SAFETY EVALUATION REPORT
Docket No. 71-9342
Model No. VERSA-PAC Package
Certificate of Compliance No. 9342
Revision No. 0

TABLE OF CONTENTS

SAFETY EVALUATION REPORT
Model No. VERSA-PAC Package
Certificate of Compliance No. 9342
Revision No. 0

SUMMARY

By application dated October 13, 2009, as supplemented on February 17, and April 9, 2010, Century Industries requested approval of the Model No. VERSA-PAC as a Type AF package. Revision No. 3 of the package application, dated April 9, 2010, supersedes in its entirety the application dated October 13, 2009.

The Model No. VERSA-PAC packaging consists of two designs, i.e., the Model No. VP-55, a 55-gallon drum packaging, and the model No. VP-110, a 110-gallon version of the packaging. Both models are strengthened with vertical stiffeners, two inner liners insulated by a ceramic fiber blanket and a carbon steel reinforcing plate on the bottom. A fiberglass ring is used as a thermal break at the payload cavity flange. The packaging system includes an outer set of drum closure seals and an inner secondary flat gasket seal.

The package is designed to ship solid radioactive materials containing a maximum of 350 grams of ^{235}U, enriched up to 100 weight per cent, in any non-pyrophoric form. The outer diameter of the Model No. VP-55 is approximately 23-1/16 inches (30-7/16" for the Model No. VP-110.) The maximum gross weight of the loaded package is 640 pounds (lbs.) for the Model No. VP-55, and 965 lbs. for the Model No. VP-110.

NRC staff reviewed the application using the guidance in "Standard Review Plan for Transportation Packages for Radioactive Material," NUREG-1609. The full scale tests and analyses performed by the applicant demonstrate that the package provides adequate structural, thermal, containment and criticality protection under normal and accident conditions.

Based on the statements and representations in the application, and the conditions listed in the certificate of compliance, the staff concludes that the package meets the requirements of 10 CFR Part 71.

References

Century Industries, "VERSA-PAC Shipping Container Safety Analysis Report," Revision No. 3, dated April 9, 2010.

1.0 GENERAL INFORMATION

The Model No. VERSA-PAC package is a Type AF package designed for the transport of solid radioactive materials with a weight not exceeding 350 grams of ^{235}U enriched up to 100 per cent.

1.1 Packaging

The Model No. Versa-Pac packaging consists of two designs, i.e., the Model No. VP-55, a 55 gallon drum, and the Model No. VP-110, a 110 gallon version, both including an outer set of drum closure seals and an inner secondary flat gasket seal. The exterior skin of the packaging is a UN1A2/X400/S 16 gauge carbon steel material for the Model No. VP-55 and a UN1A2/Y409/S 16 gauge carbon steel material for the Model No. VP-110.

Both models use a 12 gauge bolted closure ring, standard carbon steel lugs, ASTM A 307 bolts and nuts, a closed-cell ethylene propylene diene methylene terpolymer (EPDM) gasket, and a drum cover reinforced by a 10 gauge thick plate and ½ inch bolts (four or eight bolts, depending upon the model) to provide additional strength to the packaging closure ring.

Both models are strengthened with vertical stiffeners (four stiffeners for the Model No. VP-55, and eight stiffeners for the Model No. VP-110), two inner liners insulated by a ceramic fiber blanket and a ¼ inch carbon steel reinforcing plate on the bottom. The packaging's interior is completely insulated with layers of a ceramic fiber blanket around the containment cavity. Rigid polyurethane foam disks, installed at the top and the bottom of the packaging, complete the insulation. A ½ inch thick fiberglass ring is used as a thermal break at the payload cavity flange to limit the flow of heat to the payload cavity through the steel flange components.

The payload cavity, manufactured with a 10 gauge carbon steel sheet, has three circumferential welds and one longitudinal weld. The upper end of the cavity is fitted with a flange ring with a blind flange. A fiberglass sleeve gasket is placed between the flange ring and the blind flange is secured with twelve bolts.

The packaging does not utilize any specific device or attachment for either lifting or tie-down. Neutron or gamma shielding is not required for the contents allowed to be shipped in the package.

The primary containment boundary of the package is defined as the inner containment cavity, the containment end-plate, the inner flange ring, the fiberglass sleeve gasket, the blind flange, the bolts, washers and insert holders.

The approximate dimensions and weights of the two models are indicated in Table No. 1-1- below:

Table No. 1-1

Model No. Versa-Pac Packaging System Dimensions and Weights

Model	Packaging OD (inch)	Packaging Height (inch)	Payload containment cavity ID (inch)	Payload containment cavity Height (inch)	Packaging Weight (lbs.)
VP-55	23-1/16	34-3/4	15	25-7/8	390
VP-110	30-7/16	42-3/4	21	29-3/4	705

1.2 Contents

Contents shall be in solid form, either in homogeneous (powder or crystalline) or non-homogeneous form, with no free-standing liquids. Quantity shall not exceed 350 grams U-235, enriched up to 100 weight per cent. Contents shall be stable and non-pyrophoric, with both the auto-ignition temperature and the melting points greater than 600ºF. The decay heat of the contents is limited to 11.4 watts (W) for both package models.

Contents authorized for shipment include uranium oxides, uranium metal, uranyl nitrate crystals and other uranium compounds. The uranium compounds may also contain carbon or graphite. Uranyl nitrate crystals may be in the form of uranyl nitrate hexahydrate, trihydrate or dehydrate.

The contents may be pre-packaged in hydrogenous or non-hydrogenous materials, as specified in Table No. 1-4 of the application. Materials with auto-ignition temperatures greater than 600ºF and a hydrogen density greater than 0.141g/cm^3 are not authorized.

The maximum weight of the authorized contents is 250 lbs for the Model No. VP-55 package, and 260 lbs for the Model No. VP-110 package. There are no moderating materials or neutron absorbers in the contents, nor any other material in the package, that would create a chemical, galvanic, or other reaction leading to the release of combustible gases.

The package is not approved for shipment of plutonium above minimum detectable quantities.

1.3 Materials

The materials of construction for the Model No. Versa-Pac package are listed in Tables No. 1-2 and 1-3 of the application.

Specifications for the polyurethane closed cell foam, the ceramic fiber insulation and the structural fiberglass components are included in Appendices No. 1.3.3, 1.3.4, and 1.3.5 of the application.

Material and manufacturing control processes are carried out using written procedures to ensure that all critical characteristics are met.

Staff reviewed the materials selected for use in the fabrication of components of the Model No. VERSA-PAC packaging system and found that they meet the service requirements of such components.

1.4 Criticality Safety Index

The Criticality Safety Index (CSI) for the Model No. VERSA-PAC package is 1.0. Thus, 50 packages may be transported in a non-exclusive use conveyance.

1.5 Drawings

The packaging is constructed and assembled in accordance with Drawings No. VP-55-LD-1, Rev. No. 3 and VP-55-LD-2, Rev. No. 5, for the Model No. VP-55; VP-110-LD-1 Rev. No. 3, and VP-110-LD-2, Rev. 4, for the Model No. VP-110 package.

1.6 Evaluation Findings

A general description of the package is presented with special attention to design and operating characteristics and principal safety considerations. Drawings are included in Appendix No. 1.3.1 of the application. The application identifies the Century Industries Quality Assurance Program, and the applicable codes and standards for the design, fabrication, assembly, testing, operation and maintenance of the package. NRC staff evaluated the Model No. VERSA-PAC package and documented the security assessment separately, as it contains sensitive information that cannot be made publicly available. The security assessment should be reviewed prior to approval of any amendment to this application.

The staff finds that the information presented in this section of the application provides an adequate basis for the evaluation of the Model No. VERSA-PAC package against 10 CFR Part 71 requirements for each technical discipline.

2.0 STRUCTURAL REVIEW

The objective of the structural review is to verify that the structural performance of the package meets the requirements of 10 CFR Part 71, including performance under the tests and conditions for both normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

2.1 Structural Design

2.1.1 Description of Structural Design

The Model No. VERSA-PAC package design utilizes standard shop dimensions, tolerances and structural materials, as indicated in the Licensing Drawings, in Table Nos. 1-2 and 1-3 of the application as well as in the General Note Sheet in Appendix No. 1.3.2 of the application.

The Model No. VP-55 body is fabricated from 16-gauge carbon steel, with minimum design specifications UN1A2/X400 S, while the closure ring is 12-gauge carbon steel. The packaging is strengthened with four longitudinal stiffeners, fabricated from carbon steel square tubing, equally spaced around the circumference of the drum. In addition, 16-gauge outer and inner liners provide additional radial stiffness to the drum. The volume between the inner liner and the 10-gauge containment cavity is filled with ceramic fiber insulation with specifications as stated in Appendix No. 1.3.4 of the application. The containment cavity is closed by a gasketed lid with twelve ½ inch bolts.

The Model No. VP-110 body is fabricated from 16-gauge carbon steel, with minimum design specifications UN1A2/Y409 S, while the closure ring is 12-gauge carbon steel. The packaging is strengthened with eight longitudinal stiffeners, fabricated from carbon steel square tubing, equally spaced around the circumference of the drum. In addition, two 16-gauge outer and inner liners provide additional radial stiffness to the drum. The volume between the inner liner and the 10-gauge containment cavity is filled with ceramic fiber insulation with specifications as stated in Appendix No. 1.3.4 of the application. The containment cavity is closed by a gasketed lid with twelve ½ inch bolts.

The Model No. VERSA-PAC design does not include lifting or tie-down devices.

2.1.2 Design Criteria

The structural design criteria are designated as those that affect the containment boundary and other package structures contributing to the overall structural performance of the package. The containment boundary is defined as the containment cavity, its flat gasket seal and blind flange. Miscellaneous structural failure modes such as brittle fracture, fatigue, and buckling are evaluated and found by the applicant to be satisfactory. The staff finds that brittle fracture and buckling are adequately characterized and evaluated.

The design criteria for structural analysis of the package under NCT and HAC conditions are as follows:

1. -40ºF for the minimum allowable temperature, 25 psig for the reduced external pressure, and the steel yield strength for the thermal stress.
2. Positive closure is maintained at all times during transport through 16 bolts for the Model No. VP-55 and 20 bolts for the Model No. VP-110.
3. Under a penetration event, the containment boundary must not be breached.
4. The containment boundary materials must not be susceptible to brittle fracture.
5. Chemical and galvanic reactions do not impair the function of the packaging during its 10-year design lifetime.
6. The package outer diameter and height remain essentially unchanged from their nominal as-built dimensions for NCT conditions.
7. The average outside diameter of the Model No. VP-55 package is maintained greater than 21.1 inches and the minimum height is greater than 33.6 inches at all times under HAC for criticality control requirements.
8. The average outside diameter of the Model No. VP-110 package is maintained greater than 28.5" and the minimum height is greater than 41.8 inches at all times under HAC for criticality control requirements.

2.1.3 Weights and Centers of Gravity

Table No. 1-2 of the application provides the weights of each component of the Model No. VERSA-PAC package. The center of gravity for a loaded Model No. VP-55 package is located at 18.9 inches from the base of the package along a vertical axis in the geometric center of the package, while the center of gravity for a loaded Model No. VP-110 is located at 17.5 inches from the base of the package.

2.1.4 Codes and Standards

Fabrication, assembly, testing and inspection of the Model No. VERSA-PAC package are conducted in accordance with standard operating procedures in compliance with the applicable codes and standards such as American Society for Testing and Materials (ASTM), American Society of Mechanical Engineers (ASME) and American Welding Society (AWS). In particular, welding shall be conducted by qualified personnel in accordance with AWS D1.1.

2.2 Material Properties

2.2.1 Materials Evaluation

The design of the Model No. Versa-Pac package utilizes the same materials for both the VP-55 and VP-110 models. Thus, the materials' evaluation is identical for both models, and no differentiation between the models is necessary.

The package design employs standard carbon steel shipping drums (manufactured per the international standard UN/1A2/X400/S or UN/1A2/Y409/S, depending upon the model of the package) along with carbon steel stiffeners, ceramic fiber insulation, polyurethane foam, fiberglass, neoprene rubber, and a carbon steel containment body.

Contents are limited to uranium oxides, uranium metal, uranyl nitrate crystals, or other solid uranium compounds. The contents may be packaged in metallic, hydrogenous or non-hydrogenous packaging materials. No liquid contents are permitted.

2.2.2 Chemical or Galvanic Reactions

The drum and containment vessel are fabricated of carbon steel. Some components (e.g., bolts, washers) are either zinc-plated carbon steel or austenitic stainless steel (e.g., Type 304). The galvanic potential between these different materials is low. This, combined with the fact that normal operation will not include any continuous exposure to moisture or water, means that there is no possibility for galvanic corrosion of any consequence.

The applicant considered the possibility for chloride induced corrosion of the important-to-safety (ITS) carbon steel components. Some insulating materials may be a source of soluble chlorides when they become wetted. Consequently, it is typical industry practice to specify and test for soluble chlorides in insulating materials. To address this potential concern, the applicant specifies that all insulating materials used in constructing the Model No. Versa-Pac package must be tested for soluble chlorides and meet specified maximum values. Under normal conditions of use, water intrusion is not likely to occur frequently nor in great quantities. Should water intrusion occur, any resulting corrosion would not be exacerbated by the presence of deleterious amounts of soluble chlorides.

The approved contents for the package are limited to solids, i.e., uranium oxides , uranium metal, uranyl nitrate crystals, or other solid uranium compounds. These materials are stable in solid form at the temperatures they would be exposed to during normal and design accident conditions. The absence of any liquid content eliminates the possibility for chemical or galvanic corrosion due to leakage of contents.

In addition, the payload is wrapped in an inert packaging (various plastic or metal containers or packaging materials such as polyethylene or metal foil) to isolate the contents from the containment cavity enclosure. This further removes the possibility for any adverse galvanic or chemical reaction between the contents and the containment cavity. For general corrosion control of the steel components, an alkyd enamel primer and paint are applied to both interior and exposed steel surfaces.

2.2.3 Effects of Cold Temperature

To comply with 10 CFR Part 71.71(b), the package was tested at -20ºF to assure that no brittle fracture of ITS components occurs. No observable differences in the drop test results were noted for the low temperature test versus the normal ambient temperature test. Therefore, a low temperature has no effect on the package performance.

2.2.4 Materials and Material Testing

The metallic materials of construction (drum, containment vessel) are procured and fabricated to consensus industry standards. The drums are manufactured to the UN1A2 international shipping drum standard. The various containment vessel components are fabricated from ASTM standard materials in accordance with the AWS D1.1 Welding Code. Mechanical properties of materials are specified in the Table No. 2-2 of the application. Thermal properties of materials are specified in Table No. 3.5.1-3 of the application. The properties of these materials have been tabulated in the application and found to be acceptable for their respective applications.

2.2.5 Conclusion

The staff finds that the Model No. Versa-Pac package (i) meets the regulatory requirements for preventing or mitigating galvanic or chemical reactions, (ii) is unaffected by cold temperatures, and (iii) is constructed with materials and processes in accordance with acceptable industry codes and standards.

2.3 Fabrication and Examination

Section No. 2.3 of the application indicates that the package is fabricated using standard operating procedures, conventional metal cutting, fitting, and welding techniques and all components are fabricated based on the requirements delineated on the packaging drawings. Fabrication materials, specified in the Licensing Drawings, are receipt-inspected for dimensional acceptability, material conformance to specification requirements and traceability markings.

The applicant states that each component is examined as specified on the packaging drawings. Codes and standards used in packaging fabrication and examination are described. Chapter No. 8 of the application specifies the requirements for fabrication acceptance and maintenance examination.

The applicant provides an overview of a typical fabrication sequence for this package. Staff reviewed this sequence and determined that it is of reasonable detail to fully describe the fabrication sequence.

2.4 General Standard for All Packages

The applicant demonstrates by full scale testing the structural performance of the package dynamic response to NCT and HAC drop tests.

2.4.1 Minimum Package Size

The package meets the requirements of 10 CFR 71.43(a) for minimum size.

2.4.2 Tamper-Indicating Features

The package ring closure bolt is fitted with a wire tamper seal. Removal of the bolt (hence damaging the tamper seal) is required to access the radioactive contents. This satisfies the tamper-indication requirement of 10 CFR 71.43(b).

2.4.3 Positive Closure

Positive closure is demonstrated by the use of a gasketed ½" thick blind flange with twelve carbon steel clad ½ inch bolts for the primary containment system, a package cover bolted with four carbon steel clad ½ inch bolts for the Model No. VP-55 (eight bolts for the Model NO. VP-110), and a standard package closure ring with a 5/8" bolt. All closure bolts are torqued at 60 ft-lbs. Thus, inadvertent opening is not credible.

The NCT and HAC test results demonstrate the effectiveness of the closure system. Therefore, the containment system cannot be opened unintentionally and the requirements of 10 CFR 71.43(c) are satisfied.

2.5 Lifting and Tie-Down Standards for All Packages

2.5.1 Lifting Devices

The package does not utilize any specific device or attachment for lifting and is handled with normal means such as forklifts or other methods as determined by the user. Thus, the requirements of 10 CFR 71.45(a)(1) for lifting devices are not applicable.

2.5.2 Tie-Down Devices

The package does not incorporate any structural feature that is used as a tie-down device. Thus, the requirements of 10 CFR 71.45(b)(1) are not applicable.

2.6 Normal Conditions of Transport

Full scale prototypes of both models, i.e., VP-55 and VP-110, were tested under NCT. Two orientations, i.e., the free drop center of gravity over corner on lid edge and the horizontal side crush, were evaluated and tested for potential impact to the thermal and criticality designs of the package. In both cases, significant damages resulted to the package but the lid and package closure remain intact and subsequent puncture tests do not challenge the package shell, inner or outer closures.

2.6.1 Heat

The applicant evaluates, in Chapter No. 3 of the application, the maximum temperature of the packaging under NCT and finds that it is 144ºF, i.e. well below the maximum allowable temperature of 600ºF for the contents of the package.

At this maximum temperature, the bounding maximum pressure that is developed is 9.8 psig. This is well below the maximum allowable pressure of 25 psig for the containment boundary.

The applicant evaluates the differential thermal expansion (DTE) of the package components and finds that (i) the steel components do not independently develop significant stresses, (ii) the blanket insulation is not damaged by thermal expansion effects because it is compressible, and (iii) the rigid foam insulation has very small expansion lengths, estimated from 1/16" to 1/240", that are absorbed by the microstructure of the foam at the steel surface and by the allowable tolerances on the parts themselves.

The staff reviewed the structural performance of the package under the hot conditions of transport and concluded that the DTE has been properly evaluated and that thermal stresses generated are structurally negligible. Thus, the requirements of 10 CFR 71.71(c)(1) are satisfied.

2.6.2 Cold

The applicant evaluates the impacts of a cold environment on the package performance by considering an ambient temperature of -40°F combined with no insolation and no decay heat. At this temperature, the increased foam compression strength and modulus result in a stiffer package response under drop conditions and more of the load is transferred to the containment boundary on impact.

The applicant evaluates the results of the drop tests at a normal ambient temperature and at -40°F and concludes that no observable differences can be noted.

The staff reviewed the applicant's evaluation and finds that the NCT cold condition is of negligible consequence for this package design. The requirements of 10 CFR 71.71(c)(2) are satisfied.

2.6.3 Reduced External Pressure

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. Such pressures are within the design internal and external pressures (25 psig) of the containment; therefore, the staff finds that the requirements of 10 CFR 71.71(c)(3) are satisfied.

2.6.4 Increased External Pressure

An increased external pressure of 20 psia results in a net internal pressure of 20 psia or a next external pressure of 3.3 psia. Such pressures are within the design internal and external pressures (25 psig) of the containment. The staff finds that the requirements of 10 CFR 71.71(c)(4) are satisfied.

2.6.5 Vibration

Vibration testing conducted on the outer drum during the performance design qualification tests, as set forth in 49 CFR 178.608, indicated that there is no failure to the drum ring closure system. Test results are provided in the manufacturer's UN test certificate. Vibration incident to transport does not produce settling, compaction or a loss of structural cohesion for any of the materials used in the packaging.

In addition, the bolted closure, through the lid attached to the internal structure, utilizes bolts that are torqued to a prescribed rating of 60 ft-lb. The bolts, once torqued, are locked into place with locking washers, thus preventing the loss of bolts during shipment.

Staff finds that the results presented support the conclusion that the effects of vibration do not impact the performance of the package and that the requirements of 10 CFR 71.71(c)(5) are satisfied.

2.6.6 Water Spray

A one hour water spray simulating a rainfall of 2 inches per hour is not significant to the structural design of the package because the outer vessel is designed to withstand exterior pressure loads higher than those applied by the water spray.

2.6.7 Free Drop

The applicant performed full scale testing to demonstrate that the package maintains its integrity and effectiveness after a 4 feet free drop.

The staff reviewed the test results, particularly the horizontal side crush test results as the worst-case damaging test, and finds that the package is capable of maintaining its structural integrity, thus meeting the requirements of 10 CFR 71.71(c)(7).

2.6.8 Corner Drop

The corner drop test does not apply since the gross weight of the package exceeds 220 lbs, in accordance with 10 CFR71.71(c)(8).

2.6.9 Compression

The test report for the NCT Evaluation Test Series indicates that the model VP-55, numbered 10553, previously utilized for the shallow angle drop tests, was also used for both the compression and penetration tests.

The applicant calculates the compressive stress of the primary load bearing members of the package and finds a margin of safety against compressive failure of 56.7. The staff reviewed the calculations and the results of the physical testing reported in Appendix 2.12.5 NCT test report for compression and penetration, and finds that the package complies with the requirements of 10 CFR 71.71(c)(9).

2.6.10 Penetration

The impact from a 13 lb rod does not penetrate the shell of the package. There is no noticeable or measurable damage to the impact surface. The package complies with the requirements of 10 CFR 71.71(c)(10).

2.7 Hypothetical Accident Conditions

2.7.1 30 Feet Free Drop

The applicant performed full scale testing of both the VP-55 and VP-110 models in a variety of sequenced drops, punctures, shallow angle drops and crush tests, as specified by 10 CFR 71.73. Tests were videotaped and photographed and post-drop damage measurements were recorded after each drop.

The end drop test resulted in a 2 - 3/ 8 inch long slight crumpling at the bolt closure, but all welds, closures, and bolts remained intact. The side drop test resulted in a buckling around the closure bolt area, as well as on the lid, and a decrease of the diameter of 1 inch in the bolt impact direction but the containment closure and welds remained intact. The corner drop impact test resulted in a depression of 11/16 inches deep into the lid and an additional side deformation 2-1/2 inches deep by 20 inches long but all welds, bolts, and containment closure remained intact.

The oblique drop, performed to test the inner containment area closure system, resulted in a slit in the outer drum but no internal breach of the inner liner took place. The diameter of the outer drum lid, across the top surface of the package, was reduced in the direction of the impact upon the bolt by approximately 3 inches.

The review of the results shows that the package can withstand multiple impacts with only minor damage to the exterior surfaces in all drop configurations. Based on the applicant's test results, staff concludes that the package will not suffer deformations that allow breach of the containment under HAC-30 foot drop conditions

2.7.2 Crush

The applicant performed testing, with a crush plate placed to impact the package directly on both the closure and top flange areas as well as also over the bottom edge of the package. Test results demonstrate that the package does not show an opening to the internal structure or the seals after a crush test. The staff finds that the package complies with the requirements of 10 CFR 71.73(c)(2).

2.7.3 Puncture

The applicant performed testing of both models, i.e., VP-55 and VP-110, in a variety of orientations, including side, center bottom, center top and center of gravity through the bolt closure. Test results indicate that 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 of the package.

Based upon these results, both areas were punctured during this test series. The tests demonstrate that the puncture drop tests do not result in any opening, tear or failure of the package, nor in any open pathway to the insulation materials, nor to any loss of the payload.

Staff found that the results presented support the conclusions made by the applicant relative to the puncture drop event. The requirements of 10 CFR 71.73(c)(3) are met.

2.7.4 Thermal

The applicant utilizes temperature information derived from the postulated fire events to determine the impacts on the structural integrity of the package. The main conclusions drawn by the applicant are that:

(i) the maximum temperature recorded at the top of the payload cavity, just below the polyurethane plug, is 552ºF, i.e., below the maximum allowable HAC temperature of 600ºF, and

(ii) the MNOP of the package is near atmospheric pressure even if the internal pressure of the containment may be as high as 9.8 psig under HAC conditions due to the fact that the package is not a sealed system.

Staff reviewed the evaluation presented by the applicant and finds the reasoning and conclusions credible; therefore, the package meets the requirements of 10 CFR 71.73 (c)(4).

2.7.5 Immersion - Fissile Material

Moderator inleakage to the most reactive credible event is assumed for the criticality evaluation of the package. Thus, the fissile material immersion test is not required.

2.7.6 Immersion - All Packages

A damaged prototype was tested in an immersion chamber at 23 psig for 15 minutes and no additional damage was noted due to the immersion. The staff evaluated the test results and found that the requirements of 10 CFR 71.73(c)(6) are met.

2.8 Evaluation Findings

On the basis of the review of the applicant's responses and the statements and representations in the application, the staff concludes that the package is adequately described and evaluated to demonstrate that its structural capabilities meet the requirements of 10 CFR Part 71.

3.0 THERMAL REVIEW

The objective of the review is to verify that the thermal performance of the package has been adequately evaluated for the tests specified under both NCT and HAC conditions of transport and that the package design satisfies the thermal requirements of 10 CFR Part 71.

3.1 Description of the Thermal Design

3.1.1 Design Features

Both models, i.e., VP-55 and VP-110, include vertical stiffeners fabricated from carbon steel square tubing, two inner liners of rolled carbon steel insulated by a ceramic fiber blanket encasing the vertical tubing, and a carbon steel reinforcing plate at the bottom. The package's interior is completely insulated with the appropriate layers of ceramic fiber blanket around the containment area with a rigid polyurethane foam disk on the top and on the bottom to complete the insulation of the package.

The thermal break, a ½ inch thick fiberglass ring, is sandwiched between the steel components to limit the flow of heat to the payload cavity through the steel flange components. There are no moving parts to the thermal break and its functionality is maintained as long as it separates the steel components. The volume between the inner liner and the containment body is filled with ceramic fiber insulation.

There is no special heat transfer mechanism provided for the package's heat load. The package has no pressure relief systems, but includes four holes between the insulation and the containment to vent gases that might be produced in the fire event.

The primary containment boundary is defined as the payload cavity with its associated welds, the containment end plate, the inner flange ring, the silicone-coated fiberglass gasket, the cavity blind flange, and the bolts.

3.1.2 Contents Decay Heat

The decay heat of the contents is limited to 11.4 W for both models, with no single item having a decay heat greater than 20 W/m^3.

3.1.3 Summary Table of Temperatures

The contents of the Model No. Versa-Pac package are limited to those materials with auto-ignition temperatures and melting points greater than 600ºF. Contents that decompose or melt below 600ºF are not authorized for shipment. Table No. 3-1 of the application summarizes NCT and HAC temperatures for the package. Allowable temperature limits for the contents of the package are 500ºF for NCT and 600ºF for HAC conditions.

3.1.4 Summary Tables of Maximum Pressures in the Containment System

The NCT and HAC maximum internal pressures of the cavity of the Model No. VP-55 are presented in Table No. 3-1 of the application. The staff reviewed the description of the containment structure and confirmed the applicant's evaluations because the package is not a sealed system and the MNOP is near atmospheric pressure.

The staff also confirmed that the thermal performance of the Model No. VP-55 is bounding because of identical heat loads in both models.

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

The thermal properties are provided in Tables No. 3.5.1-3, 3.5.1-4, and 3.5.1-5 of the application and the mechanical material properties, including the linear thermal expansion coefficient, are provided in Table No. 2-2 of the application.

Contents are stable solids that do not undergo any physical state changes (solid to liquid or solid to gas) below 600ºF, with a melting point temperature greater than 600ºF. Unstable payloads are not authorized for shipment.

Water moisture, if present, is converted to steam during the fire and escapes via the package closure gaskets.

The staff checked Table No. 1-4 of the application for melting points and auto-ignition temperatures for selected packaging materials, i.e., PTFE, carbon steel and aluminum, and found that the package is in compliance with 10 CFR 71.43(d) requirements.

3.2.2 Component Specifications

The Model No. Versa-Pac package is insulated to protect the containment boundary during HAC. The insulation materials, i.e., ceramic fiber insulation and fiberglass, have been shown by the manufacturers to perform adequately over extended periods of time, with no shrinkage, settling, or loss of insulating properties. Their properties and specifications are shown in Table No. 3.5.1-2 of the application.

Both the ceramic fiber insulation and the fiberglass thermal break do not burn because their melting points are well above the 1475ºF temperature specified in the regulations. Further, the steel components of the package are serviceable to 800ºF per the ASME Code, and have a melting point of about 2500ºF. The staff validated the melting point of about 3200ºF for the ceramic fiber insulation material and the melting point of about 3600ºF for the fiberglass. Thus, the staff confirmed the applicant's specifications.

The applicant conservatively demonstrated that there is a maximum allowable external and internal working pressure of 15 psig. The package is capable of sustaining the expected working pressures without any collapse of the payload cavity. The staff finds that the maximum allowable working pressure of 15 psig for a sealed cylinder is acceptable for the non-sealed payload cavity of the package, in compliance with 10 CFR 71.35 and 71.71.

3.3 General Considerations

3.3.1 Evaluation by Analysis

The thermal performance of the Model No. Versa-Pac package is evaluated by a modeling analysis for all conditions of transport. The applicant developed a quarter-symmetric transient finite element model using ALGOR 18.1, and modeled both the VP-55 and VP-110 packages with and without contents, and furthered simulated the VP-55 model without contents and without decay heat.

The model imposes an initial condition of 100ºF on all nodes at the beginning of the thermal events. The applicant selected the VP-55 model without decay heat and without contents for the thermal evaluation because of its bounding performance.

The staff reviewed the evaluation of the thermal performance of the package during HAC conditions. The applied heat load, heat transfer coefficients and initial conditions are shown in Table No. 3-2 of the application. The applicant simulated the air gap, i.e., 5/8 inch for the VP-55 model, between the top of the cavity inner lid and the bottom of the outer lid, as a conduction equivalent condition in the thermal model, as specified in Appendix No. 3.5.1 and simplified the heat transfer inside the package as a heat conduction-only condition in Appendix No. 3.5.2 of the application.

The staff reviewed the methodology described in Appendix No. 3.5.2 of the application, and confirmed that the modeling approach was correct because the radiation heat transfer across the gap is logically accounted for and is also conservatively enhanced by a factor of 2. Other conservative factors included the fact that the view factor between the bodies is close to 1, the heat flux out of the system is negligible, there is no radiation to the environment, the surface area of each body is equal, and that the surface temperatures are approximately known from the previous iteration step in the model.

The staff reviewed the methodology and found that the load steps of both NCT and HAC analyses (for the transient and cool-down periods) are acceptable and described in sufficient details to meet the thermal regulatory requirements of 10 CFR 71.35, 71.71, and 71.73.

3.4 Thermal Evaluation under NCT

3.4.1 Heat and Cold

The applicant performed the thermal analysis under NCT cold conditions with zero decay heat and a minimum temperature of -40ºF for the packaging and the contents. The results of the analysis predicted that all package component temperatures are well below the allowable limits within the safety margin limits, as specified in Table No. 3-1. The applicant performed the thermal analyses under NCT hot conditions with still air at 100°F and a top surface insolation of 246 Btu/hr-ft^2-°F (800 g-cal/cm^2) and a curved surface insolation of 123 Btu/hr-ft^2-°F (= 400 g-cal/cm^2). The applicant predicted the maximum payload temperature of 144°F and the maximum external surface temperature of 140°F under NCT.

The staff confirmed the methodology used in the analysis: the peak payload temperature of 140°F is well below the allowable limit of 500°F, in compliance with 10 CFR 71.71. The staff also found that, even with the predicted external surface temperature of 140°F, which is over the limit of 122°F for a non-exclusive use shipment, the package is acceptable for both non-exclusive and exclusive conveyance, due to the fact that the modeling simulation was not performed in the shade (with solar heat).

The staff analyzed the contribution of solar insolation on the package surface temperature and concluded, through a confirmatory analysis, that a solar heat of 400 g-cal/cm^2 can increase the surface temperature by more than 35°F. Therefore, the staff found that the package meets the requirements of 10 CFR 71.71(c)(2) and 10 CFR 71.43(g).

The applicant evaluated a maximum internal pressure of 14.7 psia under NCT. The staff found that the package is in compliance with 10 CFR 71.35 and 71.71, because the package is not a sealed system and the maximum normal operating pressure (MNOP) is near atmospheric pressure.

3.4.2 Maximum Thermal Stresses

The evaluation of thermal stresses is not required because of the low decay heat of the contents, i.e., 11.4 W, and the resulting low thermal gradients between components under NCT.

3.5 Thermal Evaluation under HAC

3.5.1 Fire Test and Cooldown Conditions

The applicant imposed an initial condition of 100ºF on all nodes of the thermal model at the beginning of the thermal analysis, without simulating damages from drop tests because local reductions in wall thickness due to drop tests have been shown to be limited to the outer 1 ½ inches of the package.

The applicant performed the HAC analysis to an ambient temperature of 1475ºF for the 30-minute fire event. The cool-down sequence, initialized with the temperatures recorded for each node at the end of the 30 minute fire sequence, was run for a 2 hour period with the peak temperature of the contents occurring within the first hour after the cessation of the fire.

3.5.2 Maximum Temperatures and Pressure

All component temperatures are below the allowable limits and are within the safety margins. The maximum temperature is 552ºF at the top of the cavity, just below the polyurethane plug. The maximum internal pressure is 14.7 psia under HAC because the Model No. Versa-Pac package is not a sealed system and the MNOP is near atmospheric pressure.

3.5.3 Maximum Thermal Stresses

The applicant performed a thermal stress evaluation, using the ALGOR code, for the polyurethane plug that is utilized within the payload cavity. The applicant conservatively selected the polyurethane plug to produce the highest thermal stress for purposes of bounding the expected performance and utilized static stress conditions with linear material models, and the thermal and mechanical material properties provided in Tables No. 3.5.5-1, 3.5.5-2, and 3..5.5-3 of the application. The applicant evaluated the maximum thermal stress of 78 psi with the maximum thermal differential at 150 minutes after the start of the fire.

The staff reviewed the thermal stress evaluation, performed by the applicant, and found that (i) the selection of the polyurethane plug is a bounding case for the thermal stress evaluation because of its higher thermal expansion coefficient than from other components, and (2) the choice of 150 minutes after the start of the fire is appropriate for evaluation.

3.6 Evaluation Findings

The staff reviewed the package description, the material properties, component specifications and the methods used in the thermal evaluation, and found reasonable assurance that they are sufficient to provide a basis for evaluation of the package against the thermal requirements of 10 CFR Part 71. The allowable temperature limits for the payload of the Model No. Versa-Pac package are 500^{o}F for NCT and 600^{o}F for HAC.

The staff reviewed the package preparations for shipment and found reasonable assurance that the package material and component temperatures will not extend beyond the specified allowable limits during NCT, and will not exceed the specified allowable short-time limits during HAC conditions, consistent with the tests specified in 10 CFR 71.71.

4.0 CONTAINMENT REVIEW

The staff reviewed the package containment design to verify that it has been adequately described and evaluated under NCT and HAC conditions, as required per 10 CFR Part 71.

4.1 Description of the Containment System

The containment boundary of the package is defined as the inner containment cavity, the containment end-plate, the inner flange ring, the fiberglass gasket, blind flange and reinforcing ring, the bolts, washers, and insert holders. There are no penetrations, valves or venting devices used within the containment boundary.

A prescribed torque of 60 ft-lbs is applied to the closure bolts to assure positive closure of the containment boundary.

4.2 Containment under NCT

Drop tests described in Chapter No. 2 of the application have demonstrated that the package design prevents loss or dispersal of its contents under NCT, in compliance with 10 CFR 71.71 and 71.73 requirements. Further, the package remains subcritical under NCT as demonstrated in Chapter No. 6 of the application.

Since the package is not a sealed system, the internal pressure is maintained near atmospheric pressure under NCT. The maximum temperature of the contents stays below 212ºF and any potential water moisture remains in the liquid state within the cavity.

4.3 Containment under HAC

Drop tests described in Chapter No. 2 of the application have demonstrated that the package design prevents loss or dispersal of its contents under HAC, in compliance with 10 CFR 71.71 and 71.73 requirements. Further, the package remains subcritical under HAC as demonstrated in Chapter No. 6 of the application.

Since the package is not a sealed system, the internal pressure is maintained near atmospheric pressure under HAC. During an HAC fire event, any potential water moisture is converted to steam and any pressure buildup is released through the package gaskets. Based on the test results and the structural review, as mentioned in Section No. 2.7.1 of this report, the staff concludes that all containment welds, bolts, and closures still remain intact after the HAC 30-foot free drop test, and that the package does not allow any breach of the containment and any loss of the contents from the containment vessel.

4.4 Evaluation Findings

Based on the review of the statements and representations in the application, the staff finds that the Model No. VERSA-PAC containment design has been adequately described and evaluated and that the package design meets the containment requirements of 10 CFR Part 71.

5.0 SHIELDING REVIEW

Contents allowed for shipment in the Model No. Versa-Pac package do not require shielding and no shielding evaluation is performed for this package. However, it is always the responsibility of the shipper to ensure compliance with the radiation standards of 10 CFR 71.47.

6.0 CRITICALITY REVIEW

The objective of the criticality review is to verify that the criticality performance of the package meets the requirements of 10 CFR Part 71, including performance under NCT and HAC. The criticality safety evaluation defines generic but bounding contents to cover all possible constituents. The neutron multiplication factor (k-eff) is below 0.95 during all NCT and HAC conditions.

6.1 Description of Criticality Design

6.1.1 Packaging Design Features

The packaging design features that are important to criticality safety are the cavity diameter, body and body welds, the packaging outer diameter, the blind flange and the seals as well as the number of packages in a conveyance. Each payload is limited to a mass limit of 350 grams of U-235. The packaging does not use any neutron absorber and there are no fixed neutron absorbers being credited in the analysis.

The staff finds that the description of the packaging is in sufficient detail to provide an adequate basis for its evaluation and that it meets the requirements of 10 CFR 71.31(a)(1) and 10 CFR 71.33(a)(5). A limit of 50 packages per non-exclusive shipment is determined based on a CSI value of 1.0. The staff finds that, by specifying the allowable number of packages that may be transported in a single shipment, the applicant meets the requirements of 10 CFR 71.35(b).

6.1.2 Summary Table of Criticality Evaluations

The staff reviewed Table No. 6-1 of the application and finds that the applicant performed criticality evaluations for arrays of packages in HAC conditions varying in size from 216 packages to 936 packages. The staff notes that the HAC conditions bound the NCT conditions for both the single package and array cases.

The applicant shows that, under NCT and HAC conditions, a model array size of 272 packages has a k-eff less than the applicable upper subcriticality limit (USL) of 0.94. The staff finds that this meets the requirements of 10 CFR 71.59(a)(1) and (2).

The staff reviewed Table No. 6-5 of the application and found that the applicant performed criticality evaluations for a single package in a damaged condition, optimally moderated with polyethylene, with the most reactive form of the fissile material, and with close full reflection of the containment system on all sides using 30-cm of water. The applicant justified that polyethylene was bounding as the most reactive moderator by limiting hydrogen moderation to 0.141 g/cm^3.

In Table No. 6-5 of the application, the applicant shows that the maximum k-eff for the limiting configuration is less than the USL of 0.94. The staff finds that this meets the requirements of 10 CFR 71.55(b), (d) and (e).

The applicant independently evaluated the interspersed moderation within packages regions, i.e., the payload, the payload insulation region, the inner and outer liners, the top and bottom insulation and the exterior package regions were independently evaluated. Results of the applicant's evaluation are shown in Table No. 6-12 of the application and bounding results are presented in Table No. 6-1. With a modeled package array size of 272 packages under HAC conditions with 0.0001 interstitial moderation and polyethylene moderation mixed in with the fissile material, the results are within the USL of 0.94 when considering region interspersed water moderation.

6.1.3 Criticality Safety Index

The applicant calculated the Criticality Safety Index (CSI) to have a value of 1.0. This is based on the analysis performed using an array of 272 packages, giving N a value of 54.4 (5N= 272, N= 54.4; CSI= 50/54.4= 0.919, rounded to 1.0).

The staff finds that the CSI was appropriately determined per 10 CFR 71.59(b). The staff finds that the application meets 10 CFR 71.59(a)(3) because the value of N is not less than 0.5.

6.2 Fissile Material Contents

Contents include uranium oxides, uranium metal, uranyl nitrate crystals, and other uranium compounds, e.g., uranyl fluorides and uranyl carbonates enriched up to 100 wt% U-235. Contents are limited to 350 grams U-235 in any non-pyrophoric form. The criticality safety analysis is based on 350 grams of 100% enriched U-235 as uranium metal, which bounds all other forms of uranium compounds.

The package is evaluated assuming optimum moderation using a bounding high density polyethylene plastic with a density below 0.141 g/cm^3. Since materials with a hydrogen density greater than 0.141 g/cm^3 are not allowed in the package, the polyethylene moderation bounds various pre-packaging materials such as polypropylene, PVC, PTFE, Teflon, or metallic materials.

The staff finds that the applicant described the contents in sufficient detail to provide an adequate basis for its evaluation. The staff finds that the applicant has defined adequately the type, maximum quantity, and chemical and physical form of the fissile materials in compliance with the requirements of 10 CFR 71.31(a)(1), 10 CFR 71.33(b)(1) through (3).

6.3 General Considerations for Criticality Evaluations

6.3.1 Model Configurations

The applicant constructed a unit model to conservatively represent the HAC damaged package configuration for the VP-55 design as the worst case scenario for both the VP-55 and VP-110 designs under NCT and HAC, since the smaller size package results in a more reactive package array when compared to undamaged VP-55 and VP-110 models. The staff finds this acceptable.

The staff reviewed Chapter No. 2 of the application to determine the effects of NCT and HAC conditions on the packaging and its contents. From the tests required in 10 CFR 71.73, any damage only impacts the package inner radius, outer radius and height, as summarized in Table No. 6-3 of the application and listed in page No. 17 of Appendix No. 2.12.4. The staff notes that the payload inner diameter listed in Appendix No. 2.12.4 is 1/16 inch smaller, after the 30-ft slap down test, than the diameter actually modeled. However, the staff also notes that a reduction in the modeled diameter of the package has little or no effect on the more reactive in-homogeneous (lumped fissile mass) modeled system since the reduced diameter does not otherwise limit placement of the modeled spherical mass in the sensitivity studies. Additional reductions in the diameter do not challenge the USL value.

The staff examined the sketches of the model used for the criticality calculations and verified that the dimensions and materials are consistent with those in the drawings of the actual package. The criticality model does not include the stiffeners, bolt ring, vertical square tubing, reinforcing angles and bottom plate ring. Those were conservatively neglected resulting in modeling less than 50% of the package carbon steel. The vertical and horizontal tubing, as well as the insulation products, were modeled as optimum interspersed water moderation. Packages and arrays of packages were also modeled with full density water boundary reflection. The staff finds this acceptable.

The staff verified that the application considers deviations from the nominal design configurations by analyzing a conservative condition.

6.3.2 Material Properties

The staff verified that the densities are provided for all materials used in the models of the packaging and contents. The applicant provided the density for each material in Table No. 6-4 of the application. The atomic numbers densities used in the criticality models are the default atomic number densities from the SCALE 4.4a suite of codes. There are no materials in the package that need to be adjusted to be consistent with HAC conditions, i.e. there are no materials used in the model that change form or are important for maintaining criticality calculations.

The applicant does not use any material as neutron absorbers. The staff did not identify any criticality properties that could degrade during the service life of the package.

6.3.3 Computer Codes and Cross-Section Libraries

The applicant uses the SCALE 4.4a suite of codes with the 44-Group Standard Cross Section Library. The code sequence BOMANI, NITAWL, and KENO VI is used in all analyses. The staff finds its use acceptable for the criticality analyses for the Model No. Versa-Pac package.

The staff verified that the applicant provided other key input data for the criticality calculations. These are summarized below in Table No. 6-1 below.

Table No. 6-1: Criticality Key Input Data

Parameter	Value
Number of Neutrons per Generation	1000
Number of Generations	600
Number of Cycles Skipped Before Accumulating Data	5

The staff verified that the applicant provided representative input files. The staff also verified that the information regarding the model configuration, material properties and cross sections, is properly represented in the input files.

6.3.4 Demonstration of Maximum Reactivity

The staff reviewed the application to determine if each type of fissile material in the allowable contents was included. The applicant models the fissile contents as 350 grams U-235 as uranium metal as this is bounding for the other allowable fissile contents. The staff finds this acceptable.

The applicant uses polyethylene (CH_2) with a density of 0.98 g/cm^3 as a bounding hydrogenous moderating material to increase the hydrogen density to 0.141 g/cm^3 . The applicant evaluates a full range of moderation in Section No. 6.3.4.3 of the application and states that pre-packaging materials having a hydrogen density less than or equal to that of high density polyethylene do not need to be controlled for criticality purposes. Materials with a hydrogen density greater than 0.141 g/cm^3 are thus not authorized.

The applicant's model assumes a single homogeneous sphere of U-235 and polyethylene with a radius of 12 cm, inside the payload. The applicant performed an analysis to determine the most reactive geometry of the fissile material, by looking at single spheres, single cylinders in the payload or fissile material homogeneously throughout the payload. Once the applicant determined that a single sphere was the most reactive form, then the size of the sphere was examined. The applicant performed sensitivity analyses with various array configurations and identified the most reactive array, as reported in Section No. 6.6.2.2.8 of the application. Analyses also determined the optimal H/U ratio of 636. The staff finds that the applicant's analysis demonstrated that they have found the maximum reactivity per 10 CFR 71.55(b) requirements.

The applicant evaluated both square-pitched and triangular-pitched close-packed arrays and determined that an hexagonal (triangular-pitched) array provided more interaction between the packages and had a higher k-eff. The applicant performed sensitivity studies to determine the most reactive location of the sphere within the package and determined that having the sphere in the bottom of the package with stacked packages (to allow the closest distance between fissile material) was more conservative.

The applicant determined that the most conservative configuration is when the packages are placed closely together and with a low water density (0.0001 g/cm^3) between the packages. The applicant specified different moderator volume fractions for five different package regions, including the payload region, the insulation region, the inner and outer liners, the top and bottom insulation regions and the exterior region between the packages. Calculation results indicate that the most reactive array MOD1 with moderator volume fractions of 0.0001, 0.001 and 0.01 produces the higher k-eff. Results, summarized in Table No. 6-12 of the application, are within the USL of 0.94 when considering region interspersed water moderation. The staff finds that this meets the requirements of 10 CFR 71.59(a).

6.3.5 Confirmatory Analysis

The staff performed independent calculations to confirm the applicant's results and verify that the most reactive conditions had been correctly identified. The staff performed calculations with the CSAS26 criticality sequence of the SCALE 6 suite of codes developed by Oak Ridge National Laboratory for the use in criticality and shielding analyses. The CSAS26 sequence is a criticality sequence that uses KENO-VI geometry and multi-group cross sections. The staff used the 44-group cross section library derived from ENDF-V data.

The staff constructed its model based on design information in the application and the referenced drawings. The staff modeled the limiting conditions as identified by the applicant, i.e., a 12 cm radius sphere that has a homogeneous mixture of 350 grams U-235 metal. The materials are same as those identified by the applicant in Table No. 6-4 of the application. The staff used approximately 30cm reflection on all sides of the hexagonal array. The staff's evaluation generally agrees with the results from the applicant.

6.4 Single Package Evaluation

6.4.1 Configuration

The staff verified that the applicant's evaluation demonstrates that a single package is subcritical under both NCT and HAC conditions. The applicant created a model based on the HAC test results which bound NCT. The applicant considered a distributed fissile mass within the package geometry and a lumped fissile mass fully reflected to represent flooding of the package.

The applicant identified the most reactive array configuration in Tables No. 6-10 and 6-11 of the application, and modeled the most reactive credible configuration consistent with the condition of the package and the chemical and physical form of the contents.

The staff determined that polyethylene with an increased density from 0.92 to 0.98 g/cm^3 is the most effective moderator of all compounds listed in Table No. 6-4 of the application, as required by 10 CFR 71.55(b). The applicant specified that the density of 0.98 g/cm^3 corresponds to the maximum evaluated hydrogen density for the package of 0.141 g/cm^3, and that materials with a hydrogen density greater than 0.141 g/cm^3 are not allowed in the package.

The applicant stated in Section No. 6.3.1.1 of the application that all single package analyses include full reflection of water on all sides. The staff finds that this meets the requirement in 10 CFR 71.55(b)(3).

6.4.2 Results

For the single package evaluation, the applicant found the most reactive configuration to be with a fissile lump mixed with full polyethylene moderation, 12 cm in radius, and no packaging geometry. This configuration bounds both the HAC and NCT conditions. The maximum k-eff for these conditions is 0.8838. Since k-eff is below the USL of 0.94, the requirements of 10 CFR 71.55(d)(1) and 71.55(e) are met.

Since the applicant does not use any package geometry in the most reactive single package configuration, the package cannot be altered in such a way that would change the conclusions from the criticality safety analyses. The staff finds that the applicant meets 10 CFR 71.55(d)(2) and 71.55(d)(4).

The staff verified that (1) the fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents, (2) polyethylene moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents, and (3) there is full reflection by water on all sides consistent with the damaged condition of the package. The staff finds that the requirements of 10 CFR 71.55(e)(1) through (3) are met.

6.5 Evaluation of Package Arrays under NCT

The applicant uses a single model to represent NCT and HAC conditions, thus with the more limiting regulatory requirement of 5N, as stated in 10 CFR 59(b). The 5N criterion is used to determine a CSI of 1.0. The evaluation includes optimum interspersed moderation, optimum fissile mass moderation, close full reflection by water at the boundaries, and the fissile mass is arranged in the array to be most reactive.

When stacking the packages in the array, the fissile mass is kept towards the bottom of the package and the lower package is inverted so that the fissile mass had the closest proximity. The applicant demonstrates that a triangular pitch array could place more packages and is therefore used in the most reactive configuration.

Since k-eff for an array of 272 packages is less than the USL of 0.94 for both NCT and HAC, the staff verified that this meets the requirements of 10 CFR 71.59(a)(2) which requires that an array size 5N of undamaged packages be subcritical, and an array size 2N of damaged packages be subcritical.

All results show that arrays of 272 packages are within the USL of 0.94.

6.6 Evaluation of Package Arrays under HAC

6.6.1 Configuration

The more limiting 5N criterion is used in the determination of the CSI and the evaluation includes optimum interspersed moderation, optimum fissile mass moderation and close full reflection by water at the boundaries. Also, the fissile contents are arranged within the package to support the most reactive array configuration, i.e., when the fissile mass is oriented at the base of the package with the bottom package further inverted and the top package stacked in its normal orientation.

Both homogeneous and in-homogeneous model configurations are investigated and the packages are modeled in both a square and triangular configuration to evaluate the effect of interspersed moderation and the variations in the fissile mass moderation density. Figure Nos. 6-16 and 6-17 show the modeled drum arrays in both the triangular and square lattice, respectively.

Sensitivity calculations considered an increased fissile mass, reductions in the minimum modeled carbon steel thicknesses, an increased poly-moderation density and a lumped spherical mass placement within the package.

6.6.2 Results

The maximum K-eff for an array of 272 packages is less than 0.94 for HAC. This result is based on a fissile mass of 350 grams U-235 with poly-moderation at an increased density of 0.98 g/cm^3, which corresponds to a hydrogen density of 0.141 g/cm^3.

Increasing the poly-moderation density to 0.98 g/cm^3 bounds other carbon-hyrdogen based moderators such as paraffin with sufficient margin. Replacing the poly-moderation with graphite causes the array k-eff to decrease significantly; thus, the package array reactivity is exclusively dictated by the presence of hydrogen based moderation.

A fully poly-moderated sphere of 12 cm diameter produces the maximum k-eff result for the evaluated package array.

6.7 Evaluation Findings

Based on the review of the statements and representations in the application, the staff finds that the Model No. VERSA-PAC criticality performance has been adequately described and evaluated and that the package design meets the containment requirements of 10 CFR Part 71.

7.0 PACKAGE OPERATIONS

The objective of this review is to verify that the package operating procedures meet the requirements of 10 CFR Part 71 and are adequate to ensure that the package will be operated in a manner consistent with its evaluation for approval.

7.1 Package Loading

7.1.1 Preparation for Loading

Package preparation activities include:

(i) visual inspections to verify that there are no indications of impaired physical conditions on the package, e.g., damages, dents, corrosion, and missing hardware etc..,
(ii) the verification that the outer drum plugs and visible inner plugs are in place,
(iii) the removal of any road dirt or debris or any foreign material,
(iv) the verification that gaskets are in place and not damaged, that thread inserts for the closure bolts are in working order, and
(v) the verification that the containment flange and outer drum cover fit properly.

7.1.2 Loading of Contents

Contents may be pre-packaged in plastic bags, sealed metal cans or other appropriate forms as specified in Table No. 1.4 of the application. Contents must be contained inside the containment area of the package. The maximum loading weight shall comply with the limits given in Section No. 1.2.2 of the application.

7.1.3 Preparation for Transportation

Once contents are loaded into the package containment area, the containment blind flange and the gasket are put into place and the bolts are tightened to the specified torque of 38 to 42 foot-pounds. The outer gasket and the outer drum cover are then installed, the appropriate bolts are torqued to a prescribed value of 60 ft-pounds. Once torqued, the bolts are locked into place with locking washers, and the outer drum closure ring is installed along with the security seal.

Even though there is no special handling requirement for radiation protection because of the minimal dose rates from the contents, a radiation and contamination survey is performed prior to shipment in compliance with regulations.

7.2 Package Unloading

Package unloading operations include the receipt of the package from the carrier, the removal of the lids and bolts, the unloading of the radioactive materials and the release of the package for future transport operations.

Upon receipt from the carrier, the package is visually inspected to verify that there are no indications of impaired physical conditions; a radiological survey is performed and the seal is removed and its number recorded. The closure ring, ring bolts and drum cover, and the containment flange bolts are removed to access the contents in the containment cavity.

7.3 Preparation for Shipment

Preparations for shipment include (i) the contamination survey, (iii) the installation of the closure lid followed by appropriate torque requirements for the bolts, and (iii) package marking, labeling and vehicle placarding.

7.4 Evaluation Findings

The staff reviewed the Operating Procedures in Chapter No. 7 of the application to verify that the package will be operated in a manner that is consistent with its design evaluation. On the basis of its evaluation, the staff finds that the operating procedures provide adequate measures and reasonable assurance for safe operation of the proposed design basis fuel in accordance with 10 CFR Part 71.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The objective of this review is to verify that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71 and that the maintenance program is adequate to assure the packaging performance during its service life.

8.1 Acceptance Tests

Section No. 8.1 of the application specifies the fabrication acceptance tests to be performed by the fabricator prior to release of the packaging for use.

8.1.1 Visual Inspections and Measurements

Prior to the first use of the packaging, visual inspections are performed to:

- (i) confirm the package dimensions with the appropriate drawings,
- (ii) ensure that the gaskets, external and internal seals, are in place, and
- (iii) verify that all bolts and washers are of the correct types and sizes in accordance with the licensing drawings and that the nameplate and markings are correct.

8.1.2 Weld Inspections

Visual inspections are performed on all welds, along with magnetic particle inspections of those welds shown on the fabrication drawings to verify their compliance with the Codes and Standards, as specified in the application.

8.1.3 Structural and Pressure Tests

No structural testing is performed since no tie-down devices are a structural part of the package. The package design is qualified with a hydrostatic pressure of 29 psig as part of the UN drum qualification testing. There are no pressure relief systems in the package and the staff agrees that no other acceptance test for pressure testing is required.

8.1.4 Leakage Tests

The package does not contain any seal or containment boundary requiring leak testing.

8.1.5 Component Tests

Inspection of package components such as gasket materials and polyurethane foam is performed in accordance with the licensing drawings requirements.

8.1.6 Shielding Tests

The package does not contain any biological shielding; thus, tests for shielding integrity are not applicable.

8.1.7 Thermal Tests

The staff agrees that the thermal performance of the package materials such as steel, aluminum silica, fiberglass polyester resin, and polyurethane, does not degrade with time. Therefore, no thermal tests are needed to ensure the continued performance of the package.

8.2 Maintenance

Damage to components shall be evaluated for impact on packaging safety, and components shall be repaired or replaced accordingly in accordance with written and approved procedures. Wear and tear from normal use will not impact safety.

8.2.1 Structural and Pressure Tests

No structural or pressure testing is necessary to ensure the continued performance of the package.

8.2.2 Leakage Tests

No leakage test is necessary to ensure the continued performance of the package.

8.2.3 Component and Material Tests

Prior to each use of the package, the sealing surfaces are inspected for damage, gaskets and pads are inspected for wear and/or deterioration and replaced as necessary, the outer and inner surfaces are visually inspected for rust, corrosion or other superficial discontinuities, and repaired as necessary. Localized deformations in the outer drum of the package are permitted up to 1-inch provided that the shell material is not breached.

Every five years, all accessible surfaces and welds are inspected for cracks or discontinuities and weld defects shall be repaired in accordance with AWS D 1.1 or ASME Section IX. Flanges and covers are inspected for warpage and distortion. If visual inspection cannot assure that corrosion has not reduced the outer wall thickness of the package by 10 per cent over a 6 inch square area, ultrasonic testing or other methods of inspection shall be used to ensure acceptability.

8.3 Evaluation findings

The staff reviewed the acceptance tests and maintenance programs for the Model No. Versa-Pac package and found them acceptable.

Based on the statements and representations in the application, the staff concludes that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71. Further, the Certificate of Compliance is conditioned to specify that each package must meet the Acceptance Tests and Maintenance Program of Chapter No. 8 of the application.

CONDITIONS

The following conditions are included in the Certificate of Compliance:

(a) Uranium oxides, uranyl nitrate crystals in the form of uranyl nitrate hexahydrate, trihydrate or dehydrate, uranium metal or uranium alloys, other uranium compounds, e.g., uranyl fluorides and uranyl carbonates. The uranium compounds may also contain carbon or graphite. However, uranium hydrites and uranium carbide are not authorized for shipment.

(b) Contents may be pre-packaged in hydrogenous or non-hydrogenous containers. Payload materials shall have an auto-ignition temperature and a melting point greater than 600ºF. Materials with a hydrogen density greater than 0.141 g/cm^3 are not authorized.

(c) Contents are limited to normal form material and 350 grams U-235 enriched up to 100 weight per cent. The radionuclide inventory of the loaded contents, including U-234 and U-236, shall be less than the calculated mixture A_2 value.

(d) The package shall be prepared for shipment and operated in accordance with Chapter 7 of the application.

(e) The packaging must be tested and maintained in accordance with Chapter 8 of the application.

(f) Air transport of fissile material is not authorized.

(g) Transport of plutonium above minimum detectable quantities is not authorized.

(h) Packages must be marked with the appropriate Model Number, i.e., VP-55 or VP-110, as applicable

CONCLUSION

Based on the statements and representations contained in the application, and the conditions listed above, the staff concludes that the Model No. VERSA-PAC package has been adequately described and evaluated and that the package meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9342, Revision No. 0,
on June 15, 2010.