UNITED STATES NUCLEAR REGULATORY COMMISSION
DIVISION OF FUEL CYCLE AND MATERIAL SAFETY
SAFETY EVALUATION BY THE TRANSPORTATION CERTIFICATION BRANCH
NUCLEAR PACKAGING, INCORPORATED, MODEL NO. T-3 CASK

SUMMARY

By application dated October 20, 1978, Nuclear Packaging, Incorporated (NuPac) requested approval to deliver a large quantity of byproduct material and special nuclear material in the form of irradiated fuel rods to a carrier for transport in the Model No. T-3 shipping cask. Subsequent submittals, indicated below, transmitted additional information and revisions to the original application. Based on the statements and representations as contained in the application, as supplemented, we have concluded that the contents and packaging meet the requirements of 10 CFR Part 71 subject to the conditions stated below.

SUBMITTALS

1. NuPac applicated dated October 20, 1978.
2. NuPac supplement dated May 18, 1979.
3. NuPac supplement dated September 12, 1979.
4. NuPac supplement dated January 25, 1980.

DRAWINGS

The packaging is constructed in accordance with Westinghouse Hanford Company Drawing No. H4-61289, Sheets 1 thru 3, Revision No. 3.

Figure 3.1.5-1	Ident 69	inner fuel container
Figure 3.1.5-3	Ident 1578	inner fuel container

PACKAGE DESCRIPTIONS

A stainless steel and lead shielded irradiated fuel shipping package (cask). The cask is a right circular cylinder with upper and lower steel encase rigid polyurethane foam (20 lb/ft^3) impact limiters. The overall dimensions are 213.2 inches in length and 52 inches in diameter. The cask without the impact limiters measures 177.2 inches in length and 26.44 inches in diameter.

The outer cask shell is comprised of a one (1) inch thick stainless steel shell overlayed with a ten (10) gauge stainless steel cover. Between these two materials is a 0.08 inch diameter wire wrap, providing an air gap for additional thermal protection.

The inner shell (containment vessel) is a standard seamless stainless steel Schedule 40 pipe having an outside diameter of 8.625 inches with a nominal wall thickness of 0.322 inches. The annular space between the inner and outer shells is filled with lead having a thickness of approximately eight (8) inches.

Both the inner and outer shells are welded at each end to heavy steel closure plates with conical surfaces to assist in positioning and sealing. The containment vessel measures 147 inches in length by 7.981 inches in diameter.

The containment vessel is sealed at the bottom end with a 12.375-inch thick stainless steel plug with two (2) Viton O-ring seals. The top end of the containment vessel is sealed with a 11.625-inch thick stainless steel plug with two (2) Viton O-ring seals. The bottom plug is retained by a closure plate secured by eight (8), 1/2-13UNC x 2-1/4-inch ASTM A320, Grade L7 socket head cap screws. The top plug is secured in place utilizing sixteen (16), 1/2-13UNC x 1-3/4-inch ASTM A320, Grade L7 hex flange screws.

No drain or vents penetrate directly into the containment vessel. A drain/vent line opens directly into the area between the two (2) O-ring seals at each end of the cask (end plugs). During shipment, the lines are sealed with Viton O-ring sealed threaded fasteners.

The cask is provided with six (6) trunions, four (4) spaced 90 degrees apart at the top end and two spaced at 180 degrees apart at the bottom end of the cask. The cask is tied down at the forward and aft ends by means of a cradle and yoke assembly. The gross weight of the cask and contents is 38,000 pounds.

PACKAGE CONTENTS

(A) Type and form of material

The minimum cooling time of each fuel assembly and rod shall be 90 days; and

(i) FTR driver pins prior to irradiation containing 25 w/o PuO_2 and 75 w/o U(natural)O_2, 0.23" diameter by 36" active fuel length.

(ii) FTR carbide pins prior to irradiation containing 20 w/o PuC and 80 w/o U(natural)C, 0.37" diameter by 36" active fuel length.

(iii) EBR-II carbide pins prior to irradiation containing 25 w/o PuC and 75 w/o U(95)C, 0.315" diameter by 13.5" active fuel length.

(iv) Standard driver pins (Item 5(b)(1)(i) above) plus experimental oxide pins prior to irradiation containing 25 w/o PuO_2 and 75 w/o $U(98)O_2$, 0.23" diameter by 36" active fuel length.

(B) Maximum quantity of material per package

Not to exceed a decay heat generation of 600 watts; and

(i) Item 5(b)(1)(i) above

4.4 kg U-235 plus Pu-239 contained within inner container Ident 69, Figure 3.1.5-1.

(ii) Item 5(b)(1)(ii) above

4.1 kg U-235 plus Pu-239 contained within inner container Ident 69, Figure 3.1.5-1.

(iii) Item 5(b)(1)(iii) above

5.0 kg U-235 plus Pu-239 contained within inner container Ident 1578, Figure 3.1.5-3.

(iv) Item 5(b)(1)(iv) above

4.7 kg U-235 plus Pu-239 contained within inner container Ident 1578, Figure 3.1.5-3.

CONTAINMENT

The primary containment vessel is the stainless steel Schedule 40 pipe with a nominal wall thickness of 0.322 inches. The inner containment vessel is welded at each end to heavy steel closure plates. The primary containment vessel is sealed at both ends with double Viton O-ring seals which can be pressure tested thru O-ring test ports. Bolt-on outer steel lids with Viton O-ring seals are provided for each end of the cask, providing an additional containment boundary.

There are no boundary penetrations directly into the primary containment vessel. A drain/vent line opens into the area between the two O-ring seals at the top and bottom plug interface. Drainage/venting can be accomplished at either end by backing out the plugs past the first seal, thereby introducing the drain port to the containment area. The drain/vent ports are utilized for flushing or draining water through the cask, relieving any internal pressure prior to plug removal and for verification of O-ring integrity prior to cask transfer.

STRUCTURAL

The applicant has performed various structural analyses and engineering evaluations to satisfactorily demonstrate the package has adequate structural integrity to meet the requirements of 10 CFR Part 71. The applicant's evaluation considered applicable load combinations from Regulatory Guide 7.8, "Load Combinations for the Structural Analysis of Shipping Casks." The applicant's analysis shows that stresses are within the limits specified in Regulatory Guide 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels." The applicant has also shown that the containment vessel is designed so that brittle fracture and buckling would not occur under the test conditions specified in 10 CFR Part 71. The staff agrees with the applicant's conclusion that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

A. General Standards for All Packaging

Chemical and Galvanic Reaction

There is no contact between any constitutive materials of the packaging that could produce a chemical or galvanic reaction.

Positive Closure

Inadvertent opening of the package is prevented by means of positive closure devices. Access to either end of the containment vessel is through two bolted closures. There are no other penetrations to the containment vessel.

Lifting Devices

The package is equipped with six (6) trunions, of the same design, attached to the outer shell of the cask. Four (4) of the trunions are located near the top end of the cask and two are located near the bottom end. A minimum of two trunions are used when lifting the package at either end. Two trunions can support three times the lifted load without yielding. Failure of these devices under excessive load would not impair the containment or shielding provided by the package.

There are no devices for lifting the lids (closures) that are a structural part of the package.

Tie-Down Devices

The package is tied-down through structural connections to two trunions at each end of the cask and by engagement of a shear block at the forward (upper) end of the cask. The shear block is designed tc react loadings in the longitudinal direction. Clearance is provided at the aft trunion connection to accommodate differential thermal expansion or contraction of the cask relative to the vehicle, thereby, eliminating the possibility of inducing expansion or contraction loads in the longitudinal direction. The portions of the tie-down system which are a structural part of the package have been designed to resist, without yielding, a force applied to the center of gravity of the package having components of 2-g, 5-g, and 10-g in the vertical, transverse and longitudinal directions, respectively. The structural integrity of the cask s adequate to withstand the tie-down forces.

B. Structural Standards for Type B and Large Quantity Packaging

Load Resistance

The package was analyzed to determine its ability to support five times its weight when loaded as a sinple beam. The results of the analysis indicate that the total loading can be resisted solely by the outer shell, without yielding.

External Pressure

Both the containment vessel and the outer shell are adequate to withstand an external pressure of 25 psig.

C. Normal Conditions of Transport

Heat

The package has adequate structural integrity for the normal transport heat test. The pressure within the containment vessel was conservatively calculated by assuming all the pressurized fuel rods would fail, increasing the internal pressure in the containment vessel to 39 psig. The maximum operating temperature of the structural components is not sufficiently high to significantly effect the mechanical properties of the materials. Differential thermal expansion or contraction of cask components can only cause a relatively low level of stress in the shells because: (1) the thermal gradient through the cask all is small, and (2) the lead shielding is not bonded to the steel shells. Stress analyses performed by the applicant showed that the maximum stresses in the containment vessel, the closure bolts, and the outer shell are substantially below allowable limits.

Since the package is transported within a solar shield, the thermal analysis did not consider the contribution of incident solar radiation toward increasing the temperature of the package. However, because the stresses in the shells have a large margin of safety, the safety of the packages does not depend upon the presence of the solar shield.

Cold

The containment vessel is shipped dry and no liquids are present in the cask. The package is not subject to freezing. The containment vessel is constructed of stainless steel and is safe from brittle fracture. The 16 bolts (ASTM-A320, Grade L43) which secure the closure to the containment vessel have sufficient toughness to assure that brittle fracture will not occur a service temperature of -40°F.

Pressure

Reduced atmospheric pressure will not affect the structural integrity of the package.

Vibration

The natural frequency of the first bending mode of the package was calculated to be approximately 53 cps, assuming the cask to be a uniformly loaded simple beam. The peak response of the cask to vibration normally incident to transport would be within acceptable limits by a substantial margin.

Water Spray

Water spray will have no effect on the package.

One-Foot Free Drop

The applicant has analyzed the package to determine the effects of the one-foot drop test and has shown that the package has sufficient structural integrity to meet the acceptance standards in 10 CFR Part 71. Specifically, the applicant has shown that the stresses in the shells will be within allowable limits, the cask will provide containment of the contents, and the effectiveness of the packaging will not be reduced (i.e., the impact limiters would remain in place and shielding would be maintained).

The applicant evaluated the g-loads and stresses that would result from a one-foot drop with the cask oriented to impact on its end, corner and side. In addition, the package was analyzed at several oblique impact orientations to determine the location and magnitude of the largest internal stresses. The results of the analysis show that the stresses in the shells and the closure are within allowable limits. In performing these calculations, an error was made in computing the weight of the containment vessel and its inertial effect at the axial location of maximum bending moment for oblique impact orientations. However, the error is not sufficiently large to affect the conclusion that stresses in the package are within allowable limits.

Penetration

The exterior surfaces of the package are capable of withstanding the impact forces imposed by the penetration test. There are no unprotected valves or fittings on the outside of the cask body which could be struck by the falling bar.

D. Hypothetical Accident Conditions

30-Foot Drop Test

For the 30-foot drop test, the applicant analyzed the package in side, end, corner, and oblique impact orientations. The methods used to analyze g-loads and stresses for the 30-foot drop test were similar to the methods used to analyze the package for the one-foot drop test. Engineering tests were performed to determine the mechanical properties of the foam material used in the impact limiters. The applicant has shown that the impact limiters are capable of dissipating the kinetic energy of the fall and cushioning the impact of the package. The analysis shows that the stresses in the shells and closure are within allowable limits. The package has sufficient structural integrity to meet the acceptance standards in 10 CFR Part 71 and will provide containment of the contents to evaluate the shielding effectiveness of the package under accident conditions, the applicant conservatively calculated the extent of lead displacement that would occur if the package were dropped 30 feet without its impact limiters. The results indicate the lead could be displaced ("slump") up to 8 inches. The package is designed so that this degree of lead displacement can be accommodated without exceeding the allowable limits for external radiation.

Puncture

An ORNL-NSIC-68 equation for lead backed steel cylinders was used by the applicant to demonstrate that the outer shell of the cask would not experience a local rupture near the point of impact as a result of the puncture test. The overall effect on the cask of striking the pin in a horizontal position at mid-length was also evaluated. The applicant's analysis shows that the stresses in the shells would be within allowable limits. The top and bottom ends of the cask are protected against puncture by the impact limiters and by outer steel plates over the containment vessel closures. The applicant has analyzed the effects of conducting the puncture test with the cask in a vertical position striking the pin at the end region of the cask. The analysis considered the extent to which the impact limiters would be deformed by the preceeding 30-foot drop test. The results of the analysis demonstrated that the package has sufficient integrity to resist puncture and maintain containment of the contents under puncture test conditions at the end regions of the cask.

Thermal Stresses

The applicant has demonstrated that the package has adequate structural integrity to safely withstand the half-hour fire test. The lead shielding is not bonded to the inner or outer shells and the thermal gradient across the wall of the package does not exceed 115°F. Consequently, differential thermal expansion does not produce large stresses. The maximum internal pressure within the containment vessel, approximately 39 psig, is substantially below the pressure retaining capability of the vessel. The applicant's stress analysis of the package under fire test conditions shows that the stresses in the shells will be within allowable limits and that the package has sufficient structural integrity to maintain containment of the contents.

THERMAL

In order to determine the compliance of the Model No. T-3 packaging with the requirements of 10 CFR Part 71 Appendices A and B, the applicant has formulated a thermal analysis model of the cask using finite difference techniques. The basic model considered five longitudinal zones with maximum temperature concurring in the central zone. Each zone was in turn subdivided to represent the thermal gradients across the cask wall. The details of cask ends including seals and foam overpack impact limiters were modeled to determine their thermal response to the conditions of normal transport as well as those of the hypothetical thermal accident.. The external nodes of the cask were linked to the environment by both radiation and convection for normal transport conditions and by radiation alone for the accident damage conditions. The applicant assumed no thermal loading due to solar radiation since a solar shield is employed with the packaging during transportation.

The applicant evaluated five steady-state cases, four to select the most severe thermal case as a function of contents shipped based on an ambient temperature of 100°F and the critical configuration re-evaluated for the 130°F condition of normal transport. The most severe case being by definition the one resulting in the maximum fuel pin temperature. The four cases studied in order select the critical configuration were as follows:

Fuel Container Type	Number of Pins	Decay Heat (watts)	Max. Fuel Pin Temperature (°F)
(1) Ident 98 (carbide/ nitride fuel)	11	315	612
(2) Ident 69 (driver/ experimental oxide fuel)	109	478	619.6
(3) Ident 69 (carbide/ nitride fuel)	46	584	716.7
(4) Ident 1578 (EBR-II oxide fuel experiments)	50	600	708.9

The critical configuration being case (3) the Ident 69 (carbide/nitride fuel) containing 46 fuel pins with a decay heat load of 584 watts. This case was then re-evaluated for the 130°F ambient temperature (without solar loading due to the applicant's solar shield assumption) and the resulting maximum fuel pin temperature was 720°F.

The transient thermal analysis of the hypothetical accident used essentially the same finite difference model as the one described for the normal transport conditions. The most critical payload configuration determined by the steady-state analysis was used in this evaluation. The external environment used for the transient analysis was that of a 1475°F fire for 30 minutes with an emissivity of 0.9, assuming the package had an absorption coefficient of 0.8. The foam impact limiter assembly was assumed to char at 400°F and was subsequently replaced by an air void of equivalent dimensions. The major component temperatures resulting from the transient analysis as well as the steady-state analysis are given in the following table.

MODEL NO. T-3 CASK MAXIMUM TEMPERATURES

	Normal Transport	Hypothetical Accident
1) Fuel	720.4°F	759.7°F
2) Fuel container	501.2	570.1
3) Primary containment vessel (8 in Sch. 40 SS pipe)	170.1	359.2
4) Lead shield	168.8	355.1
5) Secondary containment vessel (26 in OD carbon steel pipe)	165.7	398.5
6) Thermal shield (10-gage SS sheet)	140.8	1283.6
7) Pusher end interior seals	134.4	207.2
8) Pusher end exterior seals	134.2	182.3
9) Plug end interior seals	134.6	189.2
10) Plug end exterior seals	134.7	200.3
11) Pusher end bolts	134.3	196.4
12) Plug end inner bolts	134.7	202.5
13) Plug end outer bolts	134.7	199.6

The applicant has calculated a maximum primary containment vessel pressure of 18 psig for the conditions of normal transport. The applicant did not consider any fuel pin rupture for the normal transport case. The maximum gas temperature was assumed to be equal to the maximum fuel pin temperature for calculating the pressure increase, a conservative assumption. For the hypothetical accident case the applicant considered the failure of all fuel pins (109 maximum number of pins shipped) and subsequent temperature increase of the gas within the primary containment vessel to the maximum fuel pin temperature of 760°F. This results in an internal pressure of 39 psig for the accident damage case. The applicant has assumed that each fuel pin which fails will add 30.5 in^3 of volume (at standard conditions) to the containment volume.

The results of the applicants' thermal analysis show that the maximum temperatures and pressures for both the condition of normal transport and the fire-accident conditions are acceptable. The lead shielding does not melt under hypothetical thermal accident conditions. The Viton O-ring temperatures do not exceed 210°F and are therefore, well within their working range. The maximum internal pressure predicted, considering failure of all fuel pins, was 39 psig. Therefore, the staff's review of the applicant's thermal analysis and data supports the conclusion that the Model No. T-3 cask design satisfies the thermal requirements of 10 CFR Part 71. This conclusion is limited to the dry shipment of a maximum decay heat loading of 600 watts.

CRITICALITY

The application contains an acceptable approach in establishing the subcriticality for the Model No. T-3 package under Fissile Class I conditions for the contents requested.

The applicant specifies a number of contents (all fuel pins) up to a maximum of 5.0 kg fissile per package. These fuel pins were modelled explicitly in the KENO Monte Carlo program using the 123-group GAM-THERMOS neutron cross sections. The NITAWL and XSDRN cross sections library were used for resonance corrections for U-238 and appropriate Pu isotopes giving a Dancoff-correction for self-shielding of a simple rod surrounded by eight close neighbors. The reflector was taken as lead in all cases.

The staff has examined in detail all the nuclear and geometric input for the KENO criticality analysis of the most reactive case (109 FTR Driver Pins, single flooded cask) and found it to be correct and represents the case intended. The largest k_{eff} was calculated as 0.634 ± 0.010.

The single flooded damaged package for all proposed contents turned out to be controlling. At least 15 inches of lead separating packages guarantees nuclear isolation and hence subcriticality for an infinite number of such packages.

SHIELDING

The subject application uses the 1D-ANISN computer code with the ORNL 22-18-group coupled neutron-gamma cross section set to calculate cask-surface and 3-feet-distant neutron and gamma dose rates. No distinction was made between shielding for normal and accident conditions.

Maximum calculated dose rates are guaranteed by using the gamma source derivable from 11 carbide-nitride pins with a 90-day decay period. Although the 11-pin shipment does not contain the maximum quantity of spent fuel, it is expected to be the worst case gamma source because of its short decay period and its subsequent high energy gamma emission spectrum. The design basis neutron source is a shipment of 109 FTR driver pins. Because of the relatively long half-life of the primary neutron source in the spent fuel, the shipment containing the most fuel material is expected to be the worst case neutron source. Shielding requirements were determined such that the sum of the two radiation components does not exceed the external dose rate limits. The maximum total dose rate at the package surface was calculated to be 75 mrem/hr; at 3 feet from the surface, the maximum total value was 9.5 mrem/hr.

To the extent that the damaged condition is equivalent to normal conditions, the shielding analysis and results are acceptable.

CONDITIONS

The safety of the cask was confirmed by the Transportation Certification Branch on the basis of the following conditions:

1. The cask shall be shipped dry (no water coolant in cask cavity).

2. In addition to the requirements of Subpart D of 10 CFR Part 71, each cask prior to first use shall meet the acceptance tests and criteria specified in Section 7.1 of the application. The leak test to satisfy ANSI N 14.5 and Regulatory Guide 7.4 in Section 7.1.3 of the application shall be a test having sufficient sensitivity to detect a leak rate (air at standard temperature and pressure leaking to 10^{-2} atm) of 10^{-7} atm cc/sec. The results of these tests shall be documented and retained for the life of the cask.

3. In addition to the requirements of Subpart D of 10 CFR Part 71, each cask shall be maintained in accordance with Section 7.2 of the application.

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