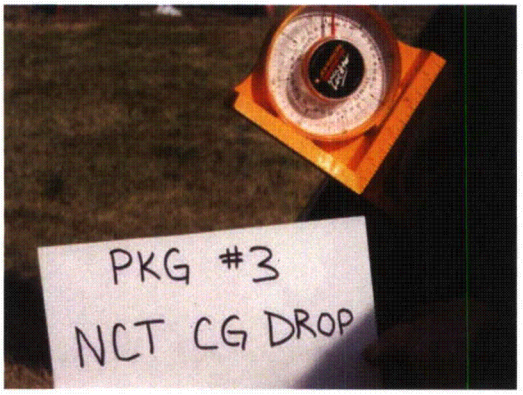
16.1 Re-Test Number 3A – NCT Center of Gravity Drop



Top View of ½" Thick Blind Flange

Pre-Test Top View of Sealed Test Article

After cooling, the test article was positioned with the orientation at 57 degrees from horizontal over the test surface target so that the impact would be through the bolted closure of the package and through the center of gravity. The normal conditions drop was made from a height of 4 feet from the lowest point of the package to the test pad surface. The package was positioned using nylon straps attached to the release mechanism. The package was release so as not to impart any rotational motion during the free fall to the test pad. The temperature was 67.5°F with wind speed of 5 mph.



57° Angle NCT Center of Gravity

Positioned NCT 4' Height Center of Gravity Drop – Pre-Test View

NCT 4' Center of Gravity Impact

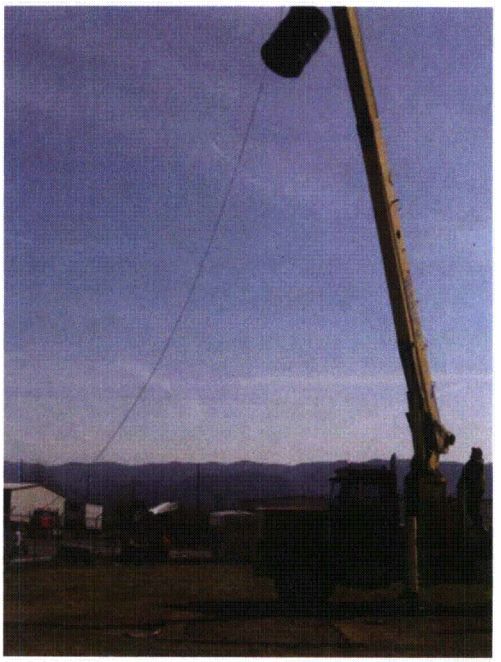
The impact resulted in a deformation on the closure bolt area with measurements of 1-3/16 inch deep by 2-1/4 inches long. All welds, bolts and closures remained intact. Damage was recorded and photographed.

NCT Post Test Damage View

16.2 Re-Test Number 3B – HAC 30' Center of Gravity Drop

Test configuration 3B was repositioned in the same attitude of 57 degrees so as to impact the identical area previously tested in test number 3A. The test article was raised to a height of 30 feet from the lowest point of the package to the surface of the test pad using nylon straps attached to the release mechanism.

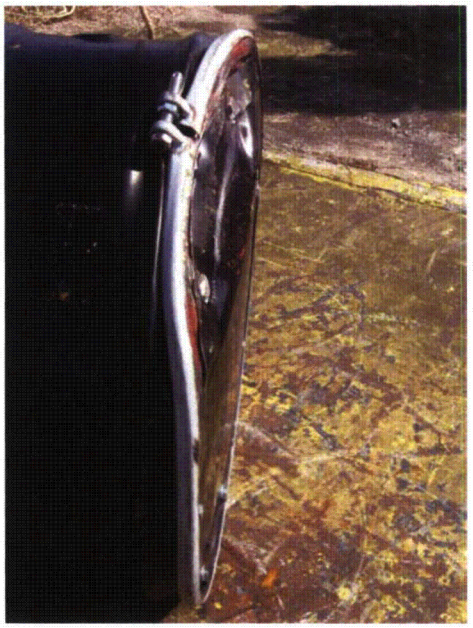
HAC Center of Gravity Drop Positioned at 57° Angle



30' Height Drop Position

HAC 30' Impact Thru the Center of Gravity

As a result of the impact a deformation on the closure bolt area totaling 2-9/16 inches deep by 20-1/2 inches long was recorded. The diameter of the package was reduced by 5/16 inch. All welds, bolts and closures remain in place. There were no tears or openings found on the package.



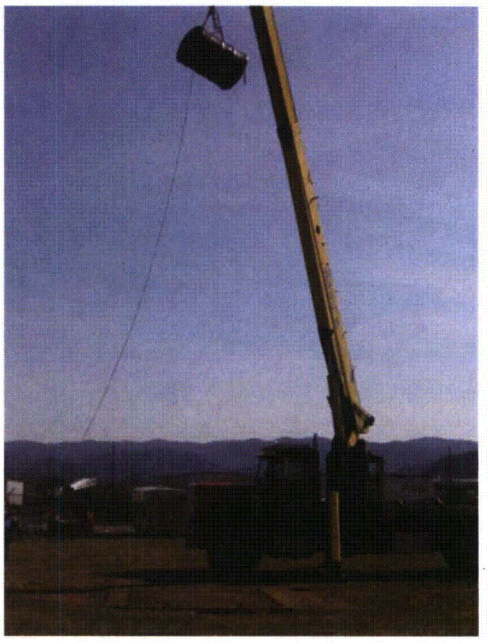
Side View – Impact Damage from 30' Center of Gravity Drop

Top View of Damage

16.3 Re-Test Number 3C – HAC Shallow Angle Accelerated Drop (Slap Test)

Using the same test package, an oblique (Shallow angle) drop was positioned over the test pad at an angle of 17 degrees from horizontal with the height of the lowest point of the package 30 feet from the top surface of the test pad target. It was positioned using nylon straps attached to the release device. The package was released so as not to impart any rotational motion during the free fall to the test pad target.

HAC 30' Shallow Angle 17° Drop Position



30' Shallow Angle Drop Position

The damage to the exterior surface produced deformation on the initial top closure, measuring 2-5/16 inches deep with a 1 inch crumple of the outer closure lid. The secondary impact produced damage measuring – on the bottom rim of the test article. The diameter of the package in the direction of the impact was reduced by approximately 1 inch. There was no damage to any bolts, welds or closures and there were no tears found on inspection of the package.

End View of Top Damage from Initial Impact of Shallow Angle Drop

Close-Up of Damage to Impact Point

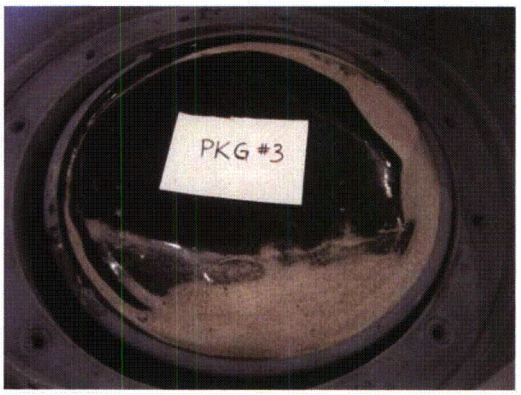
16.4 Results and Conclusions

Before opening the outer closure the torque was measure and found to be less than 20 ft/lbs. Photographs were taken and an inspection of the inner well area found only minor deformation to the sidewalls no other damage was found. The inner flange was flat and sealed with no loss of materials form within the inner containment cavity. Bolt torque of the inner flange recorded arrange of torque from 20 to 40 ft/lbs.

The conclusion of this series is that again, the design changes of increasing the flange thickness, increasing the torque requirement and the reinstallation of the flange inside pad were found to provide acceptable results.

Post Series Side View–Package Drop Total 2- NCT Drops, 3-HAC 30' Drops & 1-Puncture Drop

½" Thick Inner Blind Flange Post Test Flat & No Loss of Payload Contents



Payload and Lose Sand Remained within the Containment Cavity

17.0 POST TEST MEASEUREMENTS

On March 05, 2009, the post test inspection and measurements were taken and recorded on all test articles.

Test Article Serial Number 10550

Location	Post-Test Measurement	Description
A-C	21-1/16" ID	Inner Container
A-C	31-1/6" Ø	Outer Container
A	42"	Drum Height
A	5"	Wall – In/Our
A	29-11/16"	Inside Height
A	7-7/16"	Top Rim – Inside Flange
B	42"	Drum Height
B	7-5/16"	Top Rim – Inside Flange
B	5"	Wall – In/Out
B-D	20-7/8" ID	Inner Container
B-D	30-15/16"Ø	Outer Container
C	29-11/16"	Inside Height
C	5-1/4"	Wall – In/Out
C	42"	Drum Height
C	7-3/16"	Top Rim – Inside Flange
D	29-11/16"	Inside Height
D	42"	Outer Container
D	7-1/4"	Top Rim – Inside Flange
D	5-9/16"	Wall – In/Out

Final Tare Weight – 660 Pounds
Final Gross Weight – 920 Pounds

Test Article Serial Number 10551

Location	Post-Test Measurement	Description
A-C	20-7/8" ID	Inner Container
A-C	31-1/16" Ø	Outer Container
A	41-15/16"	Drum Height
A	5-1/16"	Wall – In/Our
A	29-3/4"	Inside Height
A	7-3/8"	Top Rim – Inside Flange
B	41-7/8"	Drum Height
B	7-3/16"	Top Rim – Inside Flange
B	5-1/8"	Wall – In/Out
B-D	20-7/8" ID	Inner Container
B-D	31-1/8"Ø	Outer Container
C	29-3/4"	Inside Height
C	5-3/16"	Wall – In/Out
C	42-3/16"	Drum Height
C	7-3/16"	Top Rim – Inside Flange
D	29-3/4"	Inside Height
D	42-1/16"	Outer Container
D	7-1/4"	Top Rim – Inside Flange
D	5-1/16"	Wall – In/Out

Final Tare Weight – 704 Pounds Final Gross Weight 964 Pounds

Test Article Serial Number 10552

Location	Post-Test Measurement	Description
A-C	20-15/16" ID	Inner Container
A-C	29-7/8" Ø	Outer Container
A	41-11/16"	Drum Height
A	5-1/4"	Wall – In/Our
A	29-5/8"	Inside Height
A	6-13/16"	Top Rim – Inside Flange
B	41-5/8"	Drum Height
B	6-7/8"	Top Rim – Inside Flange
B	5-5/16"	Wall – In/Out
B-D	20-15/16" ID	Inner Container
B-D	30-11/16"Ø	Outer Container
C	29-11/16"	Inside Height
C	5-1/16"	Wall – In/Out
C	41-11/16"	Drum Height
C	6-7/8"	Top Rim – Inside Flange
D	29-5/8"	Inside Height
D	41-7/8"	Outer Container
D	6-3/4"	Top Rim – Inside Flange
D	.5"	Wall – In/Out

Final Tare Weight - 705 Pounds Final Gross Weight – 965 Pounds

18.0 FINAL CONCLUSION OF ALL TEST RESULTS

The objective of this test program was to conduct the physical evaluation test of Century Industries Versa-Pac Shipping Container design in accordance with the Normal Conditions of Transport (NCT) and the Hypothetical Accident Conditions (HAC) specified in 10 CFR 71 and Century Industries Test Plan TP-001 Revision 0 to verify the performance capabilities under specified conditions. The Versa-Pac was subjected to performance test simulating hypothetical accident condition for free drop, crush, shallow angle and puncture described in 10 CFR 71.71 and 73. Following each test, the physical condition of the test package was inspected and the results were recorded and photographed.

The acceptance criteria for the all test series was retention of the outer closure, no openings, tears or failure that would lead to loss of material, no open pathways to the insulation materials and no loss of the inner containment payload.

The test series results provided information that the internal blind flange of the containment cavity allowed payload contents to escape into the outer well of the package during two of the initial three test series.

To correct this condition it was determined that a increase in the thickness of the blind flange, addition of a neoprene sponge rubber pad affixed to the inside of the flange and an increase in the torque requirement would be needed. With completion of these changes two previously utilized test articles were refitted with the changes and subjected to the identical test series which caused the unacceptable results.

Following the re-test of these packages, when subjected to the original test series requirements, the post test inspection found that the acceptance criteria had been successfully met.

There was no shift in the payload cavity, no contents outside the containment cavity and no unacceptable damage to the inner or outer surfaces of the Versa-Pac Shipping Container. Additionally, the results of these physical performance evaluation tests demonstrate that the package system is capable of meeting the requirements of 10 CFR 71 and Century Industries Test Plan TP-0001 Revision 0.

19.0 TEST DROP TOTALS

Three Versa-Pac Shipping Containers were subjected to a total of 5 test series during the test program described above, along with the preliminary testing as follows in the table below:

Item	55 Gallon – Preliminary Prototype	110 Gallon Preliminary Prototype	110 Gallon Test Article
4' NCT Drops	1	1	5
30' HAC Drops	1	1	5
30' Shallow Angle	N/A	N/A	2
30' Crush Plate	1	1	1
1 Meter Puncture	3	4	2

20.0 ATTACHMENTS, REFENECES & CALIBRATION RECORDS

Attachment A – Test Plan TP-001 Revision 0
Attachment B – Test Specification TS-001-1 Revision 0
Attachment C – Century Industries NCT and HAC Test Record
Attachment D – Preliminary Drop Test Results & Conclusions
Attachment E – Training & Calibration Records
Reference 1 – 10 CFR Part 71
Reference 2 – NUREG 6818

Attachment A

Test Plan TP-001 Revision 0

(Consisting of 28 pages)

1

Century Industries
Bristol, Virginia 24209

Versa-Pac Shipping Container
Test Plan
TP-001 Revision 0

US NRC Docket No. 71-9342

Prepared By:
Century Industries
William M. Arnold

Prepared By: William M. Arnold – Signature of File Date: January 20, 2009

Reviewed By: Heather Little – Signature on File Date: January 20, 2009

Record of Revision

Revision No.	Description of Revision	Date
0	Original Issue	01-20-09

Table of Contents

1.0 INTRODUCTION

Century Industries Versa-Pac Shipping Container is designed for the shipment of Type A radioactive and fissile materials in the form of U-metal oxides, fluorides and nitrates for both product and scrap materials. The fissile payload was design for 350 grams at 100% enrichment and a criticality safety index of 1.5.

The Versa-Pac Shipping Container was designed in two basic versions, a UN1A2 - 55 gallon and 110 gallon outer drum with a 16 gauge body, bottom and cover, in addition to the standard 12 gauge closure ring with a 5/8" ASTM A307 bolt, the cover is reinforced and secured using the addition of bolts attached to the internal structure of the package as detailed in the design drawings. The internal structure consists of vertical and horizontal stiffeners at specified points around the package. Outer and inner 16 gauge liners, with an inner insulating ceramic fiber blanket between the liners complete the primary inner structural components. A secondary barrier of insulation consisting of ceramic fiber blankets; surround the inner containment body. The payload gasket is a woven fiberglass yarn in a flexible substrate, coated with a high grade silicone rubber. The gasketed payload containment cavity is made of 10 gauge body and bottom with a ¼" thick top flange to which a 3/16" top cover is secured using 12 – ½" bolts. The payload cavity is attached to the internal structural components by use of a bolted connection through a fiberglass thermal break between the payload cavity and the structure. Closed Cell Polyurethane foam is utilized to provide insulation and added impact protection, to both the top and bottom of the Vera-Pac. Plastic plugs enclosed within the body of the structure provide a path for venting to external acetate vent plug on the exterior of the drum. The cavity is designed to be loaded directly or with the use of an insert to reduce the inside diameter or with up to a 30 gallon drum.

It was designed in accordance the requirements of 10 CFR Part 71 [1]] and Century Industries – QA-8 Plan for Manufacture of Versa-Pac Shipping Containers [2].

Preliminary testing conducted on both 55 and 110 gallon version prototype containers provided essential information about the reactions of both versions when subjected to initial HAC drop test requirements. Drop tests on both versions included 30' drops on the top corner thru the center of gravity, a 30' drop onto the bottom corner thru the center of gravity producing no unexpected damage results in both versions. Also conducted were 30' crush plate drop onto the sides of both packages at the bolted top connections, the 55 gallon version produced the egg-shape impact results expected with no opening at the impact area, while the 110 gallon proved to need additional stiffeners and bolt connections at spacing similar to the 55 gallon version to avoid a gap located at the lid closure interface. This correction has been incorporated into the 110 gallon version by reducing the spacing of the top lid bolt closures to be more in line with the 55 gallon version. A series of puncture test drops were made on both the 55 and 110 gallon version. Both were subjected to puncture drops in the center of the top and bottom with only minor indentations of ¼" to 3/8" deep on the bottom and ¾" deep in the center top of the containers. The containers were also dropped on the side near one of the vertical stiffeners producing indentations of 5/16" on the 110 gallon and ¾" in the 55 gallon version. An additional puncture test was conducted thru the center of gravity onto the bolt

closure ring in the same area that a 30' drop was previously conducted with no additional damage noted. Both inner containers remained sealed with no loss of contents. These packages were loaded at weights of 231 lbs. loaded directly into the 55 gallon and 266.5 lbs loaded in an inner 30 gallon drum, placed into the containment area of the 110 gallon package respectfully.

2.0 SCOPE AND OBJECTIVE

2.1 Scope

This test plan describes the methods, guidelines and requirements that are to be utilized during the performance of the task described in this procedure.

2.2 Objective

The objective of this test plan is to provide the requirements for a series if physical test to demonstrate the performance capabilities of the Versa-Pac Shipping Container in satisfying the requirements of 10 CFR 71 [1], Century Industries – Test Specification TS-0001 [3] and this test plan for both normal and hypothetical accident conditions of transport.

The primary objectives of this test plan are as follows:

1. Define the responsibilities of the personnel performing the drop test series.
2. Define the general requirements
3. Define the test sequences that will be performed.
4. Define the required configurations for each test.
5. Define the required pre-test and post test measurements.
6. Define the data acquisition requirements for each test.
7. Define the documentation requirements.

3.0 RESPONSIBILITIES

Century Industries has the overall responsibility for the test program and is responsible for the design and analysis of the test articles, development of the test specification, the test plan and oversight of the Versa-Pac test series. Century Industries is also responsible for the procurement, fabrication and inspection of the test articles. The test series will be performed in accordance with the applicable requirements of Century Industries QA Program QA-1 [4], Test Specification TS-001 [3] and this test plan.

Individual responsibilities include the following:

1. Test Program Manager: This individual is responsible for the overall management and implementation of the test program. The Test Manager has the authority to resolve any question that may arise between members of the team.

2. Test Engineer: This individual is responsible for preparation of the equipment and facilities required to conduct the testing. They are also responsible for the both the pre-test and post test measurements and documentation.

3. Quality Assurance: This individual; is responsible for the QA oversight and witness of the test series

4.0 TEST SEQUENCES

Based upon preliminary prototype testing of both the 55 and 110 gallon versions, testing indicated that the 110 gallon version will bound the 55 gallon Versa-Pac version. Three prototypes are planned for fabrication for the test series. All test articles will be tested using a 30 gallon drum containing 250 pounds of the test media, placed within the inner package cavity, a residual amount of sand will be placed into the inner cavity so that some material will face the possibility of release from within the inner cavity to the external surface of the package between the inner and outer closures. The inner drum is being utilized to simulate a piston action within the inner containment cavity of the test articles.

Three separate test series are planned, as shown in Table 1 below to verify satisfactory compliance with 10 CFR 71 [1] and this plan:

4.1 Test Series No. 1 – Flat Top Drop Orientation

This series will include an NCT free drop, one HAC free drop and one puncture drop. During this test surfaces are to be examined and measured and the damage recorded between drops.

4.2 Test Series No. 2 – Flat Side Drop Orientation

This series will include an NCT free drop, one HAC free drop and one HAC crush plate drop. During this test surfaces are to be examined and measured and the damage recorded between drops.

4.3 Test Series No. 3 – Center of Gravity Over Top Corner

This series will include an NCT free drop, one HAC free drop and one HAC shallow angle drop. During this test surfaces are to be examined and measured and the damage recorded between drops.

Note: A Puncture Test will be conducted on one of the test packages based upon initial drop damage.

Table 1 –Planned Test Sequences

Package Number	Test Number	Test Description	Test Objective
1	1A	NCT 4' Top End Drop	Test Top Closure
	1B	HAC 30' Top End Drop	Test Top Closure
	1C	HAC 1Meter Flat Side Puncture Drop	Test Side Wall Between Vertical Stiffeners
2	2A	NCT 4' Horizontal Side Drop	Evaluate Side Deformation
	2B	HAC 30' Horizontal Side Drop	Evaluate the Side Deformation and Closure From Impact
	2C	HAC 30' Crush Plate Drop	Evaluate the Side Deformation From Crush
3	3A	NCT 4' Center of Gravity Drop	Test the Top Closure
	3B	HAC 30' Center of Gravity Drop	Evaluate the Damage From a C.G. Closure Drop
	3C	HAC 30' Shallow Angle Accelerated Drop	Evaluate the Damage From an Accelerated Shallow Angle Drop
To Be Determined	4A	HAC 1 Meter Puncture Drop	Evaluate & Attack a Vulnerable Area

Notes:

1. All NCT Drops are from a height of 4' feet, HAC drops are from a height of 30 feet and all puncture drops are from a height of 40 inches. Distance measured from the lowest point of the package to the test pad surface.
2. All tests are conducted from a test article starting cooling chamber temperature of -40°F.

5.0 TEST SERIES REQUIREMENTS

5.1 General Requirements

5.1.1 Quality Assurance

All testing shall be witnessed using the Quality Assurance oversight as required in the test specification.

5.1.2 Rigging

Rigging methods shall be chosen such that the test article is lifted in the correct inclination and orientation as necessary. Rigging locations shall be positioned so as not to interfere or affect the performance or response of the Versa-Pac during the test series.

5.1.3 Measuring and Equipment

The guidelines for measurement and test equipment are described in the Test Specification TS-001 []. All items that require calibration shall be conducted against a certified known that are referenced to the National Institute of Standards and Technology (NIST), for scales the applicable state standards and bureaus are acceptable. Where such standards do not exist, the basis for the calibration shall be documented.

Height measurements may be established using either; a pre-measured line and plumb bob attached to the lowest point of the test article, a properly calibrated laser or other means that are verifiable.

5.1.4 Test Media

The test media may consist of the proper combination of either lead, gravel, sand, steel shot and/or clean soil needed to obtain the appropriate payload test weight. The test weight of each test article must be within +5/-0 pounds of the required test weight of 250 pounds.

5.1.5 Environmental

The requirements for environmental controls are described in the Test Specification TS-001 [3] and shall be recorded as required by each individual test sequence.

5.1.6 Electronic Recording Documentation

All aspects of the test series shall be recorded as required in the test plan using equipment as specified within the Test Specification TS-001 [3].

6.0 TEST PACAKAGE NO. 1

6.1 Test Number 1A – NCT Top End Drop

6.1.1 Test Configuration

Test 1A is a free drop onto the top end of an undamaged test article from a height of 1.2 meters (4 Feet) as shown in Figure 1. The test article suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad in a vertical orientation so that the lowest point of the package is at 1.2 meters (4 feet) above the top surface of the test pad. The test article should be released so that it does not impart rotational motion into the package free fall to the test pad.

6.1.2 Pre-test Requirements & Measurements

Prior to performing Test Number 1A, the following pre-test activities are to be complete:

- Measure and record the test article temperature upon removal from the conditioning room.
- Record the test article serial number.
- Measure the centerline and the near side distance to the edge of the cavity, prior to closure of the inner containment cavity. All measurement locations should be marked on the package.
- Take photographs of the interior and exterior of the package to provide visual evidence of the pre-test condition.
- Weigh and record the empty test article.
- Load the pre-loaded 30 gallon inner drum into the test article inner containment cavity.
- Spread one (1) pound of residual sand/dirt into the inner containment cavity.
- Verify that components used for the inner containment cavity are in good condition and are the proper components per the drawings.
- Install the containment cavity gasket and blind flange. Snug all lid bolts prior to applying the required torque of 40 ft. lbs. in an alternating torque rotation.
- Install the outer gasket and reinforced drum lid using the appropriate bolts as required by the drawing, applying torque of 40 ft. lbs to the closure bolts in the proper alternating manner.
- Install outer drum ring and torque to 60 ft. lbs. and install security seal.
- Weigh and record the loaded test article.
- Upon closure, measure the height, from the bottom rim to the top of the closure ring and diameter of the outer package at the center rolling hoop of the drum. All measurement locations should be marked on the package.
- Verify that the external acetate vent plug is in place.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.

- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

6.1.3 Post-Test Requirements

Following the NCT top end drop (Test Number 1A), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any apparent damage.
- Document any apparent damage to the package, e.g. deformation or bolt failure.
- Measure the height and diameter of the test article and record the information.
- Record the information on the applicable test forms and proceed to next test sequence.

6.2 Test Number 1B – HAC - 30' Top End Drop

6.2.1 Test Configuration

Test 1B is a free drop onto the top end of the damaged test article used in Test Number 1A from a height of 9 meters (30 feet) as shown in Figure 1. The test article suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad in a vertical orientation so that the lowest point of the package is at 9 meters (30 feet) above the top surface of the test pad. The test article should be released so that it does not impart rotational motion into the package free fall to the test pad.

6.2.2 Pre-test Requirements & Measurements

- Record measurements taken from previous test of the test article on the test record.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.

- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

6.2.3 Post-Test Requirements

Following the HAC top end drop (Test Number 1B), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any additional apparent damage.
- Document any additional damage to the package, e.g. deformation or bolt failure.
- Measure the height and diameter of the test article and record the information.
- Record the information on the applicable test forms and proceed to next test sequence.

6.3 Test Sequence Number 1C – HAC 1 Meter Puncture Drop

6.3.1 Test Configuration

Test 1C is a free drop onto the side of the damaged test article used in Test Number 1B from a height of 1 meter (40 inches) as shown in Figure 1. The test article suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad in a horizontal orientation so that the lowest point of the package is at 1 meter (40 inches) above the top surface of the test pad. The test article is to be positioned so that the impact is located between the vertical stiffeners within the package. The test article should be released so that it does not impart rotational motion into the package free fall to the test pad.

6.3.2 Pre-test Requirements & Measurements

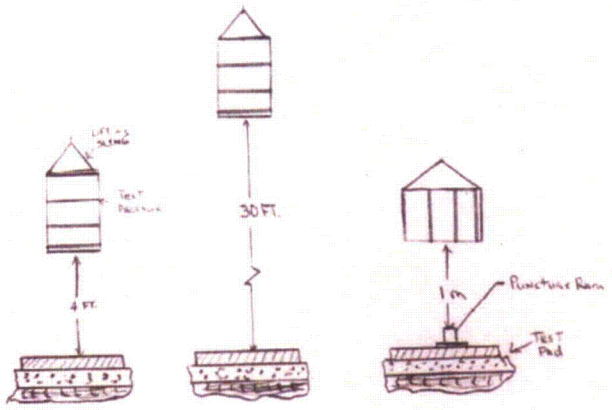
- Record measurements taken from previous test of the test article on the test record.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.

- Measure and record the air temperature at the drop pad.
- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

6.3.3 Post-Test Requirements

Following the HAC side puncture drop (Test Number 1C), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any additional apparent damage.
- Document any additional damage to the package, e.g. deformation or bolt failure.
- Record the information on the applicable test forms and proceed to next test sequence.
- Measure and record the torque of outer closure bolts.
- Open outer package and remove the outer lid.
- Photograph the interior surface of the test article and examine for any apparent indications of containment boundary loss, e.g. payload materials.
- Measure and record the torque of interior bolts and remove the inner containment cavity blind flange.
- Examine the condition of the gasket and payload contents and record the information on the test record.
- Measure and record the centerline and near side distance to the edge of the cavity.
- Remove the inner payload (if possible) and record any apparent damage or movement to the inner containment cavity.
- Photograph the inner cavity to provide visual evidence of any apparent damage.
- Complete the test sequence record.



Test No. 1A
NCT Top End Drop

Test No. 1B
HAC Top End Drop

Test No. 1C
HAC Side Puncture Drop

Figure 1 – Test Package No.1 - Drop Test Configurations

7.0 TEST PACAKGE NO. 2

7.1 Test Number 2A – NCT Horizontal Side Drop

7.1.1 Test Configuration

Test 2A is a free drop onto the horizontal side of an undamaged test article from a height of 1.2 meters (4 Feet) as shown in Figure 2. The test article suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad in a horizontal side orientation so that the lowest point of the package is at 1.2 meters (4 feet) above the top surface of the test pad. The test article should be released so that it does not impart rotational motion into the package free fall to the test pad.

7.1.2 Pre-test Requirements & Measurements

Prior to performing Test Number 2A, the following pre-test activities are to be complete:

- Measure and record the test article temperature upon removal from the conditioning room.
- Record the test article serial number.
- Measure the centerline and the near side distance to the edge of the cavity, prior to closure of the inner containment cavity. All measurement locations should be marked on the package.
- Take photographs of the interior and exterior of the package to provide visual evidence of the pre-test condition.
- Weigh and record the empty test article.
- Load the pre-loaded 30 gallon inner drum into the test article inner containment cavity.
- Spread one (1) pound of residual sand/dirt into the inner containment cavity.
- Verify that components used for the inner containment cavity are in good condition and are the proper components per the drawings.
- Install the containment cavity gasket and blind flange. Snug all lid bolts prior to applying the required torque of 40 ft. lbs. in an alternating torque rotation.
- Install the outer gasket and reinforced drum lid using the appropriate bolts as required by the drawing, applying torque of 40 ft. lbs to the closure bolts in the proper alternating manner.
- Install outer drum ring and torque to 60 ft. lbs. and install security seal.

- Weigh and record the loaded test article.
- Upon closure, measure the height, from the bottom rim to the top of the closure ring and diameter of the outer package at the center rolling hoop of the drum. All measurement locations should be marked on the package.
- Verify that the external acetate vent plug is in place.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.
- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

7.1.3 Post-Test Requirements

Following the NCT top end drop (Test Number 2A), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any apparent damage.
- Document any apparent damage to the package, e.g. deformation or bolt failure.
- Measure the height and diameter of the test article and record the information.
- Record the information on the applicable test forms and proceed to next test sequence.

7.2 Test Number 2B – HAC - 30' Horizontal Side Drop

7.2.1 Test Configuration

Test 2B is a free drop onto the horizontal side of the damaged test article used in Test Number 2A from a height of 9 meters (30 feet) as shown in Figure 2. The test article suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad in a horizontal side orientation so that the lowest point of the package is at 9 meters (30 feet) above the top surface of the test pad. The test article should be released so that it does not impart rotational motion into the package free fall to the test pad.

7.2.2 Pre-test Requirements & Measurements

- Record measurements taken from previous test of the test article on the test record.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.
- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

7.2.3 Post-Test Requirements

Following the HAC top end drop (Test Number 2B), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any additional apparent damage.
- Document any additional damage to the package, e.g. deformation or bolt failure.
- Measure the height and diameter of the test article and record the information.
- Record the information on the applicable test forms and proceed to next test sequence.

7.3 Test Sequence Number 2C – HAC 30' Crush Plate Side Drop

7.3.1 Test Configuration

Test 2C is a crush plate drop onto the horizontal side of the damaged test article covering the top closure and the top internal containment cavity closure used in Test Number 2B from a height of 9 meters (30 feet) as shown in Figure 2. The crush plate is suspended from a crane by slings and attached to a release mechanism is to be lifted above the top of the test article located on the test pad in a horizontal orientation so that the lowest point of the crush plate is at 9 meters (30 feet) above the top surface of the test article located on the test pad. The crush plate should be released so that it does not impart rotational motion into the crush plate free fall to the impact point.

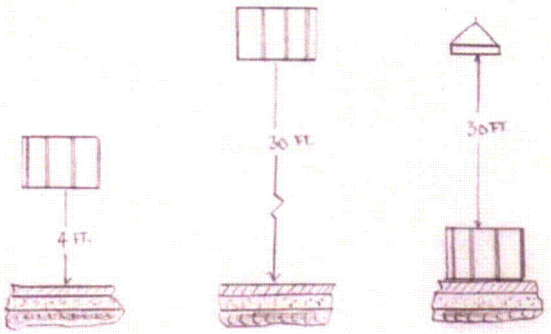
7.3.2 Pre-test Requirements & Measurements

- Record measurements taken from previous test of the test article on the test record.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.
- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

7.3.3 Post-Test Requirements

Following the HAC crush plate drop (Test Number 2C), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any additional apparent damage.
- Document any additional damage to the package, e.g. deformation or bolt failure.
- Record the information on the applicable test forms and proceed to next test sequence.



Test No. 2A
NCT Top End Drop

Test No. 2B
HAC Top End Drop

Test No. 2C
HAC Crush Plate
Side Drop

Figure 2 – Test Package No. 2 – Test Configurations

8.0 TEST PACAKGE NO. 3

8.1 Test Number 3A – NCT Center of Gravity Drop

8.1.1 Test Configuration

Test 3A is a free drop thru the center of gravity onto the top closure of an undamaged test article from a height of 1.2 meters (4 Feet) as shown in Figure 3. The test article suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad in a center of gravity thru the top closure orientation so that the lowest point of the package is at 1.2 meters (4 feet) above the top surface of the test pad. The test article should be released so that it does not impart rotational motion into the package free fall to the test pad.

8.1.2 Pre-test Requirements & Measurements

Prior to performing Test Number 3A, the following pre-test activities are to be complete:

- Measure and record the test article temperature upon removal from the conditioning room.
- Record the test article serial number.
- Measure the centerline and the near side distance to the edge of the cavity, prior to closure of the inner containment cavity. All measurement locations should be marked on the package.
- Take photographs of the interior and exterior of the package to provide visual evidence of the pre-test condition.
- Weigh and record the empty test article.
- Load the pre-loaded 30 gallon inner drum into the test article inner containment cavity.
- Spread one (1) pound of residual sand/dirt into the inner containment cavity.
- Verify that components used for the inner containment cavity are in good condition and are the proper components per the drawings.
- Install the containment cavity gasket and blind flange. Snug all lid bolts prior to applying the required torque of 40 ft. lbs. in an alternating torque rotation.
- Install the outer gasket and reinforced drum lid using the appropriate bolts as required by the drawing, applying torque of 40 ft. lbs to the closure bolts in the proper alternating manner.

- Install outer drum ring and torque to 60 ft. lbs. and install security seal.
- Weigh and record the loaded test article.
- Upon closure, measure the height, from the bottom rim to the top of the closure ring and diameter of the outer package at the center rolling hoop of the drum. All measurement locations should be marked on the package.
- Verify that the external acetate vent plug is in place.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.
- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

8.1.3 Post-Test Requirements

Following the NCT top end drop (Test Number 3A), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any apparent damage.
- Document any apparent damage to the package, e.g. deformation or bolt failure.
- Measure the height and diameter of the test article and record the information.
- Record the information on the applicable test forms and proceed to next test sequence.

8.2 Test Number 3B – HAC - 30' Center of Gravity Top Closure Drop

8.2.1 Test Configuration

Test 3B is a free drop thru the center of gravity onto the top closure of the damaged test article used in Test Number 3A from a height of 9 meters (30 feet) as shown in Figure 3. The test article suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad in a center of gravity thru the top closure orientation so that the lowest point of the package is at 9 meters (30 feet) above the top surface of the test pad. The test article should be released so that it does not impart rotational motion into the package free fall to the test pad.

8.2.2 Pre-test Requirements & Measurements

- Record measurements taken from previous test of the test article on the test record.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.
- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

8.2.3 Post-Test Requirements

Following the HAC top end drop (Test Number 3B), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any additional apparent damage.
- Document any additional damage to the package, e.g. deformation or bolt failure.
- Measure the height and diameter of the test article and record the information.
- Record the information on the applicable test forms and proceed to next test sequence.

8.3 Test Sequence Number 3C – HAC 30' Shallow Angle Accelerated Drop

8.3.1 Test Configuration

Test 3C is a shallow angle accelerated drop at an angle of 17 degrees from the horizontal side of the damaged test article from a height of 9 meters (30 feet) as shown in Figure 3. The test article should be oriented so that the top closure makes the initial impact with test pad surface. The test article suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad so that the lowest point of the package is at 9 meters (30 feet) above the top surface of the test pad. The test article should be released so that it does not impart rotational motion into the package free fall to the test pad.

8.3.2 Pre-test Requirements & Measurements

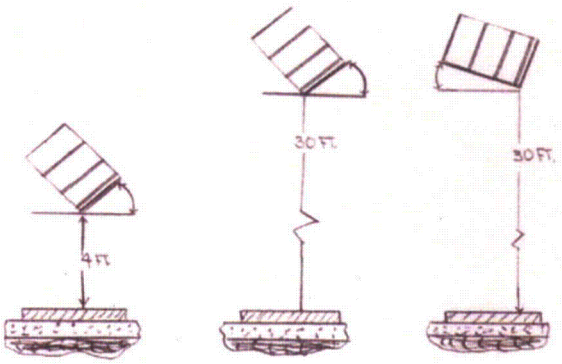
- Record measurements taken from previous test of the test article on the test record.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.
- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

8.3.3 Post-Test Requirements

Following the HAC shallow angle accelerated drop (Test Number 3C), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any additional apparent damage.
- Document any additional damage to the package, e.g. deformation or bolt failure.
- Record the information on the applicable test forms and proceed to next test sequence.

- Measure and record the torque of outer closure bolts.
- Open outer package and remove the outer lid.
- Photograph the interior surface of the test article and examine for any apparent indications of containment boundary loss, e.g. payload materials.
- Measure and record the torque of interior bolts and remove the inner containment cavity blind flange.
- Examine the condition of the gasket and payload contents and record the information on the test record.
- Measure and record the centerline and near side distance to the edge of the cavity.
- Remove the inner payload (if possible) and record any apparent damage or movement to the inner containment cavity.
- Photograph the inner cavity to provide visual evidence of any apparent damage.
- Complete the test sequence record.



Test No. 3A
NCT C.G. Top Drop

Test No. 3B
HAC C.G. Top Drop

Test No. 3C
HAC Shallow Angle
Accelerated Drop

Figure 3 – Test Package No. 3 – Test Configurations

9.1 Test Sequence Number 4 – HAC 1 Meter Puncture Drop

9.1.1 Test Configuration

Test number 4 is a free drop onto the damaged test article used in a previous, to be determined based upon particular damage assessed after the initial package series testing, from a height of 1 meter (40 inches) as shown in Figure 4. The test article will be suspended from a crane by slings and attached to a release mechanism is to be lifted above the test pad at an angle orientated to impact the damaged area so that the lowest point of the package is at 1 meter (40 inches) above the top surface of the puncture pin. The test article should be released so that it does not impart rotational motion into the package free fall to the impact point on the puncture pin.

9.1.2 Pre-test Requirements & Measurements

- Record measurements taken from previous test of the test article on the test record.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.
- Measure and record the temperature on the surface of the package.
- Once suspended measure and record the angle at which the test article is oriented to the nearest 1° increment. The measurement is to be within ± 1.0° of the specified drop orientation.
- Lift the test article to the required drop height. Measure and record the height from the surface of the test pad to the lowest point of the test article. The measured height must be at least the specified height required for the drop, but no more than plus 2 inches.

9.1.3 Post-Test Requirements

Following the HAC puncture drop (Test Number 4), the following activities are required:

- Photograph the exterior surfaces of the test article to provide visual evidence of any additional apparent damage.
- Document any additional damage to the package, e.g. deformation or bolt failure.
- Record the information on the applicable test forms and proceed to next test sequence.

- Measure and record the torque of outer closure bolts.
- Open outer package and remove the outer lid.
- Photograph the interior surface of the test article and examine for any apparent indications of containment boundary loss, e.g. payload materials.
- Measure and record the torque of interior bolts and remove the inner containment cavity blind flange.
- Examine the condition of the gasket and payload contents and record the information on the test record.
- Measure and record the centerline and near side distance to the edge of the cavity.
- Remove the inner payload (if possible) and record any apparent damage or movement to the inner containment cavity.
- Photograph the inner cavity to provide visual evidence of any apparent damage.
- Complete the test sequence record.

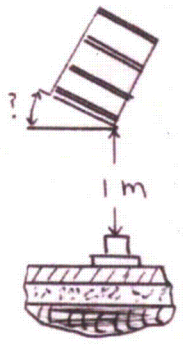


Figure 4 - 1- Meter Puncture Drop – Example Configuration

10.0 References

1. Title 10, Code of Federal Regulations, Pert 71, Packaging and Transportation of Radioactive Materials

2. Century Industries – QA-8 Plan for Manufacture of Versa-Pac Shipping

3. Title 10, Code of Federal Regulations, Part 21, Reporting of Defects and Noncompliance

4. Century Industries, Versa-Pac Shipping Container Test Specification TS-001

5. Century Industries, Quality Assurance Manual, QA-1