March 15, 2005

Mr. Norman A. Kent, Manager
Transport Licensing and Regulatory Compliance
Westinghouse Electric Company
Nuclear Fuel
Columbia Fuel Site
P.O. Drawer R
Columbia, SC 29250

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9297, REV. NO. 0, MODEL NOS. TRAVELLER STD AND TRAVELLER XL PWR FUEL SHIPPING PACKAGES (TAC L23728)

Dear Mr. Kent:

As requested by your application dated April 1, 2004, as supplemented by letters dated October 15 and November 16, 2004, and February 16, March 4, and March 10, 2005, enclosed is Certificate of Compliance No. 9297, Revision No. 0, for Model Nos. Traveller STD and Traveller XL PWR fuel shipping packages. The staff's Safety Evaluation Report is also enclosed.

The approval constitutes authority to use these packages for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471. Westinghouse Electric Company has been registered as user of the package under the general license provisions of 10 CFR 71.17 or under the provisions of 49 CFR 173.471.

If you have any questions regarding this certificate, please contact me or Stewart W. Brown of my staff at (301) 415-8500.

Sincerely,

/RA/

John D. Monninger, Chief
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9297
TAC No. L23726

Enclosures:
1. Certificate of Compliance No. 9297, Rev. No. 0
2. Safety Evaluation Report

cc: R. Boyle, Department of Transportation
J. Schuler, Department of Energy
RAMCERTS

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SAFETY EVALUATION REPORT

Docket No. 71-9297
Model Nos. Traveller STD and Traveller XL
PWR Fuel Shipping Packages
Certificate of Compliance No. 9297
Revision No. 0

TABLE OF CONTENTS

SUMMARY

By application dated April 1, 2004, as supplemented by letters dated October 15 and November 16, 2004, and February 16, March 4, and March 10, 2005, Westinghouse Electric Company (the applicant) requested approval of its Model Nos. Traveller STD and Traveller XL pressurized water reactor (PWR) fuel shipping packages.

Based on the statements and representations in the application, as supplemented, and the condition listed below, the U.S. Nuclear Regulatory Commission (NRC) has concluded that the packages meets the requirements of Title 10 of the Code of Federal Regulations (10 CFR) Part 71.

EVALUATION

1.0 GENERAL INFORMATION

1.1 Packaging Description

The Model Nos. Traveller STD and Traveller XL PWR fuel shipping packages are designed to transport non-irradiated uranium fuel assemblies or rods with enrichment up to five weight percent. The Traveller is designed to carry several types of PWR fuel assemblies as well as either boiling water reactor (BWR) or PWR fuel rods. Each Traveller packaging unit is designed to transport either one fuel assembly or one container for loose fuel rods.

The Traveller package is made up of three components: (1) the “outerpack,” (2) the “clamshell,” and (3) the fuel assembly or the “rod container.”

The outerpack is the structural component that serves as the primary impact and thermal protection for the fuel assembly or fuel rods in a rod container. The outerpack also provides lifting, stacking, and tie-down capabilities during transportation. The outerpack is a long tubular design consisting of a top and bottom half. Each half consist of a stainless steel outer shell, a layer of rigid closed cell polyurethane foam, and an inner stainless steel shell. In addition, the outerpack is lined with blocks of ultra high molecular weight polyethylene, which helps to form a conformal cavity for the clamshell and contents for low-angle drops and for criticality safety. Also, the outerpack has impact limiters at each end.

The clamshell is a structural component that protects the contents during routine handling and in the event of an accident. The clamshell also provides neutron absorption capability. The clamshell consists of an aluminum “v” extrusion, two extruded aluminum doors (attached to the aluminum “v” by piano-type hinges), and a small access door. Also, neutron absorber plates are installed, the length of each leg of the “v” extrusion and each extruded door.

The rod container is used when transporting loose fuel rods rather than a fuel assembly. The rod container comes in two forms; a stainless steel rod box or a stainless steel rod pipe.

When assembled the outerpack and the clamshell are connected together with a suspension system that reduces the forces applied to the contents.

There are two versions of the Traveller packaging; the Traveller Standard (Traveller STD) and the Traveller XL. The approximate dimensions and weights of each package/packaging follows:

<u>Traveller STD</u>

Weight:		
	Package:	2,041 kilograms (kg) (4,500 pounds (lbs))
	Packaging:	1,293 kg (2,850 lbs)
Dimensions:		
	Length	500 centimeters (cm) (197 inches (in.))
	Width	68.6 cm (27.1 in.)
	Height	100 cm (39.3 in.)

<u>Traveller XL</u>

Weight:		
	Package:	2,313 kg (5,100 lbs)
	Packaging:	1,419 kg (3,129 lbs)
Dimensions:		
	Length	574 cm (226 in.)
	Width	68.6 cm (27.1 in.)
	Height	100 cm (39.3 in.)

1.2 Drawings

The packaging is constructed in accordance with Westinghouse drawings:

No. 10004E58, Sheets 1 through 8, Revision 3, .
No. 10006E58, Revision 1
No. 10006E59, Sheets 1 and 2, Revision 1

1.3 Contents

1.3.1 Type and form of material

The content for the Traveller packaging is either a unirradiated PWR uranium dioxide fuel assembly with a maximum uranium-235 enrichment of 5.0 weight percent, or unirradiated uranium dioxide fuel rods with a maximum uranium-235 enrichment of 5.0 weight percent. Fuel rods transported in the Traveller packaging will be placed in a rod container.

1.3.2 Maximum quantity of material per package

The Traveller packaging is designed to transport one unirradiated PWR uranium dioxide fuel assembly or loose fuel rods in either a rod pipe or a rod box. The number of loose fuel rods is limited by the size of the rod container.

1.3.3 Criticality Safety Index (CSI)

The CSI is 0.7 when transporting a fuel assembly and 0.0 when transporting loose fuel rods in a rod container.

2.0 STRUCTURAL

The objective of the structural review is to determine and verify that the information presented in the “Application for Certificate of Copliance for the Traveller PWR Fuel Shipping Package,” Revision 1 (application), which includes: descriptions of the packaging, design and fabrication criteria, structural material properties, and structural performance of the package design for the tests under normal conditions of transport (NCT) and hypothetical accident conditions (HAC), are acceptable, complete, and meet the requirements of 10 CFR Part 71.

2.1 Description of Structural Design

The Traveller transportation packaging consists of two principal structural components: the outerpack and the clamshell.

The outerpack, which provides impact and thermal protection for either the fuel assembly or the rod container, is a long circular tubular construction with a top and a bottom half held together by hinge-and-bolt assemblies. Each half is made of an inner and outer 12-gage stainless steel shell and a layer of rigid polyurethane foam in between. Integral to the packaging, two impact limiters, each made of 0.096 gram per cubic cm (6 lbs per cubic foot (ft)) polyurethane form but with varied casing design, are incorporated at the top and bottom ends of the outerpack. For criticality control, the outerpack inner shell is lined with moderator blocks of ultra high molecular weight (UHMW) polyethylene, which also provide a conformal cavity for the clamshell.

The clamshell, which resides inside the outerpack cavity on a series of rubber shock mounts, is a long rectangular aluminum container designed to carry one fuel assembly or one rod container. It is comprised of a lower aluminum "v" extrusion, two aluminum door extrusions, a bottom base plate, a small access door assembly, and a number of mechanical ancillaries, including a continuous hinge to fasten each door to the "v" extrusion and the door latches. The clamshell provides structural support for either the fuel assembly or the rod container by mechanical restraining devices, such as spring-loaded pads and neoprene pads clamps. During accident conditions, it limits lateral deformation of fuel rods. For criticality control, neutron absorber panels are affixed to the inner faces of the clamshell.

2.2 Structural Design Criteria

The applicant evaluated the package primarily by a series of drop tests of full-scale Traveller XL specimens to demonstrate that the package maintains its structural functions throughout NCT and HAC. The structural design criteria require that the test results must support the assumptions used in the criticality evaluation in that there is no loss of moderator or neutron absorber, no decrease in outerpack geometry, and no increase in clamshell geometry. Finite element drop analyses were used to aid in identifying the most damaging testing orientations and in evaluating design modifications to arrive at a certification test unit on which the final series of drop tests were conducted. Miscellaneous package components, including lifting attachments and tie-down devices, were evaluated with typical mechanical design calculations. Other structural failure modes such as brittle fracture, fatigue, and buckling were also considered.

2.3 Weights and Centers of Gravity

The package is evaluated for two configurations, which vary primarily in overall length: Traveller Standard (STD) at 500 cm (197 in.) and Traveller XL at 574 cm (226 in.). The maximum gross weights of Traveller STD and Traveller XL are 2,041 kg (4,500 lbs) and 2,313 kg (5,100 lbs), respectively. The center of gravity (CG) for both configurations is approximately at the geometric center of the outerpack, which is about 58.4 cm (23 in.) above the ground level, considering the support legs, circumferential stiffeners on the upper outerpack, and forklift pockets. Table 2-1 of the application lists the weights summary, including a maximum fuel assembly weight of 748 kg (1,650 lbs) and 894 kg (1,971 lbs) for the Traveller STD and XL packages, respectively.

2.4 Mechanical Properties of Materials

The applicant provided a general description of the materials of construction in the application Sections 1.2 and 2.1. Additional information regarding the materials, fabrication details, and testing programs can be found in the application Sections 2.3, 8.1.5 and 8.2.5. The staff reviewed the information contained in these sections and the information presented in the drawings to determine whether the Traveller packages meet the requirements of 10 CFR Part 71. In particular, the following aspects were reviewed: materials selection, applicable codes and standards, weld design and specification, chemical and galvanic reactions, efficacy of absorbers, and long-term cask performance issues (such as delayed cracking, brittle failure, fatigue, and corrosion).

Most of the structural components (i.e., outerpack, clamshell, and rod container) of the Traveller packages are fabricated from Type 304 austenitic stainless steel. This type of stainless steel was selected because of its high strength, ductility, resistance to corrosion, and metallurgical stability. Because there is no ductile-to-brittle transition temperature in the range of temperatures expected to be encountered prior to or during storage, the susceptibility of Types 304 stainless steel to brittle fracture is negligible. Type 6005-T5 Aluminum is used to structurally enclose the contents in the clamshell. This type of aluminum was selected because of its good formability, weldability, and corrosion resistance. The outerpack consist of a layer of flame-retardant rigid polyurethane foam for impact protection.

Criticality control in the Traveller packaging is achieved by including neutron poison panels/plates (Boral) which are slotted into the inner face of each clamshell side. Boral has a long, proven history in the nuclear industry at the 75 percent credit level and has been used in other spent fuel transportation casks. In accordance with Section 8 of the application, chemical analysis/neutron attenuation techniques will be used to ensure that the Boral panels have the minimum boron-10 loading specified for this application. Additionally, a UHMW polyethylene is used as a neutron moderator and is located on the inside walls of the outerpack, between the outerpack and clamshell.

Table 2-2 of the application provides mechanical property data for the major structural materials including stainless steel and aluminum alloys. Most of the values in this table were obtained from American Society of Mechanical Engineers (ASME) Code, Section II, Part D. However, some of the values were obtained from other acceptable references (e.g., American Society for Testing and Materials (ASTM)). The staff independently verified the temperature dependent values for the yield stress, ultimate stress, and modulus of elasticity. Additionally, that staff reviewed the polyurethane foam specifications contained in Section 8.1.5.1 of the application. In particular, the staff reviewed the physical, chemical, thermal, mechanical, dimensional properties of the foam and ASTM Standards or tests used to determine the material properties. The staff also verified the statements made in the application pertaining to the moderator material. The applicant stated that the polyethylene moderator was selected for use in the package because it retains it chemical composition past the melt temperature. The staff verified the statements submitted by the applicant concerning the polyethylene from open literature.

The staff concludes that these material properties are acceptable and appropriate for the expected conditions (e.g., hot or cold temperatures, wet or dry conditions).

2.5 Welds and Fabrication

The applicant stated that standard fabrication methods are utilized to fabricate the Traveller series of packagings. Materials for the Traveller packagings include stainless steel and aluminum procured to ASTM A240/276 304 SS and ASTM B209/B221 standards, respectively. The fabrication processes of the Traveller packagings include basic processes such as cutting, rolling, bending, machining, welding, and bolting. All welding will be performed by qualified welders/processes in accordance with ASME Section IX. Further, each weld will be visually examined by a qualified inspector in accordance with American Welding Society D1.6. and ASME Section III, Subsection NF-5360, for stainless steel and aluminum, respectively. The staff concludes that the welded joints of the Traveller packaging will meet the requirements of the applicable ASME and AWS Codes.

2.6 General Standards for All Packaging (10 CFR § 71.43)

2.6.1 Minimum Package Size

The smallest overall dimension of the package is outer shell diameter, approximately 64 cm (25 in.). This is greater than the minimum dimension of 10 cm (4 in.) specified in 10 CFR 71.43. Therefore, the package meets the requirements of 10 CFR 71.43(a) for minimum size.

2.6.2 Tamper-proof Feature

Two tamper indicating seals are attached between the upper and lower outerpack halves to provide visual evidence that the closure was not tampered. This satisfies the requirements of 10 CFR 71.43(b).

2.6.3 Positive Closure

The Traveller series of packages cannot be opened inadvertently. Positive closure of the packages is provided by 1.9 cm (0.75 in.) diameter hex head screws. Thus, the requirements of 10 CFR 71.43(c) are satisfied.

2.6.4 Chemical, Galvanic, or Other Reactions

The Traveller series of packagings are fabricated from Type 304 stainless steel, 6000-series aluminum, polyurethane foam, and polyethylene sheeting. The stainless steel outerpack does not have any significant chemical or galvanic reactions with the interfacing components, air, or water. The aluminum clamshell is physically isolated, and environmentally protected, by the outerpack and therefore will have negligible chemical or galvanic reactions with the interfacing components, air, or water. In addition, the Type 304 stainless steel fasteners which attach various clamshell components represent a very small area ratio (cathode-to-anode ratio), which will render the reaction insignificant.

Since the applicant stated that the foam is 15 percent open cell, the staff evaluated whether any chlorides leached from the foam would cause any degradation of the stainless steel outerpack. The staff concludes that there will be very little free chlorides from the foam to cause pitting corrosion of the stainless steel based on the specifications submitted for the foam.

The outerpack hinge bolts are zinc plated for the purpose of improving galling resistance which can be a significant problem when stainless steel fasteners are inserted in stainless steel threaded holes. The plating is not required for chemical or galvanic protection.

Staff concludes that the materials used to fabricate that Traveller packagings should not cause or experience any adverse chemical or galvanic reactions during NCT.

2.7 Lifting and Tie-Down Standards For All Packages (10 CFR 71.45)

2.7.1 Lifting Devices

The applicant used a bounding weight of 6,940 kg (15,300 lbs), which is three times the weight of Traveller XL, to evaluate the attachment points and related structural details considered in various package lifting configurations. Section 2.12.2.2.2 of the application presents mechanical design calculations with all stress results shown less than the material yield strengths. This satisfies the requirements of 10 CFR 71.45(a) for lifting devices.

2.7.2 Tie-Down Devices

The packages are secured to the transportation conveyance by means of strapping across the top of the packages and placing a chain inboard from the welded plate at the package legs. The application states that there are no structural devices designed for tie-down, and a tie-down analysis is not required. Thus, the requirements of 10 CFR 71.45(b) are met.

2.8 NCT (10 CFR § 71.71)

2.8.1 Heat

The application considered temperatures between -40 degrees Celsius (EC)(-40 degrees Fahrenheit (EF)) and 70 EC (158 EF) to evaluate thermal stress and differential thermal expansion (DTE) for the package. Because the packages are not sealed to the environment, pressure stress is negated.

The application states that effects of DTE for the package is negligible. A DTE of 0.58 cm (0.23 in.) is calculated between the aluminum clamshell and the fuel assembly, which can be accommodated by the combined thickness of the base and the axial clamp cork rubber of 1.25 cm (0.5 in.). Because of marked difference in thermal expansion coefficient between UHMW polyethylene and Type 304 stainless steel, special design features are introduced to the segmented moderator panels attached to the inner face of the outerpack. This includes oversized panel attachment holes and a nominal panel-to-panel gap of 0.66 cm (0.26 in.) to accommodate DTE between the moderator panel and the inner stainless steel shells of the outerpack. The staff reviewed the DTE evaluation in Section 2.12.2.2.4 of the application and agrees that the effects associated with DTE on various package components are negligible. Thus, the requirements of 10 CFR 71.71(c)(1) are satisfied.

2.8.2 Cold

The materials used in constructing the packages are not degraded by cold at -40 EC (-40 EF). Since the load bearing components are made of stainless steel and aluminum, materials that do not exhibit brittle fracture at cold temperature, the requirements of 10 CFR 71.71(c)(2) are satisfied.

2.8.3 Reduced External Pressure

The Traveller packages are not designed to form an airtight pressure boundary. Thus, the reduced external pressure will not impact the structural integrity of the package, and the requirements of 10 CFR 71.71(c)(3) are satisfied.

2.8.4 Increased External Pressure

The Traveller packages are not designed to form an airtight pressure boundary. Thus, the increased external pressure will not impact the structural integrity of the package, and the requirements of 10 CFR 71.71(c)(4) are satisfied.

2.8.5 Vibration

By comparing natural frequencies of typical transportation vehicles to that of the fundamental mode of vibration of the tied-down package, the applicant determined that the outerpack would not undergo resonance vibration. Considering typical clamshell acceleration time history traces shown in Figure 2-1A of the application, as measured during a 483-kilometer (300-mile) trip road test, Section 2.6.5 of the application states that the rubber shock mounts effectively isolate and dampen loads and vibrations to the clamshell and its contents. Thus, the staff agrees with the applicant’s conclusion that no resonance vibration conditions which could fatigue the clamshell will occur during NCT. This satisfies the requirements of 10 CFR 71.71(c)(5).

2.8.6 Water Spray

The Traveller packaging materials of construction are not affected by the water spray test. The staff agrees with the applicant that the water spray tests of 10 CFR 71.71(c)(6) have negligible effects on the package.

2.8.7 Free Drop

The applicant performed a 1.2-m (meter) (4-ft) low angle slap-down drop test on the Traveller XL certification test unit (CTU) specimen as an initial condition for subsequent HAC drops. The package axis, with the support legs pointing up, was aligned at an angle approximately 10 degrees with the horizontal plane. Section 2.6.7 of the application discusses the drop orientation selection for structural integrity evaluation of welded joints. The staff reviewed the discussion and agrees with the applicant's evaluation that both structural and criticality control integrities will maintain, which meet the requirements of 10 CFR 71.71(c)(7).

2.8.8 Corner Drop

The corner drop test does not apply since the gross weight of the package exceeds 50 kg (110 lbs), in accordance with 10 CFR 71.71(c)(8).

2.8.9 Compression

Section 2.12.2.2.6 of the application presents an analysis of the package for the compression test by considering a bounding stacking load of 11,340 kg (25,500 lbs), which is 5 times the weight of Traveller XL. The results show that structural performance for all load-bearing components, including the stacking bracket and leg support, are acceptable. This satisfies the requirements of 10 CFR 71.71(c)(9).

2.8.10 Penetration

Section 2.12.2.2.7 of the application states that the impact energy of the pin-puncture test is approximately 400 times greater than that of the pin penetration. The staff reviewed the evaluation and agrees with the applicant's conclusion that the pin puncture is bounded by the pin penetration test. Thus, the pin penetration is not expected to result in any significant structural damage to the outerpack. This satisfies the requirements of 10 CFR 71.71(c)(10).

2.9 HAC (10 CFR § 71.73)

The applicant performed three series of 9-m (30-ft) drop tests, including development tests, on five full-scale Traveller XL specimens, to demonstrate performance of the package under the HAC.

2.9.1 9 m (30 ft) Free Drop

Table 2-5 of the application summaries the drop tests performed on the two prototype test units (PTUs), two qualification test units (QTUs), and one CTU of the Traveller XL specimens, which bound the shorter and lighter Traveller STD configuration. The clamshell in each specimen held a Westinghouse 17 x17 XL fuel assembly with dummy fuel pellets. Section 2.12.3 of the application describes the finite element impact drop analysis of the PTU and QTU for aiding in identifying the most damaging drop orientations and in evaluating the design modifications. Section 2.12.4 of the application presents details of test objectives, specimens, and results, including the final design improvements made to the packaging after testing the CTU.

A total of eight 9-m (30-ft) free-drop tests were performed on the PTUs and QTUs. Considering potential opening of the hinge joints connecting the upper and the lower outerpack halves, which could compromise fire protection capability of the outerpack, the CG-forward-of-corner drops were determined to be the most damaging. Additional finite element drop analyses established that the bottom-end CG-forward-of-corner drop with the package axis at about 18 degrees off the vertical would be the most severe in causing outerpack seam separation. In view of the clamshell and fuel assembly performance, however, the package bottom-end drop was demonstrated by both the testing and the analyses to be the most damaging. As noted in Table 2-5 of the application, a number of design changes were made to the packaging as a result of testing the PTUs and QTUs. These include the hinge/bolt configurations for both the outerpack and clamshell, the polyurethane form densities for the outerpack body, end cap, and impact limiters, as well as the puncture-resistance cover plate of the impact limiters.

Section 2.12.4.1 of the application presents drop tests results for the two PTUs. As development tests, the 10 CFR 71.73(c) test sequence was not followed, but a total of six 30-ft (9-m) drops were conducted. The tests demonstrated that the outerpack retained its pre-test circular shape with only minor, local dents occurring at the locations where the package hit the drop pad. With the design modifications, such as adding additional bolts to the head joints, the clamshell perform adequately by retaining the fuel assembly within the clamshell cavity.

Section 2.12.4.2 of the application presents drop tests results for the two QTUs. To evaluate the most damaging drop for the clamshell and fuel assembly, only one high-angle vertical drop and one bottom-end drop needed to be performed on two respective QTUs, each preceded by a 1.2-m (50-in.) shallow-angle slapdown and followed by a 1-m (40-in.) puncture-pin drop. As reported in Tables 2-36 thru 2-38 of the application, for the first specimen, and Tables 2-41 thru and 2-43, for the second, the applicant examined potential fuel rod lattice expansion and axial slippage by measuring, between the grids, the pre- and post-test fuel envelope, gap, and pitch. The tests demonstrated that the clamshell remained essentially undamaged and the fuel assembly stayed within the clamshell cavity. Some change of fuel geometry near the top and bottom nozzles was observed. The applicant stated, however, that the post-test geometry of the fuel assemblies for both QTUs was acceptable.

Section 2.12.4.3 of the application presents drop test results for the CTU. A single test sequence comprised of three drops, a 10-m (32.8-ft) bottom-end drop preceded by a 1.2-m (50-in.) shallow-angle slapdown and followed by a 1-m (40-in.) puncture-pin test, was conducted on the specimen. With adequate structural performance demonstrated already for the outerpack in previous drop tests, this single test sequence focused primarily on the clamshell and fuel assembly to satisfy the 10 CFR 71.73(c) requirement of testing the package in a position for which the maximum damage is expected. On meeting the 10 CFR 71.73(b) ambient air temperature test condition, which requires testing at the most unfavorable temperature between -29 EC (-20 EF) and 38 EC (100

EF), the application states that the CTU was thermally saturated for approximately 15 hours prior to testing, and at the time of testing, the temperature was approximately -4.4 EC (24 EF).

In a November 16, 2004, letter to justify the apparent difference between the lowest ambient air temperature and the test temperature, the applicant analyzed the end-drop for three conditions: (1) -40 EC (- 40 EF) with form densities at the upper end of the tolerance bands, (2) 24 EC (75 EF) and normal form densities, and (3) 71 EC (160 EF) with the form densities at the lower end of the tolerance bands. Figures 2-63A and 2-63B of the application present impact time-history response plots to illustrate temperature and form density effects on the outerpack/drop pad interface force and the fuel assembly deceleration, respectively. The maximum fuel assembly deceleration at the condition of 24 EC (75 EF) was calculated to be about 20 percent higher than that of -40 EC (- 40 EF). This result defies the general observation that the higher impact limiter crush strength, as associated with a lower ambient air temperature, tends to result in higher fuel assembly deceleration. However, as shown in Figures 2-63A and 2-63B of the application, for dynamic interactions among the fuel assembly, clamshell, impact limiter, outerpack end cap, and drop pad work in tandem, the fuel assembly is seen to respond in a secondary impact, which lagged the primary outerpack impact on the drop pad by about 25 ms. As further depicted in Figure 2-63A of the application, because of the relatively larger energy dissipation by the end cap at -40 EC (- 40 EF), compared to that at 24 EC (75 EF), there was less system kinetic energy left for the impact limiter to dissipate. Thus, the fuel assembly is shown unable to undergo a relatively higher deceleration. By recognizing that the severity of secondary impact can markedly be affected by the energy dissipation characteristics of the primary impact, the staff has reasonable assurance to agree with the applicant's assessment of the temperature effects on fuel assembly deceleration. On this basis, the staff agrees that the drop tests conducted at 4.4 EC (24 EF) meet the intent of testing the package with the most unfavorable temperature condition, per 10 CFR 71.73(b).

The CTU drop tests demonstrated that the outerpack performed adequately with localized damages similar to those for the PTU and QTU test series. After the fire test which followed the puncture-pin drop, the clamshell was examined and found intact and closed. The applicant noted that the simulated poison plates maintained position, the axial location of the fuel rods stayed between the bottom and top nozzles, and the moderator blocks remained intact and essentially undamaged. Tables 2-47 thru 2-49 of the application list the measured pre- and post-test fuel envelope, gap, and pitch. Lateral deformation of a single rod was predominant in causing fuel geometry change. Fracture was observed at the end plug locations for 20 fuel rods with an average width of approximately 0.08 cm (0.03 in.) and an average length of about 50 percent of the rod diameter. The applicant determined the post-test geometry of the fuel assembly acceptable in that only local rod expansion was noted in the lower 0.5 m (20 in.) of the bottom nozzle region and the cracked rod gaps were all less than a pellet diameter.

The free drop tests, in aggregate, satisfy the requirements of 10 CFR 71.73(c)(1).

2.9.2 Crush

The Traveller package weighs more than 500 kg (1,100 lbs). Therefore, the dynamic crush test of 10 CFR 71.73(c)(2) does not apply.

2.9.3 Puncture

A 1-m (40-in.) puncture-pin drop test each was performed on all five full-scale Traveller XL specimens. Except for the puncture-pin drop of the second PTU, which preceded a 9-m (30-ft) free drop, all other puncture-pin drops were administered after the corresponding 9-m (30-ft) free drops to ensure that the most severe drop orientations and locations had been covered. Section 2.7.3.2 of the application summarizes the test results. The applicant noted additional minor damage to the outerpack and determined that the puncture-pin drops did not affect thermal performance of the package. The criticality control capabilities of the package were also demonstrated in that the tests had revealed no evidence of loss of contents from the clamshell or deterioration of the polyethylene sheeting and neutron absorber sheeting in the subsequent fire test events. On this basis, the staff agrees that the tests satisfied the intent of 10 CFR 71.73(c)(3).

2.9.4 Thermal

See Section 3.0 of this safety evaluation report for thermal performance of the Traveller package.

2.9.5 Immersion - Fissile Material

The Traveller package is not leak-tight under external pressure and, under the immersion test, water will fill all internal void space. Therefore, the packaging structure is not subject to the loading of the water immersion test and the requirements of 10 CFR 71.73(c)(5) are met.

2.9.6 Immersion - All Packages

The application notes that the water is assumed to fill all internal void space and the criticality analysis assumes the worst-case flooding scenarios. Therefore, the packaging structure is not subject to the loading of the water immersion test and the requirements of 10 CFR 71.73(c)(6) are met.

2.9.7 Summary of Results For Accident Sequence

As discussed in the evaluation above, the Traveller XL CTU performed adequately under the cumulative damaging effects of the free drops, puncture-pin drop, and thermal test. The CTU tests confirmed structural integrity of the criticality control features of the package. The geometry of the clamshell remained essentially unchanged. The applicant noted the damages to the fuel assembly, such as slight change of fuel geometry and fracture of fuel rods at end plug, and determined that this change was within the acceptance criteria and the staff agrees. Thus, the requirements of 10 CFR 71.73 are met.

In the most damaging bottom-end drop, the CTU test demonstrated that, because of the buckled bottom nozzle, the 17 x17 XL fuel assembly experienced a small percentage of fuel rod cracks at the bottom end plug. The average crack size was deemed insufficient for fuel pellets to escape, thereby ensuring the containment function of the fuel cladding.

The test also demonstrated slight change of fuel assembly geometry due to localized fuel rod buckling. The applicant determined that the resulting fuel assembly geometry was acceptable for maintaining critical control of the package.

2.10 Evaluation Findings

Based on review of the statements and representations in the application, the staff concludes that the structural design has been adequately described and evaluated and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

3.0 THERMAL

The thermal review ensures that material temperature limits of the package are not exceeded. Typically, for the normal conditions of transport (NCT) the package surface temperature is limited to 50 EC (122 EF) for non-exclusive use and 85 EC (185 EF) for exclusive use, considering a maximum ambient temperature of 38 EC (100 EF) and no insolation. However, since this is a fresh fuel transportation package (no heat load) the NCT thermal evaluation becomes a moot issue, and is acceptable without further review. For the HAC fire (i.e., 800 EC (1,472 EF) for 30 minutes), the one thermal consideration is ensuring that the polyethylene moderator remains functional post fire for criticality considerations. Fuel cladding integrity is not a consideration since its design temperature 1200 EC (2,192 EF) is well above the HAC fire temperature 800 EC (1,492EF) and fresh fuel is not considered a radiological hazard.

The thermal design of the Traveller package was refined using preliminary fire tests to evaluate the hinge and impact limiter configurations. Once that testing was completed and the design finalized the Traveller package was subjected to a regulatory drop test followed by a regulatory fire test. From the drop test the outer shell was torn, exposing some of the polyurethane foam. Prior to conducting the regulatory fire test the package was preheated to approximately 38 EC (100 EF) to represent the maximum required ambient temperature prior to performing the HAC fire. The actual fire test engulfed the package for about 32 minutes and the 30 minute average fire temperature was well above 800 EC (1,492 EF).

The results from the HAC fire indicate that the temperature of the polyethylene moderator reached a maximum temperature of 177 EC (351 EF) at the axial center of the package. Measurements of the moderator temperatures were taken by placing six temperature strip sets on the stainless steel covering the moderator in the outerpack lid. An examination of the moderator after the regulatory fire indicated no significant damage and that the moderator was still capable of performing the intended design function. Even though polyethylene melts at temperatures between 125-138 EC (257-280 EF)(as indicated in Table 3-2 of the application) and four of the six temperature strip sets indicated temperatures exceeding these values, this exceedance is acceptable because the polyethylene: (1) has a high viscosity and retains excellent dimensional stability at temperatures up to 200 EC (392 EF)(reference Engineered Materials Handbook article “Ultra High Molecular Weight Polyethylene” by Harvey Stein); (2) is encapsulated with stainless steel; and (3) no damage was observed to the moderator nor its stainless steel cover as a result of the HAC drop tests.

Therefore, based on the information presented in the application the staff finds that the Traveller packaging can safely transport the fresh fuel contents in accordance with requirements in 10 CFR Part 71.

4.0 CONTAINMENT

The objective of the containment review was to verify that the Traveller design satisfies the requirements of 10 CFR Part 71 under NCT and HAC. The content for the Traveller packaging is limited to transporting unirradiated, low enriched uranium, nuclear fuel in the form of either a fuel assemble or fuel rods. A fuel assembly is comprised of fuel rods. Fuel rods are fuel pellets sealed in fuel tubes. The applicant states that the containment system for a Traveller package is the sealed fuel tube portion of the fuel rod. In accordance with 10 CFR 71.43(f), a package must be designed, constructed, and prepared for shipment so that under the tests specified for NCT there would be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels. The applicant states that it has demonstrated from repeated normal drop scenarios that there would be no loss of fissile material from the rods, and therefore no dispersal. The staff agrees that the applicant has demonstrated that the fuel pellets remain inside the fuel tubes under both NCT and HAC when tested in combination with the Traveller packaging.

Based on a review of the statements and representations in the application, the staff concludes that the 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

The objective of this review was to verify that the Traveller package design meets the external NCT and HAC. The Traveller packaging is designed to transport unirradiated fuel in the form of either a fuel assembly or as loose fuel rods in a rod container. The maximum enrichment for this unirradiated fuel is 5.0 weight percent of uranium-235. The forms of radiation that are associated with low enriched unirradiated uranium are alpha, beta, and gamma radiation. These forms of radiation are the result of radioactive decay of the uranium isotopes and their daughter products. Both the alpha and beta radiation will be easily shielded by the Traveller packaging material. The gamma radiation will result in a dose at the outer package surface of less than two milli-Sieverts per hour (mSv/h) (200 milli-roentgen equivalent man per hour (mrem/h)). This meets the 10 CFR 71.47(a) radiation dose limit for the external surface of a package being transported by nonexclusive means.

Based on the statements and representations in the application, the staff has reasonable assurance that the shielding design meets the external radiation standards in 10 CFR Part 71.

6.0 CRITICALITY

6.1 DESCRIPTION OF CRITICALITY DESIGN

6.1.1 Design Features

The Traveller is a Type A fissile material package designed to transport unirradiated uranium fuel assemblies or fuel rods with enrichments up to 5.0 weight percent. The contents include one PWR fuel assembly or unassembled BWR or PWR fuel rods in a single shipping container. Criticality safety for the package is provided by: 1) controls on fissile mass, 2) maintenance of material geometry, 3) the presence of neutron poisons, and 4) the presence of moderating materials. The package consists of three parts: 1) an outerpack, 2) a clamshell, and 3) a fuel assembly or a rod container (rod pipe or rod box) containing loose fuel rods. The fuel assembly or rod container is secured inside the clamshell during transport.

The rod pipe for holding unassembled fuel rods is a Schedule 40 stainless-steel pipe with an inside diameter of 12.819 cm or 15.380 cm (5.047 in. or 6.055 in.). The rod box is a long rectangular stainless steel box with a square cross section and inside dimension of approximately 12.7 cm (5 in.).

The clamshell is a long rectangular box with a square cross section whose diagonal runs vertically and consists of a lower aluminum "v" extrusion and two hinged aluminum access doors for inserting the contents. Inset in each of the four sides of the square cross section is a BORAL plate containing boron which serves as a neutron poison. The clamshell is suspended inside the outerpack by rubber shock mounts.

The outerpack is a long cylindrical container which can open into two semi-cylinders to gain access to the clamshell box. The outerpack primarily consists of polyurethane foam between two thin steel shells to act as an impact limiter. In addition, UHMW polyethylene blocks are encased in stainless-steel boxes and attached to the inside of the outerpack. There are four polyethylene blocks, one parallel to each side of the clamshell square cross section, and these blocks act as a neutron moderator. The combination of the moderator blocks and poison plates acts as a flux trap to provide criticality control.

The Traveller has two configurations, the Traveller STD and an extra long version of the Traveller XL. The Traveller STD has an overall length of 500 cm (197 in.) and the clamshell is 439.4 cm (173 in.) long with an inner cross section of approximately 22.9 cm (9 in.) square. The Traveller XL has an overall length of 574 cm (226 in.) and the clamshell is 513.1 cm (202 in.) long with an inner cross section of approximately 24.1 cm (9.5 in.).

The criticality sections of the application were reviewed for completeness of information and consistency. The information, parameters and dimensions provided were sufficient to perform a review and are acceptably consistent throughout the applicable chapters. The reported criticality results were found to be within acceptable limits.

6.1.2 Summary Table of Criticality Evaluation

Tables are provided in the application which summarize the maximum calculated values of k_{eff} for a single package and an array of packages under the NCT and the HAC. Table 6-2 gives the results for one PWR fuel assembly in the Traveller STD packaging and Table 6-1 gives the associated results for the Traveller XL packaging. Table 6-3 of the application gives results for an Traveller XL package containing either loose rod container. All of the values of k_{eff} calculated by the applicant and adjusted for statistical uncertainty are within acceptable limits.

6.2 FISSILE MATERIAL CONTENTS

The allowed contents in the Traveller consists of unirradiated uranium dioxide fuel rods for commercial reactors either in a single fuel assembly or as unassembled rods as follows:

Fuel Assembly

One unirradiated PWR uranium dioxide fuel assembly with a maximum uranium-235 enrichment of 5.0 wt percent. The parameters of the fuel assembly may be as follows:

Parameters for 14 x 14 Fuel Assemblies

Fuel Assembly Description	14 x 14	14 x 14	14 x 14
Fuel Assembly Type	W-STD	W-OFA	CE-1/CE-2
No. of Fuel Rods per Assembly	179	179	176
No. of Non-Fuel Rods	17	17	20
Nominal Guide Tube Wall Thickness	0.043 cm (0.017 in.)	0.043 cm (0.017 in.)	0.097 cm (0.038 in.)
Nominal Guide Tube Outer Diameter	1.369 cm (0.539 in.)	1.336 cm (0.526 in.)	2.822 cm (1.111 in.)
Nominal Pellet Diameter	0.929 cm (0.366 in.)	0.875 cm (0.344 in.)	0.956/0.966 cm (0.376/0.381 in.)
Nominal Clad Outer Diameter	1.072 cm (0.422 in.)	1.016 cm (0.400 in.)	1.118 cm (0.440 in.)
Nominal Clad Thickness	0.062 cm (0.024 in.)	0.062 cm (0.024 in.)	0.071/0.066 cm (0.028/0.026 in.)
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	19.70 cm (7.76 in.)	19.70 cm (7.76 in.)	20.60 cm (8.11 in.)
Nominal Lattice Pitch	1.412 cm (0.556 in.)	1.412 cm (0.556 in.)	1.473 cm (0.580 in.)

Parameters for 15 x 15 Fuel Assemblies

Fuel Assembly Description	15 x 15	15 x 15
Fuel Assembly Type	STD/OFA	B&W
No. of Fuel Rods per Assembly	205	208
No. of Non-Fuel Rods	20	17

Nominal Guide Tube Wall Thickness	0.043/0.043 cm (0.017/0.017 in.)	0.043 cm (0.017 in.)
Nominal Guide Tube Outer Diameter	1.387/1.354 cm (0.546/0.533 in.)	1.354 cm (0.533 in.)
Nominal Pellet Diameter	0.929 cm (0.366 in.)	0.929 cm (0.366 in.)
Nominal Clad Outer Diameter	1.072 cm (0.422 in.)	1.072 cm (0.422 in.)
Nominal Clad Thickness	0.062 cm (0.024 in.)	0.062 cm (0.024 in.)
Clad Material	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	21.39 cm (8.42 in.)	21.66 cm (8.53 in.)
Nominal Lattice Pitch	1.430 cm (0.563 in.)	1.443 cm (0.568 in.)

Parameters for 16 x 16 Fuel Assemblies

Fuel Assembly Description	16 x 16	16 x 16	16 x 16	16 x 16
Fuel Assembly Type	W-STD	CE	NGF	ATOM
No. of Fuel Rods per Assembly	235	236	235	236
No. of Non-Fuel Rods	21	20	21	20
Nominal Guide Tube Wall Thickness	0.046 cm (0.018 in.)	0.102 cm (0.040 in.)	0.041 cm (0.016 in.)	0.057 cm (0.023 in.)
Nominal Guide Tube Outer Diameter	1.196 cm (0.471 in.)	2.489 cm (0.980 in.)	1.204 cm (0.474 in.)	1.354 cm (0.533 in.)
Nominal Pellet Diameter	0.819 cm (0.323 in.)	0.826 cm (0.325 in.)	0.784 cm (0.309 in.)	0.914 cm (0.360 in.)
Nominal Clad Outer Diameter	0.950 cm (0.374 in.)	0.970 cm (0.382 in.)	0.914 cm (0.360 in.)	1.075 cm (0.423 in.)
Nominal Clad Thickness	0.057 cm (0.023 in.)	0.064 cm (0.025 in.)	0.057 cm (0.023 in.)	0.072 cm (0.029 in.)
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	19.72 cm (7.76 in.)	20.63 cm (8.12 in.)	19.72 cm (7.76 in.)	22.95 cm (9.03 in.)
Nominal Lattice Pitch	1.232 cm (0.485 in.)	1.285 cm (0.506 in.)	1.232 cm (0.485 in.)	1.430 cm (0.563 in.)

Parameters for 17 x 17 and 18 x 18 Fuel Assemblies

Fuel Assembly Description	17 x 17	17 x 17	18 x 18
Fuel Assembly Type	W-STD/XL	W-OFA	ATOM
No. of Fuel Rods per Assembly	264	264	300

No. of Non-Fuel Rods	25	25	24
Nominal Guide Tube Wall Thickness	0.041/0.051 cm (0.016 /0.020 in.)	0.041 cm (0.016 in.)	0.065 cm (0.026 in.)
Nominal Guide Tube Outer Diameter	1.204/1.224/1.24 cm (0.474/0.482/0.488 in.)	1.204 cm (0.474 in.)	1.240 cm (0.488 in.)
Nominal Pellet Diameter	0.819 cm (0.323 in.)	0.784 cm (0.309 in.)	0.805 cm (0.317 in.)
Nominal Clad Outer Diameter	0.950 cm (0.374 in.)	0.914 cm (0.360 in.)	0.950 cm (0.374 in.)
Nominal Clad Thickness	0.057 cm (0.023 in.)	0.057 cm (0.023 in.)	0.064 cm (0.025 in.)
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	21.39 cm (8.42 in.)	21.39 cm (8.42 in.)	22.94 cm (9.03 in.)
Nominal Lattice Pitch	1.260 cm (0.496 in.)	1.260 cm (0.496 in.)	1.270 cm (0.500 in.)

In addition, non-fissile base-plate mounted core components and spider-body core components are permitted. However, neutron sources or other radioactive material are not permitted. Also, materials with moderating effectiveness greater than full density water are not permitted. Finally, there is no restriction on the length of top and bottom annular blankets.

Loose Fuel Rods

Unirradiated uranium dioxide fuel rods with a maximum uranium-235 enrichment of 5.0 wt percent. Fuel rods shall be transported in the Traveller package inside either a rod pipe or rod box as specified in License Drawings 10006E58 or 10006E59. The fuel rods shall meet the parametric requirements given below:

Parameter	Limit
Maximum Enrichment	5.0 weight percent uranium-235
Pellet diameter	0.508 – 1.524 cm (0.20 – 0.60 in.)
Maximum stack length	Up to rod container length
Cladding	Zirconium alloy
Integral absorber	Gadolinia, erbia, and boron
Wrapping or sleeving	Plastic or other material with moderating effectiveness no greater than full density water
Maximum number of rods per container	Up to rod container capacity

6.3 GENERAL CONSIDERATIONS

6.3.1 Model Configuration

The applicant evaluated single package and array configurations in the criticality analyses. The analyses considered both NCT and HAC. The model of the outerpack includes about 60 percent of the structural stainless steel in the inner and outer shells. The model of the clamshell neglected the inner cork rubber pads and the inner dimensions of the Traveller STD and Traveller XL were conservatively modeled as 23.1 cm (9.1 in.) square and 24.4 cm (9.6 in.) square, respectively. The shock mounts were longitudinally spaced to maximize the neutron interaction between packages in an array. The rod box and rod pipe were modeled with the fuel rods spreading out to the outer dimension of the container and neglecting the container material. The model descriptions were reviewed and found to be either bounding or consistent with the specifications and drawings provided in the application.

6.3.2 Material Properties

The BORAL poison plates are specified to be fabricated with a minimum areal density of 0.0240 grams (0.035 ounce) of boron-10 per square cm. In all cases, the criticality analysis took credit for only 75 percent of this minimum poison content. Also, in all cases, the polyethylene moderator blocks were modeled at 90 percent of nominal density to account for degradation with aging and in the accident. Finally, in all cases, the fuel pellets were modeled at 100 percent of theoretical density. The material properties and compositions given in Section 6.3.2 of the application were reviewed and found to be acceptable.

6.3.3 Computer Codes and Cross-Section Libraries

The applicant performed its criticality analysis using the KENO-VI geometry capability in the SCALE criticality code issued by the Oak Ridge National Laboratory. The applicant used the 44-group cross section library which is based on ENDF/B-V nuclear data.

6.3.4 Demonstration of Maximum Reactivity

The applicant performed a number of sensitive analyses to determine the most reactive configuration for the final criticality evaluation. A series of calculations was performed to determine the most reactive fuel assembly type of the specified contents. The 17x17 OFA assembly was found to be most reactive and a hypothetical extra long version (active fuel length of 429.3 cm (169 in.)) was used as the design basis fuel assembly for the subsequent criticality analyses. Calculations were performed to compare the reactivities of the Traveller STD and Traveller XL. The Traveller XL was found to be bounding.

Sensitivity evaluations were performed on variations in the following areas: partial flooding in the package, preferential flooding of the various voids within the package, density of interspersed moderation for the accident array, length of the lattice expansion region in the fuel assembly after the accident, non-uniform distribution of the lattice expansion, axial fuel rod displacement, variations in the poison plate content, density of the moderator blocks, thickness of the outerpack shell, outside diameter of the outerpack, presence of annular pellets, variations in thickness of the cladding and guide tubes, and package array size. Where a significant sensitivity was found, the final evaluation model assumed the bounding condition.

The unassembled fuel rods were modeled conservatively as bare pellet stacks without cladding or other non-fuel components. The bare pellets were modeled in a triangular lattice array where the diameter and pitch were varied within the outer dimensions of each rod container type to determine the maximum value of k_{eff}.

The maximum values of k_{eff} were all within the acceptable limits.

The sensitivity analyses were reviewed and found to provide an acceptable basis for determining an appropriate set of bounding conditions and configurations for this analysis.

6.3.5 Confirmatory Analyses

Staff performed confirmatory calculations on the Traveller STD and Traveller XL using models similar to the applicant's. The calculations included both a single package and package array under the HAC. Staff's calculations used KENO-VI in the SCALE system with both the 44-group and 27-group cross section libraries. The calculations only considered the configuration with a fuel assembly as contents since the applicant found this case to be much more reactive than the rod containers with unassembled rods. The calculations confirmed the applicant's conclusion that dry conditions outside the fuel assembly envelope maximized the value of k_{eff} for the accident array case. The results of the staff's calculations found acceptable agreement with the applicant's results, are within the acceptable limits on k_{eff}, and support the finding that the application meets the criticality requirements of 10 CFR Part 71.

6.4 SINGLE PACKAGE EVALUATION

The applicant performed calculations for a single package under the NCT and HAC. In the analysis of unassembled fuel rods in a rod container, the normal condition results were bounded by the accident conditions values.

6.4.1 Configuration

The normal conditions configuration modeled a dry package with the polyurethane foam and shock mounts at normal density. The outerpack of the package was reflected by 20 cm (7.9 in.) of water.

The hypothetical accident configuration modeled a fully flooded package with water in place of the polyurethane foam. The sensitivity studies found that full density water was most bounding for the single package accident analysis.

The results of the accident testing showed some expansion of the fuel assembly lattice after the 9-m (30-ft) end drop. Consequently, the modeling for the accident case assumed a uniform expansion of a 100 cm (39.3 in.) long section at the bottom of the fuel assembly. The extent expansion was limited only by the inside wall of the clamshell dimension (assumed to be 23.1 cm (9.1 in.) for the Traveller STD and 24.4 cm (9.6 in.) for the Traveller XL). The applicant performed a sensitivity study and found that k_{eff} was maximized when the fuel rods expanded out to the limit of contact with the clamshell wall. The applicant also performed an analysis of different configurations of non-uniform expansion where a part of the fuel assembly lattice was compressed to rod-to-rod contact and remainder of the fuel lattice had a larger expansion. This study showed that k_{eff} was maximized when the lattice expansion was uniform across the assembly.

6.4.2 Results

The results of the applicant's single package analysis are given in the following table.

SINGLE PACKAGE ANALYSIS (k_{eff})

Package Configuration	Conditions	
	Normal	Accident
Traveller STD - Fuel Assembly	bounded by XL	0.865
Traveller XL - Fuel Assembly	0.201	0.885
Rod Box	bounded by accident case	0.704
Rod Pipe	bounded by accident case	0.746

6.5 EVALUATION OF PACKAGE ARRAYS UNDER NORMAL CONDITIONS OF TRANSPORT

6.5.1 Configuration

The applicant modeled an infinite number of packages in a triangular array under the NCT. The packages were modeled as described in Section 6.4.1 above for a single package under normal conditions.

6.5.2 Results

The applicant calculated maximum k_{eff} values of 0.256 for the Traveller STD and 0.272 for the Traveller XL when containing the 17x17 FOA fuel assembly. The results for packages with a rod container were bounded by the case for an array under HAC.

6.6 EVALUATION OF PACKAGE ARRAYS UNDER HYPOTHETICAL ACCIDENT CONDITIONS

6.6.1 Configuration

The applicant modeled 150 packages in a triangular pitch array under the HAC. Each package was modeled with a preferential flooding configuration that had full density water in the pellet-clad gap and in the fuel assembly envelope. The other cavities of the package were dry and a void was placed in the region of the polyurethane foam and the shock mounts. The region between packages was dry but the array was reflected by water. The fuel assemblies were modeled with a 100 cm (39.3 in.) long segment at the bottom end that had an uniformly expanded lattice as described in Section 6.4.1 for the single package accident analysis.

An infinite array of packages was modeled for the analysis of packages with a rod container.
The applicant initially declared that the shock mounts which position the clamshell inside the outerpack are not safety related, and thus, a specification for the mounts was not provided in the drawings. The applicant performed an analysis to calculate k_{eff} for an array of packages where the clamshell is allowed to move around within the outerpack. The adjusted value of k_{eff} for one of the configurations analyzed exceeded the upper subcriticality limit by a small margin. Consequently, a specification and inspection frequency for the shock mounts was added to the maintenance procedures to reflect the quality of the shock mounts used in the package testing. Based on the performance of these shock mounts during the package testing and on risk informed considerations, this provision was determined to provide reasonable assurance that the package design would remain critically safe under the HAC.

6.6.2 Results

The applicant calculated k_{eff} values of 0.897 for an array of Traveller STD packages and 0.939 for an array of Traveller XL packages containing the 17x17 FOA fuel assembly. The results for an optimized array of packages containing a rod container were 0.699 for the rod box and 0.748 for the rod pipe.

6.7 BENCHMARK EVALUATIONS

6.7.1 Applicability of Benchmark Experiments

The applicant included 55 critical experiments in its benchmark evaluation. The benchmarks were grouped into four classifications of simple lattice, separator plate, flux trap, and water hole experiments. No one group had all of the characteristics of the Traveller package but the four groups were selected to cover the important features of the Traveller package.

The benchmarks were reviewed and found to be appropriate for the Traveller analysis.

6.7.2 Bias Determination

The applicant performed a calculation with the USLSTAT code and obtained an upper subcritical limit of 0.94 for the calculated value of k_{eff} after being adjusted for statistical uncertainty.

6.8 EVALUATION FINDINGS

Based on a review of the representations and information supplied by the applicant, and the analyses performed by staff, the staff concludes that the nuclear criticality safety design has been adequately described and evaluated by the applicant, and finds reasonable assurance that the package meets the criticality safety requirements of 10 CFR Part 71.

7.0 OPERATING PROCEDURES

Chapter 7 of the application specifies operating procedures for the Traveller package. The chapter includes sections on the preparation of package for shipment, package receipt, preparation of the package for transport, unloading, and shipping as an empty package.

Based on the statements and representations in the application, the staff concludes that the operating procedures package meet the requirements of 10 CFR Part 71 and that these procedures are adequate to assure the package will be operated in a manner consistent with its evaluation for approval. Further, the Certificate of Compliance has been conditioned to specify that the package must be prepared for shipment and operated in accordance with the Operating Procedures in Chapter 7 of the application, as supplemented.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

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

Section 8.1 of the application specifies various acceptance tests which will be performed prior to the first use of the package. These tests include: 1) ensuring correct materials of construction; 2) verifying that package components are within tolerances on the engineering drawings; 3) ensuring that the components fit together properly; and 4) examining all welds. In addition the applicant will perform acceptance testing on both the polyurethane foam and BORAL material components of the Traveller packaging.

The Traveller packaging utilizes a closed-cell polyurethane form. Section 8.1.5.1 of the application specifies the properties that must be demonstrated before this material can be used as a Traveller component. These properties include the following: density, mechanical properties, flame retardant characteristics, thermal properties, water absorption, and chemical composition.

For the BORAL component the applicant will select sample coupons from plates and evaluate them using chemical analysis and/or neutron attenuation techniques to verify presence, proper distribution, and minimum boron-10 content, as described in Section 8.1.5.2 of the application for absorber, BORAL. The minimum allowable boron-10 content are provided on the engineering drawings. Any panel with a boron-10 loading less than the minimum allowed will be rejected.

To ensure the BORAL meets the drawing requirements, the plates will be inspected on a periodic basis not to exceed five years per Section 8.2.5. This will ensure that the BORAL maintains its durability throughout its service lifetime. The visual inspection will verify that the plates are present and in good condition. This includes inspection of the BORAL core for chipping or flaking resulting from brittleness. There are no significant loads applied to the BORAL plates, therefore no durability problems should arise during normal conditions of transport. The staff concluded that the acceptance tests are adequate for verifying the presence, proper distribution, minimum boron-10 content, and durability of the BORAL at the 75 percent credit level.

Section 8.2 of the application specifies a maintenance program for the package. The maintenance program includes a visual examination of all exposed surfaces before each use. If any defect is found the package will be segregated and addressed in accordance with site procedures before the next use. In addition, all threaded components and braided fiberglass sleaving will be inspected and appropriate action taken should a damage component be found. Finally, the neutron absorption plates will be inspected at least once every five years.

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 and that the maintenance program is adequate to assure packaging performance during the service life of the package. Further, the Certificate of Compliance has been conditioned to specify that each packaging must be acceptance tested and maintained in accordance with the Acceptance Tests and Maintenance Program in Chapter 8 of the application, as supplemented.

9.0 CONDITIONS

The Certificate of Compliance includes the following condition of approval:

10. In addition to the requirements of Subpart G of 10 CFR Part 71:

    (a) The package must be prepared for shipment and operated in accordance with the Operating Procedures in Chapter 7 of the application, as supplemented.

    (b) Each packaging must be acceptance tested and maintained in accordance with the Acceptance Tests and Maintenance Program in Chapter 8 of the application, as supplemented.

CONCLUSION

Based on the statements and representations in the application, as supplemented, and the conditions listed above, the staff concludes that the design has been adequately described and evaluated and the package meets the requirements of 10 CFR Part 71. Furthermore, the staff has concluded, based on this same information, that the package will also meet the requirements of the revised 10 CFR Part 71.

Issued with Certificate of Compliance No. 9297, Revision No. 0
on March 15, 2005.