71-9289

FRAMATOME ANP

Ms. Nancy Osgood
Spent Fuel Project Office
Office of Nuclear Material Safety & Safeguards
U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

May 1, 2002

Subject: **Docket 71-9289 Application for Approval of Packaging, WE-1 Shipping Container**

Dear Ms. Osgood:

Framatome ANP, Inc. hereby submits six (6) copies of the revised application for approval of packaging of fissile radioactive material (WE-1 Container), Package Identification Number USA/9289/B(U)–85.

This submittal represents a requested revision to the existing regulatory basis for the WE-1. This submittal seeks approval for a modification of contents to include Pathfinder research fuel (enrichment ≤ 7.5 wt%). Modifications to the application have been highlighted via change bars positioned in the right hand margin of each effected page. Please note that during the review and modification of the application a few changes were made to the currently approved documentation. These changes are also marked accordingly and consist primarily of corrections to typographical errors, name changes, or re-formatting in order to accommodate the requested new contents.

This license submittal supports a 3 year research project targeted at designing, performing and documenting reactor physics and criticality benchmark experiments for ~7wt% enriched uranium-dioxide. The project will involve the Pathfinder fuel, shipped from Penn State to Sandia National Laboratory (SNL), as the base contents. The fuel needs to be downloaded from its current configuration and re-fabricated into short fuel rods. In order to allow re-fabrication of the fuel in time to perform the scheduled experiments, approval is requested by October 1, 2002.

If you have questions or comments concerning the submittal, please call me at (434) 832-5268, or William Anderson at (434) 832-2893.

Sincerely,

Robert S. Freeman, Manager
Environmental, Health,
Safety and Licensing

NMSS01
public

FRAMATOME ANP

FRAMATOME ANP, INC.
MOUNT ATHOS ROAD FACILITY

APPLICATION FOR APPROVAL
OF PACKAGEING OF
FISSILE RADIOACITVE MATERIAL
(WE-1 SHIPPING CONTAINER)

PAKAGE IDNETIFICATION NUMBER
USA/9289/B(U)-85

MAY 2002

U.S. NULCEAR REGULATORY COMMISSION

DOCKET
71-9289

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NUMBER AND TITLE

CHAPTER 1: GENERAL INFORMATION

1.1 INTRODUCTION

The WE-1 package is to be used for transporting one low-enriched uranium fuel assembly for light water power reactor core, or up to 48 Pathfinder fuel assemblies in a leak-tight canister. The nominal number of packages per shipment is to be one.

1.2 PACKAGE DESCRIPTION

1.2.1 PACKAGING

1.2.1.1 WE-1

Designation – WE-1 Shipping Container
Gross Weight – (Test Weight) 9090 lbs.
Fabrication – The design & fabrication details for WE-1 series shipping containers are detailed in drawings included in Appendix 1-1.
Coolants – Not applicable.

1.2.2 OPERATIONAL FEATURES

Not applicable.

1.2.3 CONTENTS OF PACKAGING

1.2.3.1 WE-1 CONTAINER – CONTENTS DESCRIPTION (REF. TABLE 1-1 AND TABLE 1-3)

Identification and Enrichment of Special Nuclear Material (SNM) – The SNM will be low enriched uranium derived from surplus off-specification (reprocessed) highly enriched uranium enriched up to 4.6 weight percent in the isotope U-235, or legacy Pathfinder assemblies enriched up to 7.5 weight percent in the isotope U-235.

Form of SNM – The SNM will be in the form of a clad fuel assembly. In the clad form, the assembly will not disruptively react or decompose at the Accident Thermal Condition. No chips, powders, or solutions will be offered for transport in the packaging.

Maximum Weight of Fissile Contents – 22.14 Kg 235U

Maximum Fuel Assembly Weight – 1610 lbs.

Maximum Decay Heat – Negligible

1.2.3.2 BW 17x17 FUEL ASSEMBLY PARAMETERS

The attached tables are the fuel assembly parameters for the BW17x17 design to be transported in the WE-1 fuel shipping container. The parameters indicated are used in the Criticality Analysis section to support un-contained and contained fuel assembly calculations.

TABLE 1-1

FUEL ASSEMBLY DESCRIPTION	17 X 17
FUEL ASSEMBLY TYPE	BW
NOMINAL PELLET DIAMETER	0.3195
NOMINAL CLAD THICKNESS	.022
CLAD MATERIAL	ZIRC
NOMINAL CLAD OUTER DIAMETER	0.3740
MAXIMUM STACK LENGTH	144 +/-0.225
NOMINAL ASSEMBLY ENVELOPE	8.565
Kg's 235U ASSEMBLY	24
NOMINAL LATTICE PITCH	0.496
ASSEMBLY KEFF	0.93144

Note: Geometric dimensions are in inches.

MAXIMUM URANIUM ISOTOPIC, FISSION PRODUCT, AND TRANSURANIC LIMITS FOR CONTENTS OF WE-1 SHIPPING CONTAINER

TABLE 1-2

ISOTOPE	COMPOSITION
U-232	0.010 μgm/gmU
U-234	0.10 w/o
U-235 (BW17x17)	4.60 w/o
U-235 (Pathfinder)	7.51 w/o
U-236	1.30 w/o
TC-99	5 μgm/gmU
FISSION PRODUCTS	4.4×10^5 MevBq/KgU
NP+PU	35 Bq/gmU

1.2.3.3 PATHFINDER FUEL ASSEMBLY PARAMETERS

The tables in this section detail the fuel assembly parameters for the Pathfinder design to be transported in the WE-1 fuel shipping container. The parameters indicated are used in the Criticality Analysis section to support un-contained and contained fuel assembly calculations. The fuel assemblies include a stainless steel or inconnel sleeve that protects and supports the assembly.

TABLE 1-3

FUEL ASSEMBLY DESCRIPTION	6 fuel rod triangular array
FUEL ASSEMBLY TYPE	Pathfinder
# of FUEL ASSEMBLIES PER SHIPMENT	≤ 48
NOMINAL PELLET DIAMETER	0.2075 in.
NOMINAL CLAD THICKNESS	0.034 in.
CLAD MATERIAL	Incoloy 800
NOMINAL CLAD OUTER DIAMETER	0.246 in.
MAXIMUM STACK LENGTH	72 in.
NOMINAL ASSEMBLY ENVELOPE	1 (with Sleeve)
Kg's ^{235}U ASSEMBLY	2.206
NOMINAL SLEEVE INNER DIAMETER	0.945 in.
NOMINAL SLEEVE OUTER DIAMETER	1.00 in.
ASSEMBLY KEFF (MAXIMUM OF 48 ASSEMBLIES)	0.82296

For the Pathfinder fuel, the Assembly k_{eff} is based on the optimal spacing calculations for up to 48 assemblies. The value reported is $k_{calc} + 2\sigma$. This calculation is reported in Chapter 6.

CHAPTER 2: STRUCTURAL EVALUATION

2.1 STRUCTURAL DESIGN

This chapter presents the structural evaluations that demonstrate that the design of the WE-1 Package meets all applicable structural criteria to ensure safe, reliable shipment of its unirradiated fresh fuel contents. Normal conditions of transport and hypothetical accident conditions are addressed by analytical and experimental evaluations performed in accordance with the requirements of 10 CFR 71.45, 71.71, and 71.73. Results from full-scale testing of a WE-1 Type B shipping container loaded with a standard MK-BW fuel assembly (except that the rods were loaded with tungsten carbide pellets in place of UO_2) were used to determine hypothetical accident (drop from 30 feet and pin puncture) loads.

A summary of the structural design of the WE-1 Package is presented including the design criteria used to evaluate the packaging performance. Section 2.2 is a listing of the weights of the packaging and contents. Materials of construction are presented in Section 2.3. Results from the evaluations that demonstrate compliance with the design criteria for general standards for all packages, normal conditions of transport, and hypothetical accident conditions are presented in Sections 2.6, 2.7 and 2.10 (Appendix 2-2).

2.1.1 Discussion

The WE-1 package consists of a cylindrical outer container that is designed to open into two, semi-cylindrical halves. The outer container's inner structure is a U-shaped channel supported on multiple elastomeric shock mounts. The outer container and associated structural components are fabricated primarily of mild carbon steel. Positive closure of the outer container is provided by 58 T-bolts.

Interfacing to the outer container's U-shaped channel via ten, 1 inch diameter stainless steel bolts, is a boxy inner container. Wood dunnage surrounds the periphery between the inner container and the U-shaped channel. To supplement the ten stainless steel bolts, 8 external clamp arms secure each side of the inner container to the U-shaped channel (16 total).

The inner container is comprised entirely of one inch thick, HY-80 carbon steel armor plate on all sides. The long edges are adjoined with 28, 1/2 inch diameter, Series 300 stainless steel bolts. The end plates are secured with 12, 1/2 inch diameter, Series 300 stainless steel bolts. Nine integral clamp frames, fabricated of one inch thick, HY-80 carbon steel armor plate, are used for supporting and securing a single fuel assembly within the inner container.

Refer to the Package General Arrangement Drawings for details of this design, which are included in Appendix 1-1 of this application.

The WE-1 package design has been subjected to the hypothetical accident condition (HAC), free drop and puncture conditions of 10 CFR §71.73[1]. These tests demonstrate the package's ability to adequately protect the fuel assembly payload, and establish initial conditions for the HAC fire event discussed in Chapter 3, *Thermal Evaluation*.

The WE-1 Package has been modified for shipment of non-irradiated Pathfinder fuel assemblies. A newly designed Pathfinder Canister will be used for the shipment of up to 48 Pathfinder fuel assemblies.

For Pathfinder fuel shipments, the shipping package consists of three layers of protective structures, a cylindrical outer container (or shell), a rectangular inner container (or box) and cylindrical inner sealed canister (Pathfinder Canister). All three layers provide protection against mechanical and thermal loads under normal and accident conditions of transport.

The outer container is constructed of 11-gauge carbon steel and opens into two semi-cylindrical halves. The inner rectangular container is comprised of 1-inch thick, high strength carbon steel plates that are bolted together. This inner rectangular container is bolted to a strongback. The inner most stainless steel structure is a sealed cylindrical canister (Pathfinder Canister). The fuel assemblies will be housed in this inner canister.

The Pathfinder Canister is surrounded by thermal insulation and is secured inside the rectangular container with five integral clamp frames. The clamp frames, which consist of bolted clamp arms, are bolted to the inner rectangular container. Wood blocks surround both ends of the Pathfinder Canister.

The inner rectangular container with strongback is supported to the outer cylindrical container by 14 shock mounts. Wooden blocks surround the inner rectangular container. These blocks limit the impact resulting from accident conditions.

The Pathfinder Canister serves as the primary containment for the contents. The Pathfinder Canister is made of austenitic stainless steel and has a welded body and bolted closure lid. The Pathfinder Canister is a 8 inch schedule 40 S stainless steel pipe with welded bottom plate and welded top 8"-150# weldneck flange. The closure lid is machined from an 8"-150# austenitic stainless steel blind flange. The lid has two machined grooves that contain metallic O-rings that complete the closure. The primary and secondary closure seals are 0.125 inch cross section Alloy 600 O-rings. A gasket wall thickness of 0.010 inch permits

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[1] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Materials*, United States Nuclear Regulatory Commission (USNRC), 1998.

sufficient compression (nominal 21%) of the O-ring to produce a forgiving seal design that is not impaired by minor surface imperfections. A test port on top of the lid allows a vacuum or pressure test of the annulus between the O-rings. The closure is held in place by eight 3/4-10UNRC-2A by 2.5 inch long ASTM-A-193-B8M Class 2 bolts. The bolts are located on an 11.75 inch diameter bolt circle. The bolts have a flat washer bent into place to prevent inadvertent loosening. The Pathfinder Canister has a cavity nominally eight inches in diameter and 88 inches long. The payload is cushioned within the cavity by placing filler material in any void above the stack fuel. The cavity contains air at ambient conditions.

2.1.2 Design Criteria

The design of the WE-1 package complies with the normal conditions of transport (NCT) structural requirements of 10 CFR §71.71. Compliance is demonstrated through the application of design criteria that requires no yielding of the container shell under a static loading of five times the weight of the loaded package.

The design of the WE-1 package also complies with the hypothetical accident condition (HAC) structural requirements of 10 CFR §71.73. A WE-1 package, loaded to the maximum gross weight, was subjected to the HAC free drop and puncture test conditions. These drop tests resulted in minor damage to the inner container assembly and fuel assembly. As such, analytic assessments of the WE-1 package for the HAC tests are not performed.

The Pathfinder Canister is designed to meet the standards and criteria for radioactive shipping containers as set forth in the Code of Federal Regulations 10CFR71, "Packaging and Transportation of Radioactive Material." U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels" Revision 1, dated March 1978, and Regulatory Guide 7.8, "Load Combination for the Structural Analysis of Shipping Casks for Radioactive Material," Revision 1, dated March 1989 are used in the structural evaluation.

The Pathfinder Canister materials, design, fabrication, examination and testing meet the requirements of ASME Boiler and Pressure Vessel Code, Section III, 1992 edition (herein after is referred to as a Code). Additional fabrication and welding requirements of NUREG/CR-3854, "Fabrication Criteria for Shipping Containers" and NUREG/CR-3019, "Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials," are also considered. Vessel buckling is evaluated per ASME Code.

Level A (normal) and Level D (accidental) service limit stress allowable for primary membrane, primary bending, secondary, bearing, shear and buckling stresses for containment structures and fasteners are taken from Section III of the American Society of Mechanical Engineers Boiler & Pressure Vessel (ASME B&PV) Code of 1992. Table 2.1-1 provides the stress allowable used for the Pathfinder Canister.

Material data used in the evaluation correspond to the design stress value Sm, yield strength Sy, and ultimate strength Su, at specified temperature given in the ASME B&PV Code, Section III, Class 1.

For conditions addressed by analysis, the margin of safety is calculated. The margin of safety (M.S.) is defined as

$$\text{Margin of Safety} = \frac{\textit{Allowable Stress}}{\textit{Actual Stress}} - 1$$

If the margin of safety is 10 or higher, it is defined as 'Large.'

For the Pathfinder Canister, the matrix of load combinations given in Regulatory Guide 7.8 is evaluated to determine the worst case combinations. Acceptance criteria are those presented in the applicable portions of the ASME B&PV code as outlined in Regulatory Guide 7.6.

The evaluation of the Pathfinder Canister includes results from full-scale testing of a WE-1 Type B shipping container loaded with a standard MK-BW fuel assembly (except that the rods were loaded with tungsten carbide pellets in place of UO_2) for accident conditions as specified in 10CFR7l.

Table 2.1-1 Pathfinder Canister Allowable Stresses

Stress Category	**Normal Condition**	**Accident Condition**
Primary membrane stress intensity (A)	S_m	Lesser of 2.4 S_m and 0.7 S_u
Primary membrane + bending stress intensity(B)	1.5 S_m	Lesser of 3.6 S_m and S_u
Range of primary + secondary stress intensity(C)	3.0 S_m	Not applicable
Extreme stress range of total stress intensity(D)	2 S_a	2 S_a @ 10 cycles
Bearing stress	S_y(E)	S_y for seal surface S_u elsewhere
Pure primary shear stress(F)	0.6 S_m(F)	0.42 S_u
Buckling	Margin 2	Margin 1.34
Bolts		
Membrane Stress(G)	Lesser of 2.0 S_m and S_y(I)	Lesser of 0.7 S_u and S_y(J)
Membrane + Bending Stress(G)	Lesser of 3.0 S_m and S_y(I)	S_y(H)
Shear Stress	Not Applicable	Lesser of 0.42 S_u and 0.6S_y(J)
COMBINED STRESS	Not Applicable	$(f_t/F_{tb})2 + (f_v/F_{vb})^2 \leq 1$(J)

Applicable to Pathfinder Canister, closure lid and closure bolts.

(A) Per NRC Regulatory Guide 7.6, Paragraphs C.2 and C.6, and ASME Code NB-3221.1 and Appendix F-1331.1.
(B) Per NRC Regulatory Guide 7.6, Paragraphs C.2 and C.6, and ASME Code NB-3221.3.
(C) Per NRC Regulatory Guide 7.6, Paragraph C.4, and ASME Code NB-3222.2.
(D) Per NRC Regulatory Guide 7.6, Paragraph C.7.
(E) Per ASME Code NB-3227.1.
(F) Per ASME Code NB-3227.2 and Appendix F-1331.1(a).
(G) Not considering stress concentrations.
(H) A conservative value used for accident conditions.
(I) Per ASME Code NB-3232
(J) Per ASME Code F-1335

The design requirements for the Pathfinder Canister are summarized below:

1. No significant deterioration of the effectiveness of the canister from ambient conditions of -40° F to 100°F.
2. No susceptibility of brittle fracture at cold -40°F condition.
3. Canister to maintain pressure tight seal for external pressure from 3.5 psia to 20.3 psia, and for all drop-puncture-thermal accident cases. The leakage rate of the canister less than 10^{-3} atm cc/sec air.
4. Insensitive to vibration environment.
5. Positive closure device for canister.
6. Maintain geometric form of canister as a containment barrier. No loss of contents or effectiveness of gasket.

2.2 WEIGHTS AND CENTERS OF GRAVITY

The maximum gross weight of the WE-1 package is 9,090 pounds. Of that weight, the fuel assembly is 1,610 pounds, the inner container is 3,390 pounds, and the outer container is 4,090 pounds. The center of gravity is situated near the geometric center of the package.

The maximum gross weight of the WE-1 Package containing the Pathfinder Canister and fuel is 8,500 lbs. Of that weight, the Pathfinder fuel is 480 lbs. For a fully loaded Pathfinder Canister, the center of gravity is 2.4 inches from the geometric center of the inner rectangular container, towards the Pathfinder Canister bolted closure end.

2.3 MECHANICAL PROPERTIES OF MATERIALS

The major structural components of the WE-1 package's outer container are fabricated of mild carbon steel, and the closure T-bolts are fabricated of SAE J429, Grade 5, carbon steel bolting material. The following conservative stress values are utilized for NCT analytical evaluations of the outer container: tensile yield, σ_y = 36,000 psi; shear yield, $\tau_y = 0.6 \times \sigma_y$ = 21,600 psi, tensile ultimate, σ_u = 58,000 psi; shear ultimate, $\tau_u = 0.6 \times \sigma_u$ = 34,800 psi.

The major structural components of the inner container are fabricated of HY-80 carbon steel armor plate (conforming to MIL-S-16216/SH/REV K, June 19, 1987, Type II). The inner container closure bolts are fabricated of Series 300 stainless steel bolting material. No analytic evaluations are performed on the inner container.

The non-metallic structural materials include the rubber shock mounts for the load suspension system, wood shoring used as dunnage for the inner container, rubber gaskets, and ceramic fiber insulation surrounding the fuel assembly.

Pathfinder Canister: Standard commercial material, 300 series stainless steel, is used in the construction of the Pathfinder Canister. Aluminum 6061 is used for the support spacers. The pine and oak wood spacers are used for energy absorbers. A listing of the materials and specifications is presented below.

Materials of Construction

Component	Material	Specification
Pathfinder Canister		
Cylinder	304L or 316L Pipe	ASTM-A312-Tp 304L or Tp 316L 8" Sch 40S Pipe
Bottom Plate	304L or 316L Plate	ASTM-A240 Type 304L or 316L ASTM-A479 Type 304L or 316L
Weld Neck Flange	F304L or F316L	ASTM-A182-F304L or F316L 8"-150# Welding Neck Flange
Closure Lid	F304, F304L, F316 F316L	ASTM-A182-F304L, F304, F316L or F316L, 8"-150# Blind Flange, raised
Closure Bolts	Stainless Steel	ASTM-A193 B8M Class 2
O-ring	Metallic Seal	Alloy 600
Spacer Tube		
Cylinder	304L or 316L Pipe	ASTM-A312-Tp 304L or Tp 316L 8" Sch 40S Pipe
End Plate	304L or 316L Plate	ASTM-A240 Type 304L or 316L ASTM-A479 Type 304L or 316L
Support Spacer	Aluminum	ASTM B-209 6061 T6
Impact absorber	wood	pine and oak (flame retardant treated per MIL-L-19140)

Materials used in the fabrication of the Pathfinder Canister are in accordance with ASTM standards, which are equivalent to materials listed in the ASME B&PV Code Section III. Options are given to use either 304L or 316L stainless steel for the welded components (i.e. the pipe and its mating weldneck flange, and the bottom plate). 304 and 316 stainless steel are additional options for the closure. The properties given in ASME Section III for 304L stainless steel are the lowest of these options and are used as the acceptance criteria for the analysis.

Material properties used in the structural analysis are tabulated on the following pages. The ASME B&PV Code[2.2] is the source for the mechanical properties. For the closure bolting material, the conservative properties of the Class 1 material are used instead of ASTM-A193 B8M Class 2 material.

Table 2.3-1 Pathfinder Canister/Spacer Tube Material Properties
ASTM-A182-F304L; ASTM-A312-TP304L; ASTM-A240-TYPE 304L (Plate)

Material Temperature [°F]	**-40°F(7)**	**100**	**200**	**300**	**800**
$S_y \times 10^{-3}$ [LBS/IN^2] (1)	>25	25	21.3	19.1	14.4
$S_u \times 10^{-3}$ [LBS/IN^2] (2)	>70	70	66.2	60.9	55.5
$S_m \times 10^{-3}$ [LBS/IN^2] (3)	16.7	16.7	16.7	16.7	13.0
$\alpha_m \times 10^{-6}$ [IN/IN-°F] (4)	8.21	8.55	8.79	9.00	9.82
TC [BTU/HR-FT-°F] (5)	<8.7	8.7	9.3	9.8	12.2
TD [FT^2/HR] (5)	<.152	.152	.156	.160	.184
E x 10^{-6} [LBS/IN^2] (6)	29.3	28.3	27.6	27.0	24.1

Notes:
(1) Yield Strength, ASME Section III[2.2], Table Y-1
(2) Tensile Strength, ASME Section III[2.2], Table U
(3) Design Stress Intensity, ASME Section III[2.2], Table 2A
(4) Coefficient of Thermal Expansion, Table TE-1[2.2] (18CR-8Ni)
(5) Thermal Conductivity and Diffusivity, Table TCD[2.2] (18CR-8Ni)
(6) Moduli of Elasticity, Table TM-1[2.2] (Austenitic Steels)
(7) -40° F properties are extrapolated values from ASME Section III

Table 2.3-2 Bolts – (Closure Lid) Material Properties ASTM-A193-B8M Class 1

Material Temperature [°F]	**-40°F(7)**	**100**	**200**	**300**	**800**
$S_y \times 10^{-3}$ [LBS/IN^2] (1)	>30	30	25.8	23.5	17.4
$S_u \times 10^{-3}$ [LBS/IN^2] (2)	>75	75	64.5	58.7	43.5
$S_m \times 10^{-3}$ [LBS/IN^2] (3)	>10	10.0	8.6	7.8	5.8
$\alpha_m \times 10^{-6}$ [IN/IN-°F] (4)	8.26	8.54	8.76	8.97	9.90
TC [BTU/HR-FT-°F] (5)	<7.9	7.9	8.4	9.0	11.5
TD [FT^2/HR] (5)	<.136	.136	.141	.145	.173
$E \times 10^{-6}$ [LBS/IN^2] (6)	29.3	28.3	27.6	27.0	24.1

Conservative value of Class 1 material properties are used for the Class 2 bolts.

Notes: Conservative values of S_y and S_u are taken at 800 F.

(1) Yield Strength values given change with temperature as "S_m" given in, Table 4[2.2]
(2) Tensile Strength Values given change with temperature as "S_m" given in, Table 4[2.2]
(3) Design stress Intensity, Table 4[2.2]
(4) Coefficient of Thermal Expansion, Table TE-1[2.2] (16CR-12Ni-2Mo)
(5) Thermal Conductivity and Diffusivity, Table TCD[2.2] (16CR-12Ni-2Mo)
(6) Moduli of Elasticity, Table TM-1[2.2] (Austenitic Steels)
(7) -40° F properties are extrapolated values from ASME Section III

Support Spacers at Clamp Locations
ASTM B-209 6061 T6 aluminum

S_y = 35 ksi — ASME Section III, Table Y-1,
ρ = 0.098 lbs/in^3 — ASM Metals handbook[2.34]

Wood Impact Absorbers

Pine (Eastern White, Ref. [2.7], pg. 6-124)

σ_{crush} = 4080 psi minimum, 5520 psi maximum, parallel to grain
ρ = 24 lbs/ft^3 ± 15%

Oak (White, Ref. [2.7], pg. 6-124)

σ_{crush} = 910 psi minimum, 1230 psi maximum, perpendicular to grain
ρ = 48 lbs/ft^3 ± 15%

2.4 GENERAL STANDARDS FOR ALL PACKAGES

2.4.1 Minimum Package Size

The minimum transverse dimension (i.e., the diameter) of the WE-1 package is approximately 43 inches, and the minimum longitudinal dimension (i.e., the length) is approximately 216 inches. Thus, the requirement of 10 CFR §71.43(a) is satisfied.

2.4.2 Tamper-indicating Feature

A tamper-indicating seal is installed between the outer container cover and base, as delineated on the drawings in Appendix 1-1. Failure of the tamper-indicating device provides evidence of possible unauthorized access. Thus, the requirement of 10 CFR §71.43(b) is satisfied.

2.4.3 Positive Closure

The WE-1 package is positively closed by means of fasteners that require use of tools and deliberate action to facilitate their removal. A total of 58, 1/2-13UNC, SAE J429, Grade 5, T-bolts are used to close the outer container. A total of 136, 1/2-13UNC, Series 300 stainless steel bolts are used to assemble and close the inner container. Additional detail of the packaging closure system is provided on the Package General Arrangement Drawings in Appendix 1-1 of this application. Thus, the requirement of 10 CFR §71.43(c) is satisfied.

2.4.4 Chemical and Galvanic Reactions

The WE-1 package is primarily fabricated from carbon steel, and the fuel assemblies are fabricated from stainless steel, Inconel, and Zircaloy. The inner container's thermal insulation is comprised of non-reactive ceramic fiber. Thus, no potential exists for chemical or galvanic reactions to occur. Thus, the requirement of 10 CFR §71.43(d) is satisfied.

The Pathfinder Canister is fabricated from austenitic stainless steel. Welded materials in the Pathfinder Canister are specified to be low carbon alloys to provide maximum resistance to intergranular corrosion. Non-metallic insulating materials separate the canister and the strongback box/clamps, therefore galvanic reactions are not expected. No chemical or galvanic reactions are possible between these materials and the intended contents of the Pathfinder Canister.

2.4.5 Valves

No valves are utilized in the design of the WE-1 package. Thus, the requirements of 10 CFR §71.43(e) are not applicable.

2.4.6 Package Design

As shown in Chapter 2.0, *Structural Evaluation*, Chapter 3.0, *Thermal Evaluation*, Chapter 5.0, *Shielding Evaluation*, and Chapter 6.0, *Criticality Evaluation*, the structural, thermal, shielding, and criticality requirements, respectively, of 10 CFR §71.43(f) are satisfied for the WE-1 package.

2.4.7 External Temperatures

The WE-1 package is designed for exclusive use shipment. As shown in Chapter 3, *Thermal Evaluation*, the maximum accessible surface temperature with the fuel assembly's negligible decay heat load and no insolation is 100 °F. Since the maximum external temperature does not exceed 122 °F, the requirements of 10 CFR §71.43(g) are satisfied.

2.4.8 Venting

The WE-1 package does not provide a containment boundary as no pressure-tight seals are included in the design. The fuel rod cladding is the containment boundary, and does not include any features intended to allow continuous venting during transport. The Pathfinder Canister does not include any features intended to allow continuous venting during transport. Thus, the requirements of 10 CFR §71.43(h) are satisfied.

2.5 LIFTING AND TIE-DOWN STANDARDS FOR ALL PACKAGES

2.5.1 Lifting Devices

2.5.1.1 Lifting Lug Load Calculation

Four lifting attachments that are a structural part of the WE-1 package are designed with a minimum safety factor of three against yielding to lift the loaded package in the intended manner. The lifting lugs are loaded at an angle 45° from horizontal. The lifting lugs are located symmetrically about the package's center of gravity, with the four cables/chains/straps meeting at a point directly above the package's center of gravity. The cable/chain/strap tension, T, given the vertical load is one-fourth of the 9,090 pound WE-1 package gross weight, is:

$$T = \frac{9{,}090}{4(\sin 45^\circ)} = 3{,}214 \text{ lbs}$$

A conservative value of 3,300 pounds shall be used in the subsequent analyses.

The Pathfinder Canister will not be handled when loaded with fuel (i.e. the canister is secured in the inner rectangular container before the fuel is placed into the canister). During assembly, the Pathfinder Canister without the lid and bolts weighs approximately 260 lbs and is handled by commonly available slings and/or hoist equipment. The canister does not have any lifting devices, which are part of the canister.

2.5.1.2 Lifting Lug Tear-out Analysis

Each lifting lug is fabricated of 3/8 inch thick mild steel with a 2.0 inch hole. The hole centerline is 2.0 inches from the lug outside edge and 1.5 inches above the horizontal edge of the lug's base.

For a square-edged lug, the shear stress due to tear-out may be determined from Equation D26 and Figure D10 of Faupel and Fischer[2]. For a lifting lug thickness of t = 0.375 inches, a distance from the hole centerline to the outside lug edge of d = 2.0 inches, and a hole diameter of D = 2.0 inches, the shear stress is:

$$\tau = \frac{T}{2t[d-(0.383)D]} = \frac{3{,}300}{2(0.375)[2.0-(0.383)(2.0)]} = 3{,}566 \text{ psi}$$

From Section 2.3, *Mechanical Properties of Materials*, the shear yield allowable is 21,600 psi. Thus, for a factor of safety of three, the resulting Margin of Safety is:

$$\text{M.S.} = \frac{21{,}600}{3(3{,}566)} - 1 = +1.02$$

2.5.1.3 Lifting Lug Attachment Weld Analysis

For simplicity, the 1/4 inch fillet welds (see Figure 2.5-1) that attach the bracket to the rolled angle are conservatively assumed to carry the entire load. The weld throat length is $1/4 \times \sin(45°) = 0.177$ inches.

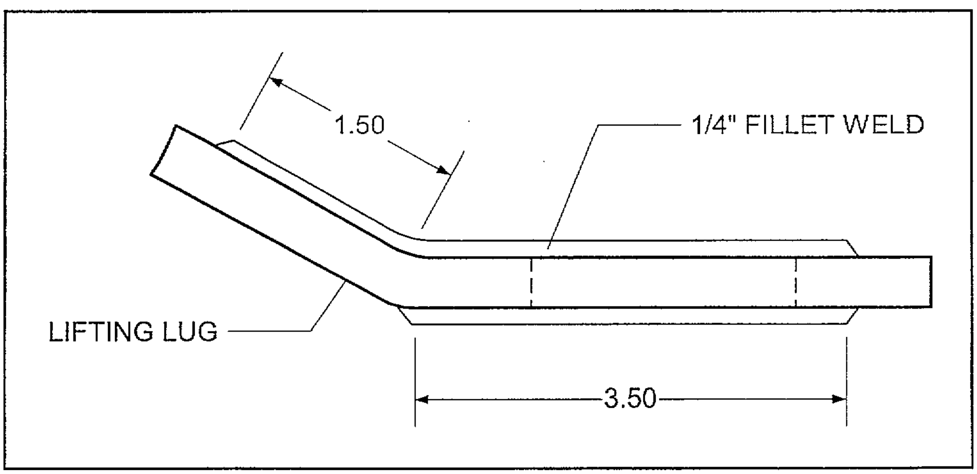

Figure 2.5-1 Lifting Lug Weld Configuration

[2] J. H. Faupel, F. E. Fisher, *Engineering Design – A Synthesis of Stress Analysis and Materials Engineering*, Second Edition, John Wiley & Sons, Inc., 1981, p1023.

The weld shear stress due to direct shear load on the weld is:

$$\tau_s = \frac{T}{t_w L_w} = \frac{3{,}300}{(0.177)(3.50 + 5.00)} = 2{,}193 \text{ psi}$$

The weld bending stress due to the 1.5 inch vertical offset is:

$$\tau_b = \frac{Mc}{I}$$

where the bending moment is 3,300 pounds × 1.5 inches = 4,950 inch-lbs. For simplicity, the 5.0 inch long top weld is treated as being parallel to the 3.5 inch long bottom weld. The distance from the right end of the two welds, shown in Figure 2.5-1, to the weld group neutral axis is:

$$\bar{x} = \frac{5.0^2 + 3.5^2}{2(5.0 + 3.5)} = 2.19 \text{ inch}$$

The moment of inertia of the weld group is:

$$I = \left(\frac{0.177}{12}\right)\left[5.0^3 + 3.5^3\right] + (0.177)\left[(5.0)\left(\frac{5.0}{2} - 2.19\right)^2 + (3.5)\left(2.19 - \frac{3.5}{2}\right)^2\right] = 2.68 \text{ in}^4$$

The maximum weld stress due to bending is:

$$\tau_b = \frac{(4{,}950)(5.0 - 2.19)}{2.68} = 5{,}190 \text{ psi}$$

The combined shear and bending stress is:

$$\tau = \sqrt{\tau_s^2 + \tau_b^2} = \sqrt{2{,}193^2 + 5{,}190^2} = 5{,}634 \; psi$$

From Section 2.3, *Mechanical Properties of Materials*, the shear yield allowable is 21,600 psi. Thus, for a factor of safety of three, the resulting Margin of Safety is:

$$M.S. = \frac{21{,}600}{3(5{,}634)} - 1 = +0.28$$

The above results demonstrate that the lifting lug and its attachment welds are adequate to withstand the required lifting loads. In addition, the relatively low Margin of Safety of the attachment welds ensure that failure of the welds occur before failure of the heavier underlying structure should inadvertent lifting lug overloading occur.

2.5.2 Tie-down Devices

There is no identified tie-down system on the WE-1 package. A combination of shoring, positioning studs and/or axial and transverse chokers (chains or straps) shall be used to secure the WE-1 package to the transport vehicle. Chokers will be passed over the package top to enable package restraint.

2.6 NORMAL CONDITIONS OF TRANSPORT

The performance requirements specified in Subpart F of 10 CFR 71 for normal conditions of transport (NCT) are met by the WE-1 package. Regulatory compliance is demonstrated in the following subsections where each normal condition is shown to meet the applicable regulatory criteria.

2.6.1 Heat

In Chapter 3.0, *Thermal Evaluation*, of this application concludes that the normal heat conditions specified in 10 CFR §71.71(c)(1) will have a negligible effect on the WE-1 package. The maximum package temperature for NCT is 122 °F.

2.6.1.1 Summary of Pressures and Temperatures

The WE-1 package is designed to provide confinement rather than containment; thus only a dust/debris seal is utilized at the outer container closure interface. Therefore, no internal pressure exists within the WE-1 package. The fuel rods comprise the containment boundary, and are pressurized with helium to 315 psig.

The fuel assembly exhibits negligible decay heat. The WE-1 package and all internal components, when loaded with the required 10 CFR §71.71(c)(1) insolation conditions, develop a maximum temperature of 122 °F.

Pathfinder Canister: The payload in the Pathfinder Canister generates no internal heat. Conservatively, the fuel is considered to be pressurized and to have leaked the gas into the canister.

Pressure	1 Atmosphere to 25.0 psia
Package Temperature	150°F maximum

2.6.1.2 Differential Thermal Expansion

Due to the relatively low temperature differentials and lack of internal restraint within the WE-1 package, differential thermal expansion is negligible.

The Pathfinder Canister is a cylinder with a bolted blind flange closure. The canister is insulated by Zircar insulation. The contents are unirradiated and have no decay heat. The canister materials are all austenitic stainless steel and have the same coefficient of thermal expansion. The closure bolts have a slightly different coefficient of thermal expansion. The components of the bolted closure have similar mass and external surfaces, therefore any thermal transient will cause negligible differential expansion. The Alloy 600 O-rings with a temperature rating of 1000°F is used for the canister gaskets.

2.6.2 Cold

As with the heat condition, the cold conditions specified in 10 CFR §71.71(c)(2) will not adversely affect the performance of the package. Brittle fracture is not a concern due to the materials of construction and the dimensions of the material's cross-section, as demonstrated in the following discussion.

The inner container is fabricated of one inch thick, high alloy, quenched and tempered, HY-80 carbon steel armor plate. Per Figure 3 of NUREG/CR-1815[3], for one inch thick, Category I fracture critical components with the component stress equal to the dynamic yield strength (i.e., $\sigma/\sigma_{yd} = 1$), the "A" temperature is 45 °F. For a NCT lowest service temperature (LST) of -20 °F per 10 CFR §71.71(b), the nil ductility transition temperature, T_{NDT} = LST - A = -20 °F - 45 °F = -65 °F. Per Table 3 of NUREG/CR-1815, -160 °F $\leq T_{NDT} \leq$ -80 °F for HY-80 plate material between 5/8 and 4 inches thick. Thus, HY-80 plate will not exhibit a ductile-to-brittle transition in the temperature range of interest.

The outer container is fabricated of relatively thin sections of mild carbon steel. Per Table 5 of NUREG/CR-1815, for Category II fracture critical components with thicknesses of 0.19 inch or less, brittle fracture is not of concern. Similarly, per Table 6 of NUREG/CR-1815, for Category III fracture critical components with thicknesses of 0.4 inch or less, brittle fracture is not of concern.

The Pathfinder Canister and closure bolts are fabricated from austenitic stainless steel. This material is not subject to a ductile-to-brittle transition above -40°F, therefore it is safe from brittle fracture. Contents of the Pathfinder Canister will not contain sufficient liquids to cause the canister to expand due to freezing. The Alloy 600 O-rings are rated for cryogenic applications. No deterioration of the O-rings are expected during normal transport.

2.6.3 Reduced External Pressure

The WE-1 package contains no pressure-tight seal and, therefore, cannot develop differential pressure. Therefore, the reduced external pressure requirement of 3.5 psia delineated in 10 CFR §71.71(c)(3) will have no effect on the package. Compared with the 315 psig internal pressure in the fuel rods, a reduced external pressure of 3.5 psia will have a negligible effect on the fuel rods.

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[3] W. R. Holman, R. T. Langland, *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick*, NUREG/CR-1815, UCRL-53013, August 1981.

The 3.5 psia external pressure translates into a bursting pressure of 11.2 psig. Stress analysis of the Pathfinder Canister is documented in Section 2.10.2 (Appendix 2-2). Table 2.6.3-1 summarizes the stress analysis results.

Table 2.6.3-1 Reduced External Pressure – Pathfinder Canister Stress Summary

Component	Primary Membranne Stress Intensity – psi (or Rated Pressure – psig)			Primary Membrance Plus Bending Stress Intensity – psi (or Rated Pressure – psig)		
	Actual	Allowable	Margin of Safety	Actual	Allowable	Margin of Safety
Cylinder	378	16,700	Large	1004	25,050	Large
Bottom Plate	38	16,700	Large	408	25,050	Large
Weld Neck Flange	ΔP = 21.5 psig	Rated at 212 psig	8.86	ΔP = 21.5 psig	Rated at 212 psig	8.86
Blind Flange	ΔP = 21.5 psig	Rated at 212 psig	8.86	ΔP = 21.5 psig	Rated at 212 psig	8.86
Closure Bolt	17353	18,600	0.07	Fatigue Life > 4000 shipments		

2.6.4 Increased External Pressure

The WE-1 package contains no pressure-tight seal and, therefore, cannot develop differential pressure. Therefore, the increased external pressure requirement of 20 psia delineated in 10 CFR §71.71(c)(4) will have no effect on the package.

Pathfinder Canister: Calculations based on ASME criteria indicate that an 8 inch schedule 40 S pipe made from 304L stainless steel is capable of withstanding an external pressure differential of at least 431 psig. The 20.3 psia external pressure specified in 10CFR7l.71(c)(4) is equivalent to less than a 5.6 psi increase in differential pressure, and is well within the allowable external pressure for the Pathfinder Canister. The pressure stresses in the canister will be lower than the reduced external pressure loading condition (Section 2.6.3). Stress analysis of the Pathfinder Canister is documented in Section 2.10.2 (Appendix 2-2).

2.6.5 Vibration

The WE-1 package contains an internal shock mount system and, therefore, cannot develop significant vibratory stresses for the package's internal structures. Therefore, vibration normally incident to transportation, as delineated in 10 CFR §71.71(c)(5), will have a negligible effect on the package.

2.6.6 Water Spray

The materials of construction utilized for the WE-1 package are such that the water spray identified in 10 CFR §71.71(c)(6) will have a negligible effect on the package.

2.6.7 Free Drop

The WE-1 package weighs less than 11,000 pounds (5,000 kg), requiring a NCT free drop test of 4 feet as delineated in 10 CFR §71.71(c)(7). The hypothetical accident condition (HAC), 30 foot free drop test required in 10 CFR §71.73(c)(1) is substantially more damaging than the 4 foot NCT free drop test. Section 2.7.1, *Free Drop*, demonstrates the WE-1 package's survivability and bounds the free drop requirements of 10 CFR §71.71(c)(7). Due to the relatively fragile nature of the fuel assembly payload in maintaining its configuration for operational use, any event that would come close to approximating the NCT free drop would cause the package to be removed from service and re-examined prior to continued use.

Pathfinder Canister: This four foot drop test is much less severe than the 30-foot free drop specified under hypothetical accident conditions of 10CFR71.73(c)(1). Previous 4 foot drop tests of similar type packages have experienced acceleration levels of approximately 10 g's for this Normal condition. The acceleration values used in the Pathfinder Fuel Canister Faulted condition analysis are 135 g's and higher. Since the Faulted condition stresses are acceptable, the Normal condition stresses are also acceptable if

$(G_{Normal} / G_{Faulted}) <$ (Normal stress allowable / Faulted stress allowable)

Primary membrane stress is most limiting and from Table 2.1-1

$(10/135) < (S_m / 2.4\ S_m)$
$0.074 < 0.42$

Therefore, the stress margins from the Faulted condition drops will bound those drops under Normal conditions.

2.6.8 Corner Drop

The WE-1 package is fabricated primarily of carbon steel and exceeds 110 pounds (50 kg) gross weight. Therefore, the corner drop test requirement of 10 CFR §71.71(c)(8) is not applicable to the WE-1 package.

2.6.9 Compression

The compressive load requirement of 10 CFR §71.71(c)(9) is easily satisfied by the WE-1 package. This conclusion can be easily demonstrated by conservatively treating the package's outer container as a simply supported beam loaded by a uniformly distributed load of five times the gross package weight. For a simply supported beam with a length L = 216.25 inches and a uniformly distributed load of $W = 5 \times 9{,}090 / 216.25 = 210$ lbs/inch, the resultant maximum bending moment, M_B, in the outer container shell is:

$$M_B = \frac{WL^2}{8} = \frac{(210)(216.25)^2}{8} = 1{,}227{,}557 \text{ inch - lbs}$$

Conservatively neglecting any of the reinforcement due to the 2½ inch angle stiffeners on the outer container exterior, the moment of inertia of the 11-gauge (0.12 inch thick), 43.00 inch outside diameter outer container shell is:

$$I = \frac{\pi}{64}\left[D_o^4 - D_i^4\right] = \frac{\pi}{64}\left[(43.00)^4 - (42.76)^4\right] = 3{,}715 \text{ in}^4$$

The maximum bending stress, σ_B, is then:

$$\sigma_B = \frac{M_B c}{I} = \frac{(1{,}227{,}557)(43.00/2)}{3{,}715} = 7{,}104 \text{ psi}$$

From Section 2.3, *Mechanical Properties of Materials*, the tensile yield allowable is 36,000 psi. Thus, the resulting Margin of Safety is:

$$M.S. = \frac{36{,}000}{7{,}104} - 1 = +4.07$$

Therefore, the WE-1 package satisfies the requirements of 10 CFR §71.71(c)(9).

2.6.10 Penetration

The WE-1 package has relatively thick shells on both the outer and inner container. Further, the package is designed without external protuberances that, if damaged, could reduce the effectiveness of the packaging. Therefore, the penetration test of dropping a 13 pound (6 kg) steel rod 40 inches (1 m) onto the package, as defined in 10 CFR §71.71(c)(10), is of negligible consequence.

2.7 HYPOTHETICAL ACCIDENT CONDITIONS

The performance criteria specified in Subpart E of 10 CFR 71 are satisfied when the WE-1 package is subjected to the hypothetical accident conditions (HAC) of transport specified in 10 CFR §71.73. The package's ability to meet the design criteria, as discussed in Section 2.1, *Structural Design*, for the various accident conditions is presented below.

Following HAC free drop and puncture testing, the fuel assembly must remain within the inner container as protection from the HAC fire event. Further, the fuel rod cladding must not leak in excess of A_2 per week per 10 CFR §71.51(a)(2) following the HAC tests delineated in 10 CFR §71.73(c). Subsequent to HAC free drop and puncture testing of a prototypic WE-1 package, leak testing of the fuel rods showed that the leak rate limit of A_2 per week was not exceeded.

The standards for the hypothetical accident conditions stipulate that a package used for shipment of radioactive material shall be designed and constructed such that if it is subjected to the specified drop, puncture, thermal, and water immersion conditions, a) the reduction in containment would not be sufficient to increase the external radiation dose rate to more than regulatory limit; b) no radiation material would be released from the package except for gases containing a total radioactivity not to exceed regulatory limit; c) the contents would remain subcritical.

Evaluation of the Pathfinder Canister for the hypothetical accident conditions described in the regulations is addressed by a combination of drop tests and analytical evaluation.

2.7.1 Free Drop

2.7.1.1 Introduction

Subpart F of 10 CFR 71 requires that a package withstand a free drop from a height of 30 feet (9 meters) onto a flat, essentially unyielding, horizontal surface in accordance with 10 CFR §71.73(c)(1). The package is to strike the surface in a position for which maximum damage is expected.

To comply with this free drop requirement, it is necessary to determine the orientation that would produce the maximum damage to and/or failure of the package. For the WE-1 package, failure is defined as leakage of the containment boundary (i.e., the fuel rod cladding) in excess of A_2 per week per 10 CFR §71.51(a)(2). Two scenarios may initiate failure: 1) causing the inner container to open sufficiently to produce fuel rod overheating and rupture during the subsequent HAC fire event, or 2) direct mechanical damage to the fuel rods resulting in excessive leakage.

2.7.1.2 Determination of the Primary Impact Angle for the Slapdown Drop

To determine the worst-case impact angle for free drop testing, a simplistic model of the WE-1 inner container/fuel assembly was modeled using the Shipping Cask Analysis System (SCANS) program[4]. The SCANS model consisted only of the inner container/fuel assembly, since the outer container can be effectively decoupled from the inner container because of the relatively soft elastomeric shock mounts. The SCANS model was then analyzed at primary impact angles of 15°, 30°, and 45° using a range of impact stiffnesses simulating the inner container's elastic behavior after impact with the surface.

The results of the various computer runs of the SCANS model are provided in Table 2.7-1. The data indicates, regardless of relative impact stiffness, that a primary impact angle of 15° always bounds the primary and secondary impact acceleration. Thus, a primary impact angle of 15° was utilized for certification free drop testing to maximize the slapdown acceleration.

[4] M. A. Gerhard, D. J. Trummer, G. L. Johnson, G. C. Mok, *SCANS (Shipping Cask ANalysis System) – A Microcomputer Based Analysis System for Shipping Cask Design Review*, Version 2a, NUREG/CR-4554.

Table 2.7-1 Comparison of Impact Accelerations for Various Primary Impact Angles at the Inner Container Center of Gravity

Inner Container Stiffness (kips/inch)	Impact Event	Primary Impact Angle		
		15°	30°	45°
10	Primary	21.0	23.1	26.7
	Secondary	33.0	32.7	30.5
20	Primary	30.0	33.0	38.1
	Secondary	46.7	46.2	42.9
40	Primary	42.5	47.0	54.2
	Secondary	65.8	65.1	60.2

2.7.1.3 Description of the WE-1 Prototype Package used for Certification Testing

The WE-1 prototype package was fabricated identically to the configuration depicted in the Packaging General Arrangement Drawing found in Appendix 1-1. The fuel assembly was a standard BW 17×17, with tungsten carbide slugs in place of the uranium dioxide fuel pellets. The fuel rods were pressurized with helium gas to the normal fuel rod pressure of 315 psig. In addition, the 24 guide tubes were filled with solid stainless steel or brass rods to maximize fuel assembly gross weight. The as-tested weight of the fuel assembly was 1,610 pounds. No other modifications/variations of the packaging or payload design were introduced.

2.7.1.4 Results of WE-1 Prototype Package Free Drop Certification Testing

The WE-1 prototype package was tested at the drop test facility at Oak Ridge National Laboratory during December 1998. As illustrated in, the WE-1 prototype package was suspended 30 feet above the impact surface. As discussed in Section 2.7.1.2, *Determination of the Primary Impact Angle for the Slapdown Drop*, the package was oriented at an angle of 15° from horizontal to maximize the slapdown force. In addition, the package was oriented at an angle 135° circumferentially clockwise from the normally transported position (aligned with a set of stacking brackets located on the outer container exterior). This circumferential orientation was chosen to maximize damage to both the inner container and internal clamp frames by striking both components on their top corner.

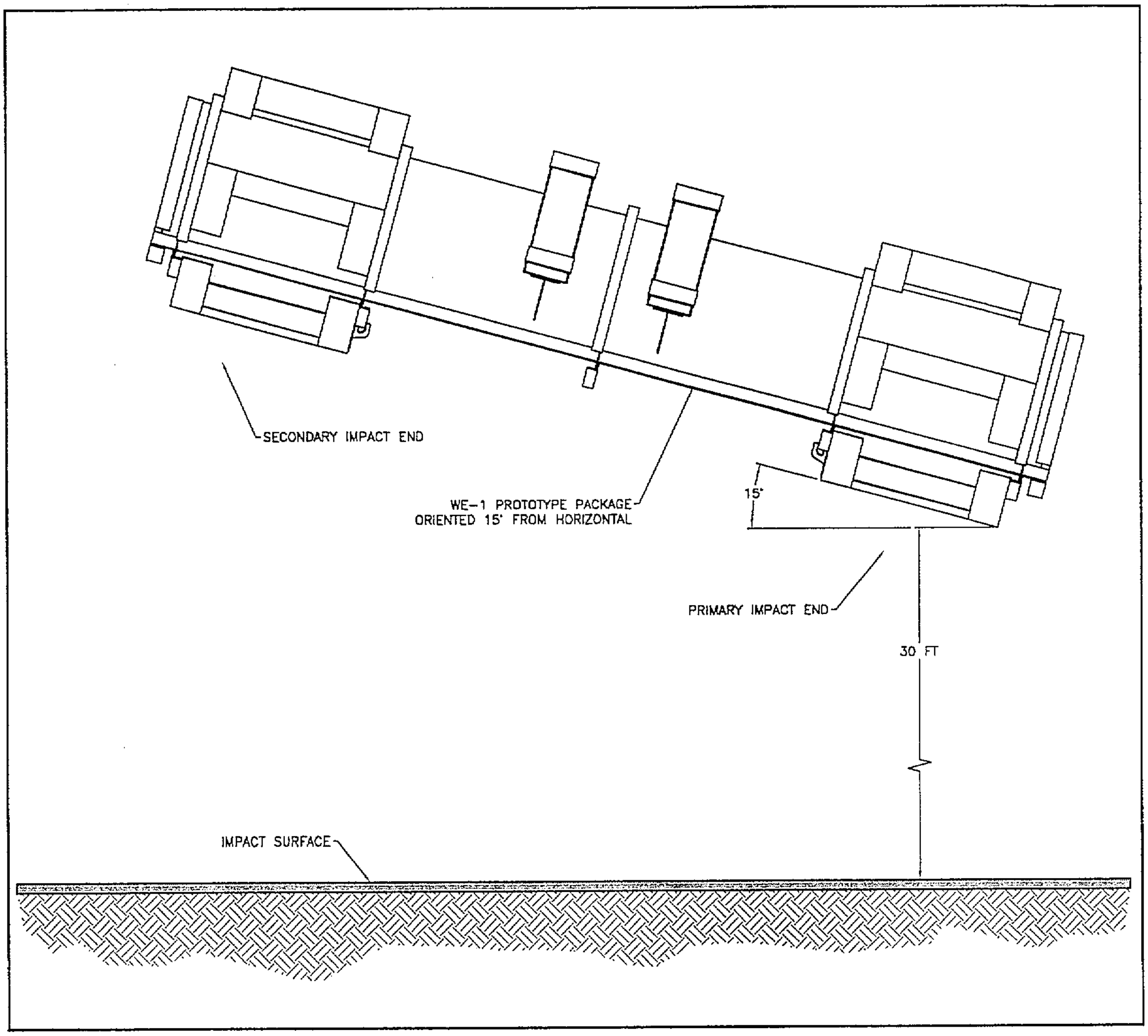

Figure 2.7-1 WE-1 Prototype Package 30 Foot Free Drop Orientation

Appendix 2-1, *WE-1 Prototype Package Certification Testing Photographs*, photo-documents the certification testing process and subsequent package disassembly.

Components located in the impact zone such as the outer container's stacking brackets and exterior, 2½ inch stiffening angles were crushed nearly flat during the 30 foot slapdown drop test. The outer container exhibited permanent radial deformations of approximately 3/4 inch at the primary impact end, and 2 inches at the secondary (slapdown) impact end. None of the 58 T-bolts securing the outer container cover to its base failed. The outer container shell was penetrated in the impact zone by each of the eight external clamp arms that were used to secure the inner container to the U-shaped channel inside the outer container.

After the 30 ft. drop and puncture tests, the sixteen external clamp arms were found intact, with none of the fasteners broken at either the inner container or U-shaped channel. Of the 56, 1/2-13UNC stainless steel bolts used to secure the top plate on the inner container, 16 were broken on the impacted corner, at the farthest (slapdown) end. Failure of these fasteners allowed the top plate to separate approximately 3/16 inch at the farthest end. Further, all of the end plate bolts (also 1/2-13UNC stainless steel bolts) on the farthest (slapdown) end of the inner container were broken. Failure of these 12 fasteners allowed the end plate to separate approximately 1/2 inch from the inner container end. The end plate was restrained from further motion due to the end bracing and surrounding wood dunnage securing the inner container. Because of the presence of the 3 inch thick ceramic fiber insulation inside the inner container, these relatively small gaps have negligible effect on the subsequent HAC fire event presented in Chapter 3, *Thermal Evaluation*.

Four, 1/2-13UNC stainless steel bolts secure each internal clamp frame to the bottom and side of the inner container. Seven of the nine fasteners failed for the clamp frames; however, the clamping force exerted by the clamp frames on the fuel assembly ensured stability for both components.

Upon opening the inner container, the ceramic fiber insulation was found intact, with little permanent deformation (i.e., <1/2 inch at one localized region at the slapdown end of the inner container). For purposes of conservatism, however, the HAC thermal analysis in Chapter 3, *Thermal Evaluation*, assumes that all the insulation is permanently crushed to 2/3 its original thickness resulting in a 150% increase in thermal conductivity. The internal clamp frame at the slap down end exhibited a small permanent diagonal displacement aligned with the axis of the drop. None of clamp frame fasteners failed.

The fuel assembly exhibited modest permanent lateral deformation of the fuel rods at the slapdown end of the inner container (2¼ inch, maximum). Permanent bending of the fuel rods in the last grid span, but not in any other span, was probably caused by three factors: 1) the largest angular acceleration and, hence, translational impact force occurred at the slapdown end, 2) the grids provide intermittent supports for the fuel rods; at each fuel assembly end the fuel rods are essentially free to move longitudinally (i.e., not axially restrained), and 3) the largest span between grids occurs at the slapdown end. These three factors combined to cause the bending stress in the fuel rods to exceed their elastic limit. Those fuel rods adjacent to the ceramic fiber insulation exhibited the least amount of permanent deformation due to the lateral support provided by the insulation. All grids "racked" in the axis of the drop; however, grid effectiveness was not diminished and structural integrity was maintained with the fuel assembly remaining intact. Less permanent deformation was noted for the end grids constructed of Inconel rather than Zircaloy for intermittent grids.

Subsequent helium leak testing was performed for the individual fuel rods once removed from the fuel assembly. With the exception of a single fuel rod, all fuel rods demonstrated "leaktight" containment integrity to a leak rate of 1×10^{-7} cc/sec, air. The exception was a single fuel rod that exhibited a leak rate of 1.0×10^{-6} cm^3/sec, helium.

10 CFR 71.51(a)(2) states that after hypothetical accident testing, no escape of radioactive material exceeding a total amount A2 in 1 week; a typical A2 quantity for this material is 5.4 kg UO_2.

In summary, certification testing of the WE-1 prototype package demonstrated its ability to satisfactorily meet the requirements of 10 CFR §71.73(c)(1) and 10 CFR §71.51(a)(2).

2.7.1.5 Free Drop – WE-1 with Pathfinder Canister

The acceleration levels for 30-foot drop were determined by analysis using the deformed condition of the MK-BW Fuel Assembly which occurred during the drop test of the WE-1 Type B container qualification (Section 2.10.3). The Pathfinder Canister stresses are within the ASME stress limits for an accident condition. Stress analysis of the Pathfinder Canister is documented in Section 2.10.2 (Appendix 2-2). The results of the stress analysis are summarized below.

Table 2.7.1.5-1 30 Foot Drop – Pathfinder Canister Stress Summary

Component	Stress Intensity - psi		
	Actual	**Allowable**	**Margin of Safety**
Cylinder			
Slapdown	34,653	40,800	0.16
End Drop	25,614	40,800	0.16
Bottom Plate			
End Drop	6,763	40,800	4.93
Bling Flange			
End Drop	<6,763	40,800	>4.93
Closure Bolt			
Tension	17,838	27,900	0.56
Shear	2,530	16,740	5.61
Tension + Shear	Ratio sum = 0.3	Ration sum = 1.0	1.33
Thread Engegment	L = 0.551 in	L = 0.948 in	0.72

Buckling of Cylinder:

$S \leq 0.4 s'$

25614 psi $\leq$ 524800 psi, $\therefore$ Design Margin = large

This buckling margin of safety is larger than the 1.34 permitted by the ASME Code.

2.7.2 Crush

Subpart F of 10 CFR 71 requires performing a dynamic crush test in accordance with the requirements of 10 CFR §71.73(c)(2). Since the WE-1 package weight exceeds 1100 pounds (500 kg), the dynamic crush test is not required.

2.7.3 Puncture

2.7.3.1 Introduction

Subpart F of 10 CFR 71 requires performing a puncture test through a distance of 40 inches (1 m) onto the upper end of a solid cylindrical, mild steel bar mounted vertically on an essentially unyielding horizontal surface in accordance with 10 CFR §71.73(c)(3). The package is to strike the puncture bar in a position for which maximum damage is expected. The puncture bar shall be 6.0 inches (15 cm) in diameter, with the top horizontal and its edge rounded to a radius of not more than 0.25 inches (6 mm), and of sufficient length to cause maximum damage to the package, but not less than 8 inches (20 cm) long. The long axis of the bar shall be vertical.

A description of the WE-1 prototype package is provided in Section 2.7.1.3, *Description of the WE-1 Prototype Package used for Certification Testing.*

2.7.3.2 Results of WE-1 Prototype Package Puncture Certification Testing

The WE-1 prototype package was tested at the drop test facility at Oak Ridge National Laboratory during December 1998. As illustrated in Figure 2.7-2, the WE-1 prototype package was suspended 1 meter above a 60 inch high puncture bar. The puncture bar was mounted to a 1 inch thick, 4 foot square steel plate that was secured to the drop pad with a plurality of intermittent welds.

The WE-1 package was oriented horizontally with respect to the longitudinal axis. As before for the free drop test, the package was oriented at an angle 135° circumferentially clockwise from the normally transported position (i.e., identical to the free drop circumferential orientation to maximize cumulative damage to the top corner of the inner container). A portion of the outer container outer shell was removed to facilitate aligning the corner of the inner container directly over the puncture bar.

Little damage to the inner container was noted; a slight denting occurred at the impacted corner. The mild steel puncture bar, however, exhibited a deep gouge caused by impact of the relatively high strength armor plate. Further discussion of package disassembly and observations is provided in Section 2.7.1.4, *Results of WE-1 Prototype Package Free Drop Certification Testing.*

In summary, certification testing of the WE-1 prototype package demonstrated its ability to satisfactorily meet the requirements of 10 CFR §71.73(c)(3).

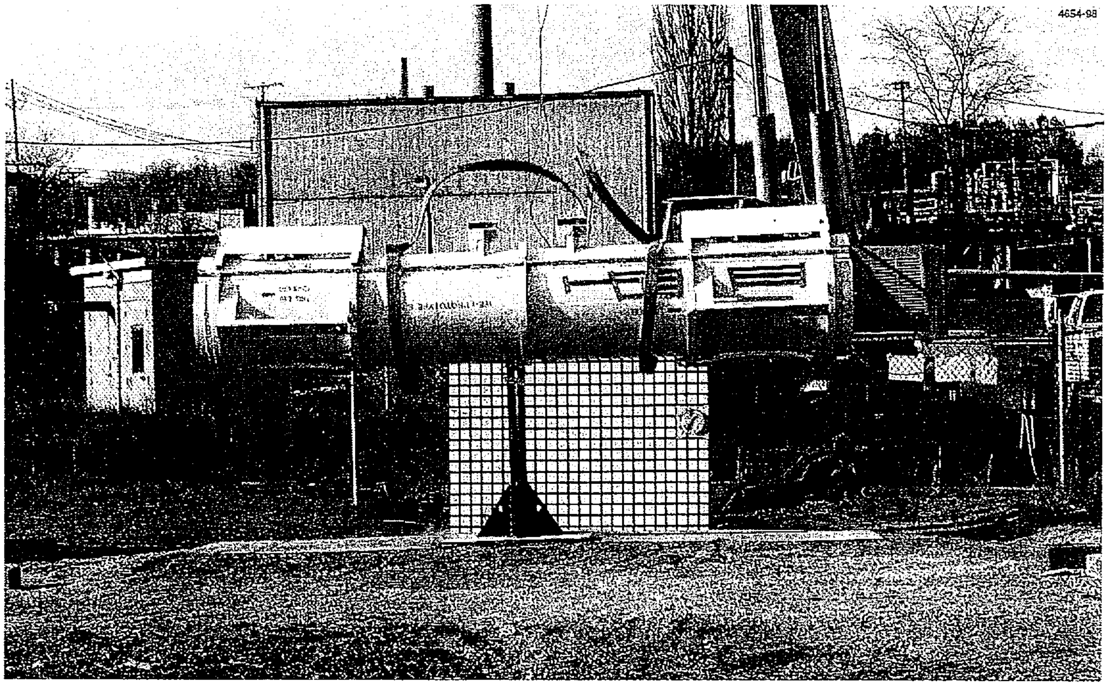

Figure 2.7-2 WE-1 Prototype Package 40 Inch Puncture Orientation

2.7.4 Thermal

The thermal evaluation of the WE-1 package for the HAC heat condition is presented in Chapter 3.0, *Thermal Evaluation*. Because the WE-1 package does not contain a pressure-tight seal, the HAC pressure is zero. The fuel assembly exhibits negligible decay heat. The maximum predicted HAC temperature for the fuel assembly is 792 °F during the fire event. The fuel rods are designed to withstand a temperature of 1,200 °F without bursting.

The thermal and thermal stress analysis of the Pathfinder Canister is documented in Section 2.10.2 (Appendix 2-2). Results of the analysis are summarized below.

The maximum temperature of the Pathfinder Canister is less than 792 °F and occurs near the support saddles. The maximum circumferential temperature gradient is 5.2 F° / inch and occurs near the support saddles. The maximum axial temperature gradient is 168 F° / inch and occurs between the bolted closure and the first support saddle. The combined thermal and internal pressure stress in the canister is

S = 81054 psi
S < 2 Sa at 10 cycles
81054 psi < 1416000 psi
Design Margin = large

Closure Bolts:
$S < S_y$ at 800 °F
15458 psi < 17400 psi

2.7.5 Immersion - Fissile Material

Subpart F of 10 CFR 71 requires performing an immersion test for fissile material packages in accordance with the requirements of 10 CFR §71.73(c)(5). The criticality evaluation presented in Chapter 6.0, *Criticality Evaluation*, assumes optimum hydrogenous moderation of the contents, thereby conservatively addressing the consequences and effects of water in-leakage.

Pathfinder Canister: For fissile material, in those cases where water leakage has not been assumed for criticality analysis, the regulation requires an immersion test under a head of three feet for period of not less than eight hours in an attitude for which maximum leakage is expected. The fully flooded condition is addressed in the Pathfinder Canister criticality analysis. Therefore, the three feet immersion test is not required.

2.7.6 Immersion - All Packages

Since the WE-1 package is not sealed against pressure, there will not be any differential pressure with the water immersion loads defined in 10 CFR §71.73(5). The water immersion will have negligible effect on the WE-1 container or the BW 17x17 fuel assembly payload.

Pathfinder Canister: The regulations require a separate undamaged canister which must be subject to water pressure equivalent to immersion under a head of water at least 50 feet for period of not less than eight hours. The Pathfinder Canister, functioning as the sealed containment boundary, is the only structural component affected by a pressure differential. Stress analysis of the Pathfinder Canister, based on ASME criteria, is documented in Section 2.10.2 (Appendix 2-2). The results of the stress analysis are summarized below.

Table 2.7.6-1 50 Feet Immersion – Pathfinder Canister Stress Summary

Component	Primary Membranne Stress Intensity – psi (or Rated Pressure – psig)			Primary Membrance Plus Bending Stress Intensity – psi (or Rated Pressure – psig)		
	Actual	Allowable	Margin of Safety	Actual	Allowable	Margin of Safety
Cylinder	382	16,700	Large	1014	25,050	Large
Bottom Plate	38	16,700	Large	412	25,050	Large
Weld Neck Flange	ΔP = 21.7 psig	Rated at 212 psig	8.77	ΔP = 21.7 psig	Rated at 212 psig	8.77
Blind Flange	ΔP = 21.7 psig	Rated at 212 psig	8.77	ΔP = 21.7 psig	Rated at 212 psig	8.77
Closure Bolt	17,257	18,600	0.08	Fatigue Life > 4000 shipments		

Stability Summary 50 Feet Immersion

Component	Actual Load	Critical Load	Margin of Safety
Vessel Cylinder	21.7 psid	431 psid	Large
Vessel Bottom Plate	24 lb/in	29910 lb/in	Large

Both of these margins of safety are larger than the 1.34 permitted by the ASME Code.

2.7.7 Summary of Damage

The most significant damage to the WE-1 prototype package occurred to the fuel assembly. The conservative nature of the drop testing ensures containment integrity of the fuel rods is maintained per the requirements 10 CFR §71.51(a)(2). The thermal analysis demonstrated acceptable fuel assembly temperatures during the HAC fire event for a fully exposed inner container. Drop testing demonstrated that the outer container remains intact and closed. The corresponding result would be a significant reduction in fuel assembly temperatures during the HAC fire event resulting in an even larger margin for fuel rod burst.

2.8 SPECIAL FORM

This section does not apply to the WE-1 package since special form is not claimed.

2.9 FUEL RODS

BW 17x17 fuel rod cladding is considered to provide containment of radioactive material under both normal and accident test conditions. Discussion of this cladding, and its ability to maintain sufficient mechanical integrity to provide such containment, is described in Section 1.2.3, *Contents*, and Chapter 4, *Containment*.

Pathfinder Canister: The Pathfinder Canister is considered to provide containment of radioactive material under both normal and accident test conditions by the leak tightness of the bolted closure. No credit is taken for the fuel rod cladding providing containment of radioactive material under normal or hypothetical accident conditions.

CHAPTER 3: THERMAL EVALUATION

3.1 SUMMARY

The WE-1 package is designed to provide thermal protection as described in Subpart F of 10 CFR 71[1] for transport of a single BW 17x17 PWR or up to 48 Pathfinder fuel assemblies with negligible decay heat. This regulatory compliance is demonstrated in the following subsections.

Given negligible decay heat, the thermal loads on the package come solely from the environment in the form of solar radiation for normal conditions of transport (NCT), as described in Section 3.4, *Normal Conditions of Transport*, or a half-hour, 1,475 °F fire for hypothetical accident conditions (HAC), described in Section 3.5, *Hypothetical Accident Conditions*.

Specific ambient temperatures and solar heat loads are considered in the package thermal evaluations. Ambient temperatures ranging from -40 °F to 100 °F are considered for NCT. The HAC fire event considers an ambient temperature of 100 °F, with solar heat loading (insolation), before and after the HAC half-hour fire event.

Details and assumptions used in the analytical thermal models are described with the thermal evaluations. Since the decay heat load is negligible, the maximum NCT temperature of 122 °F occurs on the package exterior, and the maximum HAC temperature of 792 °F occurs at the inner surface of the clamp frames (within the inner container). These analyses demonstrate that the WE-1 package provides adequate thermal protection for the fuel assembly and will maintain the maximum fuel rod temperature well below the fuel rod rupture temperature of 1,200 °F under all transportation conditions.

The WE-1 shipping package with Pathfinder Canister consists of three layers of protective structures, a cylindrical outer container (shell), a rectangular inner container (box) and cylindrical inner sealed canister (Pathfinder Canister). All three layers provide protection against thermal loads under normal and accident conditions of transport.

The outer container is constructed of 11-gauge carbon steel and opens into two semi-cylindrical halves. The inner rectangular container is comprised of 1-inch thick carbon steel plates that are bolted together. The Pathfinder Canister is a sealed cylindrical canister. The Pathfinder fuel assemblies will be housed in this Pathfinder Canister.

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[1] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Materials*, United States Nuclear Regulatory Commission (USNRC), 1998.

The Pathfinder Canister is surrounded by Zircar thermal insulation and is secured inside the rectangular inner container with five integral clamp frames. Wood blocks surround the both ends of the Pathfinder Canister. The wood used is flame retardant. The wood is an extremely effective thermal insulator.

3.2 MATERIAL PROPERTIES

The WE-1 inner container is constructed primarily of HY-80 armor plate, Series 300 stainless steel bolts, and Zircar ASB-2300 ceramic fiber insulation. The void spaces within the inner container are filled with air at atmospheric pressure. The thermal properties of the principal materials used in the thermal evaluations are presented in Table 3.2-1, Table 3.2-2, Table 3.2-3, Table 3.2-4, Table 2.3-1 and Table 2.3-2. Where necessary, the properties are presented as functions of temperature. Note that only properties for materials that constitute a significant heat transfer path are defined.

Table 3.2-1 Material Properties for Principal Structural/Thermal Components

Material	Temperature, °F	Thermal Conductivity, Btu/hr-in-°F	Specific Heat, Btu/lbm-°F	Density, lbm/in^3	Notes
HY-80 Armor Plating	70	1.83	0.11	0.283	①
	250	1.94	0.12		
	450	1.93	0.13		
	650	1.84	0.14		
	850	1.74	0.15		
	1,050	1.62	0.17		
	1,250	1.45	0.22		
	1,350	1.31	0.23		
	1,500	1.27	0.15		
Bolting Material Series 300 Stainless Steel	-20	0.692	- - -	0.289	②
	0	- - -	0.111		
	70	0.717	- - -		
	100	0.725	- - -		
	200	0.775	0.124		
	400	0.867	0.130		
	600	0.942	0.134		
	800	- - -	0.140		
	1,500	- - -	0.158		
Zircar ASB-2300 8 pcf Ceramic Fiber Insulation	0	0.0024	0.28	0.0046	③
	500	0.0024			
	1,000	0.0053			
	1,500	0.0087			
	2,000	0.0140			

Notes:

① Thermal Conductivity and Specific Heat are taken from Section II, Part D, Table TCD, of the ASME Code. Density is taken from Section II, Part D, Table NF-2, of the ASME Code. Material properties for 3½Ni-1¾Cr-½Mo-V are used.

② Thermal Conductivity and Specific Heat are taken from Section II, Part D, Table TCD, of the ASME Code. Density is taken from Section II, Part D, Table NF-2, of the ASME Code. Material properties for 18Cr-8Ni are used. The -20°F value is an extrapolation of ASME Code Data.

③ Zircar Products, Inc. Product Data Sheet, *Alumina-Silica Blanket Type ASM-2300 and ASB-2600*, Florida, NY. Thermal conductivity values reflect the ceramic fiber insulation in an uncompressed condition for NCT. HAC thermal analyses assume the ceramic fiber material is conservatively compressed to 2/3 of its original thickness resulting in thermal conductivities that are 150% of NCT values.

Table 3.2-2 Material Properties for Air

Temperature, °F	Thermal Conductivity, Btu/hr-in-°F	Specific Heat, Btu/lbm-°F	Density, g/cc	Viscosity, in^2/sec	Prandtl Number	Notes
-40	0.0011	0.242	Use ideal gas law	---	---	①② ③④
-20	0.0011			---	---	
70	0.0013			0.0261	0.708	
100	0.0013			---	---	
200	0.0015			0.0348	0.704	
300	0.0017			0.0446	0.700	
400	0.0018			0.0588	0.680	
500	0.0020			---	---	
600	0.0021			0.0796	0.680	
700	0.0023			---	---	
800	0.0024			0.1027	0.684	
900	0.0026			---	---	

Notes:

① Y.S. Touloukian, *Specific Heat – Nonmetallic Liquids and Gases*, Thermophysical Properties Research Center Data Series, Volume 6, Purdue University, 1970.

② Y.S. Touloukian, *Thermal Conductivity – Nonmetallic Liquids and Gases*, Thermophysical Properties Research Center Data Series, Volume 3, Purdue University, 1970.

③ E.R.G. Eckert, R. M. Drake, *Analysis of Heat Mass Transfer*, McGraw-Hill, New York, 1972.

④ Rohsenow, Hartnett, and Ganic, *Handbook of Heat Transfer Fundamentals*, 2nd Edition, McGraw-Hill Publishers, 1973.

Table 3.2-3 Radiative Heat Transfer Material Properties, Surface Emittance

Component	Material	Surface Emittance, ε	Solar Absorptivity, α	Notes
Outer Container Exterior Surface	Paint	0.80	0.25	①
Inner Container Surfaces	HY-80	0.50	0.50	②

Notes:

① For the HAC fire event, the paint burns away and exposes the underlying steel surfaces. This surface is assumed to char to the minimum emissivity of 0.80 is required for the HAC fire in accordance with the requirement of 10 CFR §71.73(c)(3). Therefore, a value of 0.80 provides a conservative estimate for NCT conditions and meets the 10 CFR §71.73(c)(3) requirement for the HAC fire event.

② Value taken from F. F. Gubareff, J. E. Janssen, and R. H. Torborg, *Thermal Radiation Properties Survey*, Honeywell Research Center, Minneapolis, Minnesota, 1960. Emissivity increased to 0.8 for the HAC fire in accordance with 10 CFR §71.73(c)(3).

Table 3.2-4 Temperature-Difference (ΔT) Based Heat Transfer Convection Coefficients for the HAC Post-Fire Condition

ΔT, °F	Vertical Surface	Horizontal Surface	
		Heated Side Up	Heated Side Down
50	0.0048	0.0058	0.0016
100	0.0058	0.0070	0.0018
150	0.0064	0.0078	0.0020
200	0.0068	0.0083	0.0021
250	0.0072	0.0087	0.0022
300	0.0074	0.0090	0.0023
500	0.0078	0.0096	0.0025
700	0.0083	0.0100	0.0026
1,375	0.0086	0.0103	0.0028

Notes:

① All convection coefficients are Btu/hr-in^2-°F, and calculated per Appendix 3-1.2, *Post-Fire Natural Convection Coefficient Calculation.*

Pathfinder Canister: The materials of construction of the Pathfinder Canister are standard materials with well-documented thermal characteristics. The Pathfinder Canister is entirely of stainless steel construction except for the Alloy 600 O-rings. All these materials are not sensitive to temperature within the range of –40° F to 800° F. The temperature limit for the fuel is the melting temperature of the stainless steel. Conservatively, 1,200° F Pathfinder fuel assembly temperature limits is established. The Alloy 600 O'ring has design temperature of 1,000° F.

3.3 TECHNICAL SPECIFICATION OF COMPONENTS

None of the materials used in the construction of WE-1 package, such as HY-80 armor plating, Series 300 stainless steels bolts, and ASB-2300 ceramic fiber insulation are sensitive to temperatures within the range of -40 °F to 1,475 °F that spans the NCT and HAC environment. HY-80 steel armor plating and Series 300 bolts have a melting points above 2,550 °F, and maximum service temperatures of 800 °F[2]. Similarly, the ASB-2300 ceramic fiber insulation has a maximum operating temperature of 2,300 °F[3]. Wooden wedges are used as dunnage in the WE-1 package to restrain the inner container within the outer container. Before being consumed in the HAC fire, the wood dunnage would insulate portions of the inner container from exposure to the flames. The HAC transient thermal analyses presented herein ignore the presence of the wood dunnage thereby conservatively neglecting its insulating effect.

The temperature limit for the BW 17x17 fuel assembly's rods is 1,200 °F, based on the pressure calculation provided in Section 3.5.4, *Maximum Internal Pressure*. The temperature limit for the Pathfinder fuel is the melting temperature of the stainless steel. Conservatively, 1,200° F Pathfinder fuel assembly temperature limits is established.

3.4 NORMAL CONDITIONS OF TRANSPORT

This section presents the results of thermal analysis of the WE-1 package for the normal conditions of transport (NCT) specified in 10 CFR §71.71.

3.4.1 Ambient Temperatures and Heat Input

Per 10 CFR §71.71(c)(1), the maximum environmental temperature is 100 °F, and per 10 CFR §71.71(c)(2), the minimum environmental temperature is -40°F.

Given the negligible decay heat of the fuel assembly, the thermal loads on the WE-1 package come solely from the environment in the form of solar radiation for NCT as prescribed by 10 CFR §71.71(c)(1). As such, the solar heat input into the package is 122.9 Btu/hr-ft^2 (400 gcal/cm^2 per 12 hours) for the cylindrical exterior surface of the WE-1 package.

3.4.2 Maximum Temperatures

For ambient conditions of 100 °F and maximum insolation, the peak temperature of the WE-1 package may be calculated using a heat balance equation for a unit area section of a horizontally oriented cylinder experiencing laminar natural convection[4]. The heat balance equation is:

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[2] American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section II, *Materials*, Part D, *Properties*, 1992 Edition, 1994 Addenda, United Engineering Center, 345 East 47th Street, New York, NY.

[3] Zircar Products, Inc. Product Data Sheet, *Alumina-Silica Blanket Type ASM-2300 and ASB-2600,* Florida, NY.

[4] Frank Kreith, *Principles of Heat Transfer*, 3rd Edition, Intext Educational Publishers, New York, 1973, Equation 7-27, p400.

$$\ddot{Q}_{insolation} = \ddot{Q}_{radiation} + \ddot{Q}_{convection}$$

$$\ddot{Q}_{insolation} = (122.9 \text{ Btu/hr - ft}^2)\alpha = 30.73 \text{ Btu/hr - ft}^2$$

$$\ddot{Q}_{radiation} = \sigma\varepsilon(T^4_{container} - T^4_{ambient}) = (1.37(10)^{-9} \text{ Btu/hr - ft}^2 - {}^{o}R^4)(T^4_{container} - T^4_{ambient})$$

$$\ddot{Q}_{convection} = \frac{0.27}{D^{1/4}}(T_{container} - T_{ambient})^{5/4} = (0.196 \text{ Btu/hr - ft}^2 - {}^{o}F^{4/5})(T_{container} - T_{ambient})^{5/4}$$

where the solar absorptivity of the painted outer container exterior surface is $\alpha = 0.25$, the Stefan-Boltzman constant is $\sigma = 1.714(10)^{-9}$ Btu/hr-in^2-°R^4, the emmisivity of the painted outer container is $\varepsilon = 0.80$, the outer package diameter D = 3.583 feet (43.0 inches), and the ambient temperature is $T_{ambient}$ = 100 °F.

Solving the heat balance equation results in a maximum temperature for the outer container of 122 °F. Conservatively, the entire package and payload is assumed to reach this temperature.

Given negligible decay heat, the maximum accessible surface temperature of the WE-1 package in the shade is the maximum environment temperature of 100 °F, which is less than the 122 °F limit established in 10 CFR §71.43(g) for a non-exclusive use shipment.

3.4.3 Minimum Temperatures

The minimum environmental temperature that the WE-1 package will be subjected to is -40 °F, per 10 CFR §71.71(c)(2). Given the negligible decay heat load, the minimum temperature of the WE-1 package is -40 °F.

3.4.4 Maximum Internal Pressure

The BW 17x17 fuel rods are purged with helium gas to a pressure of 315 psig. Hence, the maximum normal operating pressure (MNOP) for BW 17x17 fuel is 315 psig. Using a maximum normal operating temperature (MNOT) of 150°F the maximum internal pressure for Pathfinder Canister would be 17 psia, well within the capabilities of the containment.

3.4.5 Maximum Thermal Stress

The design of the Pathfinder Canister precludes thermal stresses. Because of construction using similar materials and appropriate clearances, differential expansion of metals is not a problem for the canister and blind flange. Due to differential thermal expansion, the Pathfinder Canister closure bolts will experience 18 lb load per bolt during MNOT of 150° F and 66 lb load per bolt during –40° F condition.

3.4.6 Evaluation of Package Performance for Normal Conditions of Transport

The Pathfinder Canister will maintain containment for all normal conditions of transport.

3.5 HYPOTHETICAL ACCIDENT CONDITIONS

This section presents the results of thermal analysis of the WE-1 package for the hypothetical accident condition (HAC) specified in 10 CFR §71.73(c)(4).

3.5.1 Thermal Model

Thermal performance of the WE-1 package is evaluated analytically using a model comprised of a 10 inch axial section of the inner container, including the internal support clamps and ceramic fiber insulation. This model, shown in Figure 3.5-1, is constructed using the ANSYS® finite element analysis code[5].

For the purposes of the HAC fire analysis, the outer container of the WE-1 package is assumed to be totally compromised. This allows the outer surface of the inner container to be fully exposed to the fire event. Likewise, all of the wood dunnage surrounding the inner container are conservatively assumed to not be present during the fire. Any wood in the package would tend to provide insulation during the fire, with any heat contribution from their combustion being negligible in comparison with the heat provided by the simulated pool fire. By ignoring the outer container and applying the fire environment directly to the inner container, the predicted temperature of the fuel assembly is conservatively upper bounded.

To provide a conservative estimate of the worst case fuel rod temperature, the fuel assembly and its corresponding thermal mass are not explicitly modeled. Further, the internal clamp frames are conservatively assumed to fully contact the inner surface of the inner container with a direct heat conduction path. The Series 300 stainless steel bolts also act as direct conduction paths from the outer surface of the inner container into the clamp frames.

The maximum fuel rod temperature is conservatively derived from the maximum temperature of either the inside surface of the support clamp or the inside surface of the ceramic fiber insulation. Additionally, the insulation between the fuel and the inner container is assigned a thermal conductivity 150% of its nominal value to simulate compression of the insulation from three to two inches resulting from the HAC drop

[5] ANSYS, Inc., *ANSYS Engineering Analysis System User's Manual for ANSYS Revision 5.3*, Houston, PA.

tests[6]. Due to the much higher conductive properties of the clamp frame, maximum temperatures always occur at its inside surface.

The material properties used in this analysis are included in Section 3.2, *Material Properties*. The ANSYS® input files are included in Appendix 3-2, *ANSYS® Input Files*.

The initial temperature distribution in the package prior to the HAC fire event is a uniform 122 °F per the NCT calculations.

3.5.2 Package Conditions and Environment

The hypothetical accident condition (HAC) fire event is specified per 10 CFR §71.73(c)(3) as a half-hour, 1,475 °F fire with forced convection ($h_{convection}$ = 2.5 Btu/hr-ft^2 per Appendix 3-1.1, *Fire Forced Convection Convection Calculation*) and an emissivity of 0.9. The environmental conditions preceding and succeeding the fire consists of an ambient temperature of 100 °F and insolation per the NCT thermal analyses.

3.5.3 Package Temperatures

The temperature response of the peak fuel rod temperature over the course of the HAC fire scenario is illustrated in Figure 3.5-2. The temperature reaches its maximum point of 792 °F at 45 minutes after the end of the fire. This peak temperature occurs on the inside surface of the support clamp, as illustrated in Figure 3.5-3.

Subsequent to the fire and post-fire cooldown period, the surface of the inner container will absorb more insolation than in the pre-fire condition, due to charring of the surface of the inner container, resulting in a higher emmisivity. As a result, the WE-1 package will have a higher post-fire steady state temperature. Using the same energy balance equation used for the NCT calculations for the outer container for an absorptivity of 0.8, the post-fire steady-state temperature is 159 °F. Conservatively, the entire package and payload is assumed to reach this temperature for post-fire, steady state conditions.

3.5.4 Maximum Internal Pressure

The maximum internal pressure of the fuel rod 1200° F was calculated using the standard gas law. The internal gas volume of the rod was corrected for the differences in thermal expansion of the U02 fuel pellets and the stainless steel plenum springs with respect to the zirconium alloy cladding. Because of the higher expansion rate of the fuel

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[6] Actual thickness measurements of the ceramic fiber insulating material showed almost no permanent deformation; however, the HAC fire calculations conservatively assume a 3-to-2 reduction in thickness. Further, although the inner container plates separated slightly at one end (i.e., ≤1/2 inch), the three inch thickness of the ceramic fiber insulation ensures direct flame impingement inside the inner container cannot occur. See Section 2.7, *Hypothetical Accident Conditions*, in Chapter 2 for more discussion regarding the results of free drop and puncture testing.

pellets with respect to the cladding, the internal gas volume decreases slightly as temperature increases.

Pathfinder Canister: The maximum internal pressure of the Pathfinder Canister at 800° F was calculated using the standard gas law. The maximum internal pressure for the Pathfinder Canister will be 35 psia and with all fuel rod rupture will be 51.6 psia.

3.5.5 Maximum Thermal Stresses

Pathfinder Canister: The thermal stresses due to temperature gradient are calculated in Section 2.10.2.7. The resulting stresses due to hypothetical fire accident are 81 ksi and are well below secondary stress allowable of 1,416 ksi. Pathfinder Canister closure bolt preload will be reduced by 578 lb due to differential thermal expansion between bolt and the canister flange.

3.5.6 Evaluation of Package Performance for Hypothetical Accident Thermal Conditions

Pathfinder Canister: The temperature of the fuel and O'ring seal will not exceed 800° F. At this temperature the canister, the Pathfinder fuel and the O'ring seal have large safety margin against regulatory and design limits. The Pathfinder Canister will maintain containment for all hypothetical fire accident conditions of transport.

ASSUMPTIONS:

1. 0.022 in. "thin-wall" cladding represents the limiting case for all FCF fuel rod designs.

2. Alloy M5 (Zr-Nbl%) cladding in the fully recrystallized condition represents the limiting case for all FCF cladding materials.

3. The maximum as-built fuel rod pre-pressure is 315 psi.

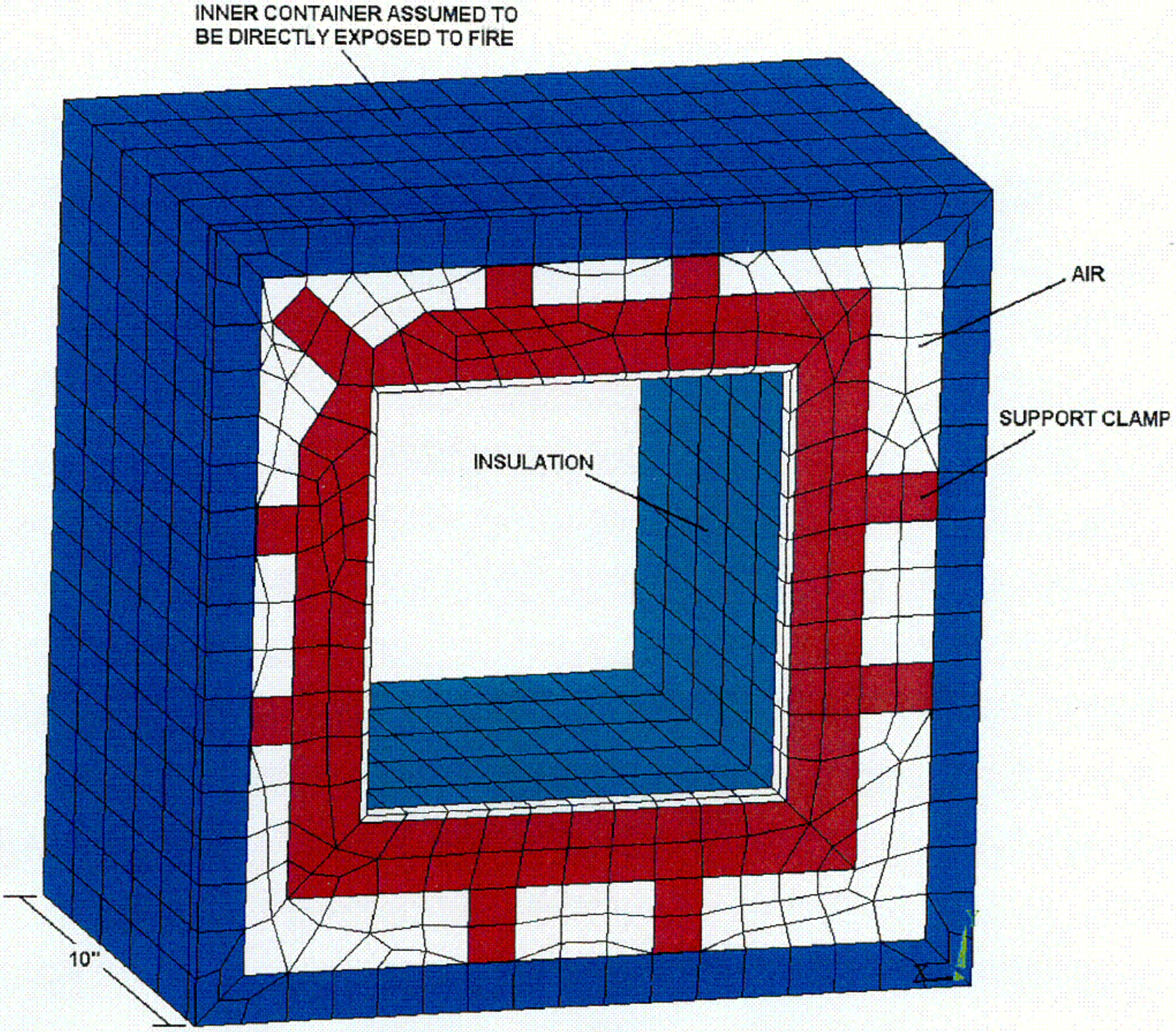


Figure 3.5-1 ANSYS® Thermal Model of the WE-1 Package Inner Container for the HAC Fire Event Calculation

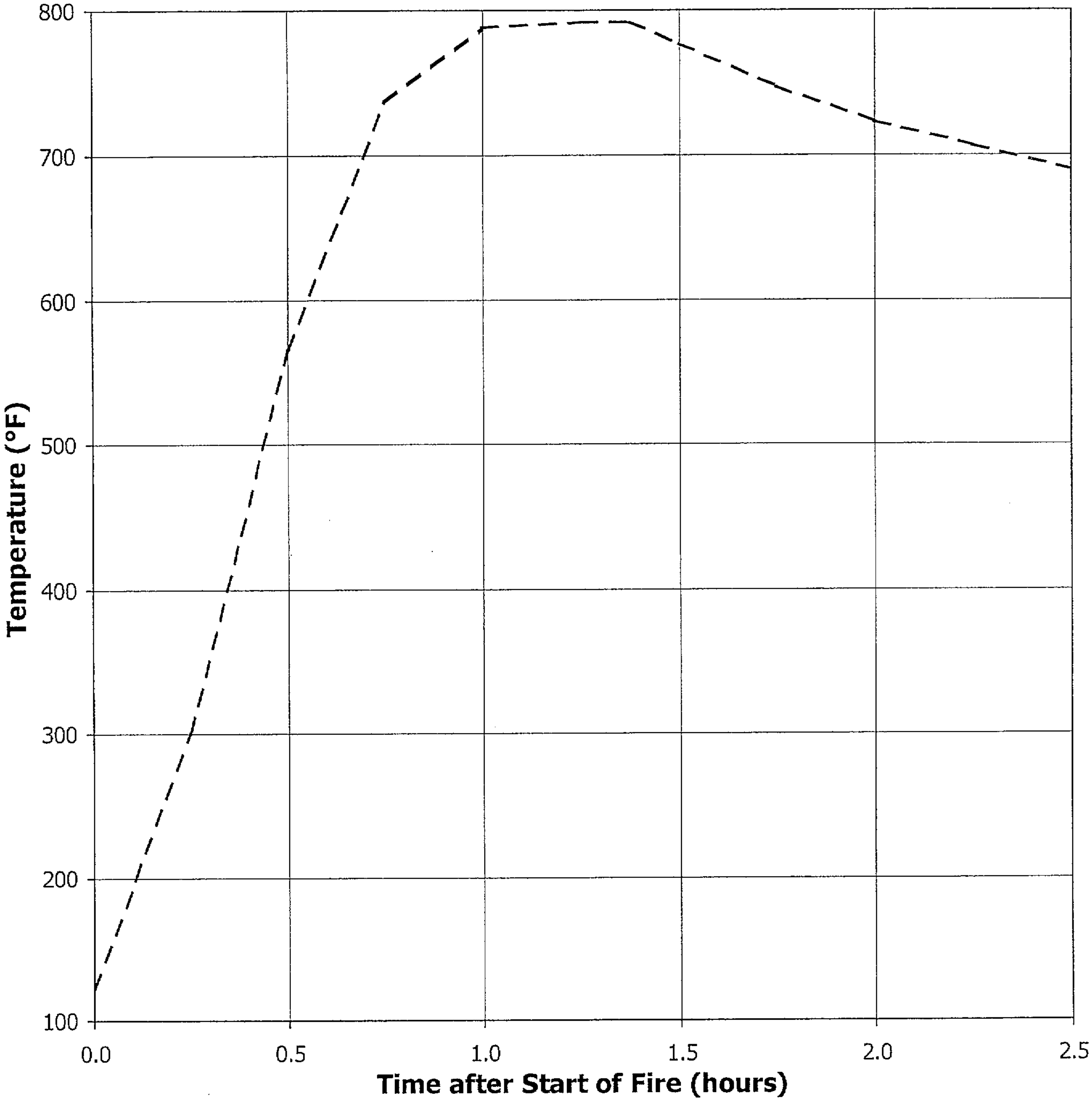


Figure 3.5-2 WE-1 Package Inner Container Peak Fuel Assembly Temperature during the HAC Fire Event (Maximum Occurs at the Inner Surface of the Support Clamp)

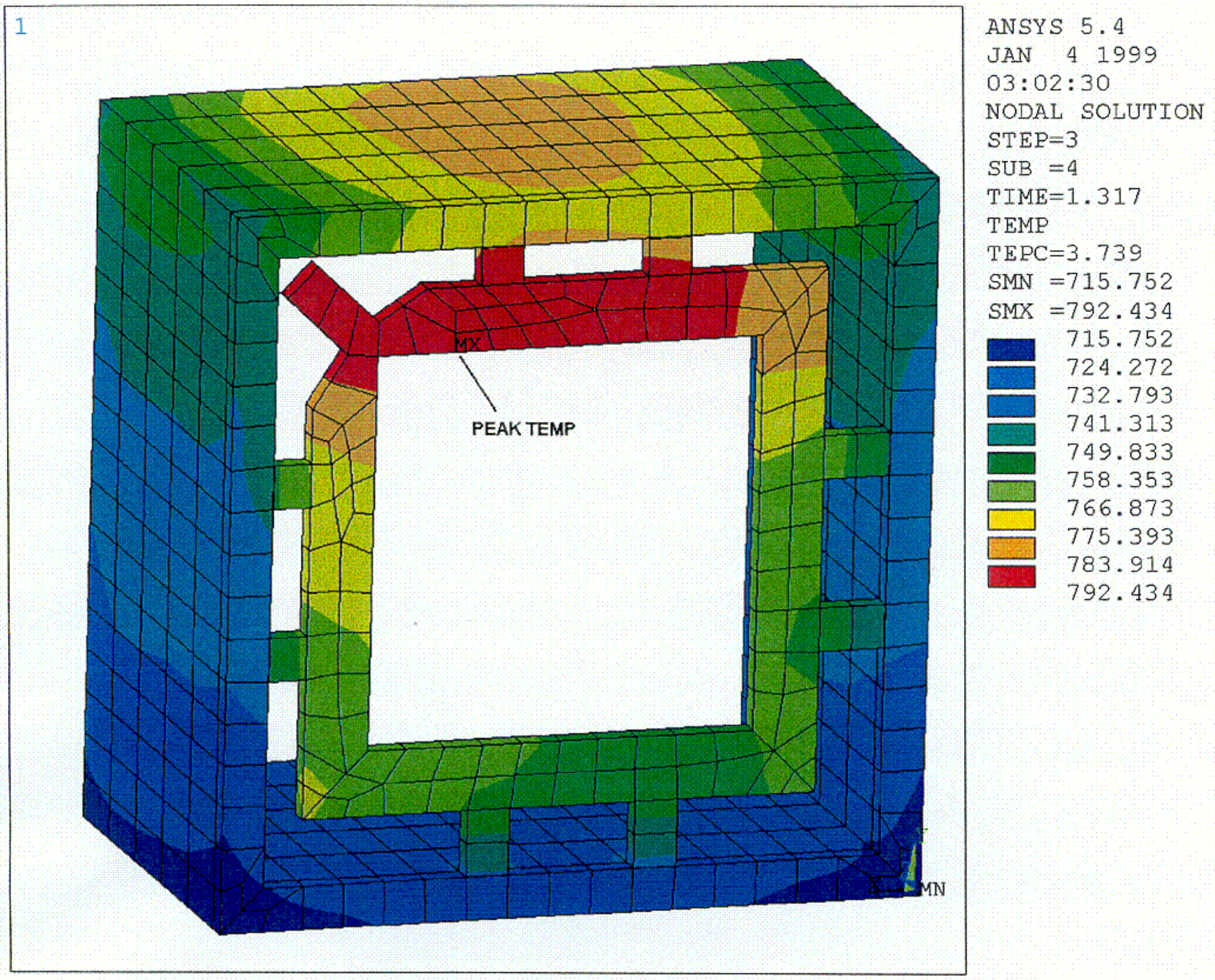


Figure 3.5-3 WE-1 Package Inner Container and Support Clamp Temperature Distribution at Time of Maximum Fuel Assembly Temperature (Ceramic Fiber Insulation Removed for Clarity)

C02

CHAPTER 4: CONTAINMENT

4.1 CONTAINMENT BOUNDARY

The WE-1 container is limited to use for transporting slightly irradiated, low enriched uranium, nuclear reactor core assemblies. The radioactive material, bound in sintered pellets having very limited solubility, has minimal propensity to suspend in air. These pellets are further sealed into cladding, to form the fuel rod portion of each assembly. The containment boundary for the WE-1 container with BW 17x17 fuel is the fuel rod cladding. Design and fabrication details for this cladding are given in Section 1.2.3 of this application.

4.1.1 PATHFINDER CANISTER

4.1.1.1 Containment Boundary for Pathfinder Canister

The Pathfinder Canister is used for transporting unirradiated Pathfinder fuel assemblies. The radioactive material, bound in sintered pellets, is in solid form and has minimal propensity to suspend in air. The containment boundary for the Pathfinder fuel is the Pathfinder Canister. The Pathfinder Canister is 8" schedule 40 S stainless steel pipe, welded end plate at bottom, weld neck flange at top and bolted blind flange with double metallic seals (o-rings). Design and fabrication details for the Pathfinder Canister are given in Section 2.1.1 of this application.

4.1.2 PATHFINDER CANISTER PENETRATIONS

The containment boundary is closed by a bolted blind flange, which is sealed by metallic o-rings. The annulus between the o-rings has a test port. The test port is sealed with a plug and o-ring.

4.1.3 PATHFINDER CANISTER SEALS AND WELDS

Two concentric O-ring metallic seal gaskets are located in grooves machined in the blind flange. The two seals are part of the containment boundary.

The range of seal gaskets operational temperatures presented in Chapter 3 is: -40 °F to 800 °F. The metallic seals are rated for temperatures from cryogenic to 1000 °F and working pressures from vacuum to 100 psi. The seals have excellent resistance to corrosion and radiation.

The seals have a non-compressed cross sectional diameter of 0.125" (0.097"/0.101" compressed) and a wall thickness of 0.010". The inner ring seal has a outer diameter of 9.25" while the outer ring seal has a diameter of 10.25". The grove width is 0.160" and grove depth 0.097"/0.101" for both seals.

The Pathfinder Canister will be tested leak tight (i.e., 1×10^{-7} cm^3/s, air, or better) during fabrication. All Pathfinder canister welds are full penetration welds in accordance with ASME Code, Division 1, Section III, Subsection NB. Compliance with ASME requirements is ensured by appropriate nondestructive examination methods. These methods verify weld structural and sealing integrity.

Prior to shipment of a loaded Pathfinder Canister, the closure lid and cover plate inter-seals annulus are pressurized to 15 psig of air for 10 minutes to verify sealing integrity.

4.1.4 CLOSURE OF PATHFINDER CANISTER

Eight (8) 3/4-10UNR02A closure lid studs provide canister closure. These studs are made of ASTM-A193-B8M Class 2 bolting material. The bolt preload reduces any gap opening (between the blind flange and upper ring flange) during regulatory conditions.

4.2 REQUIREMENTS FOR NORMAL CONDITIONS OF TRANSPORT

BW 17x17 Fuel

The nature of the contained radioactive material and the structural integrity of the fuel rod cladding and package are such that there will be no release of radioactivity under normal conditions of transport.

10CFR71.43(e) requires that a packaging valve or other device, the failure of which would allow radioactive contents to escape, must be protected against unauthorized operation and, except for a pressure relief device must be provided with an enclosure to retain any leakage. Helium leak testing of the BW 17x17 fuel rods is performed prior to shipment to demonstrate leak tight containment integrity (i.e., 1×10^{-7} cm^3/s, air, or better).

Pathfinder Canister

Chapter 2 demonstrates structural integrity of the Pathfinder Canister. The containment seal material was selected for its performance in the range of temperature including normal and hypothetical accident conditions. This canister meets 10CFR71 containment requirements under normal conditions.

4.2.1 CONTAINMENT OF RADIOACTIVE MATERIALS FOR PATHFINDER CANISTER FOR NORMAL CONDITIONS OF TRANSPORT

The Pathfinder Canister meets 10CFR71.51 containment requirements under normal conditions. The limit for the release of radioactive gases imposed by this regulation is (1x10-6) x A_2 per hour.

A_2 values and specific activity for 10 wt.% UO_2 are given in 10CFR71, Appendix A-1 and Appendix A-3 as A_2 = 0.027 Ci and S_A 4.8x10-6 Ci/g respectively.

The $(1\times10^{-6}) \times A_2$ limit determines the maximum permissible release rate for normal transport conditions.

$$R_N = (1\times10^{-6}) \times 0.027$$
$$= 2.7\times10^{-8}\ \text{Ci/Hr}$$
$$= 7.5\times10^{-12}\ \text{Ci/s}$$

The Pathfinder fuel rods are unirradiated (e.g. fresh) and as such do not contain any radioactive gases or byproducts. Thus using the method for dispersible radioactive solids for the dose rate is appropriate.

As stated in section 4.1.1 of NUREG/CR-6487 dispersible solid materials will tend to fracture and crumble due to handling, vibration or accident conditions. These conditions will tend to cause the radioactive solid material inside the containment vessel to produce a powder aerosol. The source term concentration (Ci/cm^3) can be expressed as the product of the aerosol mass density (g/cm^3) and the specific activity of the dispersible solid (Ci/g). A reasonable bounding value for the mass density of a powder aerosol is ρ = 9x10-6 g/cm^3 (page 17 of NUREG/CR-6487).

$$C_N = \rho \times S_A$$
$$= (9\times10^{-6}) \times (4.8\times10^{-6})$$
$$= 4.32 \times 10^{-11}\ \text{Ci/cm}^3$$

Equation 3 in ANSI N14.5-1997 calculates the maximum permissible leakage rate for normal transport conditions.

$$L_N = R_N/C_N$$
$$= (7.5\times10^{-12})/(4.32\times10^{-11})$$
$$= 0.17375\ \text{cm}^3/\text{s}$$

4.2.2 PRESSURIZATION OF PATHFINDER CANISTER

A maximum internal pressure of 25 psia (1.7 atm) and minimum external pressure per 10CFR71 (3.5 psia [.24 atm]) at 150 °F is considered during normal conditions.

The canister seals are leak-tested by pressure drop test of the inter-seals annulus at room temperature and with an internal air pressure of 15 psig. The leakage rate must be less than $1x10^{-3}$ cm^3/s for the canister seals.

The capillary diameter required to leak at a rate of LR = 1×10^{-3} std air cm^3/s at test conditions is found by using the leakage correlations provided in ANSI N14.5-1997.

Definitions:

a = Capillary Length = 0.125 in (diameter of Seal): a = 0.125 x 2.54 = 0.3175 cm

Pd = Downstream Pressure = 1 atm

P_U = Upstream Pressure = 15 psig = (15/14.7) + 1 atm = 2.02 atm

Pa = Average Stream Pressure = $\frac{1.0+2.02}{2} = 1.51$ atm.

T = Fluid Temperature, °K = 298 K (assume T=Ts = 298 K)

μ = viscosity of air at 298 K = 0.00185 cP (Handbook of Chemistry and Physics)

M = 29 g/mol (Air)

Ro = Universal Gas Constant = 8.31 x 107 erg/g mol·K

Equation B.5 of ANSI N14.5-1997 gives the volume leakage rate at the upstream pressure as:

$$L_T = (F_c + F_m) \times (P_u - P_d) \times (P_a / P_u) \text{ cm}^3/\text{s}$$

where

$$F_c = \lfloor 2.49 \times 10^6 \times D^4 \rfloor / (a \times \mu) \text{ cm}^3/\text{atm-sec}$$

and

$$F_m = \lfloor 3.81 \times 10^3 \times D^3 (T/M)^{0.5} \rfloor / (a \times P_a) \text{ cm}^3/\text{atm-sec}$$

are the continuum flow and molecular flow conductance respectively (equations B.3 and B.4 in ANSI N14.5-1997) and D is the diameter of the capillary.

Using trial and error and the values for the parameters given above with equations B.3 and B.4 and B.5 of ANSI N14.5-1997, the hole size to leak at a rate of 1×10^{-3} std air cm^3/s at upstream pressure (pressure drop leak test conditions) is found to be

$D = 1.311 \times 10^{-3}$ cm (13.11 μm).

Test: For $D = 1.311 \times 10^{-3}$ yields $Fc = 1.254 \times 10^{-3}$, $Fm = 5.745 \times 10^{-5}$ and $L_T = ([1.254 \times 10^{-3}]+[5.745 \times 10^{-5}] \times (2.02-1) \times (1.51/2.02) = 1 \times 10^{-3}\ cm^3/s$.

Using this diameter and plugging in the values for normal operating conditions

$T = 150\ °F = 339\ K\ (65.6\ °C)$

$P_u = 25$ psia = 25 psia / 14.7 psi/atm = 1.7 atm

$P_d = 3.5$ psia = 3.5 psia / 14.7 psi/atm = 0.238 atm

$P_a = (1.7 + 0.238)/2 = 0.969$ atm

$\mu = 0.0204$ cP ; (Interpolated from Handbook of Chemistry and Physics by using values at 74 °C and 54 °C:

$$\mu_{(65.6°C)} = 195.8 + \left[\frac{65.6-54}{74-54}\right] \times (210.2-195.8) = 204.15\,\mu P = 0.0204\ cP.$$

$$F_c = \left[2.49 \times 10^6 \times D^4\right]/(a \times \mu)\ \text{cm}^3/\text{atm-s}$$

$$F_c = \left[2.49 \times 10^6 \times (0.001311)^4\right]/(0.3175 \times 0.0204)\ \text{cm}^3/\text{atm-s}$$

$F_c = 1.136 \times 10^{-3}\ cm^3/atm\text{-}s$

$$F_m = \left[3.81 \times 10^3 \times D^3 (T/M)^{0.5}\right]/(a \times P_a)\ \text{cm}^3/\text{atm-s}$$

$$F_m = \left[3.81 \times 10^3 \times (0.001311)^3 (339/29)^{0.5}\right]/(0.3175 \times 0.969)\ \text{cm}^3/\text{atm-s}$$

$F_m = 9.54 \times 10^{-5}$

$$L_{N,MAX} = (1.136 \times 10^{-3} + 9.54 \times 10^{-5}) \times (1.7 - 0.238) \times (0.969/1.7)\ \text{cm}^3/\text{s}$$

$L_{N,MAX} = 1.026 \times 10^{-3}\ cm^3/s$

This leakage corresponds to a R_N release of aerosol powder.

$R_N = L_{N,\,MAX} \times C_N$

$= 1.026 \times 10^{-3}$ cm^3/s x 0.88 x 4.32 x 10^{-11} Ci/cc (0.88 is weight fraction of U in UO_2)
$= 3.9 \times 10^{-14}$ Ci/s
$= 1.4 \times 10^{-10}$ Ci/Hr

The maximum releasable value per 10CFR71.51 of 2.7 x 10^{-8} Ci/Hr exceeds the above value. Thus, the Pathfinder Canister meets the requirements of 10CFR71.51

4.2.3 CONTAINMENT CRITERIA FOR PATHFINDER CANISTER

A pressure drop leak test of the inter-seals annulus is performed at room temperature and with a canister cavity test pressure of 15 psig. The maximum leakage criteria is 1×10^{-3} cm^3/s. This ensures that the Pathfinder Canister provides containment.

4.3 CONTAINMENT REQUIREMENTS FOR HYPOTHETICAL ACCIDENT CONDITIONS

BW 17x17 Fuel

The nature of the contained radioactive material and the integrity of the fuel rod cladding and containment box are such that there will be no substantial release of radioactivity under hypothetical accident conditions. Before and after container testing, the fuel rods were helium leak tested. Before testing, no indications of a leak rate greater than 3×10^{-8} atm cm^3/s(10 CFR 71.51(a)(1)) were discovered. After testing, no indications of a leak rate greater than the limit specified in 10 CFR 71.51(a)(2). 10 CFR 71.51(a)(2) states that after hypothetical accident testing, no escape of radioactive material exceeding a total amount A2 in 1 week; a typical A2 quantity for this material is 5.4 kg UO_2. Using very conservative assumptions (UO_2 leaking at the same rate of helium and a density of 1gm/cm^3) the allowable leak rate would be approximately 1 x 10^{-2} cm^3 UO_2/s.

Pathfinder Canister

Chapter 2 demonstrates structural integrity of the Pathfinder Canister. The containment seal material was selected for its performance in the range of temperature including normal and hypothetical accident conditions. Thus, the canister meets 10CFR71 containment requirements under hypothetical accident conditions.

4.3.1 PATHFINDER FUEL FISSION GAS PRODUCTS

The Pathfinder fuel has never been irradiated. Thus there are no fission gas products in this fuel.

4.3.2 CONTAINMENT OF RADIOACTIVE MATERIAL FOR PATHFINDER CANISTER

The Pathfinder Canister meets 10CFR71.51 containment requirements under hypothetical accident conditions. This regulation imposes a release limit of A_2 Ci per week. A_2 is 0.027 for Pathfinder type fuel.

The maximum pressure in the canister during hypothetical accident conditions is 51.6 psia (3.51 atm). The outside pressure is the atmospheric pressure (1 atm). The maximum temperature is 800 °F.

The hypothetical accident condition uses the same calculation performed in Section 4.2.2 to calculate the leakage.

T = 800 °F = 700 K (427 °C)

P_u = 51.6 psia = 51.6 psia / 14.7 psi/atm = 3.51 atm

P_d = 14.7 psia = 1 atm

P_a = (3.51 +1)/2 = 2.255 atm

μ = 0.0344 cP ; (Interpolated from Handbook of Chemistry and Physics by using values at 466 °C and 409 °C)

$$\mu_{(427°C)} = 341.3 + \left[\frac{427-409}{466-409}\right] \times (350.1 - 341.3) = 344.079\,\mu P = 0.0344 \text{ cP.}$$

$$F_c = \lfloor 2.49 \times 10^6 \times D^4 \rfloor / (a \times \mu) \text{ cm}^3\text{/atm-s}$$

$$F_c = \lfloor 2.49 \times 10^6 \times (0.001311)^4 \rfloor / (0.3175 \times 0.0344) \text{ cm}^3\text{/atm-s}$$

$F_c = 6.735 \times 10^{-4}$ cm^3/atm-s

$$F_m = \lfloor 3.81 \times 10^3 \times D^3 (T/M)^{0.5} \rfloor / (a \times P_a) \text{ cm}^3\text{/atm-s}$$

$$F_m = \lfloor 3.81 \times 10^3 \times (0.001311)^3 (700/29)^{0.5} \rfloor / (0.3175 \times 2.255) \text{ cm}^3\text{/atm-s}$$

$F_m = 5.891 \times 10^{-5}$ cm^3/atm-s

$$L_{A.MAX} = (F_c + F_m) \times (P_u - P_d) \times (P_a / P_u) \text{ cm}^3\text{/s}$$

$L_{A,MAX} = 1.181 \times 10^{-3}\ cm^3/s$

Thus the maximum leak rate at 800 °F temperature and 51.6 psia (internal) pressure is $1.181 \times 10^{-3}\ cm^3/s$.

This leakage corresponds to a R_A release of aerosol powder.

$R_A = L_{A,\,MAX} \times C_A \quad (C_A = C_N)$
$= 1.181 \times 10^{-3}\ cm^3/s \times 0.88 \times 4.32 \times 10^{-11}$ Ci/cc (0.88 is weight fraction of U in UO_2)
$= 4.49 \times 10^{-14}$ Ci/s
$= 2.72 \times 10^{-8}$ Ci/wk

The maximum releasable value per 10CFR71.51 of 0.027 Ci/wk exceeds the above value. Thus, the Pathfinder Canister meets the requirements of 10CFR71.51.

The Pathfinder Canister satisfies containment criteria for normal and hypothetical accident conditions. Section 4.2.3 defines leak test requirements for the canister seals. These tests ensure that the Pathfinder Canister meets 10CFR71.51 containment requirements.

4.4 SPECIAL REQUIREMENTS

Not applicable because WE-1 and Pathfinder Canister is not transporting Plutonium.

4.5 REFERENCES

Metal O-Rings, page 2 and 4; Garlock Helicoflex High Performance Seals and Sealing Systems; POB 9889; Columbia, SC 29290. Phone # 803-783-1880.

ANSI N14.5 – 1997, American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment.

Handbook of Chemistry and Physics, 60th Edition, Chemical Rubber Publishing Company, 1960.

NUREG/CR-6487, Containment Analysis for Type B Packages Used to Transport Various Contents. November 1996.

CHAPTER 5: SHIELDING EVALUATION

The WE-1 container is limited to use for transporting low enriched uranium derived from surplus off-specification (reprocessed) highly enriched uranium enriched up to 4.6 weight percent in the isotope U-235, nuclear reactor core assemblies, or unirradiated Pathfinder fuel enriched up to 7.51 weight percent in the isotope U-235. Therefore, shielding design of the packaging, per se, is not necessary. Typical maximum dose equivalent rates are 2.0 millirem per hour, at any point on the external surface of the container, and 0.8 millirem per hour one meter from the external surface of the container.

CHAPTER 6: CRITICALITY EVALUATION

6.1 DISCUSSION & RESULTS

The WE-1 package containing one B&W MkBW 17x17 or up to 48 Pathfinder fuel assemblies satisfies the criticality requirements of 10 CFR 71 based upon a Transportation Index (TI) of 100. Only one package will be shipped on an exclusive use vehicle. A single package is subcritical under the normal and accident conditions for a package containing one fuel assembly as described in Table 6-2a, or 48 Pathfinder assemblies as described in Table 6-2b.

The results of the KENO V.a evaluation of the container are summarized in Table 6-1a for shipping on B&W MkBW 17x17 and Table 6-1b for Pathfinder fuel. In Table 6-1a, K_{max} is the summation of the KENO calculated k_{eff} plus the KENO bias and calculation uncertainties and are applied against the limits stated in Section 6-4A. In Table 6-2b, k_{max} is the summation of the KENO-V.a calculated k_{eff} plus twice the calculational uncertainty and is applied against the limits stated in Section 6-4B. These values represent the largest K_{max} values including both fuel and moderator optimization for the conditions listed. Since there were no significant deformations to the inner container due to the accident, the single flooded condition and the accident condition are the same.

The analytical models provide conservative values of K_{max}. The model assumptions contributing to the conservatism for the B&W MkBW 17x17 are:

- Maximum possible fuel dimensions;
- Infinite axial fuel length;
- Moderator density at 1.0 g/cc;
- Maximum hypothetical accident condition.
- Thermal insulation replaced by water in inner container.

The model assumptions contributing to the conservatism for the Pathfinder fuel assemblies are:

- Maximum fuel enrichments, densities and assembly loadings were used
- The poison wires in the center tubes are not included, having been modeled as water
- Assembly structural components were not included; the space they occupy was modeled as water
- Optimum moderator density was used
- Optimum assembly spacing was included
- Maximum hypothetical accident conditions were assumed

Table 6-1a
WE-1 KENO V.a Results

Condition	Model Configuration	K_{max}
Normal Single Package	Single package with a close 12" water reflector	0.156
Single Flooded	Single flooded package with a close 12" water reflector	0.943
Accident	Same as 'Single Flooded' condition	0.943

Table 6-1b
Pathfinder KENO V.a Results

Condition	Model Configuration	k_{max}
Transport	3 undamaged WE-1 packages with a close 12" reflector	0.257
Accident	single damaged package, fully flooded with a close 12" water reflector, 48 assemblies close pack	0.691
Accident	single damaged package, fully flooded with 12" water reflector, 40 assemblies optimally spaced	0.705
Accident	48 assemblies at optimal spacing, 12" water reflector (note: exceeds inner package dimensions)	0.821

The shipment of 48 Pathfinder fuel assemblies will entail shipping a smaller amount of fissile material than for the currently licensed MkBW 17x17. The current license for the WE-1 package enables shipment of up to 22.14 kg of ^{235}U in zircaloy cladding. A full shipment of 48 Pathfinder fuel assemblies will have a maximum loading of 8.1 kg of ^{235}U, well below the amount currently licensed. The cladding is Incoloy 800, a material with neutronic properties very similar to those of stainless steel, and thus with a greater neutron absorption capability than zircaloy. The Pathfinder assemblies sit inside a stainless steel cylindrical inner canister (Pathfinder Canister) with a nominal ID of 8 inches.

6.2 PACKAGE FUEL LOADING

The maximum dimensions and ^{235}U loading for the MkBW 17x17 fuel assembly are listed in Table 6-2a. Note that for the analysis an infinite fuel height was used. This analysis bounds the effect of modeling both the fuel assembly end-fittings and the ends of the inner and outer containers.

Table 6-2a
B&W Mk BW 17x17
Fuel Assembly Description

Assembly Type	B&W MkBW 17x17
Number of fuel rods	264
Number of non-fuel tubes	25
Fuel rod pitch, inches	0.496
Maximum pellet outer diameter, inches	0.3232
Tube material	Zr-4
Maximum active fuel length, inches	144
Maximum enrichment, w/o U-235	4.6
Maximum U-235 loading, kg	22.14

The design parameters of the Pathfinder fuel are listed in Table 6-2b. These represent nominal values, except for the uranium enrichment, which is a conservatively high bounding value. The WE-1 may hold up to 48 of these assemblies. The fuel assemblies will be kept inside their 1-inch (OD) sheaths for shipment. These sheaths may be made of any stainless steel, Incoloy or inconel alloy.

Table 6-2b
Pathfinder Fuel Assembly
Fuel Assembly Description

Assembly type	Pathfinder
Number of pins per assembly	6
Maximum Enrichment, wt % ^{235}U	7.51
Pellet diameter, inches/ cm	0.207/ 0.5258
Fuel length, inches/ cm	72/ 182.88
Nominal loading per assembly, kgU	2.206
Clad material	Incoloy 800
Sheath material	Incoloy, stainless steel or inconel alloy
Fuel clad ID, inches/ cm	0.212/ 0.5385
Fuel clad OD, inches/ cm	0.246/ 0.6248
Sleeve ID, inches/ cm	0.945/ 2.4003
Sleeve OD, inches/ cm	1.00/ 2.54

6.3 MODEL SPECIFICATIONS

The analysis was made with the CSAS routine of the SCALE 4.2 code package[1] for the B&W MkBW 17x17, and SCALE4.4a for the Pathfinder fuel assemblies The package k_{eff} was calculated with KENO V.a using the 44-group cross section set from SCALE4.3[2] for the B&W MkBW 17x17, and using the 238-group cross section set from SCALE 4.4a for the Pathfinder fuel The detailed model of the fuel assembly and shipping container, as well as the regional number densities, are described is this section for both types of fuel.

6.3.1 Description of Calculational Model

The calculation models for the WE-1 package are described in this section. Listings of the input files for the licensing results presented in Table 6-1a and Table 6-1b are contained in Appendix 6-1.

6.3.1.1 Fuel Assembly

A. B&W MkBW 17x17

One B&W MkBW 17x17 fuel assembly can be shipped in the WE-1 package without the need for neutron absorber plates. The dimensions of the B&W assembly are listed in Table 6-3. The model values for the fuel provide an optimum fuel configuration, since 1) the fuel pellet diameter is maximized; 2) the Zr-4 tube dimensions provide a minimized tubing thickness; and 3) the maximum theoretical density of 97.5% is used. Figure 6-1a provides a sketch of the fuel assembly configuration.

The analysis assumes the assembly contains UO_2 pellets with only ^{235}U and ^{238}U, i.e., the standard LWR fuel composition. However, the package will also be used to ship fuel assemblies containing low enriched uranium derived from surplus off-specification (reprocessed) highly enriched uranium. Typical slightly irradiated fuel constituents are listed Table 6-4. As shown later, this type fuel assembly is less reactive than that with the standard LWR fuel composition with the same ^{235}U enrichment. Thus, the results of this analysis will bound those for an assembly with slightly irradiated fuel with a ^{235}U enrichment α 4.6 weight percent.

Table 6-3
B&W Mk BW 17x17
Bounding[3] Fuel Assembly Model Dimensions

Matrix	Inches	Centimeters	Centimeters/2
Pitch	0.496	1.25984	0.62992
Pellet OD	0.3232	0.820928	0.410464
Clad ID	0.331	0.84074	0.42037
Clad OD	0.372	0.94488	0.47244
GT ID	0.452	1.14808	0.57404
GT OD	0.48	1.21920	0.60960
IT, ID	0.452	1.14808	0.57404
IT, OD	0.48	1.21920	0.60960
Assembly Dimension	8.432	21.41728	-

Figure 6-1a
B&W MkBW 17x17
Fuel Assembly Configuration

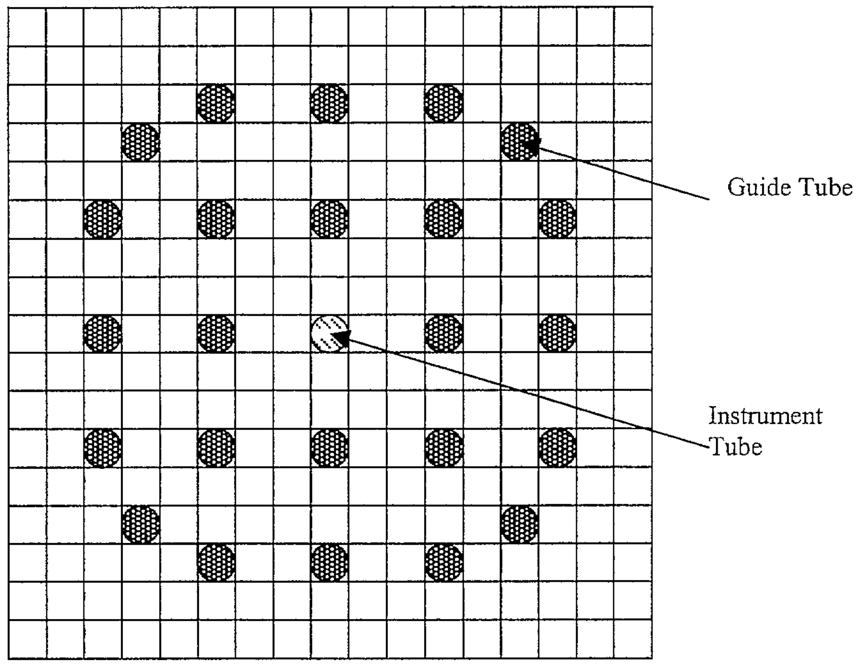


Table 6-4
Typical ^{235}U Slightly Irradiated Fuel Composition

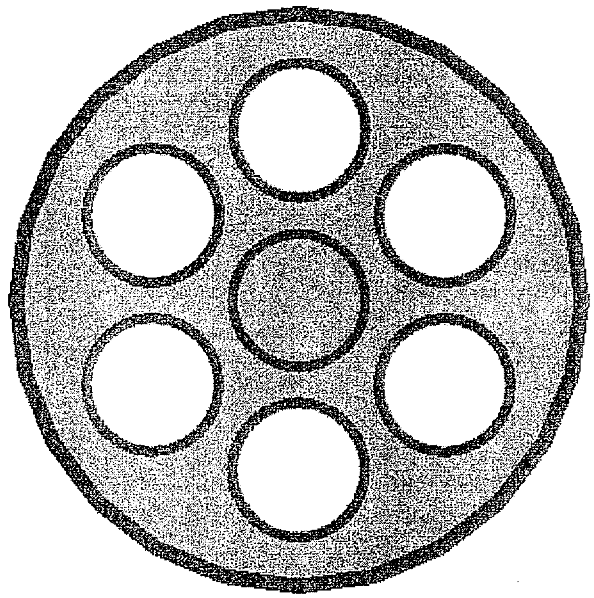
Isotope	Composition (weight percent)
^{232}U	0.0
^{234}U	0.09
^{235}U	4.385
^{236}U	1.34
^{238}U	94.185

B. Pathfinder Fuel Assemblies

A single Pathfinder fuel assembly is composed of six Incoloy 800 clad fuel pins containing UO_2 pellets. The six pins are kept in a hexagonal pattern by the use of 0.042-inch diameter spacer wires, and surround an Incoloy 800 tube containing hollow alumina pellets through which a borated steel wire runs. Neither the alumina pellets nor the borated steel wire were included in the KENO-Va model, their volume being modeled as moderator. Each assembly sits inside a 1-inch diameter sheath. Since there is no means to ensure that each fuel pin is sealed tight, 10CFR71.55(b) requires that all gaps be assumed to be filled with water for criticality analysis of the accident condition. As such, the gap between the fuel pellet and fuel clad, the space between the fuel pins and sheath, and the interior of the center pin are all assumed to be filled with water in all models where flooded conditions are assumed. Figure 6-1b shows a sketch of a Pathfinder fuel assembly as modeled in KENO-Va.

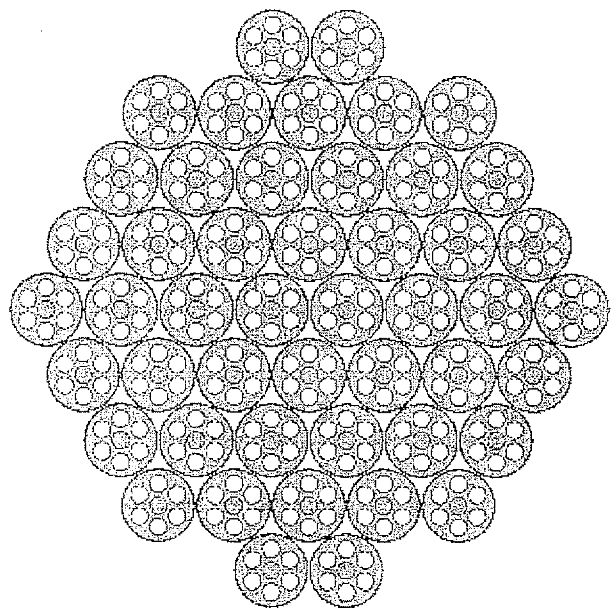
The nominal enrichment for 415 of the 417 Pathfinder fuel assemblies is 6.95%. The remaining two assemblies have enrichments of 7.5%. A bounding value of 7.51% was used in this analysis to conservatively cover all the fuel. Also, a 1% uncertainty was applied to the fuel loading, representing about 1 extra pellet per pin. This loading uncertainty increases the assumed loading of each cluster to 2206 x 1.01 = 2228.06 grams uranium. Only ^{235}U and ^{238}U were included in this model, which is typical of low-enriched fuel.

Figure 6-1b
Pathfinder Fuel Assembly Configuration



The array of 48 assemblies in a close pack triangular pitch arrangement is shown in Figure 6-2a. This array was chosen because it provides for the maximum number of assemblies that can physically fit inside an 8-inch ID Pathfinder Canister. The KENO-V.a model for the Pathfinder assemblies did not include the Pathfinder Canister or any other structural material of the WE-1 for conservatism.

Figure 6-2a
Arrangement of 48 Fuel Assemblies in a Close Pack Array



6.3.1.2 Package Specifications

A. B&W MkBW 17x17

The WE-1 package consists of an outer shell (base and cover) that is designated as the outer container. The outer container supports the inner container constructed of 1" steel walls that contains the fuel assembly. The significant dimensions[4] of the WE-1 package for the criticality calculation are listed in Table 6-5. Figure 6-2b provides a sketch of the model of the inner container. Note that a 3" layer of insulation normally fills the area between the fuel assembly and the armor plate.

For the single flooded package, a 12" water reflector surrounds the flooded inner container (the dimensions extend to infinity in the axial dimension of the container). This description is illustrated in Figure 6.3A. The base model assumes that the insulation layer in the inner container is replaced with water. A case with a 3" layer of insulation was also examined to ensure that it would not increase reactivity (see Figure 6.3B). In this model, no water infiltrates the insulation. Since only one package will be shipped, a flooded package will represent the accident condition. This condition is verified by the drop tests since after the drop tests the shell shows relatively little deformation and the inner container is intact. The fuel assembly shows some reduction in the rod pitch for the end opposite the drop due to slap-down forces. The reduction in the rod pitch will further under-moderate the assembly and result in a reduction in reactivity. Thus, the single flooded assembly model with an intact assembly will provide results that bound the post-drop package configuration.

To evaluate optimum moderation, the inner container is centered in the outer container (see Figure 6-4). A 12" water reflector surrounds the outer shell. Figure 6-5 illustrates the model for the off-centered placement of the assembly in the inner container at a corner of the container. This latter case assumes that the inner supports all fail to provide an incredible accident condition not supported by the drop tests.

Table 6-5
WE-1 Specifications for Criticality Model

Dimensions	Actual	Model
Internal Container Formed by Armor Plate		
Thickness	1"	1" (2.54 cm)
Vertical Width	16.5"	16.5" (41.91 cm)
Horizontal Width	16.5"	16.5" (41.91 cm)
Bottom of Fuel Assembly to Bottom Plate (inside)	2.917"	2.917" (7.40918 cm)
Outer Container		
Shell Thickness (13 gage) Carbon Steel	0.0897"	0.0897" (0.227838 cm)
Inner Radius	20.5"	20.5" (52.07 cm)

Figure 6-2b
Sketch of WE-1 Internal Container

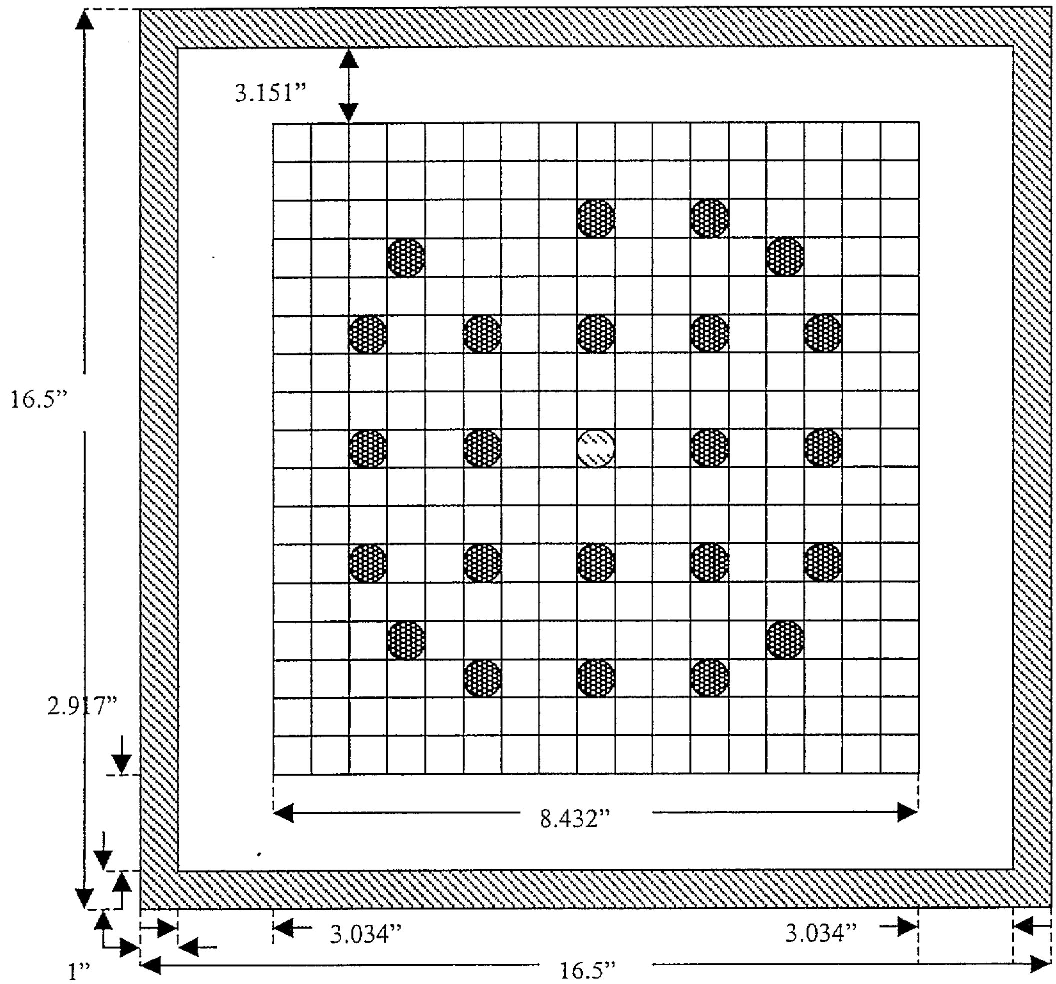
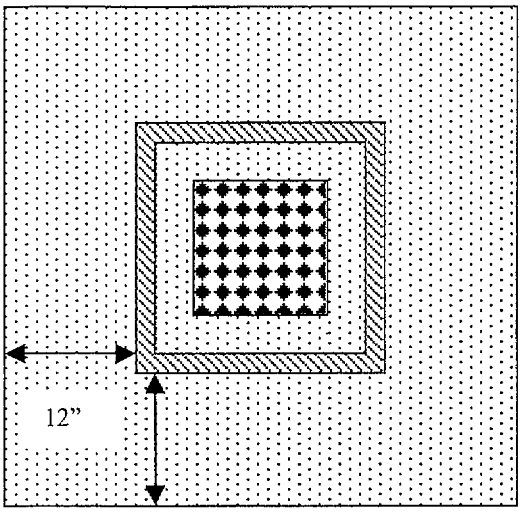
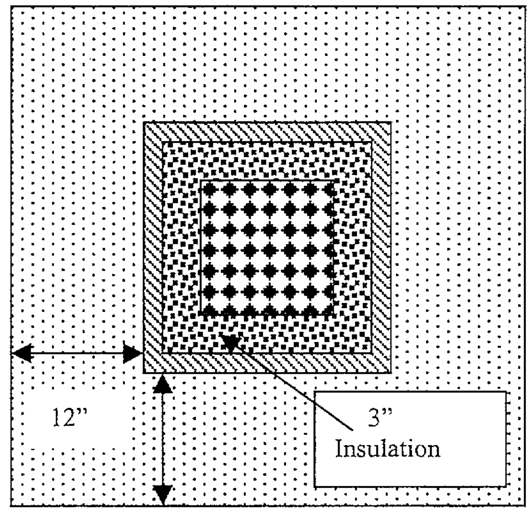


Figure 6-3
Sketch of WE-1 Single Flooded Container Models

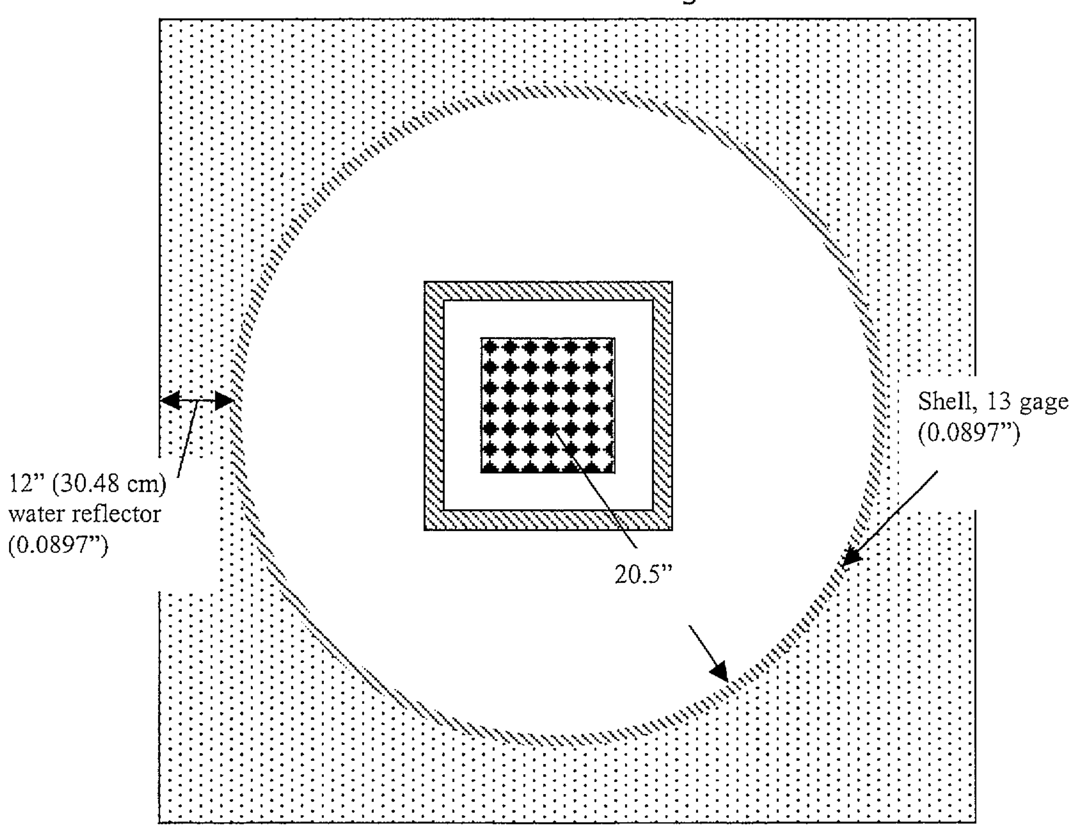


A. Base Model



B. Realistic Model

Figure 6-4
Sketch of WE-1 Normal Package Model



B. Pathfinder Fuel Assemblies

The WE-1 outer container (shell) and inner container to be used to ship Pathfinder fuel assemblies are the same as for shipping a B&W MkBW 17x17. Inside the inner container will be placed a stainless steel cylindrical inner canister (Pathfinder Canister) with a nominal ID of 8 inches. This Pathfinder Canister has a sealed bottom on one end and a lid that will be bolted into place on the other. The Pathfinder assemblies will be placed inside the Pathfinder Canister.

The arrangement of the Pathfinder assemblies is that shown in Figure 6.2a. In the KENO-V.a models of the normal array and accident conditions, the Pathfinder Canister and the inner container are not included in the model. The volume they occupy is modeled as water. This produces a conservative model as it increases reflection and decreases neutron loss from absorption in the Pathfinder Canister.

The accident condition considers that the entire canister, including gaps between the fuel and cladding, are flooded. Further models also examined the impact on reactivity of the assemblies spreading apart (which increases reactivity due to more optimal moderation), of partial flooding, and of partial loads.

6.3.2 WE-1 Normal Array Evaluation

A. B&W MkBW 17x17

The inner container is positioned off-centered in the shell, however for the normal condition model, it is assumed that the fuel assembly is centered in the shell – see sketch in Figure 6-4. With a TI = 100, three containers must be considered in the normal condition array. Figure 6-6 provides a sketch of the array model for the normal condition array in the x-y plane. An infinite axial assumption is used in this model. The KENO V.a model generates the model of the single package illustrated in Figure 6-4. It then creates the array model by filling holes in the outer cylinder of Figure 6-6 with the single package model.

Two cases are evaluated with this model with 4.6 wt% ^{235}U MkBW fuel assemblies. The first examines a voided outer cylinder with a 12" water reflector surrounding the cylinder. The second uses the same model except that the outer cylinder is filled with water. This last case places the reflector at the edge of the packages, however, a small amount of water is between the containers. The results of these cases are listed in Table 6-6. K_{max} is based upon a KENO bias of 0.0048 with a 1.763 sigma of 0.004. There is a slight increase in reactivity for the second close-reflector case. If the water were removed from between the containers in the model, there may be another small increase in reactivity. However, due to the large reactivity margin for the normal container array, the additional increase would have no significant impact on the criticality safety of the array.

Table 6-6 Three Container Array Results			
Description	k_{eff}	1σ	K_{Max}
Array with insulation	0.16290	0.00026	0.17173
Array with insulation and water surrounding containers	**0.16528**	**0.00027**	**0.17411**

Based upon this evaluation, an array on three normal packages closely surrounded with water satisfies the criticality safety criterion.

Figure 6-5 Sketch of WE-1 Container In Normal Condition

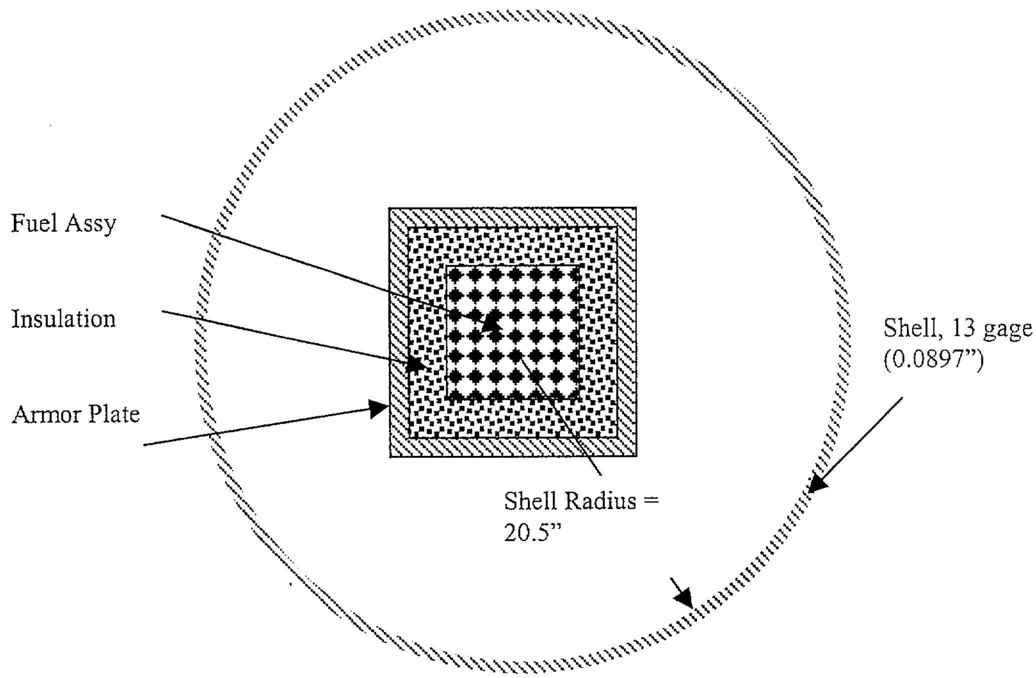
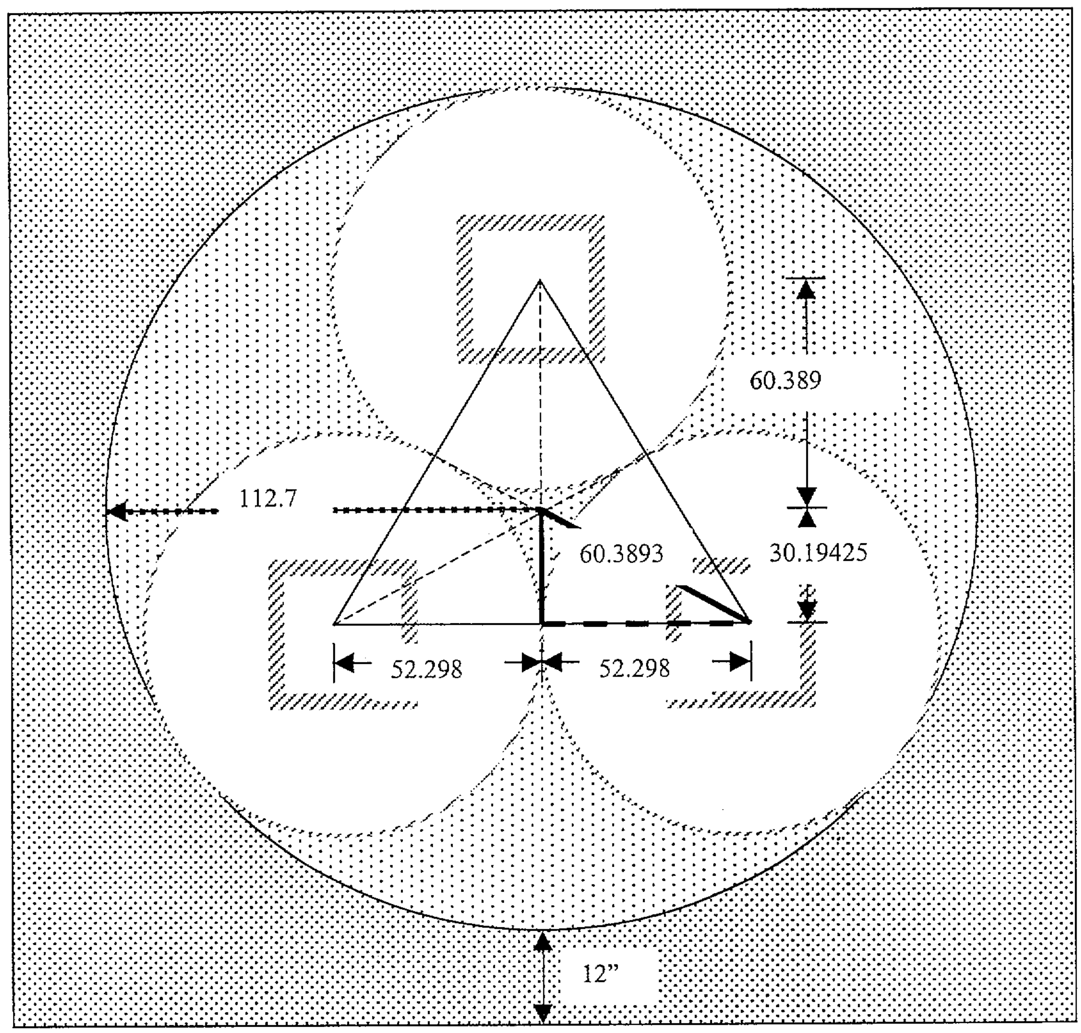


Figure 6-6 Sketch of WE-1 Container Array



B. Pathfinder Fuel Assemblies

Three WE-1 packages were assumed to be stacked in the same configuration as shown in Figure 6-6. Forty-eight Pathfinder fuel assemblies were placed inside each package. The interior of the packages were dry, but the entire configuration was surrounded by a full water reflector. The Pathfinder Canister and inner container were not explicitly included in the model.

The k_{eff} calculated by KENO-V.a for this is 0.25641 $\pm$ 0.00077. Based upon this evaluation, an array on three normal packages closely surrounded with water satisfies the criticality safety criterion.

6.3.3 Material Number Densities

A. B&W MkBW 17x17

The evaluation assumes a maximum ^{235}U enrichment of 4.6 wt. The materials used in the analysis are listed in Table 6-7a. No number densities are provided for those materials for which the SCALE standard materials specification is employed. The 4.3 weight percent fuel specifications allow a comparison between a standard LWR fuel assembly and a typical slightly irradiated fuel assembly in the package.

Table 6-7a
KENO V.a Model Material Specifications, T= 293°K

Material	KENO V.a Mat.	Density, g/cc	Weight percent or At/b-cm
Fuel (normal) ^{235}U ^{238}U	1	10.686 (0.975 TD)	 4.6 95.4
Zr (Clad)	2	default	100.0
H20	3	1.0	100.0
H20	4	1.0	100.0
H20	5	1.0	100.0
Carbonsteel	6	default	100.0
Insulation (50% Al_2O_3/50% SiO_2) Al Si O	7	0.12816 (8 lbs/cu ft)	 7.5696E-04 6.4231E-04 2.4201E-03
Insulation (50% Al_2O_3/50% SiO_2) Al Si O	8	0.09612 (6 lbs/cu ft)	 5.6772E-04 4.8173E-04 1.8150E-03
Additional Fuel Compositions for Standard/Slightly-Irradiated Fuel Comparison			
Fuel (4.385 weight percent Irradiated) ^{234}U ^{236}U ^{235}U ^{235}U	1	10.686 (0.975 TD)	0.09 4.385 1.34 94.185
Fuel (normal) ^{235}U ^{235}U	1	10.686 (0.975 TD)	 4.385 95.615

B. Pathfinder Fuel Assemblies

To determine the atom densities for Incoloy 800, a manufacturing spec sheet that was considered representative of the material was obtained. This spec sheet gives the elemental ranges for manufacturing this metal. The weight percentages of each element that give the low nickel and chromium concentrations (which are the strongest neutron absorbers) were assumed for the KENO-Va model. A density of

7.94 g/cc was used. The weight percent of each element in Incoloy 800 and the corresponding atom density is shown calculated in Table 6-7b.

Table 6-7b
Incoloy 800 Atom Densities (Metal density = 7.94 g/cc)

Element	w/o Range	w/o KENO-V.a	AW	a/b-cm
carbon	0.1 max	0.10	12.011	3.9810E-04
aluminum	0.15-0.6	0.60	26.98154	1.0633E-03
titanium	0.15-0.6	0.60	47.9	5.9894E-04
copper	0.75 max	0.75	63.546	5.6434E-04
silicon	1.0 max	1.00	28.0855	1.7025E-03
manganese	1.50 max	1.50	54.938	1.3055E-03
chromium	19.0-23.0	19.00	51.996	1.7472E-02
nickel	30.0-35.0	30.00	58.7	2.4437E-02
iron	39.5 min	46.45	55.847	3.9770E-02

6.4 CRITICALITY CALCULATION

A. B&W MkBW 17x17

The results of the evaluation are discussed in this section. The KENO V.a calculational bias must be added to the calculated k_{eff} to obtain the limiting reactivity, i.e., K_{MAX}. The defining equation is:

$$K_{MAX} = k_{eff} + \Delta k_{bias} + \sqrt{(1.763\sigma_k)^2 + (1.763\sigma_{bias})^2}$$

where,

K_{MAX} is the maximum keff including bias and uncertainties
$k_{eff} \pm \sigma_k$ is the reactivity calculated with KENO V.a and its uncertainty,
$\Delta k_{bias} \pm \sigma_{bias}$ is the KENO V.a code bias plus uncertainty.

The KENO V.a bias discussed in Section 6.5 is given as follows:

$$\Delta k = -0.0048 - 0.0008354\, x + 7.1414E\text{-}05\, x^2.$$

where 'x' is the spacing in centimeters between assemblies. The uncertainty in the bias is 0.004 including the 95/95-confidence factor of 1.763. A slight trend in bias is seen from about 0 to 12 cm as is defined by the above equation. Beyond about 12 cm, the bias is just that for a spacing of zero. For a single package, the spacing between assemblies is zero, and thus the bias for this analysis is 0.0048 with a 1.763 sigma of 0.004.

Table 6-8 lists the results for the single flooded container model. The first case represents a single flooded container closely surrounded by a 12" water reflector with the insulation layer in the inner container replaced by water. This base case provides an acceptable value of K_{MAX} for 4.6 weight percent fuel. The next two cases illustrate the reactivity difference between standard fuel and slightly irradiated fuel with the same ^{235}U enrichment. The slightly irradiated fuel is about 1% Δk less reactive than the standard fuel. Thus, additional margin will exist in this package when it contains slightly irradiated fuel.

Table 6-9 lists the results for several optimization cases. The first case includes the 3" insulation material in the flooded inner container. The replacement of the water with the insulation results in a significant reduction in reactivity. The second case offsets the assembly to a corner of the inner container. This incredible accident provides a reduction in reactivity and indicates that exact center placement of the assembly in the inner container is not limiting. The next three cases examine misted conditions in both the inner and outer containers of the package. The keff for the 0.01% dense case is assumed to be representative of a single, normal unflooded shipment. As noted a monotonic increase in reactivity is seen as the moderator density increases. Thus, a completely flooded container, the first case in Table 6-8, is bounding. The next two cases examine the effect of the wall thickness of the inner container. The plate was increased and decreased by 1/8" in these cases. The results are essentially equal within the uncertainty of the calculations. Thus, the use of the nominal thickness is not limiting.

Table 6-8
KENO V.a Results for a Single Flooded Container

^{235}U Fuel			
Description	k_{eff}	σ	K_{MAX}
Single Flooded, 12" H_2O Reflector 4.6 weight percent	0.93401	0.00076	0.94303
4.3 Weight percent Fuel for Standard and Slightly Irradiated Fuel Comparison			
Single Flooded, 12" H_2O Reflector – 4.3 weight percent ^{235}U	0.92811	0.00079	0.93715
Single Flooded, 12" H_2O Reflector - 4.3 weight percent Irradiated	0.91405	0.00075	0.92306

Table 6-9
KENO V.a Optimization Cases, 4.6 Weight percent ^{235}U Fuel

Description	k_{eff}	σ	K_{MAX}
Single Flooded, 12" H_2O Reflector w. Insulation	0.80817	0.00078	0.81720
Off-Centered Assembly in Inner Container	0.90076	0.00075	0.90977
0.01% Dense Water in Package	0.14761	0.00024	0.15643
5.0% Dense Water in Package	0.18187	0.00030	0.19070
10.0% Dense Water in Package	0.25077	0.00043	0.25964
Single flooded with 1-1/8" Plate Thickness	0.93416	0.00079	0.94320
Single flooded with 7/8" Plate Thickness	0.93340	0.00076	0.94242

B. Pathfinder Fuel Assemblies

KENO-V.a was used to model the shipment of the Pathfinder fuel under various normal and accident conditions. The purposes of these cases were to:

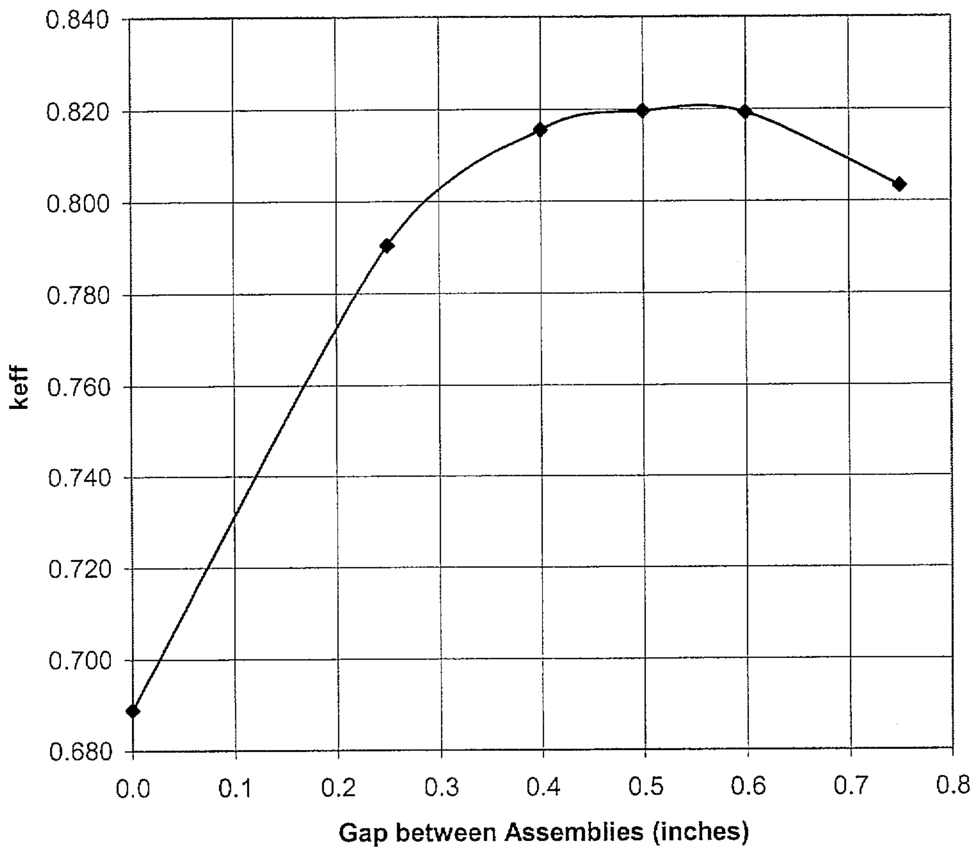
1. Determine the spacing between the assemblies that gives the maximum k_{eff} at full water moderation and reflection.
2. Determine the effect of varying moderator density from 0 g/cc to 1 g/cc, and to examine partially flooded situations.
3. Determine k_{eff} of 48 assemblies at optimal moderation and spacing
4. Determine k_{eff} for situations with fewer than 48 assemblies in the canister
5. Determine k_{eff} of 3 WE-1 packages under normal transportation conditions and full water reflection per 10CFR71.51a.

Cases were run where the spacing between the Pathfinder assemblies was varied to determine the spacing that gave the optimal moderation. Distances between adjacent assemblies varying from 0 inches (i.e., adjacent assemblies touching) to 0.75 inches (distance between clad at their closest) were modeled. The results of this analysis are shown in Table 6-10 and Figure 6-7. It is seen in Figure 6-7 that the optimal spacing occurs at about 0.5 inches.

Table 6-10
Effect of Assembly Spacing on k_{eff}

Spacing (inches)	k_{eff}	σ
0	0.68898	0.00078
0.25	0.79041	0.00092
0.4	0.81562	0.00082
0.5	0.81966	0.00080
0.6	0.81933	0.00083
0.75	0.80344	0.00083

Figure 6-7 Optimal Spacing of 48 Pathfinder Assemblies



To achieve this optimal spacing would require the volume taken by the fuel assemblies to exceed the dimensions of the Pathfinder Canister. This indicates that the fuel would be maintained at less than optimal moderation by the Pathfinder Canister, and also that any slight settling of the assemblies would decrease reactivity rather than increase it. Also it implies that criticality limits would still be maintained even if the Pathfinder Canister was breached and the assemblies reconfigured into an optimally moderated configuration.

Cases were run to examine the effect of flooding occurring only in select portions of the fuel and canister. The situations modeled were:

1. The sheaths and rods were flooded, but the volume between the sheaths was dry.
2. The volume between the sheaths was flooded, but the volumes inside the sheaths and rods were dry.
3. The fuel pins were flooded (i.e., between the fuel pellet and clad), but the remainder of the package was dry.
4. Using a 40-assembly model, the volume between the sheaths was flooded, but volumes inside the sheaths and rods were dry. The 40-assembly model was

examined because it could provide a value of k_{eff} greater than the 48-assembly model when limited to the volume of the Pathfinder Canister.

All cases used full water reflection outside of the Pathfinder Canister. The results are shown in Table 6-11, and show that all modeled cases gave a k_{eff} value less than that of the fully flooded case (keff=0.68898$\pm$0.00078).

Table 6-11
Partially Flooded Cases

Inside Pins	Inside Sheath	Between Sheaths	keff	σ
wet	wet	dry	0.62445	.00071
dry	dry	wet	0.43619	.00064
wet	dry	dry	0.40258	.00062
dry	dry	wet	0.52190*	.00071

*40 assemblies

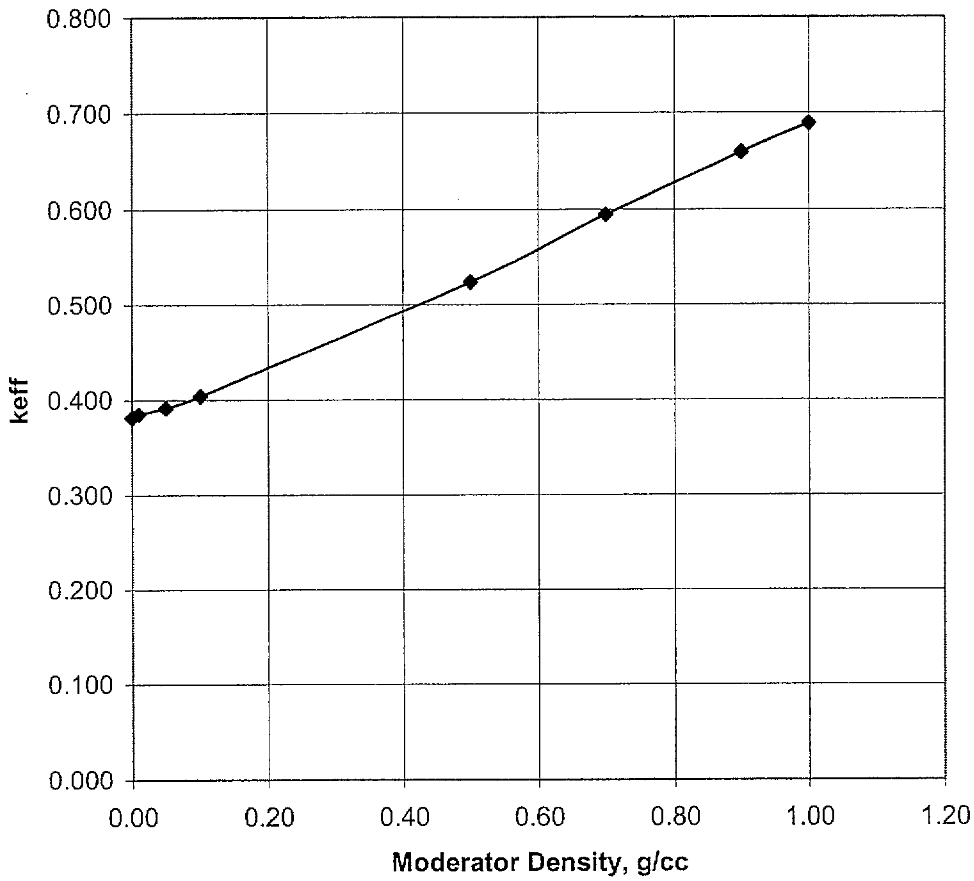
Cases were run where the density of the water moderator inside the inner canister was varied from 0 g/cc (i.e., dry) to 1.0 g/cc. Water in these cases filled all gaps between the fuel pellets and clad, inside the center tube, inside the sheaths, and between fuel assemblies. Outside of the Pathfinder Canister, full water reflection (30 cm of 1.0g/cc water) was modeled. The assemblies were in a close pack array.

The results of this analysis are shown in Table 6-12 and Figure 6-8 modeling 48 assemblies in the canister. Figure 6-8 indicates that the optimal moderator density is that of full water. As such, a density of 1.0 g/cc will be used in all models requiring flooded conditions.

Table 6-12
Effect of Moderator Density on k_{eff}

Water Density g/cc	keff	sigma
1.00	0.68898	0.00078
0.90	0.65894	0.00090
0.70	0.59429	0.00075
0.50	0.52346	0.00071
0.10	0.40412	0.00060
0.05	0.39141	0.00064
0.01	0.38464	0.00060
0.00	0.38102	0.00066

Figure 6-8 Optimal Moderation for 48 Pathfinder Assemblies



Calculations show that a fully loaded inner canister (48 assemblies) would be less than optimally moderated. KENO-V.a cases were run with 44, 40 and 36 assemblies in the canister to increase the moderator to fissile material ratio. Assemblies were removed from the model to create situations where more assemblies would be located next to water holes, and hence experience enhanced moderation.

For the 44-assembly case, assemblies in the following locations were removed:

row 4, locations 3 and 5
row 6, locations 3 and 5
For the 40 assembly case, assemblies in the following additional locations were removed:
row 2, location 3
row 5, locations 2 and 7
row 8, location 3

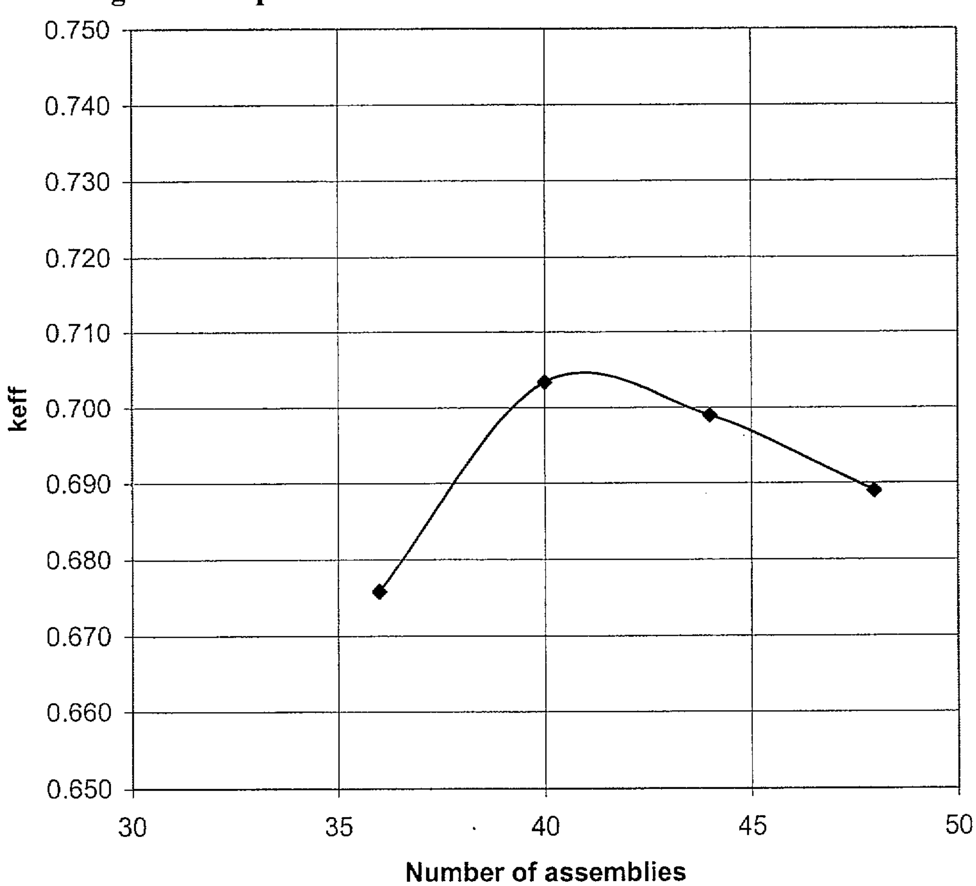
For the 36-assembly cases, rows 1 and 9 were also entirely removed.

The results are shown in Table 6-13 and Figure 6-9. It is seen that 40 is the optimal number of assemblies. When 40 assemblies are placed inside the inner canister in an optimal arrangement with each assembly next to a water hole or channel, there is a k_{eff} is 0.70334 $\pm$0.00081, which is about 0.014Δk higher than for a fully loaded configuration.

Table 6-13
Impact of Partial Fuel Loading on k_{eff}

Number of Assemblies	k_{eff}	σ
48	0.68898	0.00078
44	0.69897	0.00079
40	0.70334	0.00081
36	0.67585	0.00083

Figure 6-9 Optimal Number of Assemblies in the Pathfinder Canister



Models were created that simulated situations where a flooding accident occurred and the fuel remained in the Pathfinder Canister, but part of the Incoloy 800 was released. Since Incoloy 800 is a neutron absorber, its presence acts to hold down reactivity. These cases were run to determine how much Incoloy 800 could be lost from the Pathfinder Canister, with system remaining subcritical.

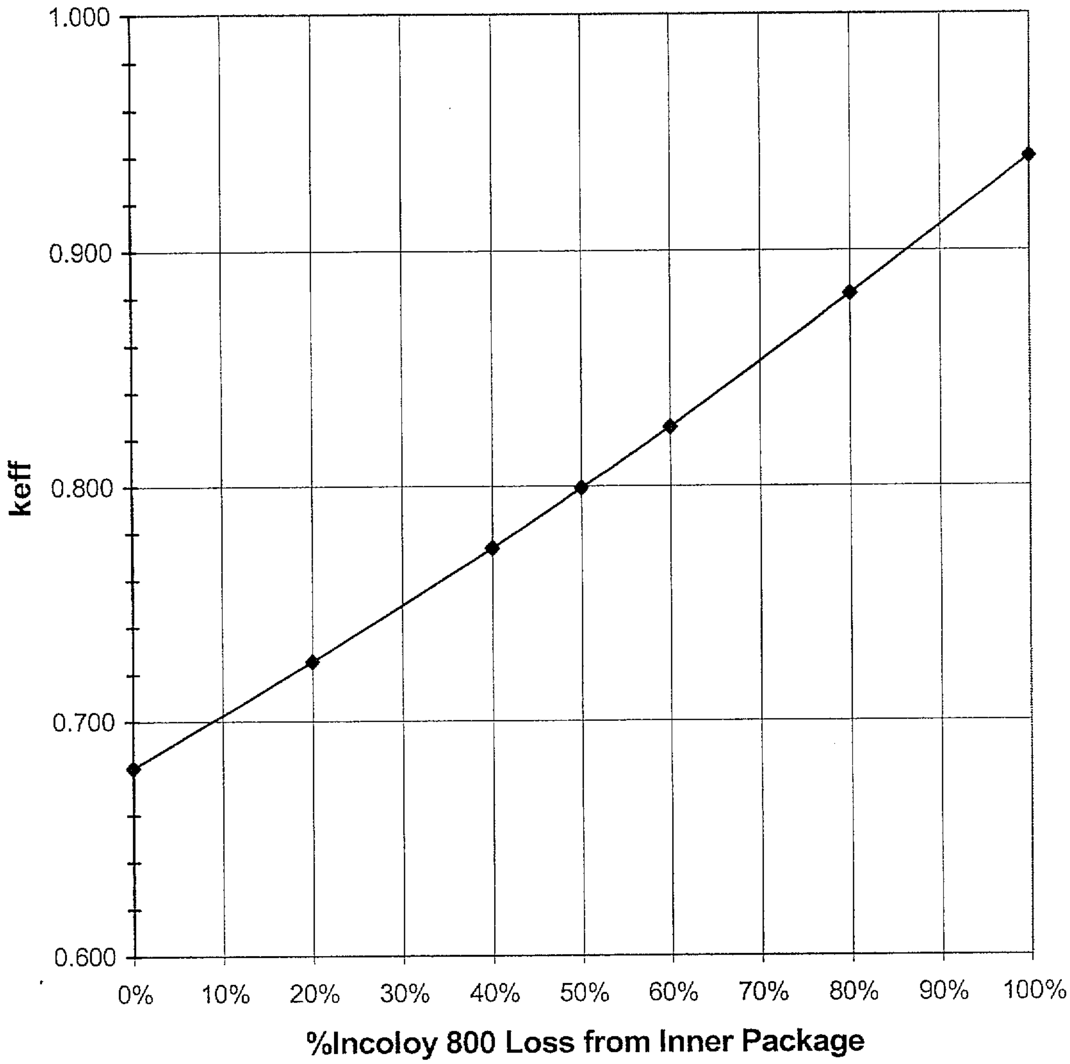
The model used here blended all fuel assembly and sheath components homogeneously in the Pathfinder Canister. Fuel accounts for 16.4% of the volume and Incoloy 800 accounts for 21.7% of the volume. The remainder of the Pathfinder Canister volume (61.9%) is filled with water. A series of cases were run that maintained the fuel volume, but decreased the amount of Incoloy 800 and replaced it with water. A 30cm water reflector surrounded the entire canister.

The results are shown in Table 6-14 and Figure 6-10. It is seen that even with 80% of the Incoloy 800 lost from the package, criticality limits are still met.

Table 6-14
Effect of Loss of Incoloy 800

%Incoloy 800 Loss	k_{eff}	σ
0	0.68008	0.00073
20	0.72553	0.00073
40	0.77347	0.00078
50	0.79915	0.00084
60	0.82533	0.00082
80	0.88175	0.00090
100	0.93981	0.00099

Figure 6-10 Effect of Loss of Incoloy 800



The historical documentation for determining the true identity of the stainless steel alloy used to make the 1" diameter assembly sheaths is not conclusive. Some documents refer to them as being made of Incoloy, other documents simply refer to them as stainless steel. All the calculations shown above assumed that the sheaths were made of Incoloy 800, consistent with that used to make the clad. A study was conducted to determine the impact on k_{eff} that may occur if the sheaths were actually made of a different stainless steel alloy.

Most stainless steel alloys (including Incoloy 800) have essentially the same neutron absorbing properties. The base case (48 assemblies, close pack, fully flooded and reflected, Incoloy 800 sheaths) was re-modeled with KENO-V.a using different types of common stainless steels for the sheaths. The results, as shown in Table 6-15, show little change in reactivity from the base case model.

Table 6-15
Impact of Different Sheath Materials on k_{eff}

Sheath Material	**k_{eff}**	**σ**	**change in k_{eff} from base case**
Incoloy 800	0.68898	0.00078	---
ss304	0.69518	0.00078	+0.00620
Inconel	0.67466	0.00080	-0.01432
ss316	0.69197	0.00077	+0.00299

The upper safety limit (USL) of 0.936 for $k_{eff} + 2\sigma$ as calculated by KENO-V.a was determined, as discussed in Section 6.5B. It was administratively decided, though, to set the USL at a lower value of 0.900. This was partly done to account for the uncertainty as to which specific alloy the sheaths are made. Table 6-15 showed that k_{eff} may be about 0.006 higher if the sheaths are made of ss304 rather than Incoloy 800. The additional decrease in the USL beyond this amount was made strictly by engineering judgement to increase conservatism.

Table 6-16 gives k_{eff} for the cases specified in 10CFR71.51a, where a single assembly is fully flooded and also for 3 undamaged packages with full water reflection. It is seen the k_{eff} is well below the USL of 0.90. Due to the conservative modeling of the system, fabrication tolerance uncertainties are included in the base k_{eff}. The cases represent the maximum achievable reactivity for their class:

Case 1: Normal Transport. Three WE-1 containers, dry conditions internally, fully reflected with 30 cm of water

Case 2: Accident Condition. Single package, 48 assemblies close pack, fully flooded, reflected with 30 cm of water.

Case 3: Accident Condition. Single package, 40 assemblies optimally moderated, fully flooded, reflected with 30 cm of water

Case 4: Accident Condition. Single package, 48 assemblies optimally arranged, fully flooded, reflected with 30 cm of water (note: this model exceeds the dimensions of the Pathfinder Canister).

Table 6-16
k_{eff} for Licensing Conditions

Case No.	k_{eff}	σ	$k_{eff}+2\sigma$
1	0.25620	.00050	.25720
2	0.68898	.00078	.69054
3	0.70334	.00081	.70496
4	0.81966	.00080	.82126

6.5 CRITICALITY BENCHMARK EXPERIMENTS

A. B&W MkBW 17x17

The KENO V.a bias evaluation is discussed in this section. An examination of light water reactor critical experiments for low-enriched ^{235}U lattices indicates a trend in the bias related to the separation distance between assemblies. A total of fifty-seven, critical light-water-moderated, low-enriched fuel configurations are evaluated with KENO V.a and the 44-group cross section library. A trend of increased bias with the separation distance between fuel arrays is such that for the 44-group set the bias reaches a maximum Δk of 0.00724 $\pm$ 0.004 (1.763σ uncertainty) with a 2.576" (6.543 cm) spacing between the fuel arrays. A brief description of the critical experiments, determination of the bias, and validation of the trend is provided in this section. A complete description is provided in Appendix 6-2. Based upon this description the KENO V.a bias is defined as:

$$\Delta k = -0.0048 - 0.0008354\,x + 7.1414E\text{-}05\,x^2.$$

where x is the spacing between fuel assemblies from 0 to about 12 centimeter. Beyond about 12 cm, the bias reverts back to that of zero spacing, or .0048. In all cases, the uncertainty in the bias is 0.004 (1.763σ).

A total of fifty-seven critical experiments were evaluated with KENO V.a to determine the bias inherent in its methodology. All experiments were conducted to simulate low-enriched, light water reactor fuel arrays in storage configurations. This simulation includes both UO_2 and mixed oxide fuel compositions. The experiments contain uranium enrichments from about 2.3 to 5.7 weight percent and plutonium enrichments from 2 to 6 weight percent. Storage geometry is simulated with variations on fuel array spacing and with interspersed absorber materials in the arrays. Thus, these experiments are directly applicable to transport applications. The experiments have been divided into four sets. The first examines a set of twenty-one critical configurations[4] performed for storage simulation with a single fuel enrichment. The second is a series of sixteen additional UO_2 criticals[6] covering a range of enrichments and conditions. The third is a set of twelve mixed oxide criticals[7]. The last set comprises eight other UO_2 critical configurations that have been approved for an international database[8]. This last set includes results from the MCNP Monte Carlo code[9] and KENO V.a with the 27-group cross section set. These latter calculations provide an independent verification of the results and trends for the 44-group KENO V.a results.

The number of benchmark experiments used and, more specifically, the range of applicability of the benchmark experiments chosen for the evaluation may be questioned. Basically, the evaluation of the complete set of 51 criticals shows essentially no sensitivity relative to fuel enrichment or fuel type, i.e. uranium oxide or mixed oxide. The mixed oxide critical results from PNL experiments (cases 1 through 8 of Table 6-2.8 of Attachment 6-2) show little sensitivity to the type of material inserted between fuel assemblies, other than to suggest a trend of smaller bias with heavier absorber loading. The Boral and stainless steel plates have a bias that is equal to the bias without a plate within statistical uncertainty, i.e. 2 sigma. The cadmium and Boraflex plates with significantly more absorber show a significant reduction in bias. The B&W critical experiments listed in Table 6-2.3 of Attachment 6-2 further illustrate this trend. These experiments were performed specifically for evaluation of fuel storage arrays and form the primary basis for the determination of the 44-group cross section bias. Figure 6-2.5 of Attachment 6-2, provides a plot of the calculation bias as a function of fuel assembly spacing for the various configurations of the 21 criticals. The data suggests a trend of increasing bias with increasing spacing between assemblies for the range of spacings considered, i.e., 0 to 6.5 cm. This trend is independent of the material between the assemblies. This trend is further confirmed by the data in Table 6-2.10 that extend the spacing by use of additional experiments approved by the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*. This trend is seen from both KENOV.a and MCNP calculations with completely different cross section sets. However, at present only experiments for water between assemblies are available in the Handbook. Thus, extension of the evaluations beyond the spacing and materials of the B&W critical experimental data is not yet possible.

B. Pathfinder Fuel Assemblies

The KENO V.a bias evaluation was performed as described in NUREG/CR-6698. An examination of 48 light water reactor critical experiments for low-enriched ^{235}U lattices was performed, involving a range of enrichment and pin spacing. All experiments were obtained from the *International Handbook of Evaluated Safety Benchmark Experiments.* All experiments were comprised of small pins using uranium as the fissile material and water as the moderator. A range of H/X was represented, as were both square and triangular pitch lattice shapes. Cladding materials included both stainless steel and low absorber metals. None of the experiments had dissolved absorber material or used strong absorbers in the fuel pins or as separate rods. The experiments were at or near room temperature, except for two that were slightly pressurized and near 100°C.

The results showed that a KENO-V.a calculated value of (keff +2σ)≤ 0.936 for the licensing cases would justify the criticality safety criterion of a maximum safety limit of 0.95. A complete description is provided in Appendix 6-2.

The validation method described in NUREG/CR-6698 provides for the determination of an upper safety limit (USL) based upon statistical evaluation of the calculational bias. This bias is defined as the difference between the k_{eff} of the critical experiment and the calculated k_{eff} for the model of the experiment. With a USL defined, any calculated k_{eff} values plus calculational uncertainty must fall below the USL to be considered subcritical.

This licensing evaluation was performed to support shipping ~6.95wt% to ~7.5 wt% fuel rods. In support of this effort, a validation of SCALE, i.e., KENO-V.a with the CSAS modules, for this enrichment was necessary. A review of the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* was made and indicated several experiments consisting of fuel rod arrays with enrichments between 5 and 10 wt% ^{235}U. Most of the experiments comprised hex arrays of fuel rods, though a few were at square pitches. The enrichments considered range from 2.3 to 9.8 wt% ^{235}U. The enrichments less than 5 wt% were included to allow trending over a wider range of enrichments. Forty-eight experiments were selected and modeled to develop the statistical bias.

The results indicated that there was little to no trend in the bias with respect to either fuel enrichment or pin pitch. As such, a single USL of 0.936 was determined as a bounding value for the evaluation of the Pathfinder fuel shipment.

CHAPTER 7: ROUTINE SHIPPING CONTAINER UTILIZATION SUMMARY OPERATING PROCEDURES

The following information contains the significant events relating to the routine use of WE-1 fuel assembly shipping containers. Complete detailed instructions are outlined within the individual plant operating procedures and quality control instructions pertinent to each specific operation.

The Pathfinder Canister is used to ship unirradiated Pathfinder fuel. The detailed loading and unloading procedures given are in compliance with subpart G of 10CFR71. These procedures have been prepared to meet the intent of NUREG/CR-4775, Guide for Preparing Operating Procedures for Shipping Packages.

7.1 INSPECTION PRIOR TO LOADING

7.1.1 Visually inspect the shipping container to assure that it has not been significantly damaged.

7.1.2 Closure bolts, washers, nuts, and sealing gasket are present and free of defects.

7.1.3 Visually inspect the strongback assembly to assure that it has not been significantly damaged.

7.1.4 Visually inspect fuel assembly clamps, retainer bars, bolts, and nuts to assure that they are present and in good condition.

7.2 LOADING PROCEDURE

7.2.1 Unbolt all closure bolts on the inner container box and remove cover assembly.

7.2.2 Install the trunnion pivot pin and spacers.

7.2.3 Unbolt closure bolts on top and side of the inner containment box; remove outer portion of the inner containment box.

7.2.4 Loosen closure bolts on clamp arms.

7.2.5 Free the strongback from the container by removing the hex nuts and washers that secure the strongback to the shock mount bolts.

7.2.6 Elevate the strongback to a vertical position.

7.2.7 Install the two strut-type stabilizer braces to the strongback, making sure these braces are adequately secured and ball lock pins or bolts and nuts are in place.

7.2.8 Load the fuel assembly into the containment box.

7.2.9 Install clamp arms at the designated areas of the assembly.

7.2.10 Remove strut-type stabilizer braces and lower strongback with fuel element into a horizontal position in the container.

7.2.11 Install insulation around the assembly.

7.2.12 Place outer portion of the inner containment box back in position; tighten closure bolts.

7.2.13 Install wood wedges around the containment box.

7.2.14 Install outer closure bolts and make wrench tight.

7.2.15 Remove the trunnion pivot pin and spacers.

7.2.16 Bolt the containment box to the shock mount supports.

Pathfinder Canister

The new canister must first be inspected by Quality Control. Shipping canisters not acceptable for use shall be marked accordingly. Assure that the WE-1 Package is to be loaded per the Certificate of Compliance and record this on the appropriate shipment documentation.

- Remove the outer upper shell assembly, end cover plate (strong back lift eye end) to the rectangular inner container (box), inner container spacer, and the wood spacer to expose the Pathfinder Canister. Take precaution to place these spacers for later use.
- Pathfinder Canister shall be visually inspected prior to every use. Verify that the maintenance inspections per Section 8.2 have been conducted within 12 months of use. Verify that the maintenance activities are performed per Section 8.2.5 for each shipment.
- Load Pathfinder fuel assemblies.
- The void spaces between fuel assemblies and the Pathfinder Canister are to be filled with packing materials as required to avoid wear and impact during shipment and handling.
- Before closure of the Pathfinder Canister, the O-rings and flange closure faces shall be examined to assure they are free of foreign material and/or defects. Seat the closure flange on the Pathfinder Canister body, lubricate the bolt threads, and check the bolts for ease of threading. If the bolts cannot be hand tightened prior to torquing, chase the threads. After applying the specified torque (40 to 50 foot-pounds), bend the lock washers to prevent subsequent loosening of the bolts.
- Closure integrity is verified by applying a leak rate test to the O-ring annulus. This test is conducted by pressurizing the O-ring annulus to 15 psig, isolating the annulus manifold/gage from the pressure source and measuring any pressure drop over a ten minute period. Pressure drop of 1/2 psig is acceptable. If the Pathfinder Canister does not pass the leak rate test, replace the O-rings and repeat the test. If the Pathfinder Canister still does not pass the leak rate test, it must be unloaded and the seal surfaces dimensionally inspected for potential refurbishment.
- Place the wood spacers in the order of their previous removal.
- Install end cover plate to the rectangular inner container (box) and secure bolts.

- Each shipment of the Pathfinder Canister shall require the preparation of, and retention for three years, of those records specified in 10CFR71.91 as appropriate.

7.3 INSPECTION

7.3.1 Verify that the fuel assembly has been released before loading the assembly. Note: Verify that all fuel rods have leak tested to demonstrate leak tight containment integrity (i.e., 1×10^{-7} cc/sec air or better). No leak testing of the fuel assemblies is required for the Pathfinder fuel.

7.3.2 Verify that the containment box is closed and all closure bolts are secured.

7.3.3 Verify general cleanliness and absence of debris on container internals.

7.4 CLOSE SHIPPING CONTAINER

7.4.1 Place the cover on the base assembly of the shipping container using the alignment pins on the base assembly flange to guide the cover assembly.

7.4.2 Secure the base and cover assemblies by tightening all outer shell closure bolts.

7.4.3 Install a Type E security seal at each end of the container.

7.4.4 Inspect the container for proper labeling.

7.5 TRUCK LOADING OF SHIPPING CONTAINER

7.5.1 Place shipping container on trailer equipped to permit chaining down of container.

7.5.2 Center and place container lengthwise on trailer.

7.5.3 Secure container to trailer bed with stops.

7.5.4 Chain container to trailer using "come along" tighteners and chains 3/8 inch minimum diameter.

7.5.5 Perform radiation surveys of the container.

7.6 UNLOADING

7.6.1 Remove chains from trailer using "come along" tighteners and chains 3/8 inch minimum diameter.

7.6.2 Remove stops from trailer bed.

7.6.3 Remove shipping container from trailer.

Pathfinder Canister is designed to be unloaded with commonly available tools and equipment. The unloading procedure will follow this sequence;

- Prior to unloading, ascertain that the radiological survey data and packing list is included with the shipment.

- Remove the outer container upper shell, end cover plate (strong back lift eye end) to the rectangular inner container (box), inner container spacer, and the wood spacer to expose the Pathfinder Canister. Take precaution to retain these spacers for later use.

- Bend the lock washers open and loosen the 8 flange closure bolts. Remove the closure flange with the bolts and washers still in the bolt hole. Place the closure flange on a clean dry surface and then remove the bolts and washers. Use caution not to damage the O-ring seals. Perform radiation survey.

- Remove the packing material and fuel assemblies from the Pathfinder Canister.

- After cleaning the Pathfinder Canister as necessary, replace the closure flange using original O'rings, new lock washers and the original bolts. Tighten bolts to prevent loosening of the bolts during handling and transportation. Do not crimp the lock washers nor torque the closure bolts as this will be done at the next usage.

- Install wood spacers, which had previously been removed.

7.7 EMPTY CONTAINER

7.7.1 Perform radiation surveys of the container.

7.7.2 Attach empty signs to container.

Pathfinder Canister

Empty Pathfinder Canister will be prepared for shipment by removing all loose material from the Pathfinder Canister. The Pathfinder Canister will be closed. Tighten bolts to prevent loosening of the bolts during handling and transportation. No locking washers are necessary. Appropriate labels will be affixed to the drum exterior to signify that it is empty.

A survey shall be performed on the WE-1 container outer surface to ascertain that there is no damage to the container.

CHAPTER 8: ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 ACCEPTANCE TESTS

8.1.1 VISUAL INSPECTION

Prior to the first use of a WE-1 Shipping Container for the shipment of licensed material, Framatome ANP, Inc. will:

(a) Ascertain that there are no cracks, pinholes, uncontrolled voids, or other defects which could significantly reduce the effectiveness of the container.

(b) Conspicuously and durably mark the container with its model number, serial number, gross weight, and an identification number assigned by the Nuclear Regulatory Commission. Prior to applying the model number, Framatome ANP, Inc. will determine that the container was fabricated in accordance with the drawings referenced in its NRC Certificate of Compliance.

8.1.2 STRUCTURAL AND PRESSURE TESTS

No structural or pressure tests are required. Supplier dimensional inspection and non-destructive tests of the welds for the Pathfinder canister are sufficient to verify structural adequacy.

8.1.3 LEAK TESTS

Leak tests of the Pathfinder Canister closure seals are required to be performed by the manufacturer to verify the O-rings will seal properly. The acceptable leak rate is 1×10^{-3} atm cc/sec using a pressure drop test. Weld joints are nondestructively examined by tests at fabrication to verify they are sound. No other acceptance leak tests are specified.

8.1.4 COMPONENT TESTS

Pathfinder Canister O-rings shall be visually inspected for surface defects that would impair their sealing capability. Flange surfaces shall be visually inspected to assure there is no raised metal on the mating seal surfaces, or scratches or dents.

8.2 MAINTENANCE PROGRAM

The WE-1 container is processed through routine refurbishment activities after each use. Details of each step are included in Chapter 7. Repairs will be done in accordance with license drawings provided in Appendix 1-1. Documentation relating to these inspections, repairs, part replacements, etc., will be produced and subsequently maintained via the existing plant records program.

8.2.1 STRUCTURAL AND PRESSURE TESTS

A visual inspection of the Pathfinder Canister shall be made annually. Visually inspect for scratches. Visually inspect O'ring seal surfaces for dents, sratches, or raised metal. Such defects shall be sanded off.

8.2.2 LEAK TESTS

A positive pressure leak test of the closure seal will be made within 12 months before use and before each fuel assembly shipment.

8.2.3 SUBSYSTEM MAINTENANCE

Not applicable.

8.2.4 VALVES, RUPTURE DISCS, AND GASKETS ON CONTAINMENT VESSEL

If Pathfinder Canister O-ring damage is apparent or suspect when the canister is loaded for shipment, the O-rings shall be replaced.

8.2.5 PRIOR TO EVERY SHIPMENT

- Inspect Pathfinder Canister components for damage.
- Pathfinder Canister O-rings shall be visually inspected for surface defects that would impair their sealing capability.
- Inspect closure surfaces for damage. Dents, scratches, or raised metal on the closure flange sealing surface shall be cause for rework. The minimum thickness to which the weldneck flange can be reduced is 0.75 inches.
- Pathfinder Canister O-rings shall be changed. While the O-rings are removed check the O-ring seal surfaces for dents, scratches, or raised metal.

APPENDIX 1-1:
LIST OF LICENSE DRAWINGS

02-1273964-00

02-1273965-01

02-1273966-00

02-1273967-00

02-1273968-00

02-5016270-00 WE-1 Configuration with Internal Pathfinder Canister

FIGURE WITHHELD UNDER 10 CFR 2.390

DWN BY DD HELLER	CHK'D BY DORFF	WE-1 SHIPPING CONTAINER ASSEMBLY LICENSE DRAWING	ME\98-16\5\A1		SCALE .06	DATE 12/2/98
PASSED BY TUCKER	APP'D BY O'DANIEL		SIZE B	DOC ID 02	DWG. NO. 1273964	REV 0

FIGURE WITHHELD UNDER 10 CFR 2.390

DWN BY DD HELLER	CHK'D BY HD DORTCH	WE-1 INNER CONTAINER LICENSE DRAWING	ME\98-16\5\A2R1	SCALE NTS	DATE 1/7/99
PASSED BY JS TUCKER	APP'D BY JW O'DANIEL		SIZE B / DOC ID 02	DWG. NO. 1273965	REV 1

FIGURE WITHHELD UNDER 10 CFR 2.390

DWN BY DA BARGER	CHK'D BY DORTCH	WE-1 SHIPPING CONTAINER UPPER AND LOWER SHELL ASSEMBLY LICENSE DRAWING	ME\98-16\5\A3		SCALE NTS	DATE 01/07/98	
PASSED BY Tudor	APP'D BY O'DANIEL		SIZE B	DOC ID 02	DWG. NO. 1273966		REV 0

FIGURE WITHHELD UNDER 10 CFR 2.390

DWN BY DD HELLER	CHK'D BY BORZY	WE-1 CONTAINER STRONGBACK ASSEMBLY DETAILS LICENSE DRAWING	ME\98-16\5\A4		SCALE NTS	DATE 01/07/98
PASSED BY TUCKER	APP'D BY O'DANIEL		SIZE B	DOC ID 02	DWG. NO. 1273967	REV 0

FIGURE WITHHELD UNDER 10 CFR 2.390

DWN BY DA BARGER	CHK'D BY	WE-1 SHIPPING CONTAINER DETAILS LICENSE DRAWING	ME\98-16\5\A5		SCALE NTS	DATE 01/08/98
PASSED BY	APP'D BY		SIZE B	DOC ID 02	DWG. NO. 1273968	REV 0

FIGURE WITHHELD UNDER 10 CFR 2.390

DWN BY WE BAILEY	CHK'D BY DA BARGER	WE-1 CONFIGURATION WITH INTERNAL PATHFINDER CANISTER (LICENSE DRAWING)	PROJ NO. PTE_SHIPCON_1		SCALE NTS	DATE 04/23/02
PASSED BY	APP'D BY		SIZE B	DOC ID 02	DWG NO. 5016270	REV 0