16r. 56
ORNL/ENG/TM-15

Safety Analysis Report for Packaging: The Unirradiated Fuel Shipping Container

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MASTER

ORNL/ENG/TM-15
Dist. Category 5-71

Contract No. W-7405-eng-26

ORNL Engineering

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Date Published - September 1979

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

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ABSTRACT

The Unirradiated Fuel Shipping Container was designed at the Oak Ridge National Laboratory for the transport of unirradiated fuel elements. The container was evaluated analytically to determine its compliance with the applicable regulations governing containers in which radioactive and fissile materials are transported, and the evaluation is the subject of this report. Computational and test procedures were used to determine the structural integrity and thermal behavior of the container relative to the general standards for normal conditions of transport and the standards for hypothetical accident conditions. Results of the evaluation demonstrate that the container is in compliance with the applicable regulations.

1. GENERAL INFORMATION

1.1 Introduction

The Unirradiated Fuel Shipping Container was developed at the Oak Ridge National Laboratory in 1978; three containers of differing dimensions were designed. The containers will be fabricated, inspected, and filled with phenolic foam in accordance with the drawings in Appendix A.

The primary use of the containers is to ship fuel elements. The containers provide impact and thermal resistance for the fuel elements during transport for both normal and accident conditions by rail, highway, air, and water modes. The contents for which the design was evaluated are outlined in Sect. 1.2.3. They comply with Department of Energy regulations contained in the Code of Federal Regulations, Title 10, Part 71;¹ in the AEC Manual Chapter 0529;² and in all Immediate

Action Directives in effect as of this report date. The containers also comply with U.S. Department of Transportation regulations published in the Code of Federal Regulations, Title 49, Part 173.³ Calculations, engineering logic, test results, and documents demonstrating compliance are presented in the following sections of this report. Copies of the approval documents are reproduced in Appendix E.

1.2 Package Description

1.2.1 Container description

The features of the package are illustrated in Fig. 1.1 and listed in Table 1.1; fabrication drawings are in Appendix A. The container consists of a basket and a cylindrical housing. Each container has an outside dimension (OD) of 24-1/2 in., except for the National Bureau of Standards container, which has a 25 in. OD. The basket for the Oak Ridge Research Reactor (ORR), Bulk Shielding Reactor (BSR), and Pool Critical Assembly (PCA) fuel elements is 39-7/8 in., with the overall length of the container being 56-5/8 in. The basket for the Brookhaven National Laboratory (BNL) fuel elements is 58-3/4 in., with the overall length of the container being 75-1/2 in. The basket for the National Bureau of Standards (NBS) fuel elements is 70-5/16 in., with the overall length of the container being 87-1/8 in. The area between the basket and outer housing is filled with phenolic foam. The phenolic foam provides some structural support and is an effective thermal insulator. Vent holes 3/16 in. in diameter are located in the sides and bottom of the external housing for release of gas pressure that may be generated by decomposition of the phenolic in a fire. After the container is filled with foam, these vent holes are sealed against the weather by two coats of an epoxy paint that does not react with the phenolic foam. The epoxy seals are designed to vent in a fire, since the epoxy paint will decompose at temperatures well below 1000°F. This ability has been demonstrated by Mallet and Newlon on very similar epoxy seals.⁴

The closure of the basket is afforded by 16-in.-OD, 1/8-in.-thick flanges. Eight 3/8-in. hex-head bolts secure the closure. At the base of the vessel, the inner and outer housings are separated by a cross

	OVERALL LENGTH (in.)	OUTSIDE DIA. (in.)
ORR	56 1/2	24 1/2
BNL	75 1/2	24 1/2
NBS	87 1/2	26

Fig. 1.1. The unirradiated fuel element shipping container.

Table 1.1. Design summary of unirradiated fuel containers

Container type	UCC-ND drawing number	Inside cavity length (in.)	Element length (in.)	Inside cavity cross section (in.)	Maximum width element (in.)	Minimum width element (in.)	Maximum fu-7 elements (g)	Container length (in.)	Container body OD (in.)	Base (in.)	Lid OD (in.)	Gross weight loaded (lb)
ORR (Oak Ridge National Laboratory)	X3E-10191-002 & -003	38-3/4	38-3/8	4 x 4	3.397 ±.005	3.033 ±.001	370	36-5/8	24-1/2	29 x 29	29	580
BSR & PCA (Oak Ridge National Laboratory)	X3E-10191-002 & -003	34-3/4	38-3/8	4 x 4	3.397 ±.005	2.996 ±.000 -0.010	370	36-5/8	24-1/2	29 x 29	29	580
HFBR (Brookhaven National Laboratory)	X3E-10191-010 & -011	57-1/2	57-1/4	4 x 4	3.218 ±.005	2.878 ±.000 -0.005	370	75-1/2	24-1/2	29 x 29	29	700
NBSRR (National Bureau of Standards)	X3E-10191-100 & -101	69-3/16	68-51/64	4-1/2 4-1/2	3-13/16 ±0.15	3-1/8 ±.015	370	87-1/8	24-1/2	30-17/2 30-1/2	30-1/2	850

structure of lumber 5-1/2 in. deep. A foam-filled plug 5-3/4 in. high fits on top of the inner housing and is secured by 6-5/8-in. hex-head bolts with lock washers and nuts.

The materials of construction, as specified on MCC-ND data sheets DS-XDE 10191-1,2,3, and Rev. 1 are stainless steels and aluminum to ASTM specifications.

The inner container is a basket that is permanently fixed in the top of the outer container by four 2 x 1/2 x ~5 in.-long phenolic spacers bolted to the basket and container by eight 1/4-in.-diam bolts with lock washers and nuts. The bottom of the basket is secured by four threaded rods welded to the bottom of the container. The basket has a capacity of seven fuel elements. Three different containers have been constructed to ship different size fuel elements. The only difference in the containers will be the overall length, basket length, and basket cross section.

The weights of the baskets are 119, 92, and 66 lb. The net weights of the packages (cylinder plus basket plus forklifting device) are 660, 550, and 450 lb. Therefore, all calculations will be based on a gross weight of approximately 850 lb. Compliance of this heavier package with design specifications demonstrates that the lighter packages would be well within design limits.

1.2.2 Operational features

The container is specifically designed to house seven fuel elements. Three different containers are available to transport ORNL, NBS, or BNL fuel elements.

1.2.3 Contents

The containers are designed to transport seven fresh or unirradiated fuel elements from the fabricator to the applicable reactor site. These reactors are (1) the ORR, the BSR, and the PCA, located at Oak Ridge, Tennessee; (2) the National Bureau of Standards Research Reactor (NBSRR), located near Washington, D.C.; and (3) the BNL High-Flux Beam Reactor (HFBR), located at Upton, N.Y. The elements are of similar construction.

They are curved plate with U_3O_8 -Al cores clad with type 6061 aluminum. The minimum ^{235}U enrichment is 93%. Other characteristics of the elements are listed in Table 1.1, and drawings of the elements are in Appendix B.

2. STRUCTURAL EVALUATION

The package complies with the structural requirements of the regulations.¹ The calculational results and engineering logic presented in the following subsections demonstrate compliance with these performance criteria. Additional evaluations considered pertinent to the safety and operability of the package are included. The effects of both normal and specified accident conditions on the structural integrity of the package are considered.

2.1 Mechanical Properties of Materials

The values shown in Table 2.1 are conservative, but are typical of container materials.⁵⁻⁷ The static properties shown provide a reasonable approximation of dynamic conditions if care is taken to ensure that the use of static values results in a conservative evaluation. For most structural materials the static properties are much less than the dynamic properties. Numerous reports substantiate this, including ref. 8.

2.2 General Standards for All Packages

The general standards for all packaging cover the chemical and galvanic reactions of the materials of the package and closure of the package. The containers will be constructed of type 300 stainless steel filled with phenolic foam. There has been no evidence of any corrosive reactions between these materials and the contents.

2.2.1 Closure

The standards specify that the package be equipped with a positive closure that will prevent inadvertent opening. In this case the lid of

Table 2.1 Mechanical properties of container materials

Property	Symbol	Type 304L stainless steel	Carbon steel
Yield stress (psi)	σ	28,000	30,000
Ultimate tensile strength (psi)	σ	75,000	48,000
Modulus of elasticity (psi)		28×10^6	29×10^6
Elongation in 2 in. (%)		50	20
Density (lb/in. ³)	ρ	0.290	0.283
Allowable shear stress,			
$\tau_{\max} = \sigma_y / 2$ (psi)	$\tau_{\max}$	14,000	15,000

the basket is secured by eight 3/8-in. hex-head bolts with lock washers and nuts and qualifies as a positive closure. Closure of the outer lid is attained by six 5/8-in. bolts with hex nut and lock washer.

2.2.2 Container lifting device

If there is a system of lifting devices that is a structural part of the package, the regulations require that this system be capable of supporting three times the weight of the loaded package without generating stress in any material of the package in excess of its yield strength. This section is not applicable because there are no lifting devices, and the container is designed for forklift handling.

2.2.3 Lid lifting device

The lids of the outer housing and basket are of such size and shape as to make hand lifting applicable and to preclude the need for any integral lid lifting device.

2.2.4 Tie-down devices

Because these containers have no integral system of tie downs, no calculations as to force-withstanding capacity are required by the general standards. In transit the containers are secured by the same techniques used for conventional cargo without lifting lugs.

2.3 Standards for Type B and Large-Quantity Packaging

The structural standards for large-quantity packaging cover load resistance of the packaging and the external pressure which the package must withstand. Compliance of the Unirradiated Fuel Shipping Container with these requirements is discussed in the following subsections.

2.3.1 Load resistance

When regarded as a simple beam supported at its ends along any major axis, the container must be able to withstand a static load normal to and uniformly distributed along its length that is equal to five times its fully loaded weight without generating stress in any material in the shield in excess of the yield strength of that material. The equivalent cross section of the container analyzed in this study is illustrated in Fig. 2.1.

The cross section of the container is composed of the outer 1/8-in. stainless steel shell, the phenolic foam, and the 16 gauge stainless steel (GA. SST) basket as shown in Fig. 1.1. For a thin shell the moment of inertia about its center is

$$I = \int y^2 dA = 4 \int_0^{\pi/2} (r_m^2 \sin^2 \theta) t r_m d\theta = \pi r_m^3 t ,$$

where

r_m = radius (in.),

t = thickness (in.).

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(a) SHIELD AS SIMPLE BEAM

(b) EQUIVALENT CROSS SECTION OF SHIELD

Fig. 2.1. Container as a simple beam.

Neglecting the effect of the phenolic foam and the basket, the moment of inertia of the container is

$$\begin{aligned} I &= \pi t(r)^3 \\ &= \pi(0.125)(13.0)^3 \\ &= 862.8 \text{ in.}^4. \end{aligned}$$

The maximum bending stress is given by the expression

$$\sigma = Mc/I = 5WLr_0/8I;$$

so

$$\sigma = (850)(87.125)(13.0)/8(862.8) = 697 \text{ psi,}$$

where L is the length of the outer housing. Since this stress is less than the yield stress for either housing material, it is concluded that the container complies with the simple beam requirement.

2.3.2 External pressure

The regulations require that the shipping package be adequate to ensure that the containment vessel will suffer no loss of contents if subjected to 25 psig external pressure. For the purposes of stress calculations, it will be assumed that the foam-filled cavity is at the external pressure. One potential consequence of external pressure is buckling of the cylindrical shells of the shield. Since the outer shield housing is not airtight, there can be no pressure differential across it. Since the inner housing (basket) is not sealed, there can be no pressure differential across it. Therefore, this section is not applicable.

2.4 Compliance with Standards for Normal Conditions of Transport

The regulations for normal conditions of transport for a single package require that the effectiveness of the package will not be substantially reduced by the normal conditions of transport, that there will

be no release of radioactive material from the containment vessel, and that there will be no gases or vapors in the package which could, through any credible increase of pressure or an explosion, significantly reduce the effectiveness of the package. There is no circulating coolant other than atmospheric air, and there is no mechanical cooling device required or provided. The container and basket are so designed that the contents will not be vented to the atmosphere under normal conditions of transport. These conditions include the effects of heat, cold, pressure, free drop, and penetration.

The container should exhibit acceptable performance with respect to all of the normal transport conditions.

2.4.1 Heat

The package must be able to withstand direct sunlight at an ambient temperature of 130°F in still air without reducing the effectiveness of the packaging. A simplified one-dimensional heat transfer analysis (Sect. 3.1) was used to compute the steady-state temperature distribution in the package under the specified conditions. The surface temperature under these conditions would be approximately 208°F, and the temperature at the center of the package would be approximately 208°F.

The temperature that would exist in the package will not adversely affect the container. The materials of construction do not suffer significant loss of physical properties at these temperatures. The maximum service temperature of the phenolic foam³ is 300°F, which is also well above the temperature encountered.

The regulations² set forth by the Department of Transportation further stipulate that the temperature of any accessible surface of the fully loaded shipping package shipped by common carrier shall not exceed 122°F when the package is in the shade in still air at an ambient temperature. For this computation, an ambient temperature of 100°F is assumed, and since the containers have no internal heat load, the temperature of the surface will be 100°F.

2.4.2 Cold

The shipping package must be able to withstand an ambient temperature of -40°F (420°R) in still air in the shade. Because the containers have no internal heat load, the temperature of the entire package will be -40°F , and because the containers are not sealed, no pressure differential will result.

At -40°F the type 304L stainless steel to be used would not suffer brittle fracture because its transition temperature is considerably lower than -40°F . In addition, the container closure bolts will be fabricated of stainless steel to avoid the low-temperature-embrittlement problem.

2.4.3 Pressure

The regulations for normal conditions of transport specify that the package be able to withstand a reduction in atmospheric pressure to 0.5 atm (the resulting pressure being 7.35 psia) at the 130°F ambient temperature condition. Because the basket is not sealed the pressure in the basket will be the same as the atmospheric pressure. Therefore, this section is not applicable.

2.4.4 Vibration

The outer housing of the container is to be 1/8-in. stainless steel with a 26-in. outside diameter (maximum sized - NBSRR - container); transport vibrations would not be expected to affect the integrity of the container. The phenolic foam should further isolate the basket against vibrations. The bolts that secure the lids are equipped with lock washers to prevent loosening.

2.4.5 Water spray

The containers will be fabricated of stainless steel and will not suffer appreciable corrosive damage during the water spray test. The phenolic foam is also not affected by water spray.

2.4.6 Free drop

The regulations for normal conditions of transport require that a package weighing less than 10,000 lb be capable of withstanding a free drop through a distance of 4 ft onto a flat, essentially unyielding horizontal surface, striking the surface in a position in which maximum damage is expected to result. Under this impact, there should be no release of package contents (Sect. 2.5.1). The tests reported in these sections are much more severe; therefore, it can be concluded that the package would survive the 4-ft drop without loss of containment or integrity.

2.4.7 Compression

It is required that packages weighing less than 10,000 lb be capable of withstanding a compression load of five times the container weight, or 2 psi distributed uniformly across the top and bottom, whichever is greater.² In this instance, five times the gross weight of 850 lb is somewhat greater than that of the 2-psi condition. The maximum compressive stress in the walls is

$$\sigma = P/A = 5W/\pi D_0 t = (5)(850)/\pi(25.875)(0.125) = 418 \text{ psi},$$

where

D_0 = mean diameter of outer wall (in.),

t = wall thickness (in.).

Thus the package can support five times its weight with relatively low stresses generated in the walls.

2.4.8 Penetration

The regulations for normal conditions of transport also stipulate that the package be capable of withstanding the impact of the flat end of a vertical steel cylinder which weighs 13 lb, has a diameter of 1-1/4 in., and is dropped from a height of 4 ft, normally onto the exposed surface of the package that is expected to be the most vulnerable to puncture. This test would not reduce the effectiveness of the container

and would result in no more than a dent in the surface of the container. Tests were conducted at ORNL to verify these conclusions (see Appendix D).

2.5 Compliance with Standards for Hypothetical Accident Conditions

The standards for the hypothetical accident conditions stipulate that a package used for the shipment of fissile or a large quantity of radioactive material shall be so designed and constructed and its contents so limited that if it is subjected to the specified free drop, puncture, thermal, and water immersion (fissile material packages only) conditions, the reduction in containment would not be sufficient to increase the external radiation dose rate to more than 1000 millirems/hr at 3 ft from the outside surface of the package; no radioactive material would be released from the package except for gases containing total radioactivity not to exceed 0.1% of the total radioactivity of the contents of the package; and the contents would remain subcritical. The following sections will show compliance with the standards for hypothetical accident conditions.

2.5.1 Free drop

The first in the sequence of hypothetical accident conditions to which the container must be subjected is a free drop through a distance of 30 ft onto a flat, essentially unyielding surface. The container must strike the surface in the position expected to cause maximum damage.

A full-scale test model of a fire and impact shield of construction similar to that of the unirradiated shipping container and the ORNL Gas-Cylinder Fire and Impact Shield was designed, fabricated, and tested at the Oak Ridge Gaseous Diffusion Plant as reported by Mallett and Newlon.⁴ These tests demonstrated compliance with the regulations after being subjected to the regulatory accident.¹⁻³ The fire-resistant phenolic foam insulation used in the test container was the same as that to be used in the subject container. The volume of deterioration of the tested shield did not exceed 5% for this package and would indicate no damage to the inner container.

The drums tested by Mallett and Newlon⁴ had locking ring type closures whereas the ORNL gas-cylinder fire and impact shield and the unirradiated fuel shipping containers have a uniform closure design. The gas-cylinder package utilizes 8-3/8-16 UNC bolts, whereas the unirradiated fuel container has 6-5/8-11 UNC bolts. The Mallett and Newlon closure utilized a single 3/8-16 UNC bolt in the locking ring closure.⁴

The flanged and bolted closure employed on the containers is designed to reduce the possibility of loss of lid in the event of an impact such as a 30-ft free-fall. Note that the closure is not sealed and does not form part of either the primary or secondary containment. To comply with regulations the lid need only remain in place in order to maintain thermal (fire) protection. Closure flanges and bolts are fabricated from ductile materials that would deform locally near the point of impact, if subjected to a free-fall. We acknowledge that failure of the fastener directly at the impact point is possible, though not probable. Such a failure would not change the magnitude of permanent deformation of the container from the model tested at ORGDP.⁴

2.5.2 Puncture

The second in the sequence of hypothetical accident conditions to which the package must be subjected is a free drop through a distance of 40 in. to strike, in a position in which maximum damage is expected, the top end of a vertical, cylindrical mild-steel bar mounted on an essentially unyielding horizontal surface. The mild-steel bar shall be 6 in. in diameter, with the top horizontal and its edge rounded to a radius of not more than 1/4 in., and of such length that it will cause maximum damage to the container but not less than 8 in. long. The long axis of this bar shall be normal to the surface of the container upon impact.

In their report on a similar package, Mallett and Newlon⁴ presented the results of a puncture test. Their container was dropped on its side and was indented about 1.25 in. without rupture of the wall. Because of the similar design, it is concluded that the subject shield would behave in a like fashion and that no rupture would occur.

2.5.3 Water immersion

The final condition in the specified hypothetical accident is immersion in water to a depth of 3 ft for a period of 24 hr. The container is not sealed, so the container cavity would be completely filled with water. The primary containment (aluminum clad fuel) would not be breached as a result of any of the accident conditions; hence the unirradiated fissile material would not be in contact with the water, and no radioactive material would be transferred to the water. The fully loaded container filled with water and fully reflected by water remains subcritical.¹⁰ The phenolic foam of the container does not degrade upon water immersion; thus the criticality calculations are valid during the entire time of the immersion test.

3. THERMAL EVALUATION

The package must remain effective after exposure to severe thermal environments. Applicable normal and accident environments are specified in the regulations¹⁻³ and are discussed below. Analytical evaluations and tests have been utilized to demonstrate the ability of the package to remain effective after exposure to the specified environments.

3.1 Normal Conditions of Transport

The package must be able to withstand direct sunlight at an ambient temperature of 130°F in still air without reducing the effectiveness of the packaging. A simplified one-dimensional heat transfer analysis¹¹ was used to compute the steady-state temperature distribution in the package under the specified conditions.

To determine the temperature of the outside surface of the container, an expression that includes convective and radiative heat transfer effects² is used. The expression is of the form

$$q = q_c + q_r ,$$

$$q = h_c A (T_s - T_a) + 0.173 \bar{F}_{12} A \left\{ [(T_s + 460)/(100)]^4 - [(T_a + 460)/(100)]^4 \right\} , \quad (1)$$

where

q_c = convective heat flow (Btu/hr),

q_r = radiative heat flow (Btu/hr),

h_c = convective heat transfer coefficient¹² = $0.19(T_s - T_a)^{1/3}$
Btu/hr·ft²·°F,

A_c = convective heat transfer area = 52.1 ft²,

T_s = surface temperature (°F),

T_a = ambient temperature, 130°F,

A = radiative heat transfer area = A_c (ft²),

ϵ = emissivity of the painted shield surface (ref. 12, Table 5.2),

$\bar{F}_{12}$ = gray body shape factor¹² (≈ 0.6).

The heat load q on the package is only the solar heat load.

Because of the cyclic nature of solar heat load and the large time constant associated with containers of this type, the solar heat load per unit area can be approximated by numerically integrating the area under a normal incident solar energy curve (Fig. 5.3 in ref. 12) and is equal to 144 Btu/ft²·hr. (This average solar heat flux is the same as was used in an example problem on p. 143 in ref. 12.) The solar contribution is the only heat load in this calculation, and the exposed surface area will be conservatively calculated as the convective heat transfer area, including the top and sides but not the bottom:

$$\begin{aligned} A &= \pi r^2 + 2\pi r l \\ &= \pi(15.25)^2 + (2)(\pi)(13.0)(82.875) \\ &= 7500 \text{ in.}^2 = 52.1 \text{ ft}^2. \end{aligned}$$

The solar heat load is

$$q_s = (144)(52.1) = 7500 \text{ Btu/hr.}$$

The net heat load at the surface is

$$q = 7500 \text{ Btu/hr.}$$

The surface heat transfer equation [Eq. (1)] was solved via an iterative process to determine the surface temperature T_s corresponding to $q = 7500 \text{ Btu/hr.}$ In this case $T_s \cong 208^\circ\text{F.}$

Since there is no internal heat load, the maximum temperature of the container is the same as at the surface, 208°F.

3.2 Thermal Accident

The third in the sequence of hypothetical accident conditions specified by the regulation to which the package must be subjected is exposure for 30 min within a source of radiant heat having a temperature of 1475°F and an emissivity coefficient of 0.9. For calculation purposes the surface of the package is assumed to have an absorption coefficient of 0.8. The package shall not be cooled artificially until 3 hr after the test period has ended, unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hr.

Similar packages with the same fire-resistant foam insulation, as reported by Mallett and Newlon,⁴ were tested according to the above requirements. The complete results indicate that at no point in the package inner liner will the temperature reach 200°F. It is concluded, therefore, that the fuel shipping container will not exceed 200°F under the same conditions.

4. CONTAINMENT

It is required¹⁻³ that packages maintain containment of their radioactive contents during normal and specified accident conditions. The containment boundaries and capabilities of the fuel shipping container are outlined below.

In this package, the fuel element cladding constitutes the primary containment of the nuclear material. The basket lid and outside housing lid will provide further containment of the fuel unirradiated elements.

5. SHIELDING

This section is not applicable, since the container will not be used to transport irradiated fuel elements.

6. CRITICALITY

The container loaded with any of the five types of fuel listed in Table 1.1 may be used as a Fissile Class I package.¹⁰

The analyses¹⁰ conservatively assumed that the package contained nine fuel elements in 3 x 3 square matrix instead of the proposed seven in a triangular matrix. It was also assumed that the principal damage to the package as a result of package test requirements (10-CRF-71, Energy) was that resulting from a fire. Tests^{4,13} with the borated phenolic foam insulation indicated a char depth of from 2 to 2.5 in. may be expected. The damage package evaluations were performed for a charred depth of 3 in. The absence of water from the inner container results in a very low K_{∞} , less than 0.2. Water in the inner container, or fuel element baskets, results in a K_{∞} no greater than 0.9.

7. QUALITY ASSURANCE

The regulations¹ require packaging to be designed, fabricated, and operated in conformance with an established formal quality assurance program. Compliance with this requirement is discussed in the following subsections.

7.1 Fabrication, Inspection, and Acceptance Tests

The fabrication, inspection, and acceptance tests are specified on the drawings X3E10191-002, X3E10191-003, X3E10191-010, X3E10191-011, X3E10191-100, X3E10191-101, and data sheets DS-XDE-10191-1, DS-XDE-10191-2, and DS-XDE-10191-3. The welds will be made and inspected according to the data sheets. The ferrous materials to be used in the container are specified on the data sheets to ASTM standards. The phenolic foam will

be poured as specified on the data sheets and job specification JS-31536-1, Rev. 1, dated March 28, 1968, *Fire Resistant Phenolic Foam*. Acceptance criteria are specified on the data sheets. Dimension inspection and inspection of finishes shall be performed per the data sheet to ensure that they are within the specified tolerances. A certificate of compliance with the drawings and data sheets will be issued to the owner.

7.2 Routine Operating and Inspection Procedures

The ORNL Operations Division has established routine operating and inspection procedures and standard check lists to ensure that all shipments are safe, comply with the regulations,¹⁻³ and comply with all ORNL procedures and regulations. Copies of the procedures and the check-lists are presented in Appendix C.

7.3 Periodic Maintenance and Inspections

Prior to each shipment, routine inspections are performed with the owners' procedures and check lists. The ORNL procedures are presented in Appendix C as an example. Maintenance is required only when routine inspections indicate damage. There are no time-degradable padding materials used in the construction of the containers except for gaskets, padding, and cement used in the construction of containers. Any damage or degradation to these would be detected during routine inspection and replacement effected.

7.4 Records

It is the responsibility of the owner to assume that his containers are fabricated to the specifications on the drawings and data sheets. In addition, the owner shall maintain fabrication and inspection records in an auditable form for the life of the container.

REFERENCES

1. *Code of Federal Regulations*, Title 10, Part 71, "Transport of Licensed Materials;" see also *Fed. Regist.* 31, 9941-49 (July 1966).
2. U.S. Atomic Energy Commission, "Safety Standards for the Packaging of Fissile or Other Radioactive Materials," AEC manual, vol. 0000, General Administration: Part 0500, Health and Safety, chap. 0529 (June 16, 1973).
3. *Code of Federal Regulations*, Title 49, Part 173, "Transportation;" see also *Fed. Regist.* 33, 14920-31 (October 1968).
4. A. J. Mallett and C. E. Newlon, *Protective Shipping Packages for 8- and 12-Inch Diameter UF₆ Cylinders*, ORGDP K-1714 (April 1967).
5. The International Nickel Company, *Properties of Some Metals and Alloys*, A-297 (1971).
6. 1974 *Annual Book of ASTM Standards*, Part 3, Steel - Sheet, Strip, Wire.
7. 1974 *Annual Book of ASTM Standards*, Part 5, Steel - Bars, Forgings.
8. D. S. Clark, *The Influence of Impact Velocity on the Tensile Characteristics of Some Aircraft Metals and Alloys*, NACA TN-868 (October 1942).
9. R. D. Seagren, *Oak Ridge National Laboratory Returnable Type B Gas Shipping Package*, ORNL/TM-3544 (October 1971).
10. J. T. Thomas, *Nuclear Criticality Safety Assessment of ORR, NBS, and HFBR Fuel Element Shipping Package*, ORNL/CSD/TM-77 (January 1979).
11. F. Kreith, *Principles of Heat Transfer*, International Textbook, Scranton, Pa., 1965.
12. L. B. Shappert, *Cask Designer's Guide*, ORNL/NSIC-68 (February 1970).
13. A. J. Mallett and C. E. Newlon, "New End-Loading Shipping Container for Unirradiated Fuel Assemblies," *Proceedings of Second International Symposium on Packaging and Transportation of Radioactive Materials*, Con 681001 IAEA, 1968.

APPENDIX A

Fabrication Drawings and Data Sheets

DATA SHEET

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE, TN - PADUCAH, KY

PROJECT TITLE	DATA SHEET NO	REV	ISSUE DATE
ORR Unirradiated Fuel Element Shipping Container	DS-XDE-10191-1	1*	1-16-79
JOB TITLE	PAGE OF	REQUISITION NO	
	1 2		
EQUIPMENT	PROCURED BY	INSTALLED BY	
	EJN 10191		
	PROJECT NO	ESO OR WO	
	BUILDING	PLANT	

Fabrication Notes for Dwgs. X3E-10191-002, Rev. A and X3E-10191-003, Rev. A

1. Functional Acceptance Criterion

The fuel element basket assembly (Part Number 2) will be acceptable if, when assembled and centered in the shipping container body (Part Number 8) an inspection bar 3 15/16 x 1/16 inches square and a straightness of 1/32 in. over its full length of 40 in. can be freely inserted and withdrawn from each and every one of the 7 fuel cavities. The inspection bar may have a maximum corner radius of 0.125 ± 0.015 in.

2. Fuel Element Basket Assembly Fabrication

The fuel element basket assembly (Part Number 2) may be fabricated by a combination of formed (bent) shapes and welded joints at the fabricator's option. The seams shall be joined by welds of 1/2 in. long on 4 in. centers or equal. The functional acceptance criterion shall be per note 1.

3. Suggested Fuel Basket Assembly Procedure

- Cross timbers (Part Number 14) installed in the shipping container body (Part Number 8).
- The threaded rods, nuts and lockwashers (Part Numbers 8F, 5 and 6) installed and tightened on the fuel basket assembly bottom plate (Part Number 2B).
- The fuel element basket assembly (Part Number 2) lowered into the shipping container body (Part Number 8) with the threaded rods (Part Number 8F) passing through the holes in the shipping container's bottom plate (Part Number 8C).
- The phenolic spacers (Part Number 10) will be installed between the fuel element basket upper plate (Part Number 2C) and the clip (Part Number 8E) on the inner surface of the container. The holes in the phenolic spacers will be adjusted to locate the fuel element basket in the center of the container body within ± 1/16 in.
- The threaded rod (Part Number 8F) at the bottom of the container body will be tensioned through the channel fixture (see Dwg. X3E-10191-101) by applying a 10 ft/lb torque. The threaded rods will be tack-welded, the channel fixture removed, the welds completed and finally the excess rods will be removed and the bottom plate ground smooth.

4. Welds

A. Welding and Inspection of Weld Joining Stainless Steel to Stainless Steel

All welds shall be performed according to the provisions of a qualified procedure and in accordance with the weld symbols on the fabrication drawings.

Furnish the following manufacturer's data in quantities indicated	NUMBER OF COPIES			TYPE OF DATA (CONTINUED)	NUMBER OF COPIES		
	W/Bds	Approval	Certified		W/Bds	Approval	Certified
1. Outline dimensional drawings				6. Test & Inspection Reports			
2. Operation & Performance data				7. Materials Certification			
3. Literature & Parts list				8.			
4. Operating & Maint. instructions				9.			
5. Installation instructions				10.			
PREPARED BY <i>RW Mowring</i>	APPROVED BY <i>JH Evans</i> F.C. Davis <i>by JHE</i>			PRINCIPAL ENGINEER <i>RW Mowring</i>	PROJECT ENGR. IMANAGER		

JUN 1981
12 15 79

The fabricator shall qualify all welding procedures used in accordance with Section IX of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. A 100% visual inspection is required for all welds and the welds shall comply with paragraph 8.15 of AWS D1.1-1975. Visible defects such as cracks, pinholes, incomplete fusion, cold laps, porosity and under cuts shall be removed and repaired by grinding, or by grinding and rewelding. The repaired weld shall meet the quality requirements of the original weld. Written inspection reports are not required.

B. Welding and Inspection of Weld Joining Carbon Steel to Stainless Steel

The welding process is DC Gas tungsten-arc, argon shielded. The filler material shall be ERNICKR-3 (Inconel 82T). The preheat temperature shall be 60-300°F. A 100% visual inspection is required for all welds and the welds shall comply with paragraph 8.15 of AWS D1.1-1975. Visible defects such as cracks, pinholes, incomplete fusion, cold laps, porosity and undercuts shall be removed and repaired by grinding, or by grinding and rewelding. The repaired weld shall meet the quality requirements of the original weld. Written inspection reports are not required.

5. Materials

- A. Lumber shall be douglas fir or southern pine, with moisture content 18% or less, No. 2 or better grade. The plywood may be any grade.
- B. Stainless sheet per ASTM A240 or A167, type 304 or 347 hot finished and annealed.
- C. Stainless plate per ASTM A240, type 304 or 304L or 347 hot rolled.
- D. Aluminum sheet, AA2024-T4 or 6061-T6 ASTM B209.
- E. Steel bar and structural shapes, type 304L or 347, ASTM 276 or A479, hot rolled, annealed and pickled.
- F. Screw, alloy steel ASTM A449, SAE 5, 105,000 psi min. tensile.
- G. Nut, stainless steel type 303, ASTM A194, Grade 8F.
- H. Sheet, phenolic laminated brown or natural fine weave continuous filament wovenglass, fabric laminate melamine resin base nema Grade GB-112M.
- I. Sheet neoprene, 50 to 60 durometer hardness.
- J. Screw, stainless steel, any 300 series.
- K. Carbon steel plate per ASTM A-516 grade 60 hot rolled and annealed.

6. Foam Filling

Foam filling shall be fire resistant phenolic foam and water proofed per job specification JS-31536-1 and as follows.

- A. Fill the top section by foaming in one pour into top shell (container lid) and using a mold of specified finished shape. Weight of foam filling shall be 2 1/2 lb $\pm$ 10%.
- B. Fill the bottom section between the fuel element basket and container body in two approximately equal weight pours with the exposed finish surface being shaped by foaming into a mold. Weight of finished foam filling the bottom section shall be 35 lb $\pm$ 10%. Materials may be substituted per K/TL-729, Evaluation of Materials in Fire-Resistant Phenolic Foam, C. E. Daugherty, G. E. Harris and R. R. Wright, March 1, 1978.

JS-31536-1
Original

K/TL-729
Substitute

Material 2

Union Carbide Corporation (UCC) V-6663

Material 6

Owens-Corning Fiberglas No. 833

Material 4

PO-2685 Eastman

Material 5

Technical Grade Oxalic Acid, H₂C₂O₄

7. Dimensional Inspection and Inspection of Finishes

All dimensions, angles and finishes shall be shop inspected to insure they are within the specified tolerance. A certification of compliance with the drawings and data sheets will be issued by the fabricator to the owner.

*General revisions to reflect the replacement of carbon steel components with stainless steel components:

- (1) Item 4, welding change to carbon steel to stainless steel welding requirement.
- (2) Item 5, deletion of carbon steel specification and addition of stainless steel specifications.
- (3) Deletion of painting requirements.
- (4) Item 6, addition to foam filling requirements.

DATA SHEET

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE, TN - PAD. 1 AM, KY

PROJECT TITLE
HFBR Unirradiated Fuel Element Shipping Container

EQUIPMENT

DATA SHEET NO.		REV.	ISSUE DATE
DS-XDE-10191-2		1*	1-16-79
PAGE	OF	REQUISITION NO.	
1	3		
PROCURED BY		INSTALLED BY	
EJN 10191			
PROJECT NO.		ESO OR WO	
BUILDING		PLANT	

Fabrication Notes for Dwg. X3E-10191-010, Rev. A and X3E-10191-011, Rev. A

1. Functional Acceptance Criterion

The fuel element basket assembly (Part Number 2) will be acceptable if, when assembled and centered in the shipping container body (Part Number 8) an inspection bar 3 15/16 x 1 1/16 inches square and a straightness of 1/32 in. over its full length of 40 in. can be freely inserted and withdrawn from each and every one of the 7 fuel cavities. The inspection bar may have a maximum corner radius of 0.125 ±.015 in.

2. Fuel Element Basket Assembly Fabrication

The fuel element basket assembly (Part Number 2) may be fabricated by a combination of formed (bent) shapes and welded joints at the fabricator's option. The seams shall be joined by welds of 1/2 in. long on 4 in. centers or equal. The functional acceptance criterion shall be per note 1.

3. Suggested Fuel Basket Assembly Procedure

- Cross timbers (Part Number 14) installed in the shipping container body (Part Number 8).
- The threaded rods, nuts and lockwashers (Part Numbers 8F, 5 and 6) installed and tightened on the fuel basket assembly bottom plate (Part Number 2B).
- The fuel element basket assembly (Part Number 2) lowered into the shipping container body (Part Number 8) with the threaded rods (Part Number 8F) passing through the holes in the shipping container's bottom plate (Part Number 8C).
- The phenolic spacers (Part Number 10) will be installed between the fuel element basket upper plate (Part Number 2C) and the clip (Part Number 8E) on the inner surface of the container. The holes in the phenolic spacers will be adjusted to locate the fuel element basket in the center of the container body within 1/16 in.
- The threaded rod (Part Number 8F) at the bottom of the container body will be tensioned through the channel fixture (see Dwg. X3E-10191-101) by applying a 10 ft/lb torque. The threaded rods will be tack-welded, the channel fixture removed, the welds completed and finally the excess rods will be removed and the bottom plate ground smooth.

4. Welds

A. Welding and Inspection of Weld Joining Stainless Steel to Stainless Steel

All welds shall be performed according to the provisions of a qualified procedure and in accordance with the weld symbols on the fabrication drawings.

Furnish the following manufacturer's data in quantities indicated	NUMBER OF COPIES			TYPE OF DATA (CONTINUED)	NUMBER OF COPIES		
	W.B.'s	Approval	Certified		W.B.'s	Approval	Certified
1. Outline & dimensional drawings				6. Test & inspection Reports			
2. Operation & Performance data				7. Materials Certification			
3. Literature & Parts list				8.			
4. Operating & Maint. instructions				9.			
5. Installation instructions				10.			
PREPARED BY <i>RW Manning</i>	APPROVED BY <i>H. S. ...</i>			PRINCIPAL ENGINEER <i>RW Manning</i>	PROJECT ENGR. MANAGER		

UCN-25417
12-10-77

The fabricator shall qualify all welding procedures used in accordance with Section IX of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. A 100% visual inspection is required for all welds and the welds shall comply with paragraph 8.15 of AWS D1.1-1975. Visible defects such as cracks, pinholes, incomplete fusion, cold laps, porosity and under cuts shall be removed and repaired by grinding, or by grinding and rewelding. The repaired weld shall meet the quality requirements of the original weld. Written inspection reports are not required.

B. Welding and Inspection of Weld Joining Carbon Steel to Stainless Steel

The welding process is DC Gas tungsten-arc, argon shielded. The filler material shall be ERNICKR-3 (Inconel 82T). The preheat temperature shall be 60-300°F. A 100% visual inspection is required for all welds and the welds shall comply with paragraph 8.15 of AWS D1.1-1975. Visible defects such as cracks, pinholes, incomplete fusion, cold laps, porosity and undercuts shall be removed and repaired by grinding, or by grinding and rewelding. The repaired weld shall meet the quality requirements of the original weld. Written inspection reports are not required.

5. Materials

- A. Lumber shall be douglas fir or southern pine, with moisture content 18% or less, No. 2 or better grade. The plywood may be any grade.
- B. Stainless sheet per ASTM A240 or A167, type 304 or 347 hot finished and annealed.
- C. Stainless plate per ASTM A240, type 304 or 304L or 347 hot rolled.
- D. Aluminum sheet, AA2024-T4 or 6061-T6 ASTM B209.
- E. Steel bar and structural shapes, type 304L or 347, ASTM 276 or A479, hot rolled, annealed and pickled.
- F. Screw, alloy steel ASTM A449, SAE 5, 105,000 psi min. tensile.
- G. Nut, stainless steel type 303, ASTM A194, Grade 8F.
- H. Sheet, phenolic laminated brown or natural fine weave continuous filament wovenglass, fabric laminate melamine resin base nema Grade GB-112M.
- I. Sheet neoprene, 50 to 60 durometer hardness.
- J. Screw, stainless steel, any 300 series.
- K. Carbon steel plate per ASTM A-516 grade 60 hot rolled and annealed.

6. Foam Filling

Foam filling shall be fire resistant phenolic foam and water proofed per job specification JS-31536-1 and as follows.

- A. Fill the top section by foaming in one pour into top shell (container lid) and using a mold of specified finished shape. Weight of foam filling shall be $2 \frac{1}{2} \text{ lb} \pm 10\%$.
- B. Fill the bottom section between the fuel element basket and container body in two approximately equal weight pours with the exposed finish surface being shaped by foaming into a mold. Weight of finished foam filling the bottom section shall be $45 \text{ lb} \pm 10\%$. Materials may be substituted per K/TL-729, Evaluation of Materials in Fire-Resistant Phenolic Foam, C.E. Daugherty, G. E. Harris, and R.R. Wright, March 1, 1978

JS-31536-1
Original

K/TL-729
Substitute

Material 2

Union Carbide Corporation (UCC) V-6663

Material 6

Owens-Corning Fiberglass No. 833

Material 4

PO-2685 Eastman

Material 5

Technical Grade Oxalic Acid, $\text{H}_2\text{C}_2\text{O}_4$

7. Dimensional Inspection and Inspection of Finishes

All dimensions, angles and finishes shall be shop inspected to insure they are within the specified tolerance. A certification of compliance with the drawings and data sheets will be issued by the fabricator to the owner.

*General revisions to reflect the replacement of carbon steel components with stainless steel components:

- (1) Item 4, welding change to carbon steel to stainless steel welding requirement.
- (2) Item 5, deletion of carbon steel specification and addition of stainless steel specifications.
- (3) Deletion of painting requirements.
- (4) Item 6, addition to foam filling requirements.

DATA SHEET

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE, TN - PADUCAH, KY

PROJECT TITLE		DATA SHEET NO.	REV.	ISSUE DATE
NBSRR Unirradiated Fuel Element Shipping Container		DS-XDE-10191-3	1*	1-16-79
JOB TITLE		PAGE	OF	REQUISITION NO.
		1	3	
EQUIPMENT		PROCURED BY	INSTALLED BY	
		EJN 10191		
		PROJECT NO.	ESO OR WO	
		BUILDING	PLANT	

Fabrication Notes for Dwg. X3E-10191-100, Rev. A and X3E-10191-101, Rev. A

1. Functional Acceptance Criterion

The fuel element basket assembly (Part Number 2) will be acceptable if, when assembled and centered in the shipping container body (Part Number 8) an inspection bar $4\frac{7}{16} \pm 1/16$ inches square and a straightness of $1/32$ in. over its full length of 70 in. can be freely inserted and withdrawn from each and every one of the 7 fuel cavities. The inspection bar may have a maximum corner radius of 0.125 ± 0.015 in.

2. Fuel Element Basket Assembly Fabrication

The fuel element basket assembly (Part Number 2) may be fabricated by a combination of formed (bent) shapes and welded joints at the fabricator's option. The seams shall be joined by welds of $1/2$ in. long on 4 in. centers or equal. The functional acceptance criterion shall be per note 1.

3. Suggested Fuel Basket Assembly Procedure

- Cross timbers (Part Number 14) installed in the shipping container body (Part Number 8).
- The threaded rods, nuts and lockwashers (Part Numbers 8F, 5 and 6) installed and tightened on the fuel basket assembly bottom plate (Part Number 2B).
- The fuel element basket assembly (Part Number 2) lowered into the shipping container body (Part Number 8) with the threaded rods (Part Number 8F) passing through the holes in the shipping container's bottom plate (Part Number 8C).
- The phenolic spacers (Part Number 10) will be installed between the fuel element basket upper plate (Part Number 2C) and the clip (Part Number 8E) on the inner surface of the container. The holes in the phenolic spacers will be adjusted to locate the fuel element basket in the center of the container body within $\pm 1/16$ in.
- The threaded rod (Part Number 8F) at the bottom of the container body will be tensioned through the channel fixture (see Dwg. X3E-10191-101) by applying a 10 ft/lb torque. The threaded rods will be tack-welded, the channel fixture removed, the welds completed and finally the excess rods will be removed and the bottom plate ground smooth.

4. Welds

- Welding and Inspection of Weld Joining Stainless Steel to Stainless Steel
All welds shall be performed according to the provisions of a qualified procedure and in accordance with the weld symbols on the fabrication drawings.

Furnish the following manufacturer's data in quantities indicated:	NUMBER OF COPIES			TYPE OF DATA	NUMBER OF COPIES		
	W/Bids	Approval	Certified		W/Bids	Approval	Certified
1. Operating & Maintenance Drawings				6. Test & Inspection Reports			
2. Operating & Performance data				7. Materials Certification			
3. Literature & Parts list				8.			
4. Operating & Maint. Instructions				9.			
5. Installation Instructions				10.			
APPROVED BY	APPROVED BY			PRINCIPAL ENGINEER	PROJECT ENGR. MANAGER		
<i>R.W. Mouring</i>	<i>JAG</i>			<i>R.W. Mouring</i>	<i>JAG</i>		

The fabricator shall qualify all welding procedures used in accordance with Section IX of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. A 100% visual inspection is required for all welds and such as cracks, pinholes, incomplete fusion, cold laps, porosity and under cuts shall be removed and repaired by grinding, or by grinding and rewelding. The repaired weld shall meet the quality requirements of the original weld. Written inspection reports are not required.

B. Welding and Inspection of Weld Joining Carbon Steel to Stainless Steel

The welding process is DC Gas tungsten-arc, argon shielded. The filler material shall be ERN1CR-3 (Inconel 82T). The preheat temperature shall be 60-300°F. A 100% visual inspection is required for all welds and the welds shall comply with paragraph 8.15 of AWS D1.1-1975. Visible defects such as cracks, pinholes, incomplete fusion, cold laps, porosity and undercuts shall be removed and repaired by grinding, or by grinding and rewelding. The repaired weld shall meet the quality requirements of the original weld. Written inspection reports are not required.

5. Materials

- A. Lumber shall be douglas fir or southern pine, with moisture content 18% or less, No. 2 or better grade. The plywood may be any grade.
- B. Stainless sheet per ASTM A240 or A167, type 304 or 304L or 347 hot rolled.
- C. Stainless plate per ASTM A240, type 304 or 347 hot rolled.
- D. Aluminum sheet, AA2024-T4 or 6061-T6 ASTM B209.
- E. Steel Bar and structural shapes, type 304L or 347, AST, 276 or A479, hot rolled and pickled.
- F. Screw, alloy steel ASTM A449, SAE 5, 105,000 psi min. tensile.
- G. Nut, stainless steel type 303, ASTM A194, Grade 8F.
- H. Sheet, phenolic laminated brown or natural fine weave continuous filament wovenglass, fabric laminate melamine resin base nema Grade GB-112M.
- I. Screw, stainless steel, any 300 series.
- J. Sheet neoprene, 50 to 60 durometer hardness.
- K. Carbon steel plate per ASTM A-516 grade 60 hot rolled and annealed.

6. Foam Filling

Foam filling shall be fire resistant phenolic foam and water proofed per job specification JS-31536-1 and as follows.

- A. Fill the top section by foaming in one pour into top shell (container lid) and using a mold of specified finished shape. Weight of foam filling shall be 2 1/2 lb $\pm 10\%$.
- B. Fill the bottom section between the fuel element basket and container body in two approximately equal weight pours with the exposed finish surface being shaped by foaming into a mold. Weight of finished foam filling the bottom section shall be 60 lb $\pm 10\%$. Materials may be substituted per K/TL-729, Evaluation of Material in Fire Resistant Phenolic Foam, C. E. Daugherty, G. E. Harris, and R. R. Wright, March 1, 1978.

JS-31536-1
Original

K/TL-729
Substitute

Material 2

Union Carbide Corporation (UCC) V-6663

Material 6

Owens-Corning Fiberglas No. 833

Material 4

PO-2685 Eastman

Material 5

Technical Grade Oxalic Acid, $H_2C_2O_4$

7. Dimensional Inspection and Inspection of Finishes

All dimensions, angles and finishes shall be shop inspected to insure they are within the specified tolerance. A certification of compliance with the drawings and data sheets will be issued by the fabricator to the owner.

*General revisions to reflect the replacement of carbon steel components with stainless steel components:

- (1) Item 4, welding change to carbon steel to stainless steel welding requirement.
- (2) Item 5, deletion of carbon steel specification and addition of stainless steel specifications.
- (3) Deletion of painting requirements.
- (4) Item 6, addition to foam filling requirements.

JOB

SPECIFICATION

STANDARD REFERENCE INFORMATION

UNION CARBIDE CORPORATION
NUCLEAR DIVISION

ORRDP, OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY

SUBJECT

FIRE RESISTANT PHENOLIC FOAM

NUMBER	JS-31526-1 Rev. 1
DATE	3-28-68
REVISED	3-28-68
PAGE	1 of 5

SCOPE

This specification shall cover materials and procedures for mixing and applying foamed-in-place fire resistant phenolic foam where specified on the drawings.

MATERIALS AND PROPORTIONS

All materials used in the fire resistant foam shall be as listed below and shall be prepared by blending, screening, etc., as defined. Substitutions of materials may be made only where noted. Total quantity of materials shall be as required to fill the container cavities and provide the finished foam weight as defined on the drawings. Individual weight quantity of each component material shall be such to provide a finished foam material mixture of the proportionate blend specified below.

<u>Material</u>	<u>Vendor - Trade Name</u>	<u>Component Weight per 100 Lb. of Matl. (Lbs.)</u>
<u>Liquid Components</u>		
Phenolic Resin	UCC Plastics Division BRL-2760 (Foam Density 1.8-2.0 Lbs./ft. ³)*	65.8 ± 0.2
Surfactant	UCC Plastics Division Silicone Surfactant L-530, or equal	2.0 ± 0.1
Refrigerant 113	DuPont Freon 113, or equal	6.6 ± 0.1
<u>Powder Components</u>		
Boric Anhydride (B ₂ O ₃), Powder, Reagent Grade, -100 + 200 Mesh	Varlacoid Chemical Company No. 1136, or equal	4.1 ± 0.1

* Resin foam value as determined by method used at the Marietta Ohio Plant of the UCC Plastics Division.

3-28-68
JL

APPROVED BY: *Paul Zimmerman*

STANDARD REFERENCE INFORMATION

SUBJECT

FIRE RESISTANT PHENOLIC FOAM

NUMBER	JS-31536-1 Rev. 1
DATE	3-28-66
REVISED	3-28-68
PAGE	2 of 5

<u>Material</u>	<u>Vendor - Trade Name</u>	<u>Component Weight per 100 lb. of Matl. (Lbs.)</u>
<u>Powder Components (Contd)</u>		
Boric Anhydride (B_2O_3) Powder, Reagent Grade, -200 Mesh	Varlacoid Chemical Company No. 1137, or equal.	4.1 ± 0.1
Oxalic Acid, $H_2C_2O_4$, Anhydrous Powder, Reagent Grade	Baker and Adamson No. 1135, or equal	8.2 ± 0.1
<u>Reinforcing Component</u>		
Fiberglass Rovings 1/4" Chopped Lengths	Owens-Corning Fiberglas No. 805 (HSI), or equal	1.2 ± 0.1

MATERIAL STORAGE REQUIREMENTSPhenolic Resin

1. Store in airtight storage container.
2. Maximum shelf life is three months from date of manufacture if stored at room temperature.

or

Maximum shelf life is six months from date of manufacture if stored at a temperature of $40^\circ \pm 5^\circ F$.

NOTE: Date of manufacture should be marked on the storage container.

Pre-blended Liquid Components

The three liquid components may be pre-blended or stored separately. If pre-blended, the liquid mixture may be stored in airtight storage containers at a temperature of $40^\circ \pm 5^\circ F$ for a period of time not exceeding one month prior to final blending, provided this additional time does not exceed the maximum storage life for the phenolic resin. If the liquid components are stored separately, the same storage requirements must be observed for the phenolic resin component.

Powder Components

All powders shall be stored in airtight storage containers at room temperature before and after pre-blending to prevent absorption of moisture.

APPROVED BY: _____

UNCLASSIFIED
DATE 1-28-83

STANDARD REFERENCE INFORMATION

SUBJECT

FIRE RESISTANT PHENOLIC FOAM

NUMBER	JS-31536-1 Rev. 1
DATE	3-28-60
REVISED	3-26-58
PAGE	3 of 5

All Other Materials

Store all other component materials in airtight storage containers at room temperature until ready for blending.

PREPARATION OF RECEIVER CONTAINER AND ACCESSORIESContainer

In preparing a container for receiving the foamed-in-place filling, all loose inner pieces shall be securely anchored in place to prevent displacement by the foam, and vent holes to prevent voids in the finished foam and to provide gas relief when exposed to high heat shall be drilled as defined on the drawings. The necessary blocking, framing, bracing, etc., shall be installed to hold in place the container shell, ends, lining, etc., as applicable, and prevent distortion to out-of-tolerance condition during the foaming operation.

Molds

Molds to shape exposed surfaces of foam shall be installed and secured in position just after the final foam raw material is placed so foam can expand into the mold. Air vent holes not exceeding 1/4" in diameter may be made at intervals in a mold to allow for escaping air and thereby prevent void spaces in the finished surface. Molds shall be made of such strength to prevent distortion to out-of-tolerance condition during the foaming operation. A mold release (e.g. Emerson and Cuming mold release compound No. 122S or DuPont Teflon) shall be applied to mold surfaces which will contact foam material so that the mold can be removed without damaging the finished foam surface.

Cleaning Before Foaming

All sawdust, bits of wood, metal filings, water droplets, grease, oil, and other foreign particles shall be removed from the molds or container cavities before foam raw material is added.

MIXING PROCEDURESPre-Blending

Liquid Components - Pre-blend liquid components in any order by combining the ingredients and stirring to a uniform consistency. Temperature of the phenolic resin shall be 60° ± 5°P when it is added to the mix. If final blending is to be delayed, reseal the blended components so atmospheric exposure is reduced to a minimum.

UCM-3748
(1-2-61)

STANDARD REFERENCE INFORMATION

SUBJECT	NUMBER
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	DATE
	3-28-66
FINE RESISTANT PHENOLIC FOAM	REVISED
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Powder Components

Screen all components through a sieve (National Bureau of Standards No. 40) and pre-blend to a uniform consistency. Reseal blended components so atmospheric exposure is reduced to a minimum.

Final Blending

1. Add liquid components or pre-blended liquid components to mixer tub and stir to a uniform consistency, about 2 minutes for pre-blended components. Temperature of the phenolic resin or pre-blended liquid components shall be $60^{\circ} \pm 5^{\circ}\text{F}$ when it is added to the mix.
2. Add fiberglass and mix to a uniform consistency.
3. Add the pre-blended powder components rapidly and mix to a uniform consistency, 30 to 60 seconds.
4. Quickly transfer the mixed raw material to the receiver container so that the foaming action takes place within the container.

PLACING AND CURING FOAM MATERIAL

The mixed foam raw material shall be spread evenly over the bottom surface of the receiver container so foam expands in relatively uniform layers. The first pour of bottom section should be tamped immediately after foaming begins to minimize size of void spaces. Air cure at room temperature for at least one hour to allow for full expansion of foam.

After foaming action and curing is completed on a pour, the next pour of material can be spread evenly on top of the previous expanded layer. All sequential pours shall proceed with a minimum delay so that atmospheric exposure of the internal fibers is minimized. The number of pours shall be as specified on the drawings. After the final pour, the foam shall be allowed to cure at least four hours at room temperature before bracing, molds, and accessories are removed.

NOTE: Sequential pours are self bonding to the previous pour with no apparent voids or cleavage planes.

REMOVAL OF BRACING, MOLDS, AND ACCESSORIES AND FINISHING WORKGeneral

All bracing, molds, and any accessories not part of the finished container, as defined on the drawings, shall be removed after foaming and curing operations are completed. Any extruded foam material (e.g. extrusions through

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APPROVED BY _____

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FIRE RESISTANT PHENOLIC FOAM		

air vent holes) shall be carefully trimmed and removed to provide a smooth surface over the exterior and interior surface of the container. Foam material splashed onto exposed surfaces of the container shall be removed.

All mold release, grease, dust, etc., which would prevent a coating from adhering properly shall be removed from the finished foam surfaces, prior to coating, by wiping with a soft cloth saturated with tri-chloroethylene.

Patching Voids in Finished Foamed Surface Material

Voids spaces in the finished foam surface shall be patched by filling with additional foam raw material and allowing the material to expand and cure. Excessive foam or rough spots left by this process shall be dressed smooth with the surrounding surface to give an overall uniform surface.

Waterproofing

Seal watertight all holes in outer shell and inner liner when applicable, (e.g. vent holes, gaps around caps for fill holes, nail and screw holes, etc., as applicable) with two coats of epoxy** prior to finish coat of paint. Seal watertight all exposed surfaces of foam with two coats of epoxy.

CLEANING AGENTS

Cellosolv, acetone, or other cleaning agents may be used for cleaning utensils or removing particles of splattered foam from metal parts only of container surfaces.

OTHER

The following typical chemical analysis of cured foam may be used as reference data for nuclear calculations.

	<u>Wt. %</u>
Carbon	41.0
Hydrogen	4.5
Boron	3.2
Silicon	2.2
Chlorine	0.5
Nitrogen	nil
Fluorine	nil
Oxygen	48.6 (by difference)

** Epoxy shall be Araldite #502 epoxy with hardener #951 as manufactured by Ciba Products Company, Fairlawn, New Jersey, or equal.

UC-31536
(1) 5-68

APPROVED BY _____

APPENDIX B

Fuel Element Drawings

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APPENDIX C

Routine Packaging and Inspection Procedures

PRE-USE INSPECTION CHECKLIST
UNIRRADIATED FUEL ELEMENT SHIPPING CASKOak Ridge National Laboratory
Oak Ridge, Tennessee

Container Serial No.

Reference Drawings: X3E-10191-002
X3E-10191-003

BY

DATE

- A Visually inspect container exterior for shipping damage, rust and general state of repair.
- B Visually inspect container interior for rust, condition of foam, moisture and general state of repair.
- C Visually inspect neoprene spacers and gasket.
- D Visually inspect basket closure bolts, nuts and lock washers for condition and conformance to D-1 through D-5.
- 1 Number required - 8 each
 - 2 Bolts - Hex Hd. 3/8"-16 UNC-2 1-1/4" long alloy steel ASTM A-449, SAE 5, 105,000 psi min tensile.
 - 3 Nuts - SST 3/8"-16 UNC (welded to basket)
 - 4 Lock washer - 3/8" carbon steel
 - 5 Nuts and bolts engage freely by hand
- E Visually inspect closure bolts, nuts and lock washers for condition and conformance to E-1 through E-5.
- 1 Number required - 6 ea.
 - 2 Bolts - Hex Hd. 5/8"-11 UNC-2 1-1/4" stainless steel Type 304 ASTM A-193 Grade B8.

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- 3 Nuts - SST 3/8"-16 UNC (welded to container flange)
- 4 Lock washer - 3/8 carbon steel
- 5 Nuts and bolt engage freely by hand.

List deficiencies found and corrective action taken below.

Approved by: _____

PROCEDURE FOR LOADING
ORR UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER

	DATE	NAME
1. Record element numbers
1____ 2____ 3____ 4____ 5____
6____ 7____		
2. Clean inside of shipping container		
3. Inspect container. No loose or foreign material to be present inside shipping container. Record container number ____.		
4. Visually inspect cask exterior for shipping damage, rust and general state of repair.		
5. Visually inspect basket spacer and gasket.		
6. Visually inspect basket closure, bolts, nuts and lock washers for condition and conformance to 6-a through 6-c.		
a. Number Required		
b. Bolts - Hex Hd.		
c. Nuts		
d. Lock washers carbon steel 3/8" nominal size		
e. Nuts and bolts engage freely by hand.		
7. Visually inspect lid closure, bolts, nuts and lock washers for condition and conformance to 7-a through 7-e.		
a. Number Required		
b. Bolts - Hex Hd.		
c. Nuts		
d. Lock washers carbon steel 5/8" nominal size		
e. Nuts and bolts engage freely by hand.		
8. Load elements. This operation to be witnessed by ORNL representative.
Heat seal one end of polyethylene tube.
Slide element into tube.
Heat seal top end of polyethylene bag. Use vacuum cleaner to pull air out of bag.
Place element(s) in container (maximum 7 elements). Replace cover on container. Be certain the element is below the flat of the cover and that the polyethylene bag is tucked in properly. Bolt basket lid in place. (Torque bolts to 25 ft-lbs.)		

9. Place container lid in place and bolt to container. (Torque bolts to 25 ft-lbs.)
10. Radioactivity inspect (10 CFR Part 71)
Write and apply radioactive Class I label.
Accept ____ Reject ____
11. Place - tamper - safe seal U.S. Treasury Type "E" (cup type) on shipping container.
Record Seal # _____
Witnessed by inspection or QA Representative

Time _____ Date _____

I have witnessed sequence 11 and accept delivery of the fuel elements. I certify that fuel element numbers listed in seq. 1 and loaded in seq. 8 is tamper-safe sealed in the shipping container with the above numbered tamper-safe seal.

ORNL Representative _____

Enter seal number in daily inspection log.

12. Check shipping container for: this operation to be witnessed by ORNL Representative.
 1. All bolts in lid and tight.
 2. Tamper-safe seal in place on lid.
 3. Radioactive label.
 4. Shipping label and shipping papers securely attached.

Witnessed oper. 12

ORNL Representative _____

APPENDIX D

Penetration Tests

 UNION
CARBIDE

INTERNAL CORRESPONDENCE

NUCLEAR DIVISION

To: File

Date:

Location:

January 29, 1976

Development Engineering

 Cc: K. K. Chipley
 E. M. King
 J. M. Robinson
 L. B. Shappert

On December 22, 1975, I performed the "Penetration" Test described in Annex 1 of AEC MC-0529 on the existing packages and models listed on the attached data sheet. In all cases the resulting damage was a small dent. It is now obvious that this test will not reduce the effectiveness of steel or stainless steel jacketed packages and that the resulting damage is insignificant.

 John Evans

JE:gl

Attachment

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Page 2 - Certificate No. 9853 - Revision 0

contained in fuel plates as reactor fuel elements.

(2) Fissile Class: I

DATA SHEET
PENETRATION TEST - AEC MC 0529

CONTAINER		LOCATION	INDENTATION	
			DIA.	DEPTH
B. of E.	648	Side	3/8	.006
ORNL	8L12-115	Top Body	5/16	.007
ORNL	8L12-115	Plug	1/2	.065
LIL Test Container		Side	3/8	.005
Tube Shield		Side	3/8	.003
55 Gal. Drum		Side	≈ 3	.137
55 Gal. Drum		Top	≈ 2 1/4	.147
ORNL	456-200	Side	7/16	.005
B. of E.	2022	Side (Aluminum Wrapper)	1/2	.036
B. of E.	2022	Side (Steel Shell Thick Paint)	3/8	.020

APPENDIX E

Approval Documents

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

February 28, 1979

To: R. W. Mouring

Subject: Approval of Safety Analysis Report for Packaging
Unirradiated Fuel Element Shipping Container

The draft (received February 2, 1979) of the report has been reviewed by the Transportation Committee. The draft was approved for technical content and approach — for submission to the Committee from individual members of the Committee have been forwarded for consideration.

E. M. King

E. M. King
Transportation Committee

EMK:jr

cc: Committee Members
G. H. Burger
J. A. Cox
J. H. Evans
R. V. McCord

June 7, 1979

Union Carbide Corporation
Nuclear Division
ATTN: Dr. Herman Postma
Director
Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37830

Gentlemen:

**SAFETY ANALYSIS REPORT FOR PACKAGING THE UNIRRADIATED FUEL SHIPPING
CONTAINER**

Reference is given to the letter dated April 26, 1979, from M. E. Ramsey in regard to the above subject.

The draft Safety Analysis Report for Packaging (SARP) has been reviewed by the staff of the ORO Safety and Environmental Control Division. The SARP is approved for publication.

Enclosed is a copy of the ORO Certificate of Compliance. The original Certificate of Compliance has been sent directly to the authors so that it may be reproduced for inclusion as an Appendix to the SARP. The original should be returned to ORO after publication.

The closure arrangement for these containers is considered to be an improvement over the standard drum closure ring used on the 12" diameter UF₆ overpack which was successfully tested to Type B package requirements. However, since the closures are different and an engineering evaluation does not appear feasible, we request that a drop test be made on a prototype. NRC has raised questions on the closure of the ORNL gas cylinder fire impact shield. Since licensees will be using both the unirradiated fuel shipping container and the gas cylinder fire and impact, NRC questions should be resolved.

Sincerely,

Joseph A. Lenhard
Assistant Manager for Energy
Research and Development

MS-334:WAP

DOE Form EV-418
(11/77)
10 CFR 71U.S. DEPARTMENT OF ENERGY
CERTIFICATE OF COMPLIANCE
For Radioactive Materials Packages

1a. Certificate Number	1b. Revision No.	1c. Package Identification No.	1d. Page No.	1e. Total No. Pages
9853	0	USA/9853/BF	1	3

2. PREAMBLE

2a. This certificate is issued to satisfy Sections 173.393a, 173.394, 173.395, and 173.396 of the Department of Transportation Hazardous Materials Regulations (49 CFR 170-189).

2b. The packaging and contents described in item 5 below meets the safety standards set forth in Subpart C of Title 10, Code of Federal Regulations, Part 71 - Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions.

2c. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application.

1. Prepared by (Name and address)	2. Title and Identification of report or application	3. Date
Oak Ridge National Laboratory Post Office Box X Oak Ridge, Tennessee 37830	Safety Analysis Report for Packaging: The Unirradiated Fuel Shipping Container	Aug 1979

Report: ORNL/FNG/TM-15

4. CONDITIONS

This certificate is conditional upon the fulfilling of the requirements of Subpart D of 10 CFR 71, as applicable, and the conditions specified in item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Fissile Class, Other Conditions, and References

a. Packaging:

(1) Model: ORNL Unirradiated Fuel Shipping Container

(2) Description:

Packaging for unirradiated fissile material as fuel elements. The fuel elements are positioned in a basket consisting of seven square cavities fabricated from 16 gauge plate and a base fabricated from eleven gauge plate. The plate is Type 300 stainless steel. Eight 3/8" nuts and bolts retain the basket lid, which is made from 0.125" thick aluminum, in place. The basket is positioned inside a cylindrical outer shell. The outer shell and lid are fabricated from eleven gauge plate and the base is 1/4" thick plate. The plate for the shell is Type 300 stainless steel. The outer lid is held in place by six 5/8" nuts and bolts. The basket is supported on 2" x 6" timbers inside the outer shell. The remaining space around the basket is filled with phenolic foam insulation.

There are different types of packages. Table 1 describes the details of each design.

b. Contents:

(1) Type and form of material

The uranium is enriched to 93% ²³⁵U and is in the oxide form. It is

6a. Date of Issuance	6b. Expiration Date
JUN 4 1979	

FOR THE U.S. DEPARTMENT OF ENERGY

7a. Address of DOE Issuing Office	7b. Signature, Name, and Title of DOE Approving Official
U. S. Department of Energy Post Office Box E Oak Ridge, Tennessee 37830	William H. Travis, Director Safety and Environmental Control Division

E-6

Union Carbide Corporation
Nuclear Division

2

June 7, 1979

Enclosure:
As stated

cc: C. A. Keller, MS-30, w/encl.
T. H. Hardin, AD-46, w/encl.
J. E. Rounsaville, ER-111, w/encl.
W. H. Travis, MS-33, w/encl.
R. F. Hibbs, UCC-ND, w/encl.

TABLE 1
SUMMARY DESIGN DATA
CONTAINERS AND FUEL ELEMENTS

Type	Gross Weight (lb.)	Container Outside		Base (In.)	Inner Basket		Nominal Dimensions (In.)	Maximum ²³⁵ U Per Fuel Element (g)
		Length (In.)	Diameter (In.)		Length (In.)	Cavities*		
I. A. ORR ^a	580	56 5/8	24 1/2	29 x 29	38 3/4	4 x 4	A. 38 3/8 x 3.033 x 3.397	370
B. BSR ^b & PCA ^c							B. 34 3/8 x 2.996 x 3.397	370
II. HFBR ^d	700	75 1/2	24 1/2	29 x 29	57 1/2	4 x 4	57 1/4 x 2.878 x 3.218	370
III. NBSRR ^e	850	87 1/8	26	30 1/2 x 30 1/2	69 3/16	4 1/2 x 4 1/2	68 51/64 x 3.125 x 3.8125	370

a. Oak Ridge Research Reactor

b. Bulk Shielding Reactor

c. Pool Critical Assembly

d. High-Flux Beam Reactor

e. National Bureau of Standards Research Reactor

*7 Cavities per basket; 1 fuel element per cavity

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27. R. A. Just	69. ORNL Patent Office

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77. R. E. Harris, DOE, ORO
78. Assistant Manager, Energy Research and Development, DOE-ORO
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80. R. H. Odegarden, NRC, Office of Regulation, Washington, DC 20545

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- 82-86. R. W. Powell, Brookhaven National Laboratory, Upton, NY 11973
- 87. W. A. Pryor, DOE, ORO
- 88-92. Tawfic Raby, Chief of Reactor Operations, National Bureau of
Standards, Washington, DC 20234
- 93. R. Rawl, U.S. Department of Transportation, 6th and D Street,
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- 94. J. A. Sissler, DOE, Div. of Transportation and Fuel Storage,
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