Century Industries

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

Application for License Docket No. 71-09342

Revision 3 April 09, 2010

Designed and Submitted By:

Century Industries
Bristol, Virginia

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for
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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 TWO

STRUCTURAL EVALUATION

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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.

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 72ºF to the peak steady state surface temperature of 144ºF, 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 144ºF 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^{o}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^{o}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^{o}F	Minimum allowable, -40^{o}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

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2801 Yorkmont Road, Suite 100 • Charlotte, NC 28208
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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.

Appendix 2.12.3

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

Appendix 2.12.4
Century Industries Test Report for the 55 Gallon Versa-Pac Shipping Container (Shallow Angle Drops)
(61 Pages)

Appendix 2.12.5

NCT Versa-Pac Test Report for Compression & Penetration
(Consisting of 16 Pages)

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

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

US NRC Docket Number 71-9342

Test Conducted in Accordance with Test Plan TP-002 Revision 0
And
Test Specification TS-002 Revision 0
Prepared & Conducted By:
Century Industries
William M. Arnold

Prepared By: _Signature on File - WMA_____ Date: _September 25, 2009_

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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-002 Revision 0 and Century Industries Test Specification TS-002 Revision 0 (Attachment A and B). The test program was conducted by Century Industries located in Bristol, Virginia between September 23 and September 25, 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 accelerated shallow angle drop (slap-down) physical performance evaluation tests for Century Industries VP-55, Versa-Pac Shipping Container to provide additional information and demonstrate the capabilities of the 55 gallon version to meet the requirement in accordance with the normal conditions and hypothetical accident conditions specified in Title 10 Part 71.73 [1], Test Plan TP-002 Revision 0 and Test Specification TS-002 Revision 0.

The test item was identified as 55 gallon Versa-Pac shipping container prototype and subjected to the following performance tests:

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

2. Drop testing in accordance with 10 CFR 71.71(c)(7), Shallow Angle Drop, 71.73 (c)(3), Puncture Drop, along with NUREG 6818, 30‘ Shallow Angle Drop.

3. 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 who also acted as the Quality Assurance Coordinator for the test series.

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, steel bars 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 1/2" thick top flange was secure using 12 -1/2" 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 in the 110 gallon version.

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 55 Gallon Version

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

The test series was conducted at ambient air temperatures.

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 and payload weights were made using a set of scales calibrated by Carlton Scales, Kingsport, Tennessee.

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

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	July 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 September 23, 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 10553

Location	Pre-Test Measurement	Description
A-C	15” ID	Inner Container
A-C	23-1/2” Ø	Outer Container
A	34”	Drum Height
A	2-1/8”	Wall – In/Out
A	4-1/4”	Inside Container/Outside
A	4-1/8”	Top Rim – Inside Top Flange
B	33-15/16”	Drum Height
B	4”	Top Rim – Inside Top Flange
B	2-1/16”	Wall – In/Out
B	4-1/4”	Inside Container/Outside
B-D	15” ID	Inner Container
B-D	23-5/8”Ø	Outer Container
C	4-1/4”	Inside Container/Outside
C	2-3/16”	Wall – In/Out
C	34”	Drum Height
C	4”	Top Rim – Inside Flange
D	4-3/16”	Inside Container/Outside
D	33-15/16”	Outer Container
D	4-1/8”	Top Rim – Inside Flange
D	2-1/4”	Wall – In/Out

9.2 Weights and Payload

The package tare weight was recorded on the individual test record. 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 contents of multiple size gravel, steel bar and sand. The materials once place into the containment are partially filled the containment. The payload provided a secondary piston action occurring from the payload materials to containment flange impact. 1-1/2 pounds of loose sand was place within the containment area in order to provide content material capable of breaching the containment flange seal.

Item/Serial Number	**10553**
Package Tare Weight	390
Payload Drum/Gravel and Sand	253
Loose Sand Weight	1.5
Total	**644.5 lbs.**

9.3 Loading of the Test Item

The 1/8" thick silicone coated fiberglass gasket and 1/2" 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 60 ft/lbs. The top gasket and outer closure, which includes the attached encased polyurethane foam insulation top plug, was installed on the test article and the top outer bolts installed and torqued using the same alternating method to a tension of 60 ft/lbs. The outer drum closure ring was then installed and tightened to a torque of 60 ft/lbs.

Containment Loaded With 254-1/2 Pounds of Loose Gravel

Bolted Inner Blind Flange and Top Gasket

Side View – 55 Gallon Acetate Plug

9.4 Test Article Temperature

To measure the temperature a calibrated surface thermometer was placed on the surface of the test articles and at time of the test the test article temperature was 89°F.

10.0 DROP TEST SEQUENCES

The drop test sequences were chosen to provide additional information for the Versa-Pac application and support for the previous NCT and HAC drop test series reported on March 25, 2009, Appendix 2.12.2 and the original prototype testing results are included in Attachment D. The test article was produced in accordance with the fabrication drawings and QA-8, plan for the Manufacture of Versa-Pac Shipping Containers. The test article was tested in accordance with Century Industries Test Plan TP-002 Revision 0.

11.0 TEST PACAKGE SERIAL NUMBER 10553 – TEST RECORD TS-002-1

11.1 Test Number 1-55-A – NCT - 4’ Shallow Angle Accelerated Drop (Slap-Down)

The drop test performance evaluation describe in the Test Plan TP-0002 Revision 0 was performed with the undamaged Versa-Pac Shipping Container. Test Configuration 1-55-A was a 4’ shallow angle accelerated free drop onto the bolted closure end of the test article at an angle of 17 degrees from horizontal. The air temperature at the start of this series was 90°F and wind speed was 2 mph. The test article was suspended from a crane by use of a sling connected to the release mechanism. It was lifted above the test pad so that the lowest point of the package was at 4 feet above the top surface of the test pad.

NCT 55-Gallon 17 Degree Angle

Side View 4' Shallow Angle Set-up

The test article was released so that it did not impart rotational motion into the package free fall to the test pad.

End View- NCT 4' Set-up

Post Drop Damage to Bolt End Impact Area

View of Long Side Post Impact

View of Bottom End Post Impact

The container impact on to the test pad surface and produced a 7-1/4" long x ¼" deep indentation at the rim on the top drum closure ring with no openings or tearing. The long impact side showed only minor indentations along the length of the container. The bottom secondary impact produced a 5-3/4" long x ¼" deep flat area at the bottom edge of the outer package wall. No other damage was noted. Measurements and photographs were taken showing the extent of the damage.

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

11.2 Test Number 1-55-B – HAC 30' Shallow Angle Accelerated Drop (Slap-Down)

Configuration 1-55-B was a free drop in the shallow angle configuration onto the same impact area thru the bolted closure end of the previously used test article from test number 1-55-A from a height of 30 feet-1-1/2 inch from the lowest point of the package to the test pad surface. It was positioned at an angle of 17 degrees from the horizontal. The air temperature at the start of this series was 90°F and wind speed was 2 mph. The test article was suspended from a crane by use of a sling connected to the release mechanism. It was lifted above the test pad in the shallow angle accelerated drop orientation to appropriate height listed above. 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.

Shallow Angle Accelerated 30' HAC Drop Position

Side View of HAC 30' Shallow Angle Accelerated Drop Position

Upon impact to the top end of the package the flat area at the outer drum lid closure to drum body rim was increased to a length of 11-1/2" x 3/8" deep from the previous NCT impact. The package remained sealed and closed with no opening. A small tear in the outer drum sidewall material occurred due to the impact of the drum ring closure lug/bolt impact on to the outer drum rolling hoop (top swedge), but due to the design of the Versa-Pac's inner liner, which is in contact with the outer drum wall, there was no damage to the inner liner and no breach of the package integrity. The secondary impact increased the damaged area along the bottom edge to a length of 10" x ¼" deep in the same location as the previous NCT drop. Although the closure ring had a lug break all bolts on the reinforced top remained in tact and secure.

End View – Top End Damage

End View – Bottom End Damage

Impact Damage to Closure End

Close-up of Closure End Damage

Close-up of Closure End Damage

Close-up of Sealed Lid to Package Interface

11.3 Test Number 1C – HAC 1 Meter Puncture Drop – Center of Gravity thru the Bolted Closure

Configuration 1-55-C was a puncture drop from a height of 41 inches from the lowest point of the package top closure to the top of the puncture ram, this impact location was chosen due to the previous damage incurred during the accelerated impact drops as the area most vulnerable to the puncture drop. 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 56-1/2 degrees from the horizontal position. The air temperature was 90°F and the wind speed was 2 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.

Center of Gravity – Puncture Drop Positioned over the Puncture Ram

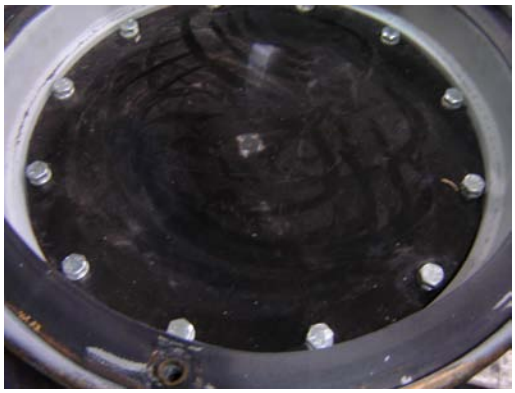
Upon impact the deformation to the impact area of the test article was measured at showing an affect area of 8-3/8” wide with a diameter of 23” at the top of the closure area. There were no tears or opening of the package as a result of the puncture drop.

Puncture Impact Damage – No Opening

As a result of this test series the outer closure bolts recorded a post test torque of 42 to 55 ft/lbs with the bolt at the impact area at 49 ft/lbs. The outer lid was removed and no loss of containment or damage to the inner containment blind flange was found. The bolt torque of the inner blind flange was found to have a range between 30-50 ft/lbs. The gaskets and the internal cavity of the containment were found to be in good condition with no damage.

Side View - Damage from Impact of Bolt Lug onto Side Wall

Top View of Package Prior to Opening



Inner Containment Blind Flange

Top End Impact Area Damage

View of Damage to Top Closure

View of Outside Impact Area

Post Test View of Test Payload

Post Test View of Inner Containment

Post Test View of Inner Containment

12.0 POST TEST MEASEUREMENTS

On September 24, 2009, the post test inspection and measurements were taken and recorded on all test articles.

Test Article Serial Number 10553

Location	Post-Test Measurement	Description
A-C	14-15/16” ID	Inner Container
A-C	23” Ø	Outer Container
A	33-15/16”	Drum Height
A	2-1/8”	Wall – In/Out
A	4-5/16”	Inside Container/Outside
A	4-1/4”	Top Rim – Inside Top Flange
B	34”	Drum Height
B	4-1/8”	Top Rim – Inside Top Flange
B	2”	Wall – In/Out
B	4-1/8”	Inside Container/Outside
B-D	15” ID	Inner Container
B-D	23-1/2”Ø	Outer Container
C	4-5/16”	Inside Container/Outside
C	2-7/16”	Wall – In/Out
C	33-5/8”	Drum Height
C	3-15/16”	Top Rim – Inside Flange
D	4-1/4”	Inside Container/Outside
D	33-15/16”	Outer Container
D	4-1/8”	Top Rim – Inside Flange
D	2-1/8”	Wall – In/Out

Final Tare Weight – 390 Pounds
Final Gross Weight – 644-1/2 Pounds

13.0 Results and Conclusions

The objective of this test program was to conduct additional physical evaluation testing of Century Industries 55 gallon version of the 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-002 Revision 0 to verify the performance capabilities under specified conditions. The 55 gallon Versa-Pac was subjected to performance test simulating normal conditions testing and hypothetical accident condition for shallow angle and puncture described in NUREG 6818, 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 testing 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.

Along with previous preliminary testing of the Versa-Pac shipping container and with the completion of the shallow angle (accelerated slap –down) drops, the results of this series of tests demonstrate that the 55 gallon version is capable of meeting the requirements set forth in 10 CFR 71 and Century Industries Test Plan TP-0002 Revision 0.

14.0 ATTACHMENTS & CALIBRATION RECORDS

Attachment A – Test Plan TP-002 Revision 0
Attachment B – Test Specification TS-001-2 Revision 0
Attachment C – Century Industries NCT and HAC Test Record
Attachment E – Training & Calibration Records

NOTE: The last paragraph of this report was amended January, 2010 by the author.

Attachment A

Test Plan TP-002 Revision 0

(Consisting of 14 pages)

Century Industries
Bristol, Virginia 24209

Versa-Pac Shipping Container
Test Plan
TP-002 Revision 0

US NRC Docket No. 71-9342

Prepared By:
Century Industries
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Prepared By: William M. Arnold – Signature of File Date: September 1, 2009

Reviewed By: Heather Little – Signature on File Date: September 1, 2009

Proprietary Information Notice

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Record of Revision

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

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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 0.9.

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 ½" 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].

In order to resolve concerns regarding the ability of the 55 gallon version to successfully meet the HAC test conditions including the slap-down (shallow angle) drop orientation Century Industries is conducting an additional test series consisting of a three foot center of gravity drop, 30 foot center of gravity drop, along with a slap-down (accelerated drop) from a height of 30 feet.

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 55 gallon Versa-Pac Shipping Container to supplement Century Industries, Safety Analysis Report under Docket Number 71-09342, 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 would bind the 55 gallon Versa-Pac version. Three prototypes were fabricated for the test series. All test articles were tested using a 30 gallon drum containing 250 pounds of the test media, placed within the inner package cavity, a residual amount of sand was placed into the inner cavity so that some material would 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 was being utilized to simulate a piston action within the inner containment cavity of the test articles. Upon completion and adjustments to the 110 gallon version all test series were successful in meeting the requirements set-forth in the original test program. After initial review and questions regarding the lack of an accelerated drop in the preliminary testing previously conducted and used to establish reasoning for use of the 110 gallon version to bind the 55 gallon package a test sample previously fabricated will be prepared to conduct the testing described within the following sections of this test plan. The 55 gallon test package will be loaded with 250 pounds of test media in the payload area of the package.

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

4.1 Test Series No. 1-55 – NCT & HAC Shallow Angle Drop

This series will include an NCT shallow angle 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
1-55	1-55-A	NCT 4' Shallow Angle Accelerated Drop	Evaluate the Damage From an Accelerated Shallow Angle Drop
	1-55-B	HAC 30' Shallow Angle Accelerated Drop	Evaluate the Damage From an Accelerated Shallow Angle Drop
To Be Determined	1-55-C	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 at the ambient air temperature.

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. 1-55

6.1 Test Number 1-55-A – NCT Center of Gravity Top Closure Drop

6.1.1 Test Configuration

Test 1-55-A 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.

6.1.2 Pre-test Requirements & Measurements

Prior to performing Test Number 1-55-A, the following pre-test activities are to be complete:

- Measure and record the test article temperature prior to drop.
- 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 test media 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 60 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 60 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 shallow angle drop (Test Number 1-55-A), 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 Sequence Number 1-55-B – HAC 30' Shallow Angle Accelerated Drop

6.2.1 Test Configuration

Test 1-55-B 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 1-55. 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.

6.2.2 Pre-test Requirements & Measurements

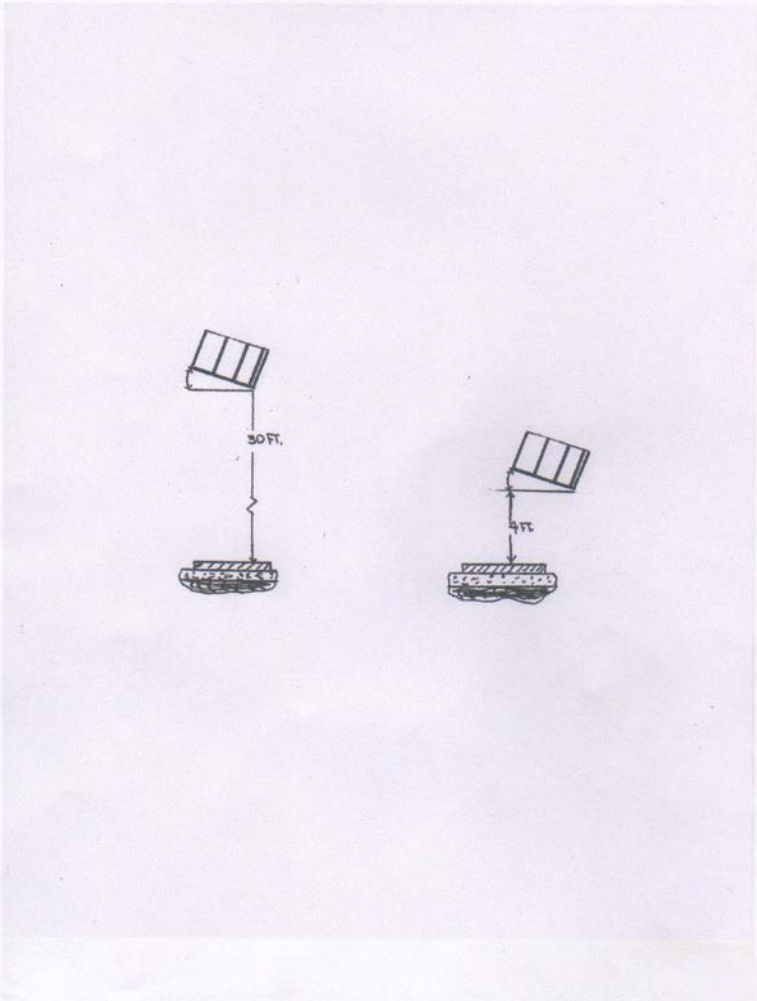
- Record measurements taken from previous test of the test article on the test record.
- Take photographs of the exterior of the test article to provide visual evidence of the test article pre-test condition.
- Measure and record the air temperature at the drop pad.
- Measure and record the temperature 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 shallow angle accelerated drop (Test Number 1-55-B), 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.



Test No. 1-55-B
HAC Shallow Angle
Accelerated Drop

Test No. 1-55-A
HAC Shallow Angle
Accelerated Drop

Figure 1-55 – Test Package No. 1-55 – Test Configurations

6.3 Test Sequence Number 1-55-C – HAC 1 Meter Puncture Drop

6.3.1 Test Configuration

Test number 1-55-C 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.

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 puncture drop (Test Number 1-55-C), 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.

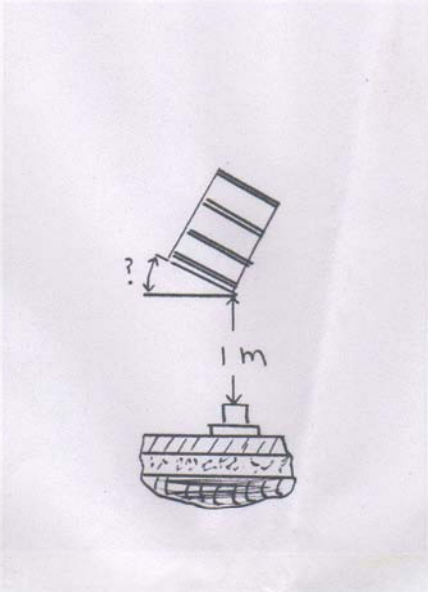


Figure 2 -55 - Meter Puncture Drop – Example Configuration

7.0 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

Attachment B

Test Specification TS-002 Revision 0

(Consisting of 12 Pages)

Century Industries
Bristol, Virginia 24209

Versa-Pac Shipping Container
Test Specification
TS-002 Revision 0

US NRC Docket No. 71-9342

Prepared By:
Century Industries
William M. Arnold

Prepared By: William M. Arnold –Signature on File Date: September 1, 2009

Reviewed By: Heather Little – Signature on File Date: September 1, 2009

Record of Revision

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

Table of Contents

1.0 INTRODUCTION

Century Industries is designing and licensing a new transportation package, called the Vera-Pac Shipping Container, in accordance with the requirements of 10 CFR Part 71 [Ref. 1]. The results of this series of test may also be used as part of the analytic information evaluating other areas of the package performance for the Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) tests of 10 CFR Part 71.

This document specifies the requirements for the confirmatory test program. A separate Test Plan will be prepared describing the specific test conditions, configurations and the sequence in which they will be carried out. Included in this document will be the fabrication specification for the test packages used in this series of test for the Versa-Pac Shipping Container.

2.0 TEST REQUIREMENTS

2.1 Pre-Test Readiness Review

Prior to performing any test series a readiness review will be conducted by Century Industries to assure the following:

1. All necessary test plans and/or procedures have been prepared in accordance with Century Industries QA program, reviewed and approved.
2. All required test articles and test facilities have been received and inspected by Century Industries personnel.
3. The documentation packages for the test articles have been reviewed and accepted by Century Industries inspection personnel.
4. Personnel are trained and available to perform the test series.
5. Test and inspection personnel have been trained in accordance with the appropriate test plans and/or procedures as required.
6. All test and Measurement equipment to be used fro the test series are current and will remain current during the testing period for which they are required.
7. Any subcontractors to be used have been trained in accordance with the test plan and/or procedures.

2.2 Pre-Test Measurements

Prior to performing any test, any per-test measurements required by the test plan must be taken and documented.

2.3 Instrumentation and Data Acquisition Systems

Prior to performing any test, the instrumentation and data acquisition system, if any, shall be checked to assure that it is properly functioning. Any instrumentation that is not properly functioning shall be either repaired or replaced. The test procedures shall include QA inspection hold points to verify that the instrumentation and acquisition equipment meets pre-test requirements.

2.3.1 Photographic Equipment

At least two consumer grade color video cameras shall be used to record the package response for each drop test series. One camera should have a field of view sufficient to capture the entire drop sequence, both free fall and impact. The field of view of the second camera should concentrate on the lower half of the impact area to provide more detailed footage of the drop sequence. The video recording of each drop test series shall be maintained for visual evidence.

Color still photographs shall be taken to document the test set-up and test results. Photographs should be taken with a minimum 3.0 Mega pixel digital camera or 35 mm standard camera equipment.

2.4 Environmental Conditions

2.4.1 Drop Test

Prior to performing each drop test series the following environmental conditions must be recorded:

1. Precipitation: Any precipitation (i.e. rain, snow. etc.) directly on the test article or test pad surface during the drop test shall be noted.

2. Wind Speed: The wind speed at the time of the drop series shall be recorded. If wind speed is considered to be strong enough to effect the drop orientation the drop test series should be delayed.

3. Package Temperature: Record the package temperature at prior to drop series.

4. Air Temperature: Record the air temperature at the drop site prior to conducting the drop series.

2.5 Test Components

2.5.1 Test Articles

The test article shall be fabricated in accordance with the requirements Section 3 of this test specification and QA-8 - Plan for Manufacture of the Versa-Pac Shipping Container [7].

2.5.2 Puncture Pin

The puncture pin must meet the requirements of 10 CFR 71(c)(3)[1]. The puncture pin must be a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 15 cm (6 inches) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (0.25 inches) and a length as to cause maximum damage to the package, but not less than 20 cm (8 inches) long. The long axis of the bar must be vertical. The puncture pin must be attached so as to prevent it from sliding or overturning during the 1-meter puncture drop test.

2.5.3 Drop Test Facility

The drop test facility must have a suitable drop test pad, lifting equipment and drop release mechanism. The drop test facilities must meet the following specifications:

1. Drop Test Pad

The drop test pad must satisfy the requirements of IAEA [2] recommendations for an unyielding target. An example of an unyielding surface is: The drop test pad should consist of a rigid steel plate mounted on a concrete pad with the combined mass of the steel and concrete at least 10 times that of the test article, with a surface area sufficient in size so as to allow the entire test article to contact the steel surface plate. The steel and concrete interface should be floated on grout and mechanically anchored to the concrete base (e.g. anchor blots). The concrete must reach design strength prior to performing any drop test series. The drop test pad steel plate should be clean, and free from any significant surface imperfections (e.g. large gouges) that could affect the response of the package.

The drop test pad must also include a provision for attaching the puncture pin device used in the 1-meter puncture drop.

2. Lifting Equipment

The drop test facility must be equipped with a lifting device (e.g. crane) and lifting slings that are capable of lifting the lowest point of the test packages to the height prescribe above the top surface of the drop test pad for all drops in the test series. The lifting equipment (e.g. crane, slings) shall have at least the working load capacity to safely handle the test article weight.

3. Drop Release Mechanism

The drop test release mechanism must be capable of releasing the test articles without causing the package to rotate during the free fall to the test pad. Mechanical or administrative means shall be provided to prevent inadvertent release of the test article.

2.6 Test Plan and Procedures

Detailed test plans and procedures shall be developed for each droop test series and approved by Century Industries prior to perform any drop test. The test plan and procedures shall include step-by-step instructions for performing the test series. Each step or sequence shall include a provision for the responsible person to initial and date to indicate completion of the step(s). Each sequence shall allow for QA Hold Points necessary to confirm critical test items.

2.7 Test Sequences

Test sequences shall comply with the requirements of 10 CFR 71 [1]. A separate test article may be used for the NCT test series. When assessing cumulative package damage for the HAC test series; the test must be performed in the order shown within the Versa-Pac Shipping Container Test Plan [9] using the same test article within any given test series.

2.8 Quality Assurance Requirements

2.8.1 Test Inspection Personnel

All personnel performing measurements and inspections required by the test plan shall be qualified and trained in accordance with the requirements of the applicable test plan and procedures.

2.8.2 Quality Assurance Hold Points

The test package manufacturing plan and test plan shall establish appropriate hold points for QA for QA personnel to perform the following activities:

1. Receipt inspection of test articles.
2. Verification that all test personnel have been trained in accordance with the test plan prior to test activities.
3. Verification that all prerequisites have been satisfied.

2.8.3 Material and Test Equipment

When calibrated measurement and test equipment is required by the test plan, the equipment shall meet the applicable requirements of Century Industries QA Program QA-1 [10].

2.9 Documentation and Reporting Requirements

The following documents must be provided after the test series has been completed:

1. Test article documentation package(s).
2. Measurement and test equipment records.
3. Personnel training and qualification records.
4. Test Plan and procedures.
5. Pre-test and post-test inspection data, photographic records, video recordings and other pertinent records.

3.0 Responsibilities

Century Industries is responsible for all activities including the preparation of fabrication control records, shop drawings, material procurement, testing and inspection, material certification records as required, welding procedures and final documentation packages.

3.1 Design Requirements

The Century Industries Versa-Pac is designed in accordance with the requirements of 10 CFR 71 [1] and the structural design in accordance with the American Welding Society D1.1 [4]. Welder and welding procedure are in accordance with the applicable requirements of AWS D1.1 [4].

3.2 Fabrication and Material Requirements

Century Industries Versa-Pac shall be fabricated in accordance with the requirements as outlined in the appropriate manufacturing plan and instructions referenced in the sections below. Century Industries Versa-Pac Shipping Container Test Plan [9]

3.2.1 Manufacturing Plan

Century Industries shall prepare a manufacturing plan for the Versa-Pac Shipping Container which should address the following items as a minimum:

- Receipt of materials
- Cutting and Preparation Instructions (Route Sheets)
- Fabrication Control Records (FCR's)
- Performance of functional tests
- Final inspections
- Package documentation review

3.2.2 Fabrication Procedures and Processes

All operations associated with the fabrication of the Versa-Pac shall include written instructions (e.g. Fabrication Control Records and/or Standard Operating Procedures). Additional instructions may be given in the form of drawings and/or sketches, along with verbal communications.

3.2.3 Base Materials

Base materials shall conform to the requirements given in the purchase orders and/or drawings as applicable.

3.2.4 Welding Materials

All weld filler materials shall conform to the requirements of the appropriate welding procedure and be in compliance with the requirements in AWS D1.1 [4].

General welding material certificates are acceptable.

3.2.5 Polyurethane Foam Insulation Materials

The Versa-Pac Shipping Container utilizes polyurethane closed cell foam to provide thermal insulation and impact protection in both the top and bottom ends of the container, this material shall be manufactured in accordance with the requirements of Century Industries Standard Operation Procedure 6.11 Revision 1 [5]. Sample foam specimens shall be taken and analyzed in accordance with the requirements of the procedure to confirm that the product meets the requirements for density, compressive strength, thermal conductivity, flame retardancy, water absorption, moisture content and chloride content. The foam manufacturer shall provide a Certificate of Compliance and a written report of all testing required by the procedure.

3.2.6 Ceramic Fiber Insulation Materials

The Versa-Pac Shipping Container body is surrounded by two separate insulation chambers which utilize a 6# refractory ceramic fiber blanket (Aluminosilicate Fiber) in accordance with the requirements of Century Industries Standard Operating Procedure 6.12 Revision 1 [6].

3.2.7 Welding

All welding shall be in accordance with applicable requirements of AWS D1.1 [4], qualified welding procedures and written instructions.

All welding personnel shall be qualified in accordance with AWS D1.1 [4].

Precautions should be taken to minimize objectionable weld spatter and arc strikes outside the weld joint.

AWS Pre-qualified Welding Procedures and/or qualified welding procedures shall be used.

3.3 Testing and Inspection Requirements

3.3.1 General

1. All test articles shall be inspected to assure that the dimensions of the test article satisfy the requirements of the drawings.

2. Inspection personnel are qualified in accordance AWS CWI or CAWI and/or ASNT-TC-1A [8], as applicable.

3. Welds requiring NDE examination are performed in accordance with Century Industries Standard Operating Procedures, as applicable.

4. Written reports for any NDE shall be completed as required by the appropriate test procedure.

5. Acceptance criteria shall meet AWS D1.1 [4] and/or the requirements of the manufacturing plan and drawings.

6. Functional tests shall be performed as required by the Fabrication Control Records.

7. All test and measurement equipment shall be properly calibrated.

3.4 Quality Assurance

All work shall be performed in accordance with Century Industries QA Program or specific requirements imposed upon its subcontractors.

The Vera-Pac Shipping Container specifications require the application of 10 CR Part 21 [3]. Century Industries is responsible for providing notification to its suppliers and subcontractors.

3.5 Material Traceability

Material traceability shall be maintained throughout the fabrication process thru the use of Route Sheets and Fabrication Control Records as appropriate and by marking on necessary components that will not result in harmful contamination or damage affecting the performance of that component in the end product.

3.6 Storage, Handling and Shipping Requirements

All test articles that must be shipped to a subcontractor's facility shall be packaged using blocking, straps, hold-down devices and/or other materials required to prevent damage to the test article during transportation. Storage and handling may be conducted using the appropriate equipment needed to safely handle the test articles.

4.0 References

1. Title 10, Code of Federal Regulations, Pert 71, Packaging and Transportation of Radioactive Materials
2. International Atomic Energy Agency (IAEA), Regulations for the Safe Transportation of Radioactive Material, No. TS-R-1
3. Title 10, Code of Federal Regulations, Part 21, Reporting of Defects and Noncompliance
4. American Welding Society, Structural Welding Code D1.1
5. Century Industries, Standard Operating Procedure, Polyurethane Closed Cell Foam Specification for Century Products
6. Century Industries, Standard Operating Procedure, Ceramic Fiber Insulation Specification for Century Products
7. Century Industries, QA-8, Plan for the Manufacture of Versa-Pac Shipping Containers
8. American Society of Nondestructive Testing (ASNT), Recommended Practice No. SNT-TC-1A
9. Century Industries, Versa-Pac Shipping Container Test Plan - TP-002
10. Century Industries, Quality Assurance Manual, QA-1

Attachment C

NCT & HAC Test Series Records

(5 Pages)

Century Industries **NCT and HAC Test Record No.** TS-002-1 **Page 1 of 5**
Bristol, Virginia **in accordance with**
Versa- Pac Test Specification, TS-002, Rev. 0

Test Package Serial No. 10553 Package Description: Versa-Pac (55-Gallon Version)

Test Program Manager: William M. Ard Date: 9-24-09
Test Engineer: William M. Ard Date: 9-24-09
Quality Assurance Coordinator: William M. Ard Date: 9-24-09

Photographic Equipment

Sony Cybershot (4.1 MegaPixel) Digital Camera DSC-P73

Calibrated Equipment Utilized

Surface Thermometer S/N: 05548
Stanlett Steel Tape Measure S/N: 08461846
16' Tape measure S/N: QC-001

Package Preparation Checklist and Measurements

Procedure Step No.	Description	Date	Initials
6.1.2	Photograph interior and exterior of the package prior to loading	9-23-09	WMA
	Measure centerline and near side distance to edge of cavity and mark on package	9.23-09	WMA
	Weigh empty test package 390 Package tare weight (lbs)	9-23-09	WMA
	Load simulated test payload ± 254½ Lbs.	9-23-09	WMA
	Spread one (1) pound of residual sand/dirt into the inner containment cavity	9-23-09	WMA
	Inspect the inner containment components for good condition and in accordance with drawings	9-23-09	WMA
	Install cavity gasket and blind flange, snug all bolts, then torque to 60 ft-lbs	9-24-09	WMA
	Install outer gasket and reinforced drum lid with proper bolts per drawing and torque to 60 ft-lbs.	9-24-09	WMA
	Install outer drum ring and torque to 60 ft-lbs	9-24-09	WMA
	Weigh loaded test package 644½ Package test weight (lbs)	9-23-09	WMA
	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX		

Century Industries **NCT and HAC Test Record No.** TS002-1 **Page 2 of 5**
Bristol, Virginia **in accordance with**
Versa- Pac Test Specification, TS-002, Rev. 0

Procedure Step No.	Description	Date	Initials
6.1.2	Measure height from bottom rim to top of closure ring and diameter of outer package at center rolling hoop of drum and mark measurements on the test package 34" Package height (in.) 23 1/2" Package diameter (in.)	9-24-09	WMA
	Verify the external acetate vent plug is in place	9-24-09	WMA
	Photograph exterior of test package for evidence of pre-test condition	9-24-09	WMA

1-55-A
Test Number (Description): NCT 4' Shallow Angle (Accelerated – Slap-Down) Drop

Procedure Step No.	Description	Date	Initials
6.1.2	Measure and record package surface &air temperature at drop pad 89 Package Surface Temperature (°F) 90 Air Temperature(°F) 2 Wind speed (mph)	9-24-09	WMA
	Measure and record the angle at which the test article is oriented to the nearest degree (within ±1 degree of specified drop orientation) 17° Angle of orientation	9-24-09	WMA
	Lift test article to required drop height	9-24-09	WMA
	Measure and record height from test pad surface to lowest point on test package (at least the specified drop height and not more than +2 inches) 48 1/2" Drop test height (in.)	9-24-09	WMA
6.1.3	Photograph exterior surfaces of test article for visual evidence of damage	9-24-09	WMA
	Document visual damage to package (e.g. deformation or bolt failure) 7 1/4" Long X 1/4" AT Rim ON Top Drum Ring - INDENTATION ON OUTER Drum Rolling Hoop. 5 3/4" FLAT AT Bottom EDGE X 1/4" Deep NO TEARING OR OPENING Sketch of Damage: Top	9-24-09	WMA
	Measure height and diameter of test package 33 15/16 Package height (in.) AT BOLT Impact 23 5/16 Package diameter (in.) AT BOLT Impact	9-24-09	WMA

Century Industries **NCT and HAC Test Record No.** TS-002-1 **Page 3 of 5**
Bristol, Virginia **in accordance with**
Versa- Pac Test Specification, TS-002, Rev. 0

1-55-B
Test Number (Description): HAC 30' Shallow Angle (Accelerated – Slap-Down) Drop

Procedure Step No.	Description	Date	Initials
6.2.2	Photograph exterior surfaces of test article for visual evidence of pre-test condition	9-24-09	WMA
	Measure and record the package surface & air temperature at the drop pad 89 Package Surface Temperature (°F) 90 Air temperature(°F) 2 Wind speed (mph)	9-24-09	WMA
	Once suspended, measure and record the angle at which the test article is oriented to the nearest degree (within ±1 degree of specified drop orientation) 17° Angle of orientation	9-24-09	WMA
	Measure and record height from test pad surface to lowest point on test package (at least the specified drop height and not more than +2 inches) 361 ½" Drop test height (in.)	9-24-09	WMA
6.2.3	Photograph exterior surfaces of test article for visual evidence of additional damage	9-24-09	WMA
	Document visual damage to package (e.g. deformation or bolt failure) MINOR TRACE DUE TO BOLT CLOSURE LUG @ SMALL Ripple IN MIDDLE OF OUTER DRUM LID. MINOR FLAT AREAS ALONG Impact Side of OUTER DRUM. NO OPENING OF CLOSURE. 11½" Long x 3/8" Deep AT LID INTERFACE ON BOLT Ring. BOLT Ring BROKEN AT Lug. 10" Long x ¼" Deep AT Bottom Edge Sketch of Damage  Top	9-24-09	WMA
	Measure and record height and diameter of test article 34 ¼" Package height (in.) AT BOLT Impact 23 ⅛" Package diameter (in.) AT BOLT Impact	9-24-09	WMA

1-55-C
Test Number (Description): HAC 1 Meter Puncture Drop C/G THRU Previous Impact AREAS

Procedure Step No.	Description	Date	Initials
6.3.2	Photograph exterior surfaces of test article for visual evidence of pre-test condition	9-24-09	WMA
	Measure and record the package surface & air temperature at the drop pad 89 Package Surface Temperature (°F) 90 Air temperature (°F) 2 Wind speed (mph)	9-24-09	WMA

Century Industries
Bristol, Virginia

NCT and HAC Test Record No. TS-002-1
in accordance with
Versa- Pac Test Specification, TS-002, Rev. 0

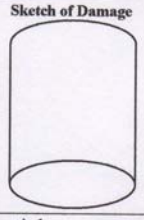
Page 4 of 5

Procedure Step No.	Description	Date	Initials
6.3.2	Once suspended, measure and record the angle at which the test article is oriented to the nearest degree (within ±1 degree of specified drop orientation) 56½° Angle of orientation C/G	9-24-09	WMA
	Measure and record height from test pad surface to lowest point on test package (at least the specified drop height and not more than +2 inches) 41" Drop test height (in.)	9-24-09	WMA
6.3.3	Photograph exterior surfaces of test article for visual evidence of additional damage	9-24-09	WMA
	Document visual damage to package (e.g. deformation or bolt failure) 8 3/8" WIDE AREA FLAT FROM PUNCTURE TEST. Top Sketch of Damage  	9-24-09	WMA
	Measure and record height and diameter of test article 33 3/16" Package height (in.) AT BOLT AREA 23" Package diameter (in.) AT BOLT AREA	9-24-09	WMA

Test Number (Description): N/A

Procedure Step No.	Description	Date	Initials
N/A	Photograph exterior surfaces of test article for visual evidence of pre-test condition	N/A	N/A
	Measure and record the air temperature at the drop pad _____ Air temperature(°F) _____ Wind speed (mph)		
	Once suspended, measure and record the angle at which the test article is oriented to the nearest degree (within ±1 degree of specified drop orientation) _____ Angle of orientation		
	Measure and record height from test pad surface to lowest point on test package (at least the specified drop height and not more than +2 inches) _____ Drop test height (in.)		
	Photograph exterior surfaces of test article for visual evidence of additional damage		

Century Industries **NCT and HAC Test Record No.** TS-002-1 **Page 5 of 5**
Bristol, Virginia **in accordance with**
Versa- Pac Test Specification, TS-002, Rev. 0

Procedure Step No.	Description	Date	Initials
N/A	Document visual damage to package (e.g. deformation or bolt failure) _____ _____ _____ _____ _____ Top **Sketch of Damage** 	N/A	N/A
N/A	Measure and record height and diameter of test article _____ Package height (in.) _____ Package diameter (in.)	N/A	N/A

Final Test Record Measurements

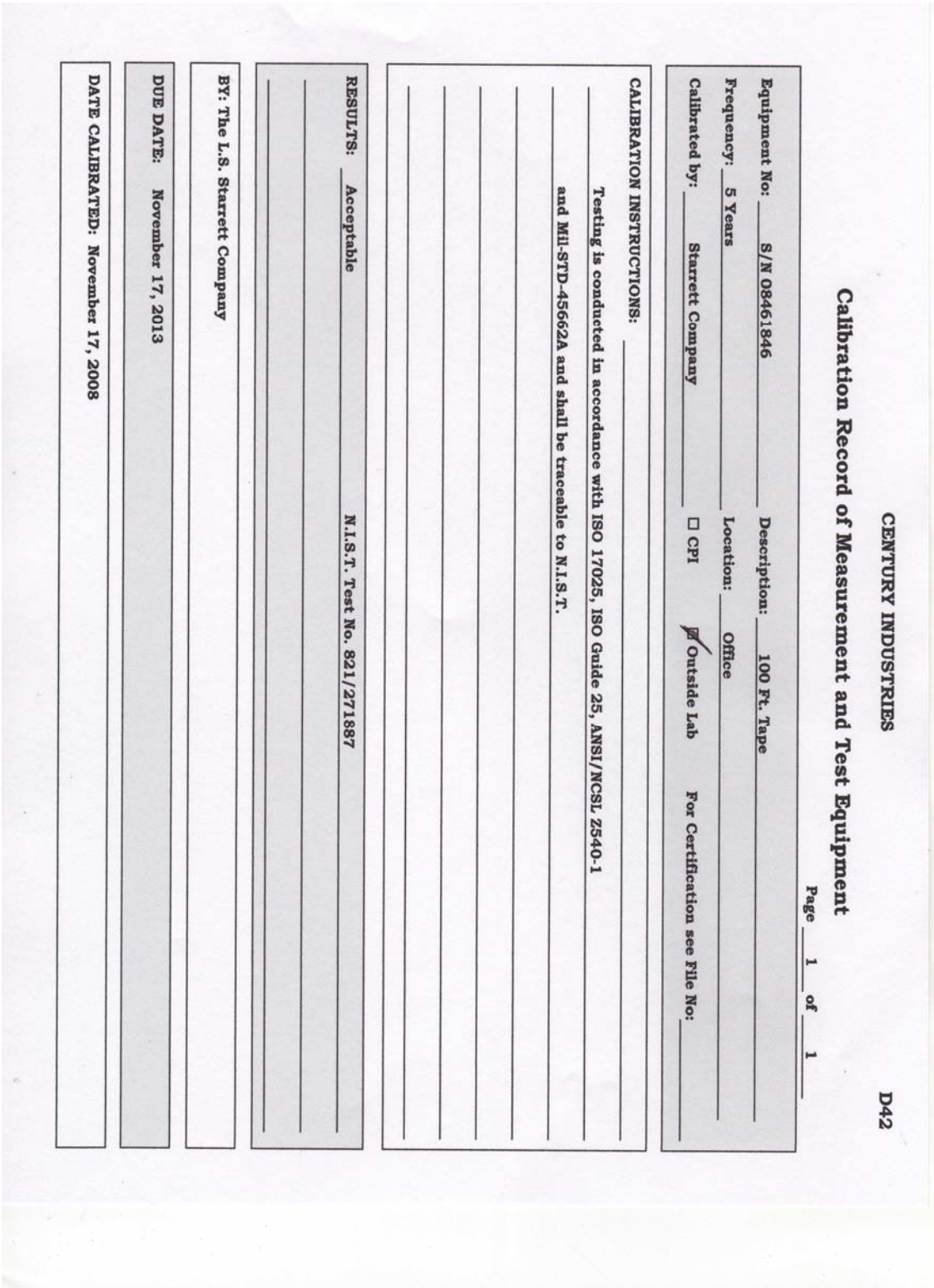
Procedure Step No.	Description	Date	Initials
6.3.3	Measure and record torque of outer closure bolts 42 to 55 Torque (ft-lbs) Impact Top Bolt 49 Ft/lb	9-24-09	WMA
	Open outer package and remove outer lid	9-24-09	WMA
	Photograph interior surface of test article and examine for any apparent indications of containment boundary loss, e.g. payload materials No Loss of Containment, No Damage To Blind Flg OR Flg. To Blind Flg. Interface.	9-24-09	WMA
	Measure and record torque of interior bolts 30-50 Torque (ft-lbs)	9-24-09	WMA
	Remove inner containment cavity blind flange	9-24-09	WMA
	Examine and document condition of the gasket and payload contents Inner Gaskets in Good Condition No Loss of Payload Contents Payload in tact.	9-24-09	WMA
	Measure and record the pre-test and post-test centerline and near side distance to edge of cavity for comparison (See attached Measurement Data Sheet)	9-24-09	WMA
	Remove (if possible) and document any apparent damage or movement to the inner containment cavity Payload Removed - No Damage or Change of Containment Found.	9-24-09	WMA
	Photograph inner cavity to provide visual evidence of any apparent damage	9-24-09	WMA

Attachment D

Training & Equipment Calibration Records

(8 Pages)

Starett 100’ Tape Measure Calibration Record



CENTURY INDUSTRIES D42

Calibration Record of Measurement and Test Equipment

Page 1 of 1

Equipment No: S/N 08461846 Description: 100 Ft. Tape

Frequency: 5 Years Location: Office

Calibrated by: Starrett Company ☐ CPI ☑ Outside Lab For Certification see File No:

CALIBRATION INSTRUCTIONS:

Testing is conducted in accordance with ISO 17025, ISO Guide 25, ANSI/NCSL Z540-1 and Mil-STD-45662A and shall be traceable to N.I.S.T.

RESULTS: Acceptable N.I.S.T. Test No. 821/271887

BY: The L.S. Starrett Company

DUE DATE: November 17, 2013

DATE CALIBRATED: November 17, 2008

Starrett®

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MCMASTER-CARR SUP CO
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ATLANTA GA 30336-2853

NOVEMBER 17, 2008

STANDARD LETTER of CERTIFICATION

THIS IS TO CERTIFY THAT THE ITEM LISTED BELOW MEETS THE REQUIREMENTS OF ACCURACY OF THE APPLICABLE SPECIFICATION ON DATE OF SHIPMENT.

STANDARDS AND EQUIPMENT USED FOR INSPECTION ARE CERTIFIED ACCURATE WITH REFERENCE TO 68 DEGREES F, TRACEABLE TO MASTER STANDARDS AT THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, WASHINGTON, D.C. CALIBRATION IS PERFORMED WITH TRANSFER STANDARDS WHICH ARE PROGRESSIVELY MORE ACCURATE IN THE ORDER OF 4: 1.

WE ATTEST THAT OUR MEASURING AND TEST EQUIPMENT, AND CALIBRATIONS PERFORMED ON THE ITEM (S) LISTED BELOW, ARE IN ACCORDANCE WITH ISO 17025, ISO GUIDE 25, ANSI/NCSL Z540-1 AND MIL-STD-45662A.

YOURS VERY TRULY,
THE L. S. STARRETT COMPANY

Candace Sheffield

DEXTER J. CARLSON,
CHIEF INSPECTOR

YOUR ORDER NO.	OUR ORDER NO.	TOOL	SPECIFICATION
QA-87917960	1335247	530-100 TAPE S/N 08461846	GGG-T-106F NIST HANDBOOK #44

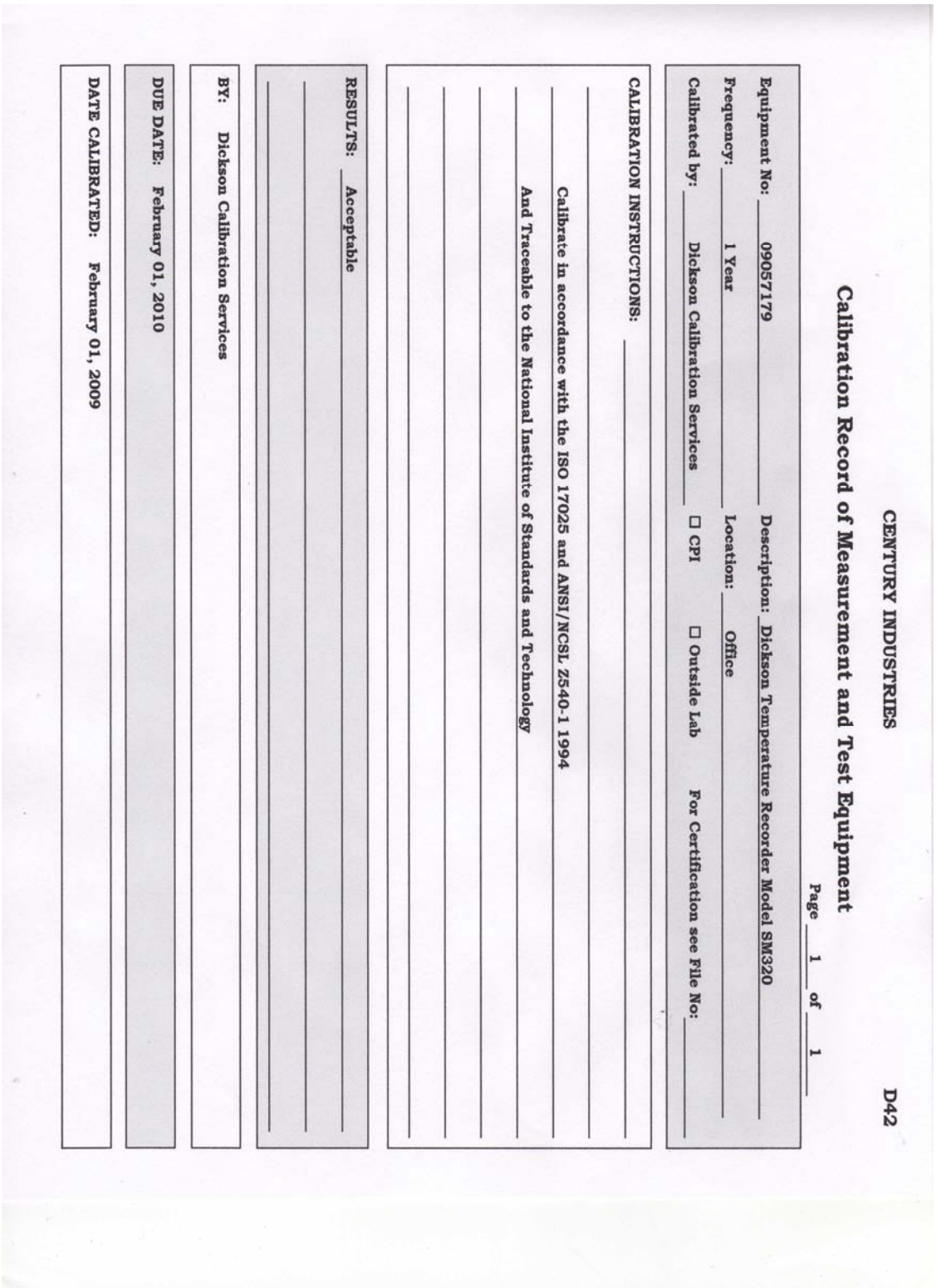
N.I. S.T. TEST NO.
821/271887

ACCURACY-WHEN THE TAPE IS SUPPORTED ON A HORIZONTAL SURFACE, AND PULLED WITH A TENSION OF 10 POUNDS AT A TEMPERATURE OF 68 DEGREES FAHRENHEIT, THE OVERALL LENGTH WILL NOT BE IN ERROR BY MORE THAN .100" IN 100' OR LESS.

The estimated uncertainties reflect a Confidence Probability of approximately 95%.

D-2

Calibration Record for Dickson Data Thermometer



CENTURY INDUSTRIES D42

Calibration Record of Measurement and Test Equipment

Page 1 of 1

Equipment No: 09057179 Description: Dickson Temperature Recorder Model SM320

Frequency: 1 Year Location: Office

Calibrated by: Dickson Calibration Services ☐ CPI ☐ Outside Lab For Certification see File No:

CALIBRATION INSTRUCTIONS:

Calibrate in accordance with the ISO 17025 and ANSI/NCSL Z540-1 1994

And Traceable to the National Institute of Standards and Technology

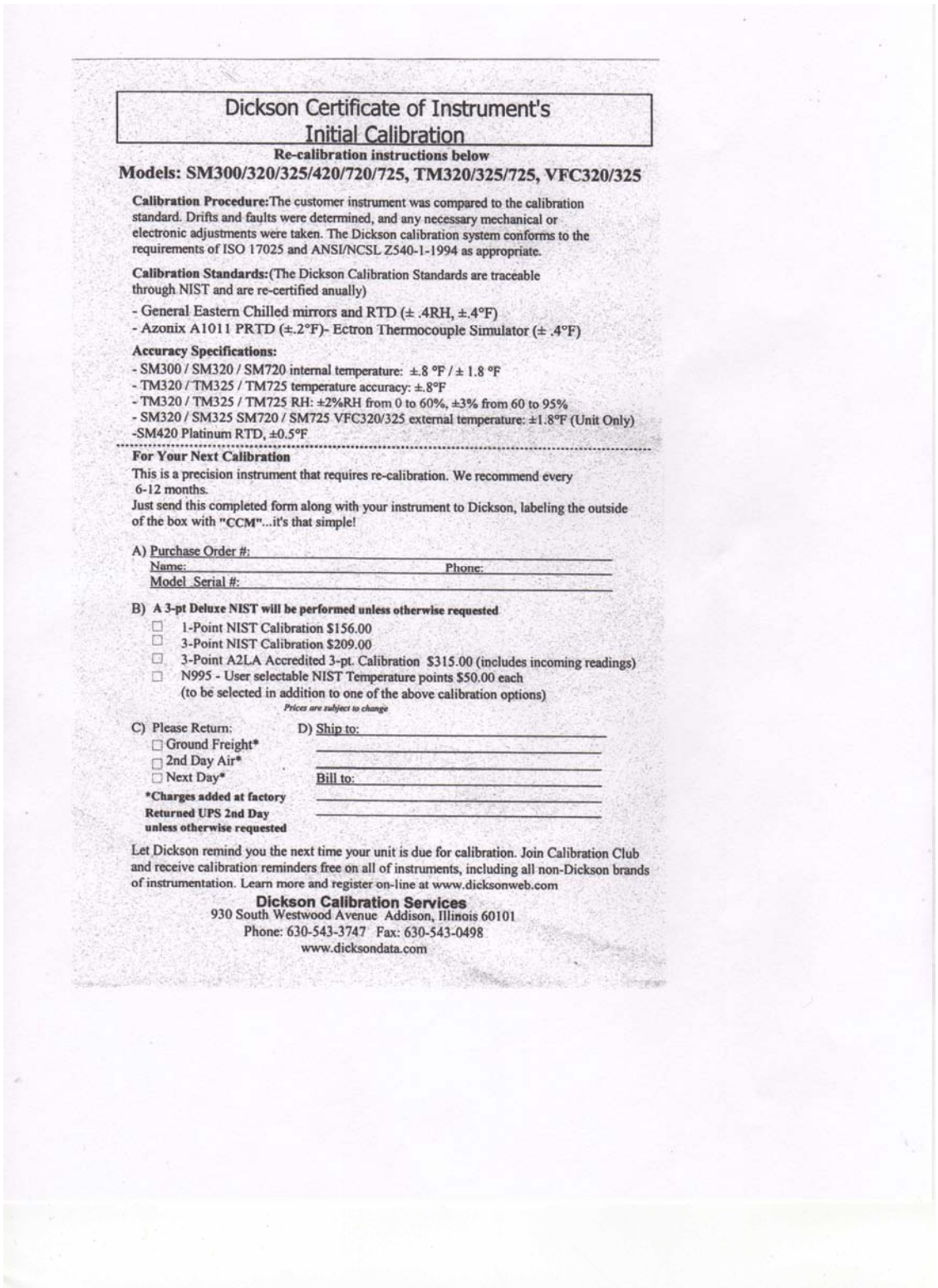
RESULTS: Acceptable

BY: Dickson Calibration Services

DUE DATE: February 01, 2010

DATE CALIBRATED: February 01, 2009

D-3



Dickson Certificate of Instrument's Initial Calibration

Re-calibration instructions below

Models: SM300/320/325/420/720/725, TM320/325/725, VFC320/325

Calibration Procedure: The customer instrument was compared to the calibration standard. Drifts and faults were determined, and any necessary mechanical or electronic adjustments were taken. The Dickson calibration system conforms to the requirements of ISO 17025 and ANSI/NCSL Z540-1-1994 as appropriate.

Calibration Standards: (The Dickson Calibration Standards are traceable through NIST and are re-certified anually)

- General Eastern Chilled mirrors and RTD (± .4RH, ±.4°F)
- Azonix A1011 PRTD (±.2°F)- Ectron Thermocouple Simulator (± .4°F)

Accuracy Specifications:

- SM300 / SM320 / SM720 internal temperature: ±.8 °F / ± 1.8 °F
- TM320 / TM325 / TM725 temperature accuracy: ±.8°F
- TM320 / TM325 / TM725 RH: ±2%RH from 0 to 60%, ±3% from 60 to 95%
- SM320 / SM325 SM720 / SM725 VFC320/325 external temperature: ±1.8°F (Unit Only)
- SM420 Platinum RTD, ±0.5°F

For Your Next Calibration

This is a precision instrument that requires re-calibration. We recommend every 6-12 months.

Just send this completed form along with your instrument to Dickson, labeling the outside of the box with **"CCM"**...it's that simple!

A) Purchase Order #: _____

Name: _____ Phone: _____

Model Serial #: _____

B) **A 3-pt Deluxe NIST will be performed unless otherwise requested**

- ☐ 1-Point NIST Calibration $156.00
- ☐ 3-Point NIST Calibration $209.00
- ☐ 3-Point A2LA Accredited 3-pt. Calibration $315.00 (includes incoming readings)
- ☐ N995 - User selectable NIST Temperature points $50.00 each (to be selected in addition to one of the above calibration options)

Prices are subject to change

C) Please Return:

- ☐ Ground Freight*
- ☐ 2nd Day Air*
- ☐ Next Day*

***Charges added at factory**

Returned UPS 2nd Day unless otherwise requested

D) Ship to: _____

Bill to: _____

Let Dickson remind you the next time your unit is due for calibration. Join Calibration Club and receive calibration reminders free on all of instruments, including all non-Dickson brands of instrumentation. Learn more and register on-line at www.dicksonweb.com

Dickson Calibration Services
930 South Westwood Avenue Addison, Illinois 60101
Phone: 630-543-3747 Fax: 630-543-0498
www.dicksondata.com

D-4

Calibration Record for PTC Surface Thermometer

CENTURY INDUSTRIES

D42

Calibration Record of Measurement and Test Equipment

Page 1 of 1

Equipment No: 05548 Description: PTC Instruments Model 330F -100°F to +160°F

Frequency: 3 Months Location: Office

Calibrated by: Century Industries ☐ CPI ☐ Outside Lab For Certification see File No:

CALIBRATION INSTRUCTIONS:

Surface thermometer shall be place on a flat surface next to the NIST Traceable gauge. The thermometers should be allowed to equalize for a period of not less than 15 minutes at the ambient air temperature. The readings shall be within ± 2°F. A second reading shall also be obtained by placing both units in a cooling chamber, allowing the gauges to equalize for not less than 15 minutes. The reading shall be within ± 2°F. Calibrate in accordance with the ISO 17025 and ANSI/NCSL Z540-1 1994 and Traceable to the National Institute of Standards and Technology.

RESULTS: Acceptable

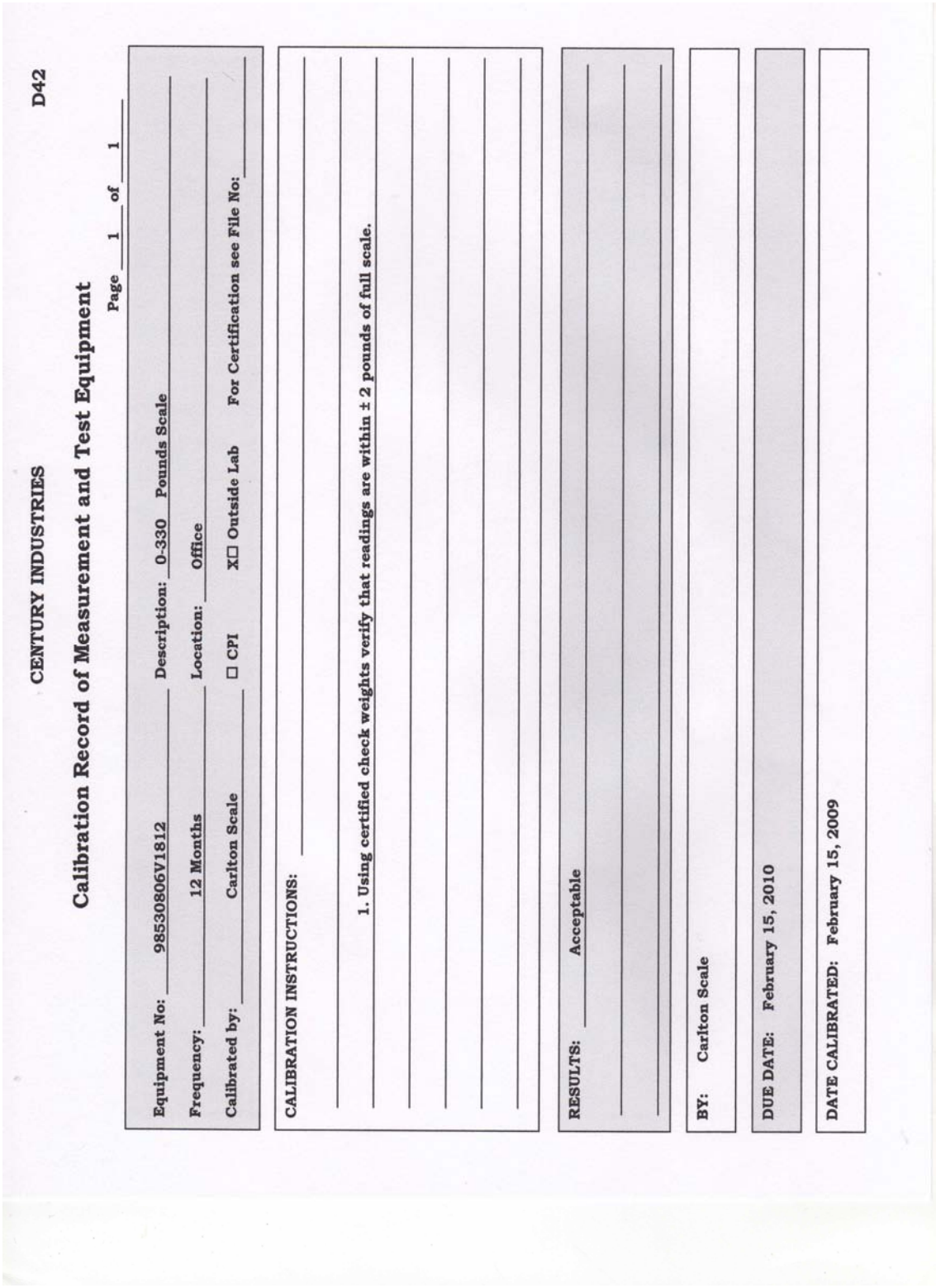
BY: Century Industries

DUE DATE: October 09, 2009

DATE CALIBRATED: July 09, 2009

D-5

Floor Scale



CENTURY INDUSTRIES D42

Calibration Record of Measurement and Test Equipment

Page 1 of 1

Equipment No: 985308006V1812 Description: 0-330 Pounds Scale

Frequency: 12 Months Location: Office

Calibrated by: Carlton Scale ☐ CPI X☐ Outside Lab For Certification see File No:

CALIBRATION INSTRUCTIONS:

1. Using certified check weights verify that readings are within ± 2 pounds of full scale.

RESULTS: Acceptable

BY: Carlton Scale

DUE DATE: February 15, 2010

DATE CALIBRATED: February 15, 2009

Indoctrination or Training Session Outline D52

Century Industries
P.O. Box 17084
Bristol, VA 24209
423-646-1864

Page 1 of 1

Title **TEST SPECIFICATION & TEST PLAN FOR THE VERSA-PAC SHIPPING CONTIANER** **Type:** ☑ Indoct. ☑ Training **Recommended Min. Duration:** 40 min.	**Dept** Testing Assistants **Outline No** 4F **Rev.** 0 **APPROVED:** Will M. Hall 2-25-09 Department Manager Date Will M. Hall 2-25-09 QA Manager Date

1. **Review duties and responsibilities per:**

   TS-001 Rev. 0 – Versa-Pac Test Specification

   TP-001 Rev. 0 – Versa-Pac Shipping Container Test Plan

D-7

Session Record **D50**

TEST PERSONNEL

Department

Century Industries

P.O. Box 17084
Bristol, VA 24209
423-646-1864

Position/Job Classification: Test Assistant

Outline Number: 4F **Date Completed** 2-25-09 **Duration** 1 HR.

Remarks:

Instructor 2-25-09 Date

The following Personnel have satisfactorily completed the above indoctrination or training outline:

Employee	Employee
Steve Salla	
Jamie Butler	
Drew Seller	
Fredy Buser	
Mark Osborne	
Heather Little	

D-8

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

Test Report

NCT Evaluation Test Series (Compression & Penetration) Of Century Industries' Versa-Pac Shipping Containers

US NRC Docket Number 71-9342

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 testing of the Versa-Pac Shipping Container in accordance with the requirements specified in 10 CFR 71. The test program was conducted by Century Industries located in Bristol, Virginia between December 15 & 16. This report includes the objective, procedure, item description, test results, test records and other applicable documents including photographs of the testing.

2.0 OBJECTIVE

The objective of this test series was to conduct the physical performance evaluation tests for Century Industries Versa-Pac Shipping Containers by the designer and manufacturer of the package, in accordance with the normal conditions specified in Title 10 Part 71.71(9) and 71.71(10).

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

1. Initial visual inspection of the outer container surfaces for pre-existing damage from the original HAC test series.

2. Penetration testing in accordance with 10 CFR 71.71(10) and Compression in accordance with 10 CFR 71.71(9).

3. Post Test Visual Inspection of the outer 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 series and were responsible for the base analysis of the test articles, and oversight of the test series

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

The test manager was William M. Arnold, President of Century Industries.

4.0 TEST ITEM IDENTIFICATION

Century Industries was responsible for the design, fabrication, inspection, and measurements of the previously tested package. 55 Gallon Package - Serial Number 10553. This package was utilized in the 55 gallon test series for shallow angle impacts and penetration test reported in Appendix 2.12.4.

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

Previously Dropped Prototype

6.0 TEST FACILITES & EQUIPMENT

6.1 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.

6.2 Measurements and Weights

Penetration rod drop heights were determined by use of a pre-measured slide tube set by a 100 foot steel tape measure Serial Number 08461846, calibrated by Starett Company and traceable to NIST.

6.3 Temperature

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.

6.4 Puncture Device

The puncture device consists of a 1.25 inch diameter carbon steel round bar, weighing 13.2 pounds.

6.5 Photographic Equipment

Color photographs were taken with a Sony 4.1 Mega pixel digital camera by Century Industries.

7.0 EQUIPMENT AND INSTRUMENT CALIBRATION

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

ITEM	MODEL	S/N	CALIBRATION DUE DATE	COMENTS
16' Tape Measure	N/A	QC-001	May 05, 2010	Used to measure drop height for penetration bar
Dickson Temperature Recorder	SM320	09057179	February 01, 2010	Used to calibrate surface thermometer and record air temperature
PTC Instruments Surface Thermometer	330F	05548	January 09, 2010	Used to measure the temperature of the test articles during the conditioning

Table 1 – Test Instruments

8.0 ACCEPTANCE CRITERIA

The acceptance criteria for this series of testing was (Penetration) 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 (Compression) no buckling of side walls.

9.0 TEST PREPARATION AND RESULTS

9.1 Initial Inspection

On December 15, 2009, the visual inspection of the previously used test item was conducted prior to performing any of the required evaluation tests in order to determine if any unacceptable damage would occur due to the penetration and compression testing.

9.2 Article Temperature

All tests were performed with the test article at ambient temperature of 65°F. Test packages had been stored inside and tests were conducted at that location.

10.0 PENETRATION DROP TEST SEQUENCE

The penetration drop test locations were chosen based upon historical drop testing of similar products and damage results. The test article was utilized in a previous HAC test series. The test article was produced in accordance with the fabrication drawings and QA-8, plan for the Manufacture of Versa-Pac Shipping Containers.

10.1 Penetration Bar Drop – Sidewall Over Vertical Stiffener

The test article was positioned horizontally on a flat 8 inch concrete floor with the penetration bar positioned vertically directly over a vertical inner stiffener thru the outer sidewall of the package. The bar was lifted to a height 40 inches (1 meter) and allowed to be released through a 2 inch PVC guide tube to provide the correct impact on the surface of the test package.

Pre-Drop Surface

Penetration Set-up

10.2 Results

The result of this impact to the sidewall of the test articles resulted in un-measurable damage to the package impact area.

Post Drop Results

10.3 Penetration Bar Drop – Sidewall Between Vertical Stiffeners

The test article was positioned horizontally on a flat 8 inch concrete floor with the penetration bar positioned vertically directly between two vertical inner stiffener thru the outer sidewall of the package. The bar was lifted to a height 40 inches (1 meter) and allowed to be released through a 2 inch PVC guide tube to provide the correct impact on the surface of the test package.

Penetration Set-up

Post Test Results No Damage

10.4 Results

The result of this impact to the sidewall of the test articles resulted in measurable damage to the package impact area with only a slight marring of the package paint.

10.5 Penetration Bar Drop – Top Drum Lid Outer Closure

The test article was positioned vertically on a flat 8 inch concrete floor with the penetration bar positioned vertically directly between on the center of the drum lid of the package. The bar was lifted to a height 40 inches (1 meter) and allowed to be released through a 2 inch PVC guide tube to provide the correct impact on the surface of the test package

Pre-Drop Surface

Penetration Set-up

10.6 Results

The results of this drop produced a slight marring of the drum lid surface.

Post Test Damage - Marring

11.0 Compression Test

The compression test was conducted in accordance with the requirement of 71.71(c)(9). The test article was utilized in a previous HAC & NCT test series. The test article was produced in accordance with the fabrication drawings and QA-8, plan for the Manufacture of Versa-Pac Shipping Containers.

11.1 Compression Loading

The test article was positioned vertically so that the load was directly applied to the top of the package. The test article weighed 624.5 pounds, to meet the requirement of 5 times the weight of the package; a load of 3,200 pounds was loaded on the top surface of the package, for a period of 24 hours.

11.2 Results

No damage or buckling of the package was found upon inspection of the test article.

Stacking Test

Stacking Test

12.0 FINAL CONCLUSIONS OF ALL TEST RESULTS

The results of this test series were found to have little to no affect on the test article and found to be in compliance with the requirements of the 10 CFR 71.71(c)(9) and 71.71(10).

13.0 ATTACHMENTS, REFERENCES & CALIBRATION RECORDS

Attachment A –Calibration Records
Reference 1 – 10 CFR Part 71
Reference 2 – NUREG 6818

Attachment A

Equipment Calibration Records

(5 Pages)

Starett 100’ Tape Measure Calibration Record

CENTURY INDUSTRIES

D42

Calibration Record of Measurement and Test Equipment

Page 1 of 1

Equipment No: S/N 08461846 **Description:** 100 Ft. Tape

Frequency: 5 Years **Location:** Office

Calibrated by: Starrett Company ☐ CPI ☒ Outside Lab **For Certification see File No:** ______

CALIBRATION INSTRUCTIONS:

Testing is conducted in accordance with ISO 17025, ISO Guide 25, ANSI/NCSL Z540-1 and Mil-STD-45662A and shall be traceable to N.I.S.T.

RESULTS: Acceptable N.I.S.T. Test No. 821/271887

BY: The L.S. Starrett Company

DUE DATE: November 17, 2013

DATE CALIBRATED: November 17, 2008

E-1

Starrett®

The L.S. Starrett Company
121 Crescent Street
Athol, MA 01331-1915 USA
Tel.: 978 249-3551
Fax.: 978 249-8495
www.starrett.com

ATTN: QUALITY ASSURANCE
MCMASTER-CARR SUP CO
6100 FULTON IND BLVD
ATLANTA GA 30336-2853

NOVEMBER 17, 2008

STANDARD LETTER of CERTIFICATION

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YOURS VERY TRULY,
THE L. S. STARRETT COMPANY

Candace Sheffield

DEXTER J. CARLSON,
CHIEF INSPECTOR

YOUR ORDER NO.	OUR ORDER NO.	TOOL	SPECIFICATION
QA-87917960	1335247	530-100 TAPE S/N 08461846	GGG-T-106F NIST HANDBOOK #44

N.I. S.T. TEST NO.
821/271887

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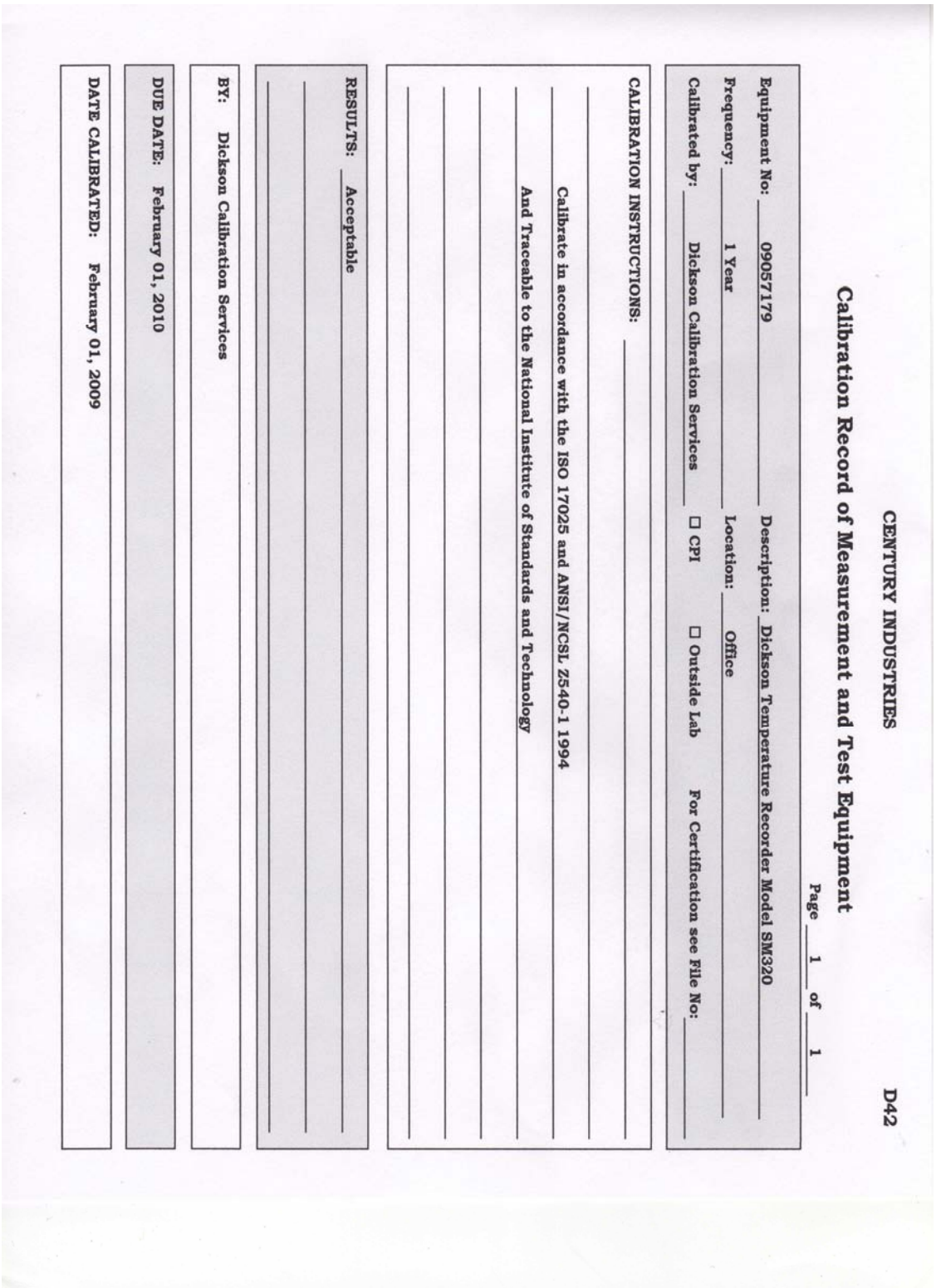
E-2

Calibration Record for Dickson Data Thermometer



CENTURY INDUSTRIES D42

Calibration Record of Measurement and Test Equipment

Page 1 of 1

Equipment No: 09057179 Description: Dickson Temperature Recorder Model SM320

Frequency: 1 Year Location: Office

Calibrated by: Dickson Calibration Services ☐ CPI ☐ Outside Lab For Certification see File No:

CALIBRATION INSTRUCTIONS:

Calibrate in accordance with the ISO 17025 and ANSI/NCSL Z540-1 1994

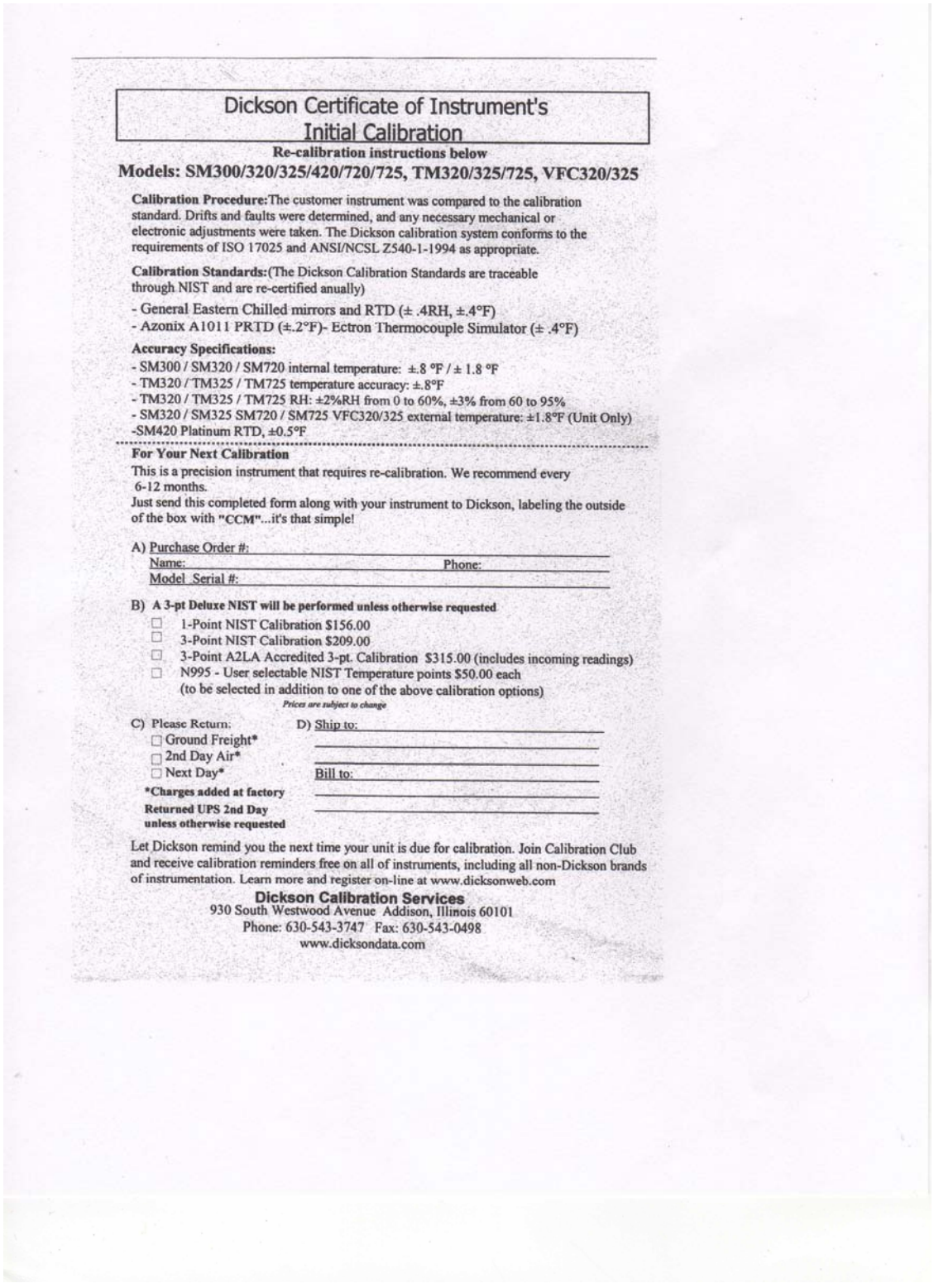
And Traceable to the National Institute of Standards and Technology

RESULTS: Acceptable

BY: Dickson Calibration Services

DUE DATE: February 01, 2010

DATE CALIBRATED: February 01, 2009



Dickson Certificate of Instrument's Initial Calibration

Re-calibration instructions below

Models: SM300/320/325/420/720/725, TM320/325/725, VFC320/325

Calibration Procedure: The customer instrument was compared to the calibration standard. Drifts and faults were determined, and any necessary mechanical or electronic adjustments were taken. The Dickson calibration system conforms to the requirements of ISO 17025 and ANSI/NCSL Z540-1-1994 as appropriate.

Calibration Standards: (The Dickson Calibration Standards are traceable through NIST and are re-certified anually)

- General Eastern Chilled mirrors and RTD (± .4RH, ±.4°F)
- Azonix A1011 PRTD (±.2°F)- Ectron Thermocouple Simulator (± .4°F)

Accuracy Specifications:

- SM300 / SM320 / SM720 internal temperature: ±.8 °F / ± 1.8 °F
- TM320 / TM325 / TM725 temperature accuracy: ±.8°F
- TM320 / TM325 / TM725 RH: ±2%RH from 0 to 60%, ±3% from 60 to 95%
- SM320 / SM325 SM720 / SM725 VFC320/325 external temperature: ±1.8°F (Unit Only)
- SM420 Platinum RTD, ±0.5°F

For Your Next Calibration

This is a precision instrument that requires re-calibration. We recommend every 6-12 months.

Just send this completed form along with your instrument to Dickson, labeling the outside of the box with **"CCM"**...it's that simple!

A) Purchase Order #: _____

Name: _____ Phone: _____

Model Serial #: _____

B) **A 3-pt Deluxe NIST will be performed unless otherwise requested**

- ☐ 1-Point NIST Calibration $156.00
- ☐ 3-Point NIST Calibration $209.00
- ☐ 3-Point A2LA Accredited 3-pt. Calibration $315.00 (includes incoming readings)
- ☐ N995 - User selectable NIST Temperature points $50.00 each (to be selected in addition to one of the above calibration options)

Prices are subject to change

C) Please Return:

- ☐ Ground Freight*
- ☐ 2nd Day Air*
- ☐ Next Day*

***Charges added at factory**

Returned UPS 2nd Day unless otherwise requested

D) Ship to: _____

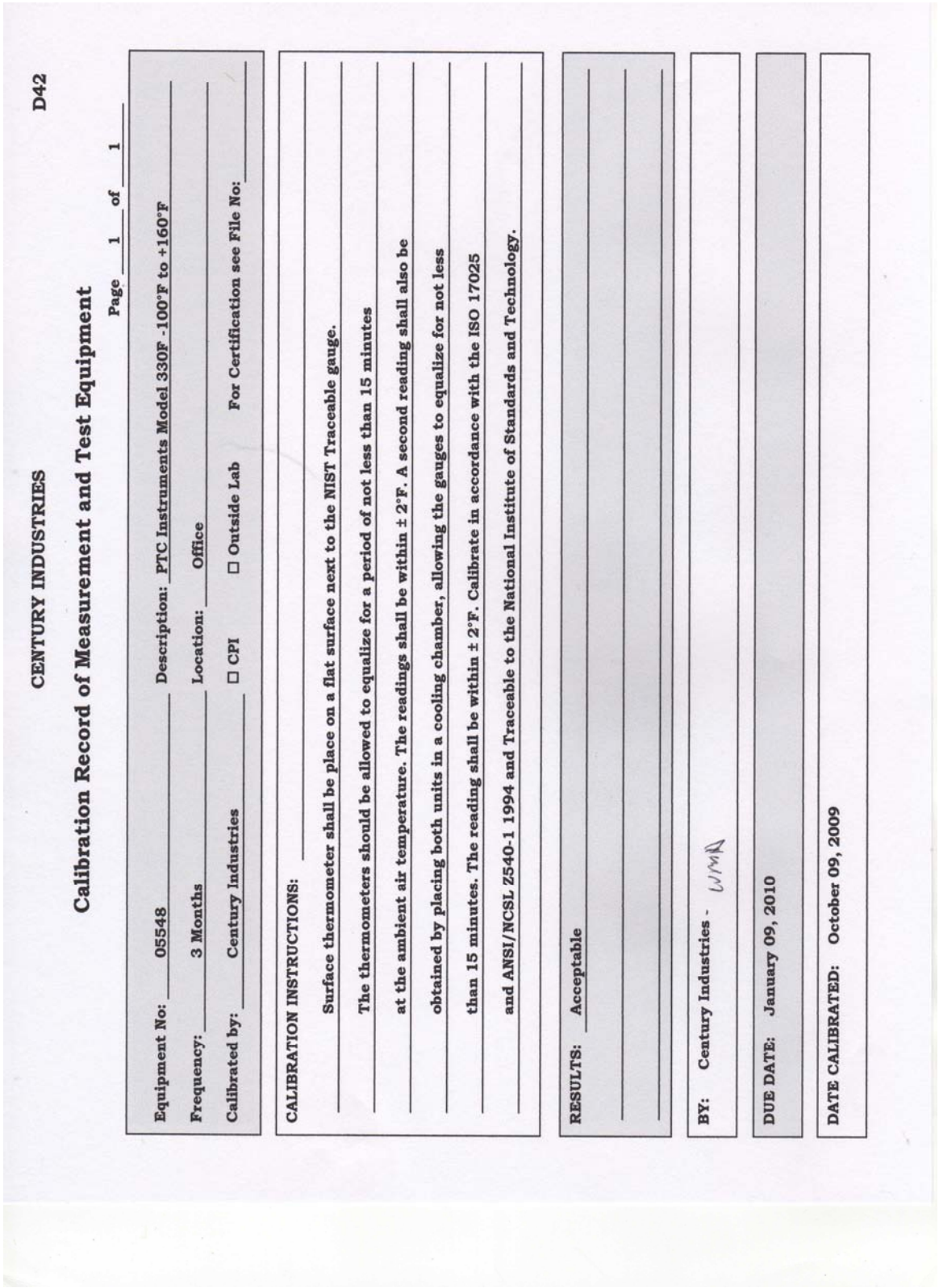
Bill to: _____

Let Dickson remind you the next time your unit is due for calibration. Join Calibration Club and receive calibration reminders free on all of instruments, including all non-Dickson brands of instrumentation. Learn more and register on-line at www.dicksonweb.com

Dickson Calibration Services
930 South Westwood Avenue Addison, Illinois 60101
Phone: 630-543-3747 Fax: 630-543-0498
www.dicksondata.com

E-4

PTC Instruments Model 330F -100°F to +100°F



CENTURY INDUSTRIES D42

Calibration Record of Measurement and Test Equipment

Page 1 of 1

Equipment No: 05548 Description: PTC Instruments Model 330F -100°F to +160°F

Frequency: 3 Months Location: Office

Calibrated by: Century Industries ☐ CPI ☐ Outside Lab For Certification see File No:

CALIBRATION INSTRUCTIONS:

Surface thermometer shall be place on a flat surface next to the NIST Traceable gauge. The thermometers should be allowed to equalize for a period of not less than 15 minutes at the ambient air temperature. The readings shall be within ± 2°F. A second reading shall also be obtained by placing both units in a cooling chamber, allowing the gauges to equalize for not less than 15 minutes. The reading shall be within ± 2°F. Calibrate in accordance with the ISO 17025 and ANSI/NCSL Z540-1 1994 and Traceable to the National Institute of Standards and Technology.

RESULTS: Acceptable

BY: Century Industries - LVMA

DUE DATE: January 09, 2010

DATE CALIBRATED: October 09, 2009

E-5