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TUNGSTEN-SHIELDED CASK

R. D. Seagren

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ORNL-TM-2626

Contract No. W-7405-eng-26

ISOTOPES DEVELOPMENT CENTER

OAK RIDGE NATIONAL LABORATORY TUNGSTEN-SHIELDED CASK

R. D. Seagren

Isotopes Division

AUGUST 1969

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Oak Ridge, Tennessee
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The author wishes to acknowledge the assistance and cooperation received from others during the design, fabrication, and testing of the tungsten-shielded casks. Gratitude is extended to the Y-12 Plant for their usual high standards of dimensional tolerance, component integrity, and assembly proficiency in the fabrication of these casks, and especially to Mr. Edgar Maeyens of that organization for his efforts as fabrication coordinator.

OAK RIDGE NATIONAL LABORATORY TUNGSTEN-SHIELDED CASK

R. D. Seagren

ABSTRACT

A small, light-weight, tungsten-shielded shipping cask was designed, fabricated, and approved for the national and international transport of "large quantities" of solid and liquid nonfissile radioactive material. The novel design reduces the weight and volume of the cask and minimizes problems previously associated with transporting casks of this type and handling them in hot cells located at ORNL and at customers' facilities. The shielding material selected meets the requirements of national and international regulatory groups.

CASK DESIGN

Under the requirements established by the Hazardous Materials Regulations Board of the Department of Transportation for shipment of large quantities of low-energy radioactive materials, casks which had been approved previously by the Bureau of Explosives would not be approved by DOT unless they could withstand the free-drop, puncture, thermal, and water-immersion conditions that make up the four hypothetical-shipping-accident tests to which all casks are now subjected. Since the lead-shielded casks that had been used at ORNL for such shipments could not meet all these tests, a new, tungsten-shielded, cask was designed, fabricated, and tested.

The design of the cask is based on the requirements of AECM-Appendix 0529, "Safety Standards for the Packaging of Radioactive and Fissile Materials." It meets the unilateral approval requirements of Marginal C-6.2.3.1(a)(i) to (xi), "Package Design for Large Radioactive Sources," of the International Atomic Energy Agency's Safety Series No. 6, Regulations for the Safe Transport of Radioactive Material.

The cask, shown in Figs. 1-3, is designed for easy manipulator loading, transfer into and out of existing hot cells, and decontamination of all interior and exterior surfaces. The cask itself is 8 in. outside diameter, the internal cavity is 3-1/8 in. in diameter by 6-1/4 in. high, and the overall height of the assembled cask is 15-1/4 in. It accommodates small USA DOT Specification 2R containers and liquid shipping bottles. Support and stability in transport are provided by external gusset plates and the wide base (16 in.), as shown in Fig. 1. The device for closing the cask consists of a standard 150-lb 4-in. slip-on welding flange as part of the cask body and a standard 150-lb 4-in. blind flange as part of the top plug. The stepped-plug design prevents radiation beaming. One of the 5/8-in. stud bolts welded to the slip-on flange is drilled for insertion of a wire seal to indicate ilicit opening.

ORNL-DWG 68-10458

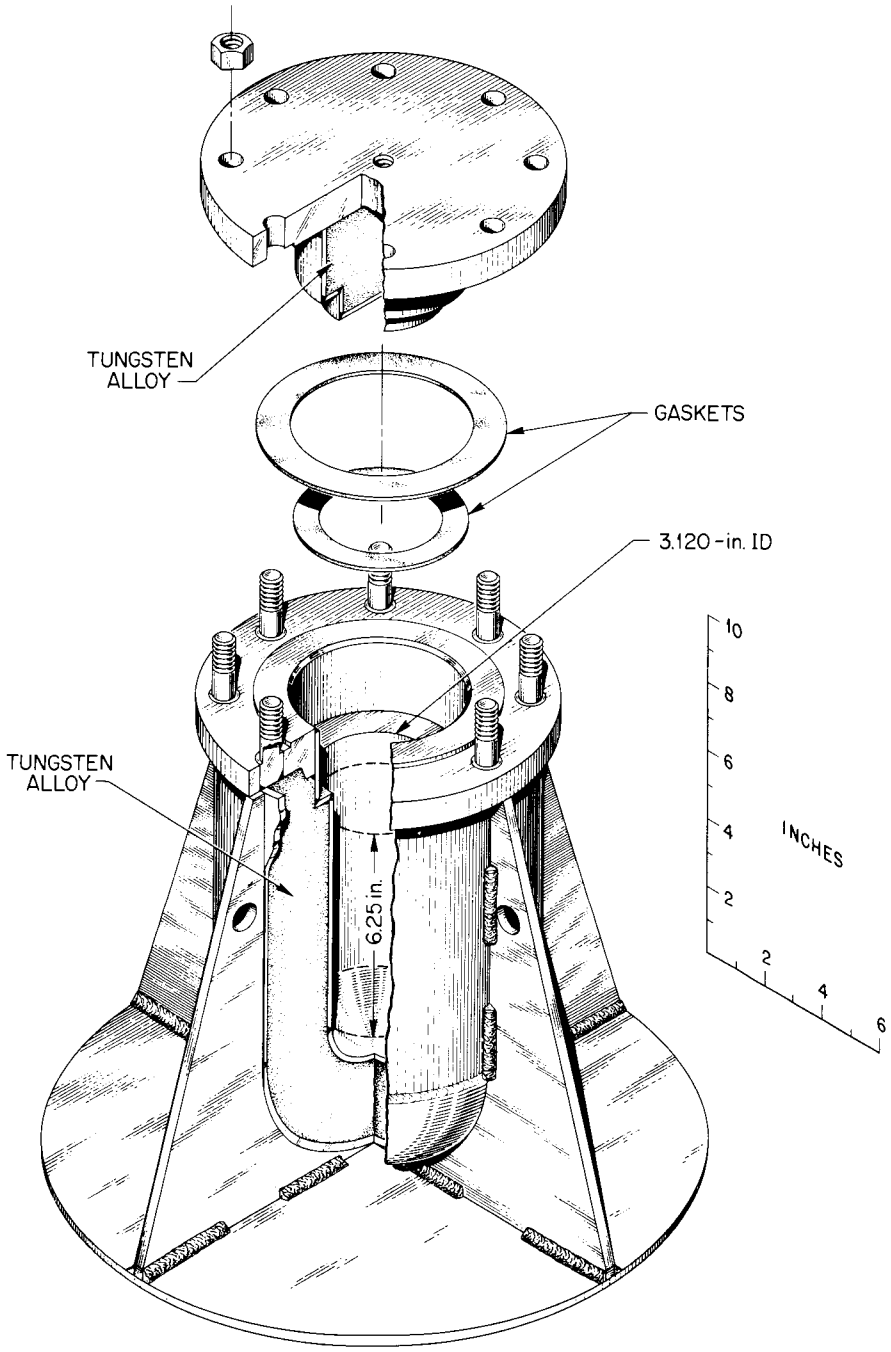

Fig. 1. Section View of Tungsten-Shielded Cask.

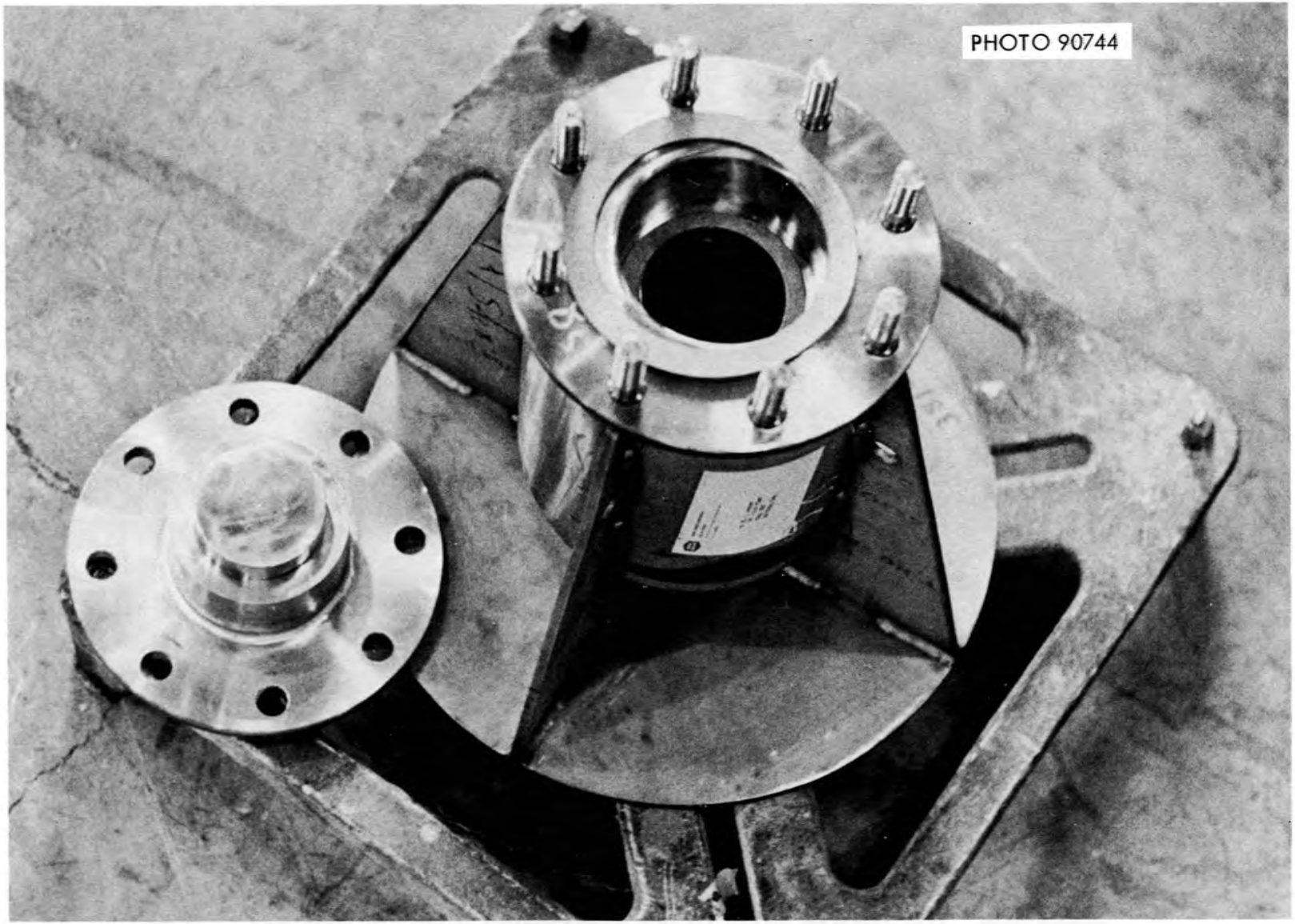

Fig. 2. Prototype of Tungsten-Shielded Cask.

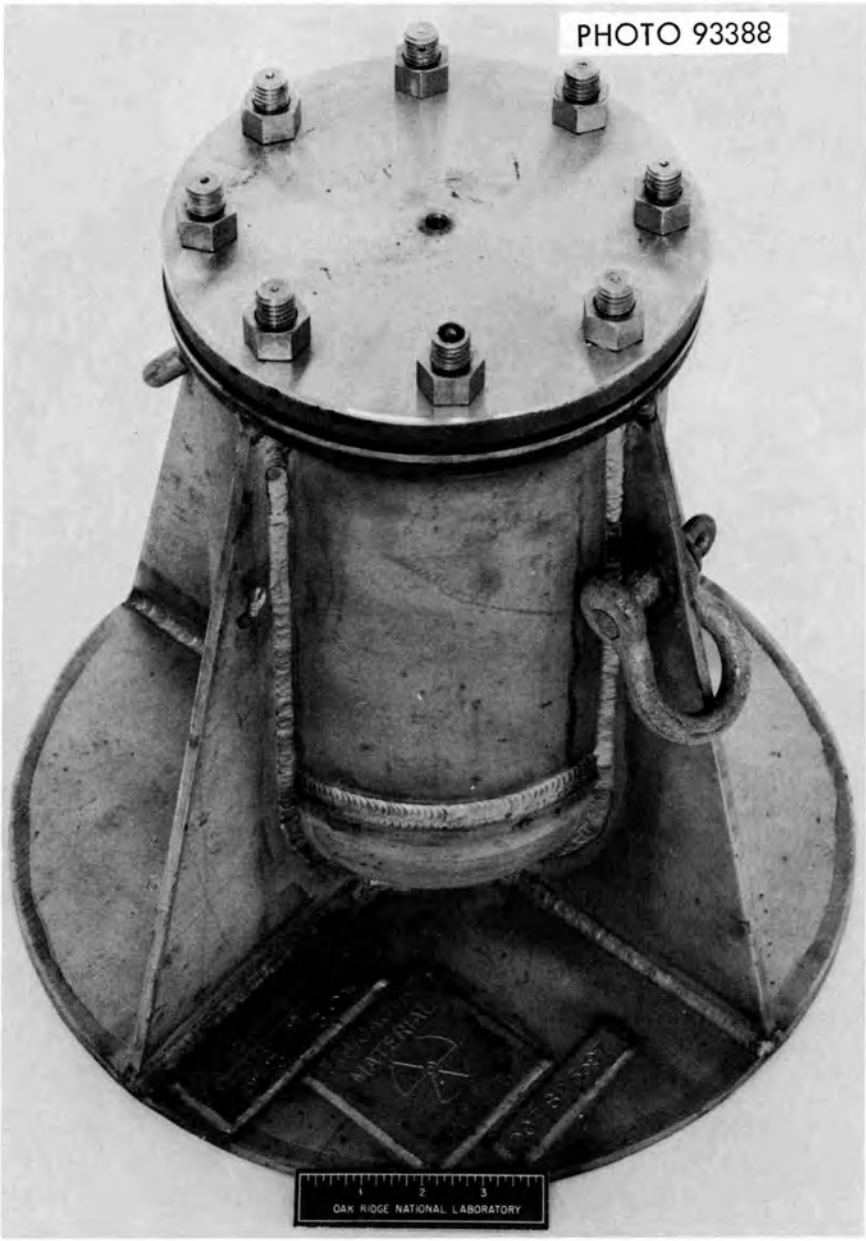

Fig. 3. ORNL Tungsten-Shielded Shipping Cask.

The cask can withstand the regulatory-required internal or external pressure of 25 psig, and each of the four lifting lugs can support 19.5 times the weight of the cask. The temperature profile of the cask, obtained by placing a 150-W electrical heater in the cask, which rested onan insulated pad, and allowing the cask to reach equilibrium in 85°F ambient air, is as follows: inner cylinder surface, 210°F; outer cylinder surface, 160°F; gusset plates, 122°F; base plate, 96°F.

SHIELDING DATA

The shield is a right cylindrical configuration with a hemispherical bottom for minimum weight requirements; the hemispherical segments of the inner and outer cladding, which is of type 304L stainless steel, are Hydroformed for uniform metallurgical structure and strength. The internal and external arch support of the cladding contributes to the impact integrity.

The shielding material is of 2-in.-thick tungsten alloy, which is the equivalent of 4 in. of lead shielding. The major constituents of the alloy are 95.29% (±0.47%) tungsten, 3.16% (±0.32%) nickel, and 1.45% (±0.15%) iron; the minor constituents are shown below:

Constituent	Amount (ppm)	Constituent	Amount (ppm)
Ag	<1*	Na	<20
Al	2	Pb	<10
B	<1	Si	12
C	60	V	<10
Ca	<10	Bi	<10
Co	<6	Mo	25
Cr	7	Sb	<20
Cu	3	Th	<100
Mg	<2	Zr	<20
Mn	4	U	<100

*The < sign indicates limit of detection of the analytical method used.

The alloy is produced by liquid-phase sintering of metal powders which have been mechanically blended in the required proportions and isostatically pressed at 30,000 psi to give parts with a green density of at least 11.0 g/cm^3. The green parts are liquid-phase-sintered above 2696°F in a hydrogen atmosphere. The alloy is not in contact with carbon or carbon atmosphere during the sintering operation. After sintering, the tungsten-iron-nickel alloy is of indeterminate composition with a fused tungsten matrix. The sintered product has a density of 18.27 g/cm^3. The alloy will not react with type 304L stainless steel, the cladding material, to form a liquid-phase tungsten-iron-nickel alloy up to 2651°F.

The alloy is machinable with conventional machine tools (94% WC, 6% Co). The recommended machining feeds and speeds are given below:

	Roughing	Finishing
Speed, fpm	60 - 80	100 - 150
Feed, in./rev	0.010 - 0.015	0.003 - 0.006
Depth of cut, in.	To 3/16	0.001 - 0.005

Because the alloy is a sintered product, some porosity can be expected. Typical densities are much better than 99% of the theoretical density, but there are many 0.010-in.-dia voids and a few voids up to 0.060 in. in diameter. These voids may give internal density variations of the order of ±1% on a in.^{3}-to-in.^{3} basis.

General data relating to the alloy are summarized below:

Chemical analysis (nominal)	95% W, 3-1/2% Ni, 1-1/2% Fe
Pressing and sintering	Cold-pressed isostatically at 30,000 psi; sintered above 2696°F
Machinability	Conventional machine tools and machining practices
Toxicity	None
Radiographic examination	Some voids 0.010 in. in diameter
Mechanical properties	
Tensile strength	102,400 psi
Yield strength	86,500 psi
Elongation	1.5%
Density	18.27 ± 0.12 g/cm^3
Thermal expansion coefficient at 77 to 932°F	5.23×10^{-6} in. in.$^{-1}$ (°F)$^{-1}$
Liquid-phase melting point	2669 to 2678°F

The shielding effectiveness of the cask was tested by loading it with 17 sealed sources containing a total of 2500 Ci of $^{90}SrTiO_3$. Radiation readings of 110 mR/hr were obtained at the surface of the cask. An upper load limit of about 5000 Ci of ^{90}Sr or equivalent total radiation energy is indicated for this design.

AECM-0529 Requirements for ORNL Tungsten-Shielded Cask

A copy of the "Certification of Approval for Fissile-Large Quantity Shipping Containers" follows. This form must be executed by the contractor and accompany the step-by-step analyses, which are discussed. The requirements outlined in AECM-0529 for large-quantity packaging for radioactive material are referenced by the applicable AECM-0529 paragraph number. Information regarding the newly designed cask follows, preceded by the marginal note "ORNL".

UNION CARBIDE CORPORATION
NUCLEAR DIVISION

CERTIFICATION OF APPROVAL FOR FISSILE-LARGE QUANTITY SHIPPING CONTAINERS

DATE SUBMITTED

PART A - TO BE COMPLETED BY CONTRACTOR

I. NAME AND ADDRESS OF AEC-ORO CONTRACTOR

Union Carbide Corporation
Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37830

Contact: R. D. Seagren

II. IDENTIFICATION OF CONTAINER, INCLUDING NAME, MAKE, MODEL, ETC.

ORNL tungsten shielded cask. Identified by a welded-on steel plate with the name of the cask, name of contractor, city, state, and contractor identification number. There is one cask of this design.

III. GENERAL INFORMATION CONCERNING CONTAINER

A. Brief description of container including demensions of outside container and inside cavity or container, weight, shielding, B of E Permit No., etc.
B. Intended use of container, including maximum amount of Fissile-Radioactive Material, chemical, and/or physical form, Class I, II, etc.
C. Resume of container test evaluation results as required by AEC-ORO 0529 including list of supporting references and/or enclosed documents, etc.
D. Drawings or other appropriate and relative data must be attached such as test results, fire tests, and radiation readings.

A. ORNL tungsten shielded cask is a right circular cylinder with a hemispherical bottom. It has a maximum outside diameter of 16 in. at the base. The cask itself has an outside diameter of 8 in. The overall height is 15 1/4 in. The inner cavity dimensions are 3 1/8 in. diameter by 6 1/4 in. high. The shielding of the cask is composed of isostatically pressed and sintered tungsten alloy with a 1/4-in. type 304L stainless steel shield outside and 1/8-in. type 304L stainless steel shield inside. The thickness of the tungsten shielding is 2 in., which is approximately equivalent to 4 in. of lead. This cask weighs 381 lb.

B. Approval is requested to ship any nonfissile radioisotope in solid form with a total maximum internal heat load of 150 W. All radioactive material will be single or double encapsulated or contained in Specification 2R containers, but specifically not limited to "special form."

Approval is also requested to ship any nonfissile radioisotope in liquid form with a maximum activity of 500 mCi/ml and a maximum quantity of 10 Ci per shipment. All liquid shipments will be further enclosed in Specification 2R containers.

C. The cask is designed to carry the quantities of radioactive material given while providing the structural, thermal, and shielding requirements of AEC Manual Chapter 0529 and all applicable DOT and Coast Guard regulations. The supporting documents containing calculations are attached.

D. ORNL drawing number C-RD-2495 is attached to this submission.

(Attach separate sheet if additional space is required)

Distribution: AEC - Original and 5 copies with drawings or attachments*
UCN Traffic - Copy (Nuclear Engineering Department only at ORGDP)
Originator - Copy

*2 Approved Copies with drawings or attachments will be returned to UCN Traffic (Nuclear Engineering Department only at ORGDP)

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IV. RESUME OF MAJOR LIMITATIONS OR RESTRICTIONS, INCLUDING SPECIAL CONTROLS OR TRANSPORT CONDITIONS, ADMINISTRATIVE PROCEDURES, MODE(S) OF TRANSPORTATION, ESCORT, ETC.

None

PART B - TO BE COMPLETED BY AEC-ORO

I. ADDITIONAL LIMITATIONS AND/OR INFORMATION

II. PURSUANT TO AECM-ORO-0529-031, THE REFERENCED CONTAINER IS APPROVED SUBJECT TO THE LIMITATIONS DESCRIBED ABOVE AND IN THE REFERENCED DOCUMENTS. THIS CERTIFICATION DOES NOT RELIEVE THE SHIPPER OF HIS RESPONSIBILITY TO OBTAIN AN ICC SPECIAL PERMIT AND TO COMPLY WITH THE REQUIREMENTS OF ANY OTHER FEDERAL REGULATIONS AS APPROPRIATE.

January 19, 1968
Date Approved

Original signed by Joseph A. Lenhard
Certification Official
Oak Ridge Operations
U. S. Atomic Energy Commission

AEC Appendix 0529

SAFETY STANDARDS FOR THE PACKAGING OF RADIOACTIVE AND FISSILE MATERIALS

II. PACKAGE STANDARDS

A. General standards for all packaging

1. Packaging shall be of such materials and construction that there will be no significant chemical, galvanic, or other reaction among the packaging components, or between the packaging components and the package contents.

ORNL: This cask is constructed of stainless steel and tungsten. In 20 years of radioisotope shipping experience, we have never experienced any significant chemical, galvanic, or other reaction between these materials under similar conditions of transport or handling; nor have we experienced any reaction between these materials of construction and the intended package contents.

2. Packaging shall be equipped with a positive closure which will prevent inadvertent opening.

ORNL: The cask is equipped with a positive closure device consisting of eight 5/8-in. bolts on the lid. Any opening of the cask would have to be deliberate and planned, not inadvertent. Additionally, one of the bolts on the lid is drilled for a wire seal to indicate whether the closure has been tampered with during shipment.

3. Lifting devices

(a) If there is a system of lifting devices which is a structural part of the package, the system shall be capable of supporting three times the weight of the loaded package without generating stress in any material of the packaging in excess of its yield strength.

ORNL: The lifting system of the cask can support much more than three times the weight of the cask without exceeding the yield strength of the material in shear. (See Appendix A for calculations.)

(b) If there is a system of lifting devices which is a structural part only of the lid, the system shall be capable of supporting three times the weight of the lid and any attachments without generating stress in any material of the lid in excess of its yield strength.

ORNL: The lid lifting device can support a load of much more than three times the weight of the lid without exceeding the yield strength of the material. (See Appendix A for calculations.)

(c) If there is a structural part of the package which could be employed to lift the package and which does not comply with subparagraph a. of this paragraph, the part shall be securely covered or locked during transport in such a manner as to prevent its use for that purpose.

ORNL: This cask was designed with smooth surfaces to eliminate the possibilities suggested by this paragraph. The eye bolt for the lid is not shipped with the cask.

(d) Each lifting device which is a structural part of the package shall be so designed that failure of the device under excessive load would not impair the containment or shielding properties of the package.

ORNL: The failure of a lifting device of the cask will not impair the shielding or containment properties of the cask nor will it impair its accident survival potential.

4. Tie-down devices

(a) If there is a system of tie-down devices which is a structural part of the package, the system shall be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, a static force applied to the center of gravity of the package having a vertical component of two times the weight of the package with its contents, a horizontal component along the direction in which the vehicle travels of ten times the weight of the package with its contents, and a horizontal component in the transverse direction of five times the weight of the package with its contents.

ORNL: The tie-down system for this cask is designed to withstand a force two times the weight of the cask in the vertical direction, ten times in the horizontal direction, and five times in the transverse direction of the cask. (See Appendix A for the calculations.)

(b) If there is a structural part of the package which could be employed to tie the package down and which does not comply with subparagraph a. of this paragraph, the part shall be securely covered or locked during transport in such a manner as to prevent its use for that purpose.

ORNL: This cask is designed so that the available components of the cask will meet the requirements of II.A.4.(a).

(c) Each tie-down device which is a structural part of the package shall be so designed that failure of the device under excessive load would not impair the ability of the package to meet other requirements of this subpart.

ORNL: The failure of a tie-down device of this cask will not impair its shielding or containment effectiveness nor will it impair its accident survival potential.

B. Structural standards for large quantity packaging

Packaging used to ship a large quantity of radioactive material shall be designed and constructed in compliance with the structural standards of this section. Standards different from those specified in this section may be approved by the manager or other designated official if the controls proposed to be exercised by the shipper are demonstrated to be adequate to assure the safety of the shipment.

1. Load resistance - Regarded as a simple beam supported at its ends along any major axis, packaging shall be capable of withstanding a static load, normal to and uniformly distributed along its length, equal to 5 times its fully loaded weight, without generating stress in any material of the packaging in excess of its yield strength.

ORNL: The cask, regarded as a simple beam supported at its ends along its major axis, will withstand a static load uniformly distributed along its length of at least five times the weight of the fully loaded cask without exceeding the yield strength of the cask material. (See Appendix A for calculations.)

2. External pressure - Packaging shall be adequate to assure that the containment vessel will suffer no loss of contents if subjected to an external pressure of 25 pounds per square inch gauge.

ORNL: The containment vessel will suffer no loss of contents if subjected to an external pressure of 25 psig. (See Appendix A for calculations.)

C. Criticality standards for fissile-material packages

1. A package used for the transport of fissile material shall be so designed and constructed and its contents so limited that it would be subcritical if it is assumed that water leaks into the containment vessel, and:

(a) Water moderation of the contents occurs to the most reactive credible extent consistent with the chemical and physical form of the contents; and

(b) The containment vessel is fully reflected on all sides by water.

2. A package used for the transport of fissile material shall be so designed and constructed and its contents so limited that it would be subcritical if it is assumed that any contents of the package which are liquid during normal transport leak out of the containment vessel, and that the fissile material is then:

   a. In the most reactive credible configuration consistent with the chemical and physical form of the material;

   b. Moderated by water outside of the containment vessel to the most reactive credible extent; and

   c. Fully reflected on all sides by water.

3. The manager or other designated official may approve exceptions to the requirements of this section where the containment vessel incorporates special design features which would preclude leakage of liquids in spite of any single packaging error and appropriate measures are taken before each shipment to verify the leak tightness of each containment vessel.

ORNL: C.1, 2, and 3 are not applicable to this cask since no fissile material will be shipped in it.

D. <u>Evaluation of a single package</u>

1. The effect of the transport environment on the safety of any single package of radioactive material shall be evaluated as follows:

   a. The ability of a package to withstand conditions likely to occur in normal transport shall be assessed by subjecting a sample package or scale model, by test or other assessment, to the normal conditions of transport as specified in II.E., and

   b. The effect on a package of conditions likely to occur in an accident shall be assessed by subjecting a sample package or scale model, by test or other assessment, to the hypothetical accident conditions as specified in II.F.

2. Taking into account controls to be exercised by the shipper, the manager or other designated official may permit the shipment to be evaluated together with or without the transporting vehicle, for the purpose of one or more tests.

3. Normal conditions of transport and hypothetical accident conditions different from those specified in II.E. and II.F., may

be approved by the manager or other designated official if the controls proposed to be exercised by the shipper are demonstrated to be adequate to assure the safety of the shipment.

ORNL: D. 1, 2, and 3 requirements are met in this discussion of the applicable paragraphs of these regulations to cask described.

E. Standards for normal conditions of transport for a single package

1. A package used for the shipment of fissile material or a large quantity of radioactive material shall be so designed and constructed and its contents so limited that under the normal conditions of transport specified in annex 1 of this part:

a. There will be no release of radioactive materials from the containment vessel;

ORNL: Subjecting this package to the normal conditions of transport or to the hypothetical accident conditions of the regulation will not result in the release of radioactive material from the containment vessel.

b. The effectiveness of the packaging will not be substantially reduced;

ORNL: The effectiveness of the package will not be substantially reduced by the normal conditions of transport.

c. There will be no mixture of gases or vapors in the package which could, through any credible increase of pressure or an explosion, significantly reduce the effectiveness of the package;

ORNL: ORNL procedures limit liquid shipments to a maximum concentration of 500 mCi/ml, which is below the concentration where radiolytic decomposition will credibly reduce the effectiveness of the package.

d. Radioactive contamination of the liquid or gaseous primary coolant will not exceed 10^{-7} curies of activity of Group I radionuclides per milliliter, 5×10^{-6} curies of activity of Group II radionuclides per milliliter; 3×10^{-4} curies of activity of Group III and Group IV radionuclides per milliliter; and

ORNL: There is no circulating coolant provided for this cask other than atmospheric air.

e. There will be no loss of coolant or loss of operation of any mechanical cooling device.

ORNL: There is no mechanical cooling device required or provided for this cask.

2. A package used for the shipment of fissile material shall be so designed and constructed and its contents so limited that under normal conditions of transport, specified in annex 1 of this part, considered individually:

   a. The package will be subcritical;

   b. The geometric form of the package contents would not be substantially altered;

   c. There will be no leakage of water into the containment vessel. This requirement need not be met if, in the evaluation of undamaged packages under II.H.1, II.I.1.a., or II.J.1., it has been assumed that moderation is present to such an extent as to cause maximum reactivity consistent with the chemical and physical form of the material; and

   d. There will be no substantial reduction in the effectiveness of the packaging, including:

      (1) Reduction by more than five percent in the total effective volume of the packaging on which nuclear safety is assessed;

      (2) Reduction by more than five percent in the effective spacing on which nuclear safety is assessed, between the center of the containment vessel and the outer surface of the packaging; or

      (3) Occurrence of any aperture in the outer surface of the packaging large enough to permit the entry of a four-inch cube.

ORNL: E.2. is not applicable to this cask since no fissile material will be shipped in it.

3. A package used for the shipment of a large quantity of radioactive material as defined in I.A.6., shall be so designed and constructed and its contents so limited that under the normal conditions of transport specified in annex 1, considered individually, the containment vessel would not be vented directly to the atmosphere.

ORNL: The containment vessel of this cask is designed with double gaskets so that it will not be vented to atmosphere under normal conditions of transport.

F. Standards for hypothetical accident conditions for a single package

1. A package used for the shipment of a large quantity of radioactive material or the shipment of fissile material when the package will contain more than 0.001 curie of Group I radionuclides, .05 curie of Group II radionuclides, 3 curies of Group III radionuclides, 20 curies of Group IV or Group V radionuclides, or radionuclides in special form, or 1000 curies of Group VI or Group VII radionuclides shall be so designed and constructed and its contents so limited that if subjected to the hypothetical accident conditions specified in annex 2 of this appendix, as the Free Drop, Puncture, Thermal, and Water Immersion conditions, in the sequences listed in annex 2, it will meet the following conditions:

   a. The reduction of shielding would not be sufficient to increase the external radiation dose rate to more than 1000 millirems per hour at 3 feet from the external surface of the package.

   b. No radioactive material would be released from the package except for gases and contaminated coolant containing total radioactivity exceeding neither:

      (1) 0.1 percent of the total radioactivity of the package contents; nor

      (2) 0.01 curie of Group I radionuclides, 0.5 curie of Group II radionuclides, 10 curies of Group III radionuclides, 10 curies of Group IV radionuclides, and 1000 curies of inert gases irrespective of transport group.

ORNL: The requirements of this paragraph are discussed in the evaluation of the package for the hypothetical accident conditions (Annex 2). The package does meet the requirements.

2. A package used for the shipment of fissile material shall be so designed and constructed and its contents so limited that if subjected to the hypothetical accident conditions specified in annex 2 of this part, as the Free Drop, Puncture, Thermal, and Water Immersion conditions, in the sequence listed in annex 2, the package would be subcritical. In determining whether this standard is satisfied, it shall be assumed that:

   a. 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;

b. Water 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

c. There is reflection by water on all sides and as close as is consistent with the damaged condition of the package.

ORNL: F.2. is not applicable since no fissile material will be shipped in this cask.

G. Evaluation of an array of packages of fissile material

1. The effect of the transport environment on the nuclear criticality safety of an array of packages of fissile material shall be evaluated by subjecting a sample package or a scale model, by test or other assessment, to the hypothetical accident conditions specified in II.H., II.I., or II.J., for the proposed fissile class, and by assuming that each package in the array is damaged to the same extent as the sample package or scale model. In the case of a Fissile Class III shipment, the manager or other designated official may, taking into account controls to be exercised by the shipper, permit the shipment to be evaluated as a whole rather than as individual packages, and either with or without the transporting vehicle, for the purpose of one or more tests.

2. In determining whether the standards of II.H.2., II.I.1.b., and II.J.2., are satisfied, it shall be assumed that:

a. The fissile material is in the most reactive credible configuration consistent with the damaged condition of the package, the chemical and physical form of the contents, and controls exercised over the number of packages to be transported together; and

b. Water 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.

ORNL: G is not applicable since no fissile material will be shipped in this cask.

H. Specific standards for a Fissile Class I package

A fissile Class I package shall be so designed and constructed and its contents so limited that:

1. Any number of such undamaged packages would be subcritical in any arrangement, and with optimum interspersed hydrogenous moderation unless there is a greater amount of interspersed moderation in the packaging, in which case that greater amount may be considered; and

2. Two hundred fifty such packages would be subcritical in any arrangement, if each package were subjected to the hypothetical accident conditions specified in annex 2 of this appendix as the Free Drop, Thermal, and Water Immersion conditions, in the sequence listed in annex 2, with close reflection by water on all sides of the array and with optimum interspersed moderation unless there is a greater amount of interspersed moderation in packaging, in which case that greater amount may be considered. The condition of the package shall be assumed to be as described in II.G.

ORNL: H is not applicable since no fissile material will be shipped in this cask.

I. <u>Specific standards for a Fissile Class II package</u>

1. A Fissile Class II package shall be so designed and constructed and its contents so limited, and the number of such packages which may be transported together so limited, that:

   a. Five times that number of such undamaged packages would be subcritical in any arrangement if closely reflected by water; and

   b. Twice that number of such packages would be subcritical in any arrangement if each package were subjected to the hypothetical accident conditions specified in annex 2 of this appendix as the Free Drop, Thermal, and Water Immersion conditions, in the sequence listed in annex 2, with close reflection by water on all sides of the array and with optimum interspersed hydrogenous moderation unless there is a greater amount of interspersed moderation in the packaging, in which case that greater amount may be considered. The condition of the package shall be assumed to be as described in II.G.

2. The transport index for each Fissile Class II package is calculated by dividing the number 50 by the number of such Fissile Class II packages which may be transported together as determined under the limitations of paragraph 1 of this section. The calculated number shall be rounded up to the first decimal place.

ORNL: I is not applicable since no fissile material will be shipped in this cask.

J. Specific standards for a Fissile Class III shipment

A package for Fissile Class III shipment shall be so designed and constructed and its contents so limited, and the number of packages in a Fissile Class III shipment shall be so limited that:

1. The undamaged shipment would be subcritical with an identical shipment in contact with it and with the two shipments closely reflected on all sides by water; and

2. The shipment would be subcritical if each package were subjected to the hypothetical accident conditions specified in annex 2 of this appendix as the Free Drop, Thermal, and Water Immersion conditions, in the sequence listed in annex 2, with close reflection by water on all sides of the array and with the packages in the most reactive arrangement and with the most reactive degree of interspersed hydrogenous moderation which would be credible considering the controls to be exercised over the shipment. The condition of the package shall be assumed to be as described in II.G. Hypothetical accident conditions different from those specified in this subparagraph may be approved by the manager or other designated official if the controls proposed to be exercised by the shipper are demonstrated to be adequate to assure the safety of the shipment.

ORNL: J is not applicable since no fissile material will be shipped in this cask.

III. OPERATING PROCEDURES

A. Establishment and maintenance of procedures

1. The shipper shall establish and maintain:

a. Operating procedures adequate to assure that the determinations and controls required by this chapter are accomplished; and

ORNL: The Isotopes Division of ORNL carefully monitors each shipment made from its facilities to assure that maximum package contents are not exceeded and the applicable regulations concerning radiation levels, transferable activity, etc., are complied with.

b. Regular and periodic inspection procedures adequate to assure that the shipper follows the procedures required by subparagraph a., of this paragraph.

ORNL: This cask is carefully inspected for damage before and after each shipment to ensure compliance with all applicable regulations.

B. Assumptions as to unknown properties

When the isotopic abundance, mass, concentration, degree of irradiation, degree of moderation, or other pertinent property of fissile material in any package is not known, the shipper shall package the fissile material as if the unknown properties have such credible values as will cause the maximum nuclear reactivity.

ORNL: Not applicable since no fissile material will be shipped in this cask.

C. Preliminary determinations

1. Prior to the first use of any packaging for the shipment of a large quantity of radioactive material or fissile materials, such packaging shall be inspected to ascertain that there are no cracks, pinholes, uncontrolled voids or other defects which could significantly reduce its effectiveness.

ORNL: During construction of this cask, all materials were specified and inspected to ensure that all specifications were met. All welded joints were dye-penetrant inspected to ensure that weld specifications were met.

2. Prior to the first use of any packaging for the shipment of a large quantity of radioactive material or fissile materials, where the maximum normal operating pressure will exceed 5 pounds per square inch gauge, the containment vessel shall be tested to assure that it will not leak at an internal pressure fifty percent higher than the maximum normal operating pressure.

ORNL: The normal operating pressure of this cask is atmospheric pressure; therefore, the requirement is not applicable.

3. Packaging shall be conspicuously and durably marked with its model number. Prior to applying the model number, an inspection shall be made to determine that the packaging has been fabricated in accordance with the approved design.

ORNL: This cask is identified by a welded-on steel plate with the name of the cask, name of contractor, city, state, and DOT special permit number. The cask was thoroughly inspected during construction to ensure that design specifications were complied with.

D. Routine determinations

Prior to each use of a package for shipment of radioactive or fissile material the shipper shall ascertain that the package with its contents satisfies the applicable requirements of section II of this appendix including determinations that:

1. The packaging has not been significantly damaged;

2. Any moderators and non-fissile neutron absorbers, if required, are present and are as authorized;

3. The closure of the package and any sealing gaskets are present and are free from defects;

4. Any valve through which primary coolant can flow is protected against tampering;

5. The internal gauge pressure of the package will not exceed, during the anticipated period of transport, the maximum normal operating pressure;

6. Contamination of the primary coolant will not exceed, during the anticipated period of transport, the limits in II.E.1.d.

ORNL: The requirements of this paragraph are complied with by a thorough and complete visual inspection before and after each use of the cask. Any suspicious area found in this inspection is investigated further by mechanical measurement and is repaired if necessary.

E. Records

The shipper shall maintain for a period of at least two years after its generation a record of each shipment of fissile material and of a large quantity of radioactive material, as defined in I.A.6., in a single package, showing where applicable:

1. Identification of the packaging by model number;

2. Details of any significant defects in the packaging, with the means employed to repair the defects and prevent their recurrence;

3. Volume and identification of coolant;

4. Type and quantity of material in each package, and the total quantity in each shipment;

5. For each item of irradiated fissile material:

   a. Identification by model number;

   b. Irradiation and decay history to the extent appropriate to demonstrate that its nuclear and thermal characteristics comply with approved conditions;

   c. Any abnormal or unusual condition relevant to radiation safety.

6. Date of shipment;

7. For Fissile Class III, any special controls exercised;

8. Name and address of the transferee;

9. Address to which the shipment was made; and

10. Results of the determinations required by III.C. and III.D.

ORNL: Applicable parts of this requirement are maintained for the life of the cask.

ANNEX 1

NORMAL CONDITIONS OF TRANSPORT

1. Heat - Direct sunlight at an ambient temperature of 130°F in still air.

ORNL: These conditions will not affect the materials of this cask or its integrity.

2. Cold - An ambient temperature of -40°F in still air and shade.

ORNL: An outside ambient temperature of -40°F will not produce a brittle type of fracture.

3. Pressure - Atmospheric pressure of 0.5 times standard atmospheric pressure.

ORNL: The cask will withstand an external pressure of at least 0.5 times greater than standard atmospheric pressure.

4. Vibration - Vibration normally incident to transport.

ORNL: This type of construction has been used in transport for many years and inspection has not revealed any damage due to vibration.

5. Water Spray - A water spray sufficiently heavy to keep the entire exposed surface of the package except the bottom continuously wet during a period of 30 min.

ORNL: Normally the cask will be stored outside, and exposure to rainfall under these conditions is not expected to cause damage.

6. Free Drop - Between 1-1/2 and 2-1/2 hours after the conclusion of the water spray test, a free drop through the distance specified below onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

Free Fall Distance

Package Weight (pounds)	Distance (feet)
Less than 10,000	4
10,000 to 20,000	3
20,000 to 30,000	2
More than 30,000	1

ORNL: We believe that this condition is satisfactorily covered in the 30-ft free-fall requirement of the hypothetical accident conditions.

7. Corner Drop - A free drop onto each corner of the package in succession or in the case of a cylindrical package, onto each quarter of each rim, from a height of one foot onto a flat essentially unyielding horizontal surface. This test applies only to packages which are constructed primarily of wood or fiberboard, and do not exceed 110 pounds gross weight, and to all Fissile Class II packagings.

ORNL: This requirement is satisfactorily discussed in the free-fall requirement of the hypothetical accident conditions.

8. Penetration - Impact of the hemispherical end of a vertical steel cylinder one and one-quarter inches in diameter and weighing 13 pounds, dropped from a height of 40 inches onto the exposed surface of the package which is expected to be most vulnerable to puncture.

ORNL: This requirement is satisfactorily discussed in the penetration requirements under the hypothetical accident conditions.

9. Compression - For packages not exceeding 10,000 pounds in weight, a compressive load equal to either five times the weight of the package or two pounds per square inch multiplied by the maximum horizontal cross section of the package, whichever is greater. The load shall be applied during a period of 24 hours, uniformly against the top and bottom of the package in the position in which the package would normally be transported.

ORNL: The cask has been demonstrated to meet the requirements of paragraph 11.B.1, which is a more stringent requirement than this.

ANNEX 2

HYPOTHETICAL ACCIDENT CONDITIONS

1. Free Drop - A free drop through a distance of thirty feet onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

ORNL: Particular effort has been expended in weld design and inspection to assure that full penetration welds were obtained in all areas of this cask. Design effort has also placed the welds in areas less subject to impact. Current testing programs have indicated that properly designed full-penetration welds will withstand 90° bend tests and will withstand 30-ft free falls in cask tests. The stress generated by the 30-ft free fall will not adversely affect any of the cask components. Cracks that may occur in the shielding material are intergranular in nature, thus offering a labyrinth path for radiation but not reducing the shielding properties.

2. Puncture - A free drop through a distance of forty inches striking, in a position maximum damage is expected, the top end of a vertical cylindrical mild steel bar mounted on an essentially unyielding horizontal surface. The bar shall be six inches in diameter, with the top horizontal and its edge rounded to a radius of not more than one-quarter inch, and of such a length as to cause maximum damage to the package, but not less than eight inches long. The long axis of the bar shall be perpendicular to the unyielding horizontal surface.

ORNL: The cask outer shell thickness of 1/4 in. meets the requirements of puncture resistance (reference: ORNL-TM-1312, Vol. 2).

3. Thermal - Exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 1475°F for 30 minutes with an emissivity coefficient of 0.9, assuming the surfaces of the packages have an absorption coefficient of 0.8. The package shall not be cooled artificially until 3 hours after the test period unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hours.

ORNL: Neither the stainless steel cladding nor the tungsten alloy shielding is pyrophoric; so they are essentially unaffected by the fire test.

4. Water Immersion (fissile material packages only) - Immersion in water to the extent that all portions of the package to be tested are under at least three feet of water for a period of not less than 8 hours.

ORNL: Since in the 30-ft free fall the stress in the lid closure mechanism is not expected to exceed the yield strength, it is not anticipated that the cask will leak when submerged in water. This cask will not be used for the transportation of fissile materials.

49 CFR 170 REQUIREMENTS FOR SPECIAL PERMIT PETITIONS

The information required by the Hazardous Materials Regulations Board of DOT for special permit petitions follows. Like the preceding material, it is referenced by the applicable paragraph number from 49 CFR 170. The information supplied by ORNL is given beneath each paragraph and is preceded by a marginal note "ORNL."

A copy of the Special Permit No. 5597 issued by DOT for the tungsten-shielded cask is given at the end of this section.

This information is required by 49 CFR 170.13 in filing petitions for special permits for waivers or exceptions.

DEPARTMENT OF TRANSPORTATION

Hazardous Materials Regulations Board
[49 CFR Part 170]

RULES OF PROCEDURE

§170.13 Filing of petitions for special permits for waivers or exemptions.

(a) Any person may petition the Board for a special permit for a waiver or exemption from any provision of Parts 171-190 of this chapter or Part 103 of Title 14 (14 CFR Part 103).

(b) Each petition must be submitted in duplicate to the Secretary, Hazardous Materials Regulations Board, Department of Transportation, 400 Sixth Street SW., Washington, D.C. 20590, and contain the following information:

(1) The regulatory provisions involved.

ORNL: The regulatory provision involved is Part 173.395(c) of the DOT regulations.

(2) The justification for the permit, including any reasons why the regulations are not appropriate, why the public interest would be served by the proposal, and the basis upon which the proposal would provide an adequate and reasonable degree of safety.

ORNL: The regulations are appropriate, since they permit large quantity radioactive shipments under specific regulations.

Nationally and internationally, the public interest would be served by the ability of organizations to safely receive large radiographic or heat sources not acceptable for shipment in DOT specification packages.

The basis upon which the proposal would provide an adequate and reasonable degree of safety is covered in the Oak Ridge Operations Office of the U. S. Atomic Energy Commission Certification of Approval for Large Quantity Shipping Containers. This approval indicates this package meets the requirements of AEC Manual, Chapter 0529, which is identical to 10 CFR 71 and equivalent to Section C-6.2.3.1 (i to xi) of IAEA regulations.

(3) A detailed description of the proposal, including when appropriate, drawings, plans, calculations, procedures, test results, previous approvals or permits, a list of specification containers, if any, to be used, a list of modified specification containers, if any, to be used, and a description of the modifications, and any other supporting information.

ORNL: The ORNL Tungsten-Shielded Cask is a right circular cylinder with a hemispherical bottom. It has a maximum outside diameter of 16 in. at the base. The cask itself has an outside diameter of 8 in. The overall height is 15-1/4 in. The inner cavity dimensions are 3-1/8 in. in diameter by 6-1/4 in. high. The shielding of the cask is composed of isostatically pressed and liquid-phase sintered tungsten alloy with a 1/4-in. 304L stainless steel cladding outside and 1/8-in. 304L stainless steel cladding inside. The thickness of the tungsten shielding is 2 in. This cask weighs 381 lb.

(4) The chemical name, common name, hazard classification, form, quantity, properties, and characteristics of the material covered by the proposal, including composition and percentage (specified by volume or weight) of each chemical, if a solution or mixture.

ORNL: Approval is requested to ship any nonfissile radioisotope in solid form with a total maximum internal heat load of 150 W. All radioactive material will be singly or doubly encapsulated or contained in Specification 2R containers, but specifically not limited to "special form."

Approval is also requested to ship any nonfissile radioisotope in liquid form with a maximum activity of 500 mCi/ml and a maximum quantity of 10 Ci per shipment. All liquid shipments will be further enclosed in Specification 2R containers.

(5) Any relevant shipping or accident experience with the container proposed.

ORNL: The following national and international shipments have been made in casks of this design with no incident or accident:

20	Ci	Strontium-90 oxide
2500	Ci	Strontium-90 titanate
2500	Ci	Strontium-90 titanate
200	Ci	Promethium-147 oxide
1000	Ci	Promethium-147 oxide
1200	Ci	Promethium-147 oxide
5792.5	Ci	Promethium-147 oxide
10	mCi	Curium-245 oxide
10	mCi	Curium isotopes
10	mCi	Curium isotopes

(6) The proposed mode of transportation, and any special transportation controls needed.

ORNL: Approval is requested to ship this package by motor vehicle, by rail, by air freight, and by water, nationally and internationally. No special transportation controls are needed for this package.

(7) The name, address, and telephone number of the petitioner, and that of the motor carrier if a tank motor vehicle is to be used.

ORNL: This request is made by Union Carbide Corporation, Nuclear Division, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tennessee 37830, phone (615) - 483-8611.

(8) A statement of recommendation regarding any changes to the regulations which would be desirable to obviate the need for similar special permits.

ORNL: There is no recommended change to the regulations, since large-quantity radioactive shipments already require special permits. This established policy should remain in force.

DEPARTMENT OF TRANSPORTATION

HAZARDOUS MATERIALS REGULATIONS BOARD

Washington, D. C. 20590

SPECIAL PERMIT NO. 5597

This special permit is issued pursuant to the authority of 46 CFR 146.05-4 of the U. S. Coast Guard Dangerous Cargo Regulations, Section 313(a) of the Federal Aviation Act of 1958, and 49 CFR 173.22(a)(1), Department of Transportation (DOT) Hazardous Materials Regulations, as amended.

1. The OAK RIDGE NATIONAL LABORATORY, is hereby authorized to ship radioactive material, n.o.s., further described as encapsulated non-fissile radioisotopes under the provisions of 46 CFR 146.25-30 and 146.25-400 of the U. S. Coast Guard Dangerous Cargo Regulations, and 49 CFR 173.393(f)(9) and 14 CFR 103.9 of the DOT regulations, in accordance with the provisions of the U. S. Atomic Energy Commission (USAEC), Oak Ridge Operations Office, approval dated January 19, 1968, and as further provided for herein.

2. The authorized packaging shall consist of a tungsten-shielded steel weldment (cask), approximately 16 in O.D. at the base, and 15 1/4 inches high. All radioactive material will be either singly or doubly encapsulated, or contained in DOT Specification 2R inner containers (mandatory for liquids). The package is described on Oak Ridge National Laboratory's drawing number C-RD-2495.

3. The closure device must have affixed to it a tamperproof lock wire and seal, or equivalent, adequate to prevent inadvertent opening of the container, and of a type that must be broken if the package is opened.

4. The authorized contents of each package shall consist of any solid, non-fissile radionuclide, having a heat load not to exceed 150 watts; or not more than 10 curies of any liquid non-fissile radionuclide with a maximum concentration of 0.5 c/ml.

5. The authorized package meets the criteria of the International Atomic Energy Agency for Type B packaging for large quantity radioactive materials.

6. Prior to each shipment authorized by this permit, the consignee shall be notified of the dates of shipment and expected arrival.

7. The outside of each package shall be plainly and durably marked "DOT SP 5597" and "RADIOACTIVE MATERIAL", in connection with and in addition to the other markings and labels prescribed by the DOT regulations. Each shipping paper issued in connection with shipments made under this permit must bear the notation "DOT SPECIAL PERMIT NO. 5597" in connection with the commodity description thereon. In accordance with 49 CFR 173.9(c) of the DOT regulations, the special permit identification may be either tag or label securely affixed to each package. For export shipments, the outside of each package shall be also marked "TYPE B".

8. The permit does not relieve the shipper from compliance with any requirement of the DOT regulations, including 46 CFR Parts 146 to 149 of the U. S. Coast Guard Regulations, except as specifically provided for herein.

9. Shipments are authorized only by cargo vessel, cargo aircraft, motor vehicle, rail freight, and rail express. Shipments by cargo aircraft are acceptable as provided by 14 CFR 103.9(a)(1) of the DOT regulations, subject to other provisions of Part 103.

10. For shipments by water, the shipper or agent shall notify the U. S. Coast Guard Captain of the Port in the port area through which the shipment is to be made, of the name of the vessel on which the shipment is to be made, and of the time, date, and place of loading. When the initial notification is given in a port area, it shall be accompanied by a copy of this permit, addressed to the attention of that Captain of the Port.

11. The shipper must furnish a record of experience to the Board if any extension or amendment to the permit is requested. This report must include the approximate number of packages shipped and the number of packages involved in any loss of contents. The modes of transportation used for these shipments must also be shown.

12. This permit shall expire April 30, 1970. Issued at Washington, D. C., this 9th day of April 1968.

Original signed by
E. G. Grundy, Capt.
For the Commandant
U. S. Coast Guard

Original signed by
S. Schneider
For the Administrator
Federal Aviation Administration

Original signed by
W. R. Fiste
For the Administrator
Federal Highway Administration

Original signed by
H. R. Longhurst
For the Administrator
Federal Railroad Administration

Address all inquiries to: Secretary, Hazardous Materials Regulations Board, U. S. Department of Transportation, Washington, D. C. 20590. Attention: Special Permits.

APPENDIX A - SUPPORTING CALCULATIONS

The following calculations support the referenced paragraphs of AECM-0529.

II. Package Standards

A.3. (a) Lifting Devices
The cask is designed to be lifted by either two of the four 3/4-in. holes near the top of the four vertical ribs. The shear area of two holes is:

$$4(1/4 \times 1/2) = 0.5 \text{ in.}^2$$
$$Y(304L\ SS) = 30{,}000 \text{ psi}$$
$$\text{Shear load} = (30{,}000)(0.5) = 15{,}000 \text{ psi} = 39 \text{ times cask weight}$$

A weight of 7500 lb (19.5 times cask weight) can be supported by one hole.

The lid lifting system consists of one 3/8-in. eye bolt which has a safe working load of 1400 lb. The lid weighs 32.5 lb.

A.4. (a) Cask tie-down device - There is no specific tie-down device provided for this cask, since it is relatively small and light. However, the lifting devices could be used for tieing the cask down. Each will support 19.5 times the weight of the cask in any direction.

II.B.1. The cask, regarded as a simple beam supported at its ends, shall be capable of withstanding a static load, normal to and uniformly distributed along its length, equal to 5 times its fully loaded weight without exceeding the yield strength of any materials.

To meet this specification, the outer shell of the cask is considered to be the only supporting member. The stress in the outer steel shell of the cask supported at the ends of its major axis is given by

$$S = \frac{M_b C}{I},$$

where

S = the maximum bending stress, lb/in.^{2},
M_b = the bending moment, in.-lb
$= \frac{WL}{8}$,
W = the cask weight, lb,
L = the length of span between the supports, in.

C = distance from the central axis to outermost fiber, in.,
I = moment of inertia, in.^{4}

Then for a uniform load of 5 times the cask weight,

$$M_b = \frac{5WL}{8} .$$

The moment of inertia, I, for circular cross section is

$$I = \pi r^3 t,$$

$$I = \pi(4)^3 (0.250),$$

$$M_b = \frac{(5)(400)(13)}{8} = 3250 \text{ in.-lb};$$

then

$$S = \frac{M_b C}{I} = \frac{(3250)(4)}{50.27}$$

$$= 259 \text{ psi.}$$

Since the yield strength of stainless steel is approximately 30,000 psi, the cask meets these criteria.

II.B.2. The closure device is a standard 150-lb flange and a blind flange capable of withstanding an external pressure of 25 psig.

For the body of the cask

$$S = \frac{pr}{T} = \frac{(25)(4)}{0.25} = 400 \text{ psi},$$

where p = pressure, psi, r = radius, in., and T = thickness, in., This value is well below the yield strength of stainless steel.

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