SAFETY ANALYSIS REPORT
FOR THE
MODEL NCI-21PF-1 PROTECTIVE SHIPPING PACKAGE
FOR 2.5 TON UF_6 CYLINDERS

Submitted by:

NUCLEAR CONTAINERS, INC.
Elizabethton, Tennessee, USA

August 1, 1989
(Revision No. 1, January 11, 1993)

This report has been prepared to demonstrate compliance with the requirements of 10CFR71 and IAEA Safety Series No. 6 in application to the U. S. Nuclear Regulatory Commission for the reissue of Certificate of Compliance No. 9234AF as a Type B certificate.

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ATTACHMENTS:

1. NRC Certificate of Compliance No. USA/9234/AF
2. Safety Analysis Report for NCI-21PF-1 dated 9/1/88
3. 10/18/88 Supplement to 9/1/88 Safety Analysis Report
4. 11/28/88 Supplement to 9/1/88 Safety Analysis Report
5. ANSI N14.1, 30B Cylinder and Valve Specs and Drawings

NUCLEAR CONTAINERS, INC.

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January 11, 1993

United States Nuclear Regulatory Commission
Washington, DC 20555

Attention: Mr. Charles E. MacDonald, Chief
Transportation Branch
Division of Safeguards and Transportation, NMSS

Reference: Docket Number 71-9234

Gentlemen:

Enclosed is Revision No. 1 to our Safety Analysis Report submitted in support of our request dated August 24, 1989, to amend Certificate of Compliance No. 9234AF, Rev. 2, to approve the NCI-21PF-1 Protective Shipping Package as a Type B package for the transportation of UF_6 enriched up to 5% U-235 contained in Model 30B UF_6 cylinders. This revised SAR is in response to questions posed in your letter dated February 13, 1990, and is in accordance with discussions we had with your staff on January 15, 1992, as summarized in the January 23, 1992, letter from your Ms. Nancy Osgood.

The SAR has bee revised to provide answers to the questions asked in your letter dated February 13, 1990, as follows:

1. Contents are fully described in Section 1.2.3 and evaluated in Appendices 1.3.3 and 1.3.4, which also includes a list of the analytical procedures used to determine the concentration of various radionuclides. The package is now limited to 1,150 A_1 values such that it is now a Category II package.

Continued on Page 2 of 2.

2. The 30B UF_6 cylinder is more fully described in Sections 1 and 2 and is more fully evaluated as the primary containment vessel in Section 4. The cylinder has also been more fully evaluated for cold temperatures (-40°F) in Section 2.6. Excerpts from ANSI Standard N14.1 are included as an Attachment to the SAR to provide the requested drawings and full descriptions of the 30B cylinder and cylinder valve.

3. Containment to Type B standards is evaluated in Section 2.5 and its corresponding appendices. Leak test requirements and procedures are incorporated which provide for testing the cylinder (a) for leaks in excess of 4×10^{-8} atm cc/sec within a 12-month period prior to a Type B shipment, and (b) for leaks in excess of 10^{-3} atm cc/sec after filling with UF_6 prior to a Type B shipment.

A full scale package with a 30B cylinder filled with a dummy load has been subjected to drop and puncture testing as planned in discussions with your staff. These tests are fully discussed in Section 2.7 and its corresponding appendices. These tests demonstrate that the 30B cylinder contained in the NCI-21PF-1 package provides the containment necessary to meet Type B standards.

4. The 30B cylinder is evaluated for a reduced external pressure of 3.5 psia in Section 2.6.

5. Section 7. <u>Operating Procedures</u> has been expanded as requested and includes requirements for routine maintenance and for annual maintenance. Section 8. <u>Quality Assurance</u> has also been expanded to address all of the above changes; both sections more fully address considerations of the 30B cylinder.

Very truly yours,

William R. Housholder
President

Encl.

SAFETY ANALYSIS REPORT
FOR THE
MODEL NCI-21PF-1 PROTECTIVE SHIPPING PACKAGE
FOR 30-INCH UF_6 CYLINDERS

Submitted by:

NUCLEAR CONTAINERS, INC.
Elizabethton, Tennessee, USA

August 1, 1989
(Revision No. 1, January 11,1993)

1. GENERAL INFORMATION

This Safety Analysis Report for Model NCI-21PF-1 Protective Shipping Packages is submitted in support of request to amend and re-issue Certificate of Compliance No. 9234, Rev. 2, as a Type B certificate in compliance with the requirements of 10CFR71 and IAEA Safety Series No. 6, 1973 edition.

The NCI-21PF-1 Protective Shipping Package is an improved version of the DOT 21PF-1 and 21PF-1B packages. The DOT-21PF-1 package was designed in the mid-1960's to provide safe transport of 30-inch UF_6 Cylinders containing uranium enriched up to 5% U-235. The DOT-21PF-1B was designed to solve water inleakage problems with the original 21PF-1 package and was authorized in 49CFR178.121 as revised in the Federal Register on September 20, 1988. The DOT-21PF-1B modifications included changing from carbon steel to stainless steel, covering the wood at the closure plane with sheet metal, changing the closure plane step joint such that it stepped down to the outside, and up-dating foam materials specifications and requirements for weighing, marking, inspecting, and maintaining the package.

Further improvements incorporated in the NCI-21PF-1 design included upgrading wood specifications, replacing the 14 closure bolts and nuts with 10 quick-opening toggle closures, and adding inverted tie-down frames to the top of the package to facilitate stacking. However, the most important improvement was the replacement of the angle-reinforced 14-gage sheet metal ends (inner and outer) with 1/4" plate ends to provide much better protection to the cylinder valve. A 1-meter puncture test on the end of the DOT-21PF-1 package resulted in a damaged and leaking cylinder valve; similar testing of the NCI-21PF-1 package resulted in no damage to the cylinder valve. This improved valve protection enables the NCI-21PF-1 to meet Type B package requirements as may be necessary for the shipment of recycled uranium.

1.1 Introduction

The NCI-21PF-1 is a Type B, Fissile Class II Package (minimum Transport Index of 5.0) for shipment of Model 30B cylinders of up to 5% enriched UF_6 containing either virgin or recycled uranium. Each cylinder is limited to 5,020 pounds of UF_6; for recycled uranium, the package is further limited to not more than 1,150 A_2 quantities of radioactive materials as determined per 10CFR71, Appendix A. The contents of individual elements and radioactive isotopes are further limited as specified in Section 1.2.3 below because of the necessity of meeting the specification requirements of ASTM C-787 for feed materials and ASTM C-996 for UF_6 which has been processed through an enrichment plant.

1.2 Package Description

1.2.1 Packaging

The NCI-21PF-1 Protective Shipping Package is an overpack for 30-inch enriched uranium hexafluoride (UF_6) cylinders. The package is a right circular cylinder constructed of two stainless steel shells, ie. an outer shell 43 inches I. D. by 92 inches long and an inner shell 30-7/8 inches I.D. by 82-5/8 inches long. The volume between the shells is filled with fire retardant, phenolic foam per USAEC Specification SP-9, and the volume between the 1/4-inch thick end plates of the two shells is filled with oak wood blocks which are made of three cross-laminated layers of boards glued and nailed together. A stepped horizontal joint permits the top half of the package to be removed from the base; the horizontal closure joint of each package half is covered with stainless steel, and a 5/8" thick silicon gasket seals the joint. The package halves are secured with ten 1-inch diameter stainless steel toggle closures.

The bottom half of the package is fitted with 1/2-inch thick tie-down plates for bolting to the floor of the carrier vehicle with eight 3/4-inch bolts. The top half of the package is fitted with inverted tie-down plates on which empty packages can be stacked; four 3/4-inch U-bolts in the inverted plates are used for lifting the package as well as for securing stacked packages together. The outer package cylinder is 43-5/8 inches O.D. by 92 inches long; the overall outside dimensions of the package are 49-1/8 inches wide by 49-1/8 inches high by 93 inches long. The tare weight of an empty package is nominally 2,250 pounds; the maximum gross weight of the loaded package is 8,700 pounds.

The NCI-21PF-1 PSP is fabricated in accordance with Nuclear Containers, Inc. Drawing No. DED-206-B, Sheets 1

through 11, Rev. 4 (see Appendix 1.3.1); this drawing is complete with dimensions, tolerances, fabrication details, materials list and specifications, weld specifications, gasket and assembly instructions, and inspection and testing requirements. The package is fitted on each side with stainless steel nameplates per NCI Drawing No. DED-207-A, Rev. 1 (see Appendix 1.3.2).

The containment vessel of the package is the Model 30B UF_6 cylinder which must be fabricated, inspected, tested, and maintained in accordance with the latest NRC approved revisions of AEC Report ORO-651 and ANSI Standard No. N14.1 which requires that the cylinder be fabricated in accordance with Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code and be ASME Code "U" stamped.

1.2.2 Operational Features

The NCI-21PF-1 package is closed by ten (10) 1-inch diameter quick-opening toggle closures which are secured from accidental opening by 1/2-inch diameter ball-lock pins. Each closure is adjustable, but socket set-screws must be loosened to release the adjusting collar.

The package is tied-down for transport by bolting to the carrier floor and is interchangeable with the DOT Specification 21PF-1A and 21PF-1B packages because all three packages have identical tie-down bolt patterns. The package is lifted by means of four 3/4-inch U-bolts mounted in two inverted tie-down bases which are also used for stacking empty packages; the stacked packages may be secured together using either 3/4" steel bolts or the lifting U-bolts. The package may also be lifted by fork truck tines under the angle reinforced bottom of the package.

The closure joint of the package is stepped down to the outside to minimize water in-leakage into the cylinder cavity and provides a metal-to-metal seat on the outboard side such that compression of the inboard gasket is controlled. The gasket is a 5/8" thick medium density, closed-cell silicone sponge rubber with a minimum continuous temperature rating of 400°F.

1.2.3 Contents of Package

The NCI-21PF-1 package is used for the safe transport of uranium hexafluoride enriched in the U-235 isotope; the UF_6 must be packaged in Model 30B UF_6 cylinders which have been fabricated, inspected, tested, and maintained in accordance with the requirements of ANSI N14.1. The package contents are limited to a maximum of 5,020 pounds UF_6 enriched to not more than 5 w/o U-235. The UF_6, which may contain either virgin and recycled uranium, must meet the requirements of ASTM C-787 for feed materials and ASTM C996 for UF_6 which has been processed through an enrichment plant. In the case of recycled uranium, the package contents must not exceed 1,150 A_2 quantities of radioactive materials as determined per 10CFR71, Appendix A and must not contain more than the following maximum quantities of radionuclides and impurities:

U-232	0.005 µg/gU
U-234	2000 µg/gU
U-235	0.05 g/gU
U-236	0.025 g/gU
U-238	balance of total uranium content
Pu + Np	Alpha activity not exceeding 3.3 Bq/gU
Tc-99	5 µg/gU
Th-228	1.17×10^{-3} µg/gU (other U-232 daughters are ignored because of very short half-lives)
Fission Products	4.4×10^{5} Mev Bq/d kgU (total contribution from gamma emitting fission products); this results in the following individual maximum activities:

Ru-106/Rh-106	2095 Bq/gU
Ru-103/Rh-103	885 Bq/gU
Ce-144/Pr-144/Pr-144[*]	8349 Bq/gU
Sb-125	1030 Bq/gU
Cs-134	283 Bq/gU
Cs-137/Ba-137[*]	778 Bq/gU
Zr-95	598 Bq/gU
Nb-95	574 Bq/gU

From ASTM C-787, the total concentration of elements that form non-volatile fluorides (including Al, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Pb, Li, Mg, Mn, Ni, K, Ag, Na, Sr, Th, Sn, Zn, and Zr) must not exceed 300 µg/gU.

Also, from ASTM C-787, the content of other elements must not exceed the following concentrations in μg/gU:

Sb < 1	As < 3	B < 1	Bi < 5	Cl < 100
Cr < 10	Nb < 1	P < 50	Ru < 1	Si < 100
Ta < 1	Ti < 1	Mo < 1.4	W < 1.4	V < 1.4

As shown in Appendix 1.3.3, recycled uranium containing the above mixture of radioisotopes has a reference A_2 value of 0.824×10^{-3} TBq and a maximum activity of 6.17×10^{-7} TBq/g U. Therefore, the total maximum activity of a cylinder containing 5,020 lb UF^6 (2,279 Kg UF^6 or 1,541 Kg U) is 0.951 TBq or 1,154 A_2 values.

Appendix 1.3.4. includes a brief description of the Uranium Reprocessing Cycle, the applicable ASTM Standards, analytical methods (including accuracies) used to determine the above contents, and some comparisons of cylinders of typical recycled uranium from the COGEMA Enrichment Facilities in Pierrelatte, France.

1.3 Appendix

1.3.1 NCI Drawing No. DED-206-B, Sheets 1 through 11, Rev. No. 4, Model NCI-21PF-1 Protective Shipping Package.

1.3.2 NCI Drawing No. DED-207-A, Rev. No. 1, Nameplate for Model NCI-21PF-1 Package.

1.3.2 Definition of Content, A_2 Calculation, and Package Classification as prepared by personnel at the COGEMA Enrichment Facility at Pierrelatte, France.

1.3.4 Description of Uranium Reprocessing Cycle, Applicable ASTM Standards, Analytical Procedures, and Radionuclide Content of Typical Recycled Uranium as prepared by personnel at the COGEMA Enrichment Facility at Pierrelatte, France.

FIGURE WITHHELD UNDER 10 CFR 2.390

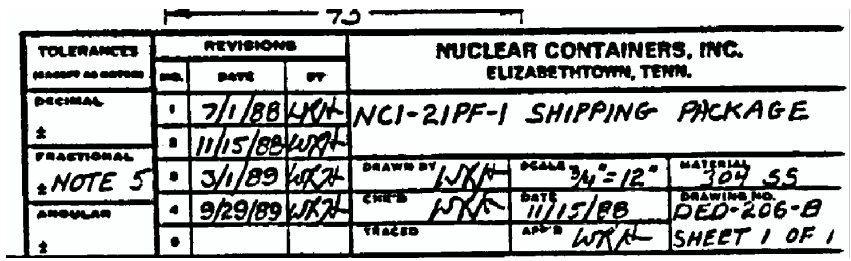

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
UNLESS OTHERWISE NOTED	NO.	DATE	BY			
DECIMAL ±	1	7/1/88	WRH	NC1-21PF-1 ASSEMBLY DETAILS		
	2	11/15/88	WRH			
FRACTIONAL ± NOTE 5	3	3/1/89	WRH	DRAWN BY WRH	SCALE 1/2=12	MATERIAL 304 SS
	4	9/29/89	WRH	CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
ANGULAR ±	5			TRACED	APP'D WRH	SHEET 2 OF 11

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
DECIMAL ±	1	7/1/88	WRH	TYPICAL ASSEMBLY DETAILS MODEL NCI-21PF-1 PACKAGE		
FRACTIONAL ±NOTE 5	2	11/15/88	WRH			
	3	3/1/89	WRH	DRAWN BY WRH	SCALE AS STATED	MATERIAL 304 SS
ANGULAR ±	4	9/28/89		CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
	5			TRACED	APP'D WRH	SHEET 3 OF 11

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
DECIMAL ±	NO.	DATE	BY	TYPICAL ASSEMBLY DETAILS MODEL NCI-21PF-1 PACKAGE		
	1	7/1/88	WKH			
FRACTIONAL ± NOTE 5	2	11/15/88	WKH			
	3	3/1/89	WKH	DRAWN BY WKH	SCALE HALF	MATERIAL 304 SS
ANGULAR ±	4	9/29/89	WKH	CHK'D WKH	DATE 6/1/88	DRAWING NO. DED-206-B
	5			TRACED	APPD WKH	SHEET 4 OF 11

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
	NO.	DATE	BY			
DECIMAL ±	1	7/1/88	WRH	TOGGLE BRACKETS MODEL NCI-21PF-1 PACKAGE		
	2	11/15/88	WRH			
FRACTIONAL ±NOTE 5	3	3/1/89	WRH	DRAWN BY WRH	SCALE 1/2	MATERIAL 304 SS
	4	8/20/89	WRH	CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
ANGULAR ±	5			TRACED	APP'D WRH	SHEET 5 OF 1

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES (UNLESS OTHERWISE NOTED)	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
DECIMAL ±	NO.	DATE	BY	TOGGLE BRACKET CASTINGS AND LIFTING U-BOLTS FOR NCI-21PF-1		
FRACTIONAL ± NOTE 5	1			DRAWN BY WXH	SCALE AS SHOWN	MATERIAL SS-SEE NOTES
ANGULAR ±	2			CHK'D WXH	DATE 9/29/89	DRAWING NO. DED-206-B
	3			TRACED	APP'D WXH	SHEET 6 OF 11
	4	9/29/89	WXH			

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
EXCEPT AS NOTED	NO.	DATE	BY			
DECIMAL .XX ± .02 .XXX ± .002	1	7/1/88	WRH	TOGGLE DETAILS		
	2	11/15/88	WRH	MODEL NCI-21PF-1 PACKAGE		
FRACTIONAL ± 1/32	3	3/1/89	WRH	DRAWN BY WRH	SCALE HALF	MATERIAL 17-4PH SS
ANGULAR ±	4	9/29/89	WRH	CHK'D BY WRH	DATE 6-1-88	DRAWING NO. DED-206-B
	5			TRACED	APP'D WRH	SHEET 7 OF 11

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
DECIMAL ±	NO.	DATE	BY	TOGGLE CLOSURE DETAILS MODEL NCI-21PF-1 PACKAGE		
	1	7/1/88	WRH			
	2	11/15/88	WRH			
FRACTIONAL ±NOTE 5	3	3/1/89	WRH	DRAWN BY WRH	SCALE HALF	MATERIAL 304 SS
ANGULAR ±	4	9/29/89	WRH	CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
	5			TRACED	APP'D WRH	SHEET 8 OF 11

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BILL OF MATERIALS

Quantities for one Model NCI-21PF-1 Protective Shipping Package; see Note 1 (Sheet 10) for material specifications. Items specified herein by trade name provide minimum requirements only; equivalent or better items may be substituted.

ITEM	DESCRIPTION (QUANTITY REQUIRED)
Outer Shell	Sheet, 14 Ga x 72" x 91-3/4" (2 ea).
Outer Ends	Plate, 1/4" x 22" x 44" (4 ea).
Inner Shell	Sheet, 16 Ga x 60" x 82-5/8" (2 ea).
Inner Ends	Plate, 1/4" x 16" x 32" (4 ea).
Inner Angles	Angle, 2" x 2" x 1/4" by 91-1/2" length (2 ea).
Support Block Angles	Formed Angle, 1-1/2" x 1-1/2" x 16 Ga Sheet by 7" lengths (16 ea).
Wood Covers (Sides)	Sheet, 14 Ga x 7" x 92" (4 ea).
Wood Covers (Ends)	Sheet, 14 Ga x 5" x 43" (4 ea).
Closure Bands	Flat Bar, 1/4" x 3" by 72" length (6 ea).
Stiffener Rings	Angle, 3" x 3" x 3/8" by 80" length (4 ea).
Bottom Lift Angles	Angle, 3" x 3" x 1/4" by 56" length (2 ea).
Base Plates	Flat Bar, 1/2" x 6" by 43" length (4 ea).
Base Angle Legs	Angle, 2" x 2" x 1/4" by 12" length (8 ea).
Base Gussets	Plate, 1/2" x 2-1/8" x 3-1/8" (2 ea).
Lifting U-Bolts	U-Bolt, 2-3/4" ID made of 3/4" rod with 2-3/8" straights threaded 1-3/4" x 10NC-2A on ends, ASTM A-193, Grade 8 Stainless Steel, ANSI B18.2.1 with proper marking and material certification (4 ea).
U-Bolt Nuts	Nut, 3/4"-10NC-2B, ASTM A-194, Grade 8A Stainless Steel, ANSI B18.2.2.SF, Heavy Hex, with proper marking and material certification (8 ea).
U-Bolt Washers	Lock Washer, 3/4" US Standard (16 ea).
Toggle Assemblies:	See Shts 5, 6, 7 & 8 and Notes 1d, 1e, 1f & 3 (10 ea).
Upper Base*	Plate (formed), 1/4" x 7" x 10" (10 ea).
Upper Bracket*	Flat Bar, 1/2" x 2-1/2" by 6" length (20 ea).
Lower Base*	Plate (formed), 1/4" x 7" x 9" (10 ea).
Lower Bracket*	Flat Bar, 1/2" x 2-1/2" by 5-1/4" lgth (20 ea).
Arm Handle	Pipe (formed), 1-1/4" Sch. 80 x 14" length (10 ea).
Arm Base*	Flat Bar, 1/2" x 2" by 2-3/32" length (10 ea).
Arm Bracket*	Flat Bar, 1/2" x 2" by 4" length (20 ea).
Upper T-Bolt	Casting, 1"-8NC-2A (10 ea).
Lower Swing-bolt	Casting, 1"-8NC-2A (10 ea).
Swing-bolt Pin	Rod, 1" dia. x 2" long (10 ea).
Pivot Bolts	Casting, 1-1/4"-7NC Hex Shoulder Bolt (20 ea).
Coupling Nut	Casting, 1-1/2" Hex x 1"-8NC (10 ea).
Set Screws	Hex Socket Set Screw, 1/4"-20NC-2A x 1/4", Self-Locking Stainless Steel, McMaster Carr No. 90251A533 (30 ea).
Lock-down Pin	Ball Lock Pin, 1/2" dia. x 2-1/2" long, Stainless Steel with ring or T-handle and attaching cable, Carr-Lane No. CL-8-BLP-T-2.5S (10 ea).
Lock-down Bracket	Flat Bar, 1/4" x 1-1/2" by 3-1/4" lgth (20 ea).
Attaching Screw	1/4" Hex Head, Self Tapping SS Screw (10 ea).

* These items may be investment castings per Notes 1(e) and 3.

ITEM	DESCRIPTION (QUANTITY REQUIRED)
Seal Lug	Pad Eye, 3/4", Stainless Steel, McMaster Carr No. 8892T12 (4 ea).
Lag Screws	1/4" x 2" Hex Head (136 ea).
Boat Nails	Plain Flat Head, #10 x 2-1/2" (100 ea).
Wooden Components:	Oak, moisture content less than 15%. Rails and Cap Boards--Select Grade; laminated components--No. 2 Common or better, see Note 6.
End Block	Cross-lamination 4-3/16" thick using 1-3/8" thick boards per Sheet 3 (4 ea, 150 board-feet).
End Rail	Board, 1-1/2" tk x 4-1/2" x 43" (4 ea, 16 brd-ft).
Upper End Cap	Board, 1" tk x 2-1/2" x 43" (2 ea, 4 board-feet).
Lower End Cap	Board, 5/8" tk x 2-1/2" x 43" (2 ea, 3 board-ft).
Side Rail	Board, 1-1/2" tk x 6-1/2" x 92" (4 ea, 45 brd-ft).
Upper Side Cap	Board, 1" tk x 3-1/2" x 92" (2 ea, 12 board-feet).
Lower Side Cap	Board, 5/8" tk x 3-1/2" x 92" (2 ea, 8 board-ft).
Support Block	Lamination, 6" thick x 5-1/2" x 9" made of five 1-3/8" thick boards, (8 ea, 25 board-feet).
Dowel Rod	Hardwood, 3/4" x 3" long (16 ea).
Wood Glue	Weldwood Waterproof Plastic Resin Adhesive (10 lb).
Nails for laminating	1/8" x 2-1/2" Coated Screw Shank Nails or No. 10 x 2" and No. 10 x 3" Concrete Nails (about 10 lb).
Phenolic Foam	Raw Materials for Fire Resistant Phenolic Foam Insulation per AEC Material and Equipment Specification No. SP-9, Rev. 1 and Supplement K/TL-729, see Notes 8 & 9 (about 260 lb total).
Upper Pad	Neoprene Sponge, 1/2" thick x 6" x 9", medium density, closed cell (4 ea).
Lower Pad	Neoprene, 3/16" thick x 6" x 9", 50 to 60 DurometerA (4 ea).
Rubber Adhesive	Rubber to Metal Cement, 3M No. 051135-08004 (2 oz) or Silicone Adhesive/Caulking described below.
Gasket	Silicone Sponge, 5/8" thick x 1-1/2" wide, medium density, closed cell, rated for continuous use at 400°F (20 feet).
Metal Preparation	PPG Ditzler DX579 MetalPrep (about 1 gallon).
Gasket Primer	Metal Primer, Clear, Albi 487S (about 1 pint).
Silicone Caulking	Silicone RTV Adhesive/Caulking, rated for continuous use at 400°F, Dow Silastic 732 (about 20-oz).
Paint, Fire	Intumescent Fire Retardant Paint, White, Albi 107A (about 1 quart).
Vent Seals	Polyethylene Plugs for 1/4" holes, Caplug No. BPF-1/4 by Protective Closures Co., Buffalo, NY (40 ea).
Paint Primer	Zinc Chromate Epoxy Primer, PPG Ditzler DP40 with DP401 hardner (about 1/2 gallon of each).
Paint	Automotive Polyurathane Enamel, PPG Ditzler DAU system, color per customer (about 2-1/2 gallons mix).

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
DECIMAL ±	NO.	DATE	BY	BILL OF MATERIALS MODEL NCI-21PF-1 PACKAGE		
	1	7/1/88	WKH			
	2	11/15/88	WKH			
FRACTIONAL ± NOTE 5	3	3/1/89	WKH	DRAWN BY WKH	SCALE	MATERIAL NOTE 1
	4	9/29/89	WKH	CHK'D WKH	DATE 6-1-88	DRAWING NO. DED-206-B
ANGULAR ±	5			TRACED	APP'D WKH	SHEET 9 OF

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NOTES

1. Unless otherwise specified, all metal items shall be as follows:

   (a) Sheet--ASTM A-240, Type 304 or 304L Stainless Steel, #2B Finish.

   (b) Plate--ASTM A-240, Type 304 or 304L Stainless Steel, #1 Finish.

   (c) Angle & Flat Bar--ASTM A276, Type 304 or 304L Stainless Steel, Hot Rolled, Annealed, and Pickled. It is acceptable for flat bar to be fabricated from sheet or plate meeting above specifications.

   (d) Toggle Castings and Swing Pins--Type 17-4PH Stainless Steel, homogenized at 2100 ± 25°F for 90 minutes in vacuum and either vacuum or nitrogen cooled to below 70°F; solution heat treated at 1900 ± 25°F for 60 minutes in vacuum and nitrogen cooled to put material in Condition A; then precipitation hardened by heat treating at 1100°F for 90 minutes and air cooling to put material in Condition H1100. Machining operations may be done in either Condition A or H1100.

   (e) Toggle Bracket and Base Castings--Type 304 or 304L Stainless Steel.

   (f) Pipe--ASTM A-312, Type 304 or 304L Stainless Steel, seamless or welded, cold drawn, annealed, and pickled. If used, elbows shall be ASTM A-403, Type 304 or 304L Stainless Steel.

   (g) Boat Nails, Lag Screws, Set Screws, Pad Eyes, & Washers--300 Series, 18-8, or 17-4PH Stainless Steel.

2. Certifications and Test Reports:

   (a) Mill test reports must be obtained and maintained on file for all stainless steel raw materials including sheet, plate, angles, flat bar, pipe and pipe fittings, and casting metal for cast toggle components.

   (b) Manufacturer's certifications must be obtained and maintained on file for gasket materials and for lifting U-bolts and nuts.

   (c) All other commercially available items may be purchased without certification, but copies of written purchase orders which stipulate the appropriate specifications must be maintained on file for each such item.

3. All cast toggle components shall be Investment Castings of Type 17-4PH Stainless Steel in the H1100 Condition as specified in Note 1(d) above; toggle brackets and bases may be investment castings of Type 304 or 304L Stainless Steel as specified in Note 1(e) above. All castings shall meet the requirements of Section VIII, Articles UG-24(a)(1) & (5) and UG-24(b) & (c), ASME Boiler and Pressure Vessel Code and shall be examined after heat treating per ASME Code, Section VIII, Appendix VII, Articles UA-80; UA-81(b) & (c); UA-82(a)(1), (2), (4), & (5); UA-83; and UA-84. However, only the first five (5) toggle base and bracket castings of each type from each casting lot shall require radiographic examination per ASME Code, Section VIII, Appendix VII, Articles UA-81(c) and UA-82(a)(1); each base and bracket item to be radiographed must first be sectioned to yield flat plate specimens. All items must be re-examined after any repairs and/or reheat treatment as required by UA-83.

4. Welds:

   (a) Unless otherwise specified, all welds shall be continuous and shall develop the full strength of the weakest member being joined; butt welds shall be full penetration welds. All welds shall be free from cracks and from excessive undercutting, pits, or spatter, and shall not be oxidized beyond normal discoloration which can easily be removed by wire brushing.

   (b) Welds shall only be by GTAW or GMAW processes using welders and welding procedures qualified on P8 materials in accordance with Section IX, ASME Boiler and Pressure Vessel Code. Only Type 308L weld rod and filler materials may be used for welding.

   (c) Do not weld over foam materials; weld over wood only when it has been coated with fire retardant intumescent paint and then use appropriate means to reduce heat to a minimum to protect the wood.

   (d) All stainless steel wire brushes, grinding wheels, and cutting discs which are used for stainless steel shall be used for stainless steel only, and shall be so marked. Carbon steel wire brushes shall not be used on stainless steel.

   (e) Welds shall be inspected in accordance with Section V, Article 9 of the ASME Code; the inner liner, outer shell, and wood cover seams shall be inspected visually--linear defects over 1/16" shall be ground out and repaired, other welds shall meet the minimum requirements indicated.

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
DECIMAL ±	NO.	DATE	BY	NOTES & SPECIFICATIONS MODEL NCI-21PF-1 PACKAGE		
	1	7/1/88	WRH			
FRACTIONAL ±NOTE 5	2	11/15/88	WRH			
	3	3/1/89	WRH	DRAWN BY WRH	SCALE	MATERIAL NOTE 1
ANGULAR ±	4	9/29/89	WRH	CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
	5			TRACED	APP'D WRH	SHEET 10 OF 11

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NOTES--continued:

5. Tolerances; unless otherwise specified:

(a) Dimensions up to 24" shall be ± 1/16".

(b) Dimensions greater than 24" shall be ± 1/8".

(c) Gasket sealing surfaces shall be flat ± 1/16" per 3 feet.

(d) Overall diagonal lengths shall be within 1/8" of each other.

6. All wood shall be inspected to ensure that it is free of rot, end splitting, loose knots, etc. prior to use; Select Grade lumber for rails and cap boards shall essentially be clear lumber with no knots greater than 1/2". Unacceptable portions may be cut off and discarded, but all boards shall be full length and shall not be spliced lengthwise; each rail or cap board must be a single board. All wood assemblies shall be glued with waterproof plastic resin glue and nailed with coated screw shank nails or concrete nails spaced no more than 6" apart.

7. Paint all wood with two coats of fire retardant intumescent paint prior to installation. Seal all screw and nail penetrations through the inner liner or outer shell with silicone RTV caulking when inserting the screw or nail; wipe off excess RTV caulking.

8. Insulation shall be Fire Retardant Phenolic Foam fabricated in accordance with US AEC Material and Equipment Specification SP-9, Rev. 1 and Supplement K/TL-729. Foam each package in place using 2 or 3 equal pours each for the cover half and the bottom half; weight of finished insulation shall be a minimum of 100 pounds in each half. Install and secure the wooden end block in each half immediately after the last pour has been made. After foaming is complete, inspect all vent holes to ensure that the foam has completely filled all void space; if any voids are found, the end blocks must be removed and foam must be added as needed to fill all voids.

9. After foam has cured, drill out all vent holes to a depth of 1/4" to 1/2" and seal each with a plastic cap-plug set in silicone RTV caulking; wipe away excess caulking and allow to cure.

10. Seal all penetrations in inner and outer shells with Silicone RTV by setting the penetrating item (lag screw, nail, vent plug, or pop rivet) in the uncurred RTV and allow to cure per manufacturers instructions.

11. After all penetrations are sealed, remove excessive weld spatter and clean all metal surfaces (especially welds) with metal preparation solution per manufacturer's instructions; use stainless steel wire brushes on weld areas and scrub brushes on remaining 2B finish areas. Rinse thoroughly and dry before proceeding to installation of paint, pads, gaskets and nameplates.

12. If the package is to be painted, apply one coat (0.00x" minimum dry primer thickness) of primer to all inner surfaces including cover plates per manufacturer's instructions. If the package is not to be painted, apply one coat of clear metal primer to the areas to which the rubber is to adhere and allow to air dry for one hour at room temperature. Install the silicone sponge gasket by applying a uniform layer (15 to 30 mils) of silicone RTV caulking to the primed metal surface and applying the gasket using only enough pressure to displace the air but not the adhesive. Seal all joints in the gasket using silicone RTV caulking; wipe away excess caulking and allow to cure. Install the rubber pads using rubber to metal cement per the manufacturer's instructions or use silicone RTV caulking as described above.

13. If package is to be painted, also apply one coat of primer (0.00x" minimum dry primer thickness) to all the outer surfaces and apply two coats (0.00x" minimum dry paint thickness) of paint to all inner and outer surfaces. Follow manufacturer's instructions in the application and drying of primer and paint coats.

14. Obtain weights of cover, of bottom, and of assembled package without a cylinder; these weights must include the appropriate weights of nameplates and hardware yet to be attached per the following notes. All weights (in pounds and kilograms) must be recorded and stamped on package name plates per Drawing No. DED-207-A.

15. After assembly of finished package, adjust all toggle closures to securely close the package giving a metal-to-metal seat without requiring excessive closing force; then tighten all set screws in each toggle coupling nut. Lock down each toggle handle using a ball-lock pin.

16. Attach the cable of each ball-lock pin to the lower toggle bracket just above it using a 1/4" self-tapping screw set in silicone caulking.

17. After package assembly and adjustment of toggle closures, apply stencils and install nameplates using 1/8" stainless steel pop rivets set in silicone caulking per Note 10. Prepare for shipment.

18. Items specified herein by trade name provide minimum requirements only; equivalent or better items may be substituted.

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
UNLESS OTHERWISE SPECIFIED	NO.	DATE	BY	NOTES & SPECIFICATIONS MODEL NCI-21PF-1 PACKAGE		
DECIMAL ±	1	7/1/88	WRH			
	2	11/15/88	WRH			
FRACTIONAL ±NOTE 5	3	3/1/89	WRH	DRAWN BY WRH	SCALE	MATERIAL NOTE 1
ANGULAR ±	4	9/29/89	WRH	CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
	5			TRACED	APP'D WRH	SHEET 11 OF.

NORTHSIDE BLUEPRINT & SUPPLY CO.

PACKAGE IDENTIFICATION PLATE

A. PLATE SHALL BE 11" WIDE X 15" LONG X 16 TO 20 GAGE SHEET, ASTM A-240, TYPE 304 STAINLESS STEEL.

B. ENGRAVE FIRST LINE OF PLATE AND "V----V" LINE(S) WITH 1/2" LETTERS; ENGRAVE ALL OTHER LINES WITH 3/8" LETTERS AS FOLLOWS:

```
USA/9234/B(U)F
RADIOACTIVE MAT'L.--TYPE B(U)F
MFG BY:
 V-----------------------------V
 QA APPROVAL NO. X-------------X
SERIAL NO. Y-------------------Y

 PKG TARE WTS IN LBS AND KGS
 DATE  COVER   BOTTOM  PACKAGE
DD-DD  PPP LB PPPP LB PPPP LB
       KKK KG  KKK KG  KKK KG
```

(Leave bottom space blank for future dates and weights)

C. ATTACH PLATE TO CONTAINER AS SPECIFIED ON DWG. DED-206-B.

V---V - NAME AND ADDRESS OF MANUFACTURER AND DATE OF MANUFACTURE (EXAMPLE: NUCLEAR CONTAINERS, INC., ELIZABETHTON, TN, USA, 11-88)
X---X - TRANSPORTATION QA PROGRAM APPROVAL NO. (EXAMPLE: USNRC-9999)
Y---Y - SERIAL NO. OF INDIVIDUAL PACKAGE (EXAMPLE: NCI-1234)
DD-DD - DATE OF WEIGHING (EXAMPLE: 11-88)
PPPP - ACTUAL TARE WEIGHT IN POUNDS (TOLERANCE: ± 2 LBS)
KKKK - ACTUAL TARE WEIGHT IN KILOGRAMS (TOLERANCE: ± 1 KG)

NOTE: WEIGH COVER WITH LIFTING EYE-BOLTS AND NAMEPLATE; WEIGH BOTTOM WITH HARDWARE AND NAMEPLATE.

REFERENCE DRAWINGS: DED-206-B, SHEETS 1 THROUGH 10, LATEST REVISIONS.

NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
NAMEPLATE FOR NCI-21PF-1 UF6 CYLINDER SHIPPING PACKAGE		
DECIMAL TOL.	SCALE	REVISION (DATE) 1 (3/1/89)
FRACTIONAL TOL.	DATE 11/15/88	DRAWING NO. DED-207-A
ANGULAR TOL.	APP'D WRH	

NORTHSIDE BLUEPRINT & SUPPLY CO.

1 - DEFINITION OF CONTENT

COGEMA has decided to use the figures appearing in standard ASTM C 996 (and C 787) for enriched UF6 (from reprocessed uranium) in order to be resolutely conservative :

- Uranium radioisotope composition :

232 U	:	0.005 µg/gU
234 U	:	2.000 µg/gU
235 U	:	0.05 g/gU
236 U	:	0.025 g/gU
238 U	:	0.923 g/g U

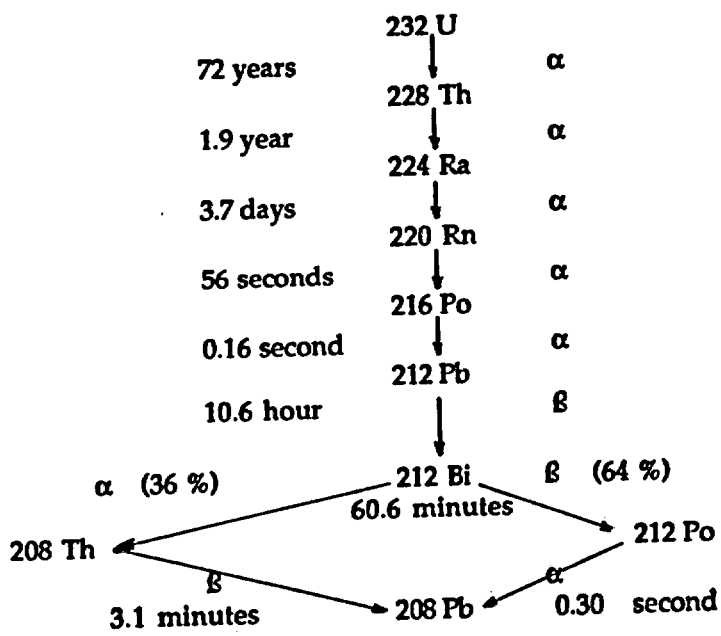
The 236 U content is not indicated in standard C 996. COGEMA uses a realistic figure of 0.025 g/gU corresponding to a standard fuel enriched to 5 %.

- Transuranics :
Maximum alpha activity for Pu and Np is 3.3 Bq/g U. This activity results practically from the isotopes 238 Pu, 239 Pu, 240 Pu and 237 Np.

Activity of 237 Np is about half of the total transuranics alpha activity.

- Technetium :
Standard ASTM C 996 specifies a 99 Tc upper limit of 5 µg/gU in the enriched UF6.

- 232 U decay chain :
232 U daughters are shown on the following diagram :



Lifetimes on this diagram are written in the decimal system. In accordance with the IAEA regulations on the transportation of radioactive materials, COGEMA takes only into account 228 Th whose lifetime is higher than 10 days (the lifetimes of the other radioisotopes are much shorter than 10 days and their activities are less or equal to 228 Th activity).

The mass of 228 Th corresponding to the maximum content of 232 U is 1.17×10^{-9} g/gU (in steady state conditions).

- Fission products :

The total contribution of gamma emitters is less than 4.4×10^5 Mev Bq/d kgU (ASTM C 996).

After four years of decay, the main gamma emitters (and their corresponding mean decay energies per desintegration, given in CEGB Report RD/B/N 4942) are the following :

Fission product	Mean decay energy (Mev/α)
106 Ru/106 Rh	0.210
103 Ru/103 Rh	0.497
144 Ce/144Pr/144^m Pr	0.0527
125 Sb	0.427
134 Cs	1.555
137 Cs/137^m Ba	0.565
95 Zr	0.735
95 Nb	0.766

(Ru 106 is however the fission product the most likely to be found in enriched UF6).

In these conditions, taking into account the ASTM value, the maximal permissible activity for each of the fission products, considered individually, is identified as follows :

Fission product	Maximal activity (Bq/g U)
106 Ru/106 Rh	2095
103 Ru/103 Rh	885
144 Ce/144Pr/144^m Pr	8349
125 Sb	1030
134 Cs	283
137 Cs/137^m Ba	778
95 Zr	598
95 Nb	574

2 - A2 CALCULATION

A2 calculation is made according to IAEA regulations (IAEA Safety Collection N° 6, Wien, 1985). The A2 coefficient of the mixture is determined from the different radioisotope A2 coefficients. These A2 values are very conservative since applied to materials in an insoluble form. It should be noted that it has not been necessary to distinguish between Pu and Np in the calculation since the A2 coefficients are identical for both of them.

The contribution of fission products has been taken into account in the following way :

- calculation of the maximal F.P. activity for each of them (see §1),
- determination of the A2 coefficients taking successively into account each of the identified fission products,
- comparaison of the results and selection of the more conservative fission product, leading to the lowest A2 coefficient.

The extremal values have been calculated respectively with 134 Cs ($A2 = 0.824 \times 10^{-3}$ TBq) and 144 Ce ($A2 = 0.829 \times 10^{-3}$ TBq) leading to the selection of 134 Cs as the reference radioisotope.

- Calculation method :

A2 for the mixture is calculated as follows :

$$A2 = \frac{1}{\sum_i \left(\frac{fi}{A2\,(i)} \right)}$$

Where f (i) is the fraction of activity of nuclide i in the mixture and A2 (i) is the appropriate A2 value for nuclide i.

The different steps of the calculation are shown in the next tabulation.

It highlights the small contribution of F.P. (and consequently the minor importance of the selection of the most conservative nuclide) and the great impact of 234 U on the A2 final determination.

The reference A2 value, derived from this calculation, is 0.824×10^{-3} TBq.

CALCULATION OF THE MIXTURE A2 COEFFICIENT

Radionuclide	Specific activity (TBq/g)	A2 (TBq)	Mass (g/gU)	Activity (TBq/g U)	Ratio activity A2
Uranium 232	0.828	3×10^{-4}	5×10^{-8}	4.14×10^{-8}	1.38×10^{-4}
Uranium 234	2.31×10^{-4}	1×10^{-3}	2×10^{-3}	4.62×10^{-7}	4.62×10^{-4}
Uranium 235	$8{,}0 \times 10^{-8}$	unlimited	5×10^{-2}	4.0×10^{-9}	
Uranium 236	2.4×10^{-6}	1×10^{-3}	2.5×10^{-2}	6.0×10^{-8}	6×10^{-5}
Uranium 238	1.24×10^{-8}	unlimited	0,923	11.44×10^{-9}	
Transuranics		2×10^{-4}	$< 2.3 \times 10^{-8}$	3.3×10^{-12}	1.6×10^{-8}
Fission products		0.5		2.8×10^{-10}	5.6×10^{-10}
Thorium 228	30.4	4×10^{-4}	1.17×10^{-9}	3.55×10^{-8}	8.9×10^{-5}
Technétium 99	6.28×10^{-4}	0.9	5×10^{-6}	3.1×10^{-9}	3.49×10^{-9}
Mixture		0.824×10^{-3}	1.000	6.17×10^{-7}	7.487×10^{-4}

3 - ASSEMBLY CLASSIFICATION

The uranium weight content of a 30 B cylinder is 1,537 Kg (corresponding to 2,274 Kg of UF6). The maximal total activity of such a cylinder, calculated from the value displayed in the tabulation, is 0.948 TBq, i.e. 1150 A2.

As that activity is in the range 30 A2 - 3000 A2, it implies the classification of the 30 B cylinder/NCI overpack in category II.

CYCLE OF REPROCESSED URANIUM

1° - REPROCESSING

- Separation of U, Pu, FP and transuranies
- Decontamination of uranyl nitrate through several solvent-washing stages
- Production of uranyl nitrate slightly contaminated with :

  -transuranies : mainly Np and Pu (α emitters)

  - fission products : long lived γ emitters (Ru)
  long lived β emitters (Tc)

  and including minor uranium isotopes : U 232, U 234, U 236.

2° - CONVERSION

- Précipitation and filtration of ammonium diuranate (ADU)
- Calcination of ADU (650 ° C)

$$ADU \rightarrow UO_3 \rightarrow U_3O_8 \xrightarrow{H2} UO_2$$

- Hydrofluoridation of uranium dioxide (600° C)

$$UO_2 + 4\,HF \rightarrow UF_4 + 2\,H_2O$$

- fluoridation of UF4 in a flame reactor :

$$UF_4 + F_2 \rightarrow UF_6$$

- purification of UF_6 and filling of cylinders (all the non volatile fluorides are eliminated during this step)

3° - ENRICHMENT

- Enrichment has been performed in a centrifugation plant with an extremely low in-plant inventory, allowing reliable measurements on the migration factors of the uranies elements and radioisotopes.

STANDARD SPECIFICATION FOR UF_6 ENRICHED TO LESS THAN 5 %

(enriched reprocessed UF_6)

ASTM C 996

Radiation from fission products and transuran

- for each detectable gamma emitting fission product, the sum of the values obtained by multiplying the activity (Bq/kg U) of each parent nuclide species by the appropriate mean gamma energy per disintegration (MeV/d) shall not exceed :

4.4×10^5 MeV Bq/ d/kg U (4.4×10^5 MeV /sec kg U)

- the alpha activity from neptunium and plutonium shall be less than 3300 Bq/kg U (200 dpm/g U)

Radionuclides (maximal obtainable values)

232 U	:	0.050 µg/g U
234 U	:	2000 µg/g U
236 U	:	no value
Tc	:	5 µg/g U

Content in elements that form non valatile fluorides (from ASTM C 787)

Σ (Al - Ba - Be - Bi - Cd - Co - Cr - Cu - Fe - Pb - Li - Mg - Mn - Ni - K - Ag - Na - Sr - Th - Sn - Zn - Zr) $\leq$ 300 µg/g U

Content in other elements (from ASTM C 787) in µg/g U

Sb < 1 - As <3 - B <1 - Bi <5 - Cl <100 - Cr <10 - Nb <1 - P <50 - Ru <1 - Si <100 - Ta <1 - Ti <1 - Mo <1.4 - W <1.4 - V <1.4

RADIOCHEMICAL CONTENT OF ENRICHEDUF6

(performed on two different cylinders)

	Cylinder nb 1	Cylinder nb 2
TOTAL U	67,60 %	67,60 %
U 234	0.0814 % /U	0.0816 %/U
U 235	3.5671 %/U	3.5689 %/U
U 236	1,1912 %/U	1.1928 %/U
U 232	6.3 ppb/U	6.2 ppb/U
Pu 238	< 0.1 Bq /g U	<0.1 Bq /g U
Pu 239 to 242	< 0.1 Bq/g U	< 0.1 Bq /g U
Np 237	< 0.1 Bq/g U	< 0.1 Bq /g U
Ru 103	< 0.1 Bq/g U	< 0.1 Bq /g U
Ru 106	<. 1 Bq /g U	< 1 Bq /g U
Nb 95	< 0.1 Bq /g U	< 0.1 Bq /g U
Zr 95	< 0.1 Bq /g U	< 0.1 Bq /g U
Ce 144	< 1 Bq /g U	< 1 Bq /g U
Co 134	< 0.1 Bq /g U	< 0.1 Bq /g U
Sb 125	< 0.1 Bq /g U	< 0.1 Bq /g U
Cs 137	< 0.1 Bq /g U	< 0.1 Bq /g U
Tc 99	< 1 ppb/U	< 1 ppb/U

ACTIVITY OF U 232 DAUGHTERS IN UF6 (example)

	Cylinder nb 1	Cylinder nb 2
α spectrometry		
Th 228	276 Bq/g U	237 Bq/g U
Ra 224	276 Bq/g U	258 Bq /g U
Rn 220	260 Bq/g U	233 Bq/g U
Po 216	256 Bq/g U	226 Bq /g U
Bi 212	92 Bq/g U	93 Bq /g U
Po 212	164 Bq/g U	131 Bq /g U
γ spectrometry		
Pb 212	202 Bq/g U	215 Bq /g U
Bi 212	137 Bq/g U	134 Bq /g U
Tl 208	76 Bq/g U	80 Bq /g U

DECONTAMINATION OF URANIUM THROUGH THE PROCESS STAGES

		UNH	UF_4	UF_6	
Elements forming non volatile fluorides (µg/g U)	Al	< 5	< 5	< 5	< 5
	Ag	< 0.5	< 0.5	< 0.5	< 0.5
	Co	< 1	< 1	< 1	< 1
	Bi	< 1	< 1	< 1	< 1
	Ca	<	< 1	< 1	< 3
	Cd	< 0.5	< 0.5	< 0.5	< 0.5
	Cr	< 2	< 2	< 1	< 1
	Cu	< 1	< 1	< 3	< 1
	Fe	7	< 1	< 5	< 5
	K	< 1	< 1	< 1	< 1
	Li	< 1	< 1	< 1	< 1
	Mg	< 1	< 5	< 1	< 1
	Mn	< 1	< 1	< 1	< 1
	Na	< 1	< 1	< 1	< 1
	Ni	< 1	< 4	< 1	< 1
	Pb	< 2	< 2	< 2	< 2
	Sn	< 2	< 2	< 2	< 2
	Th	< 0.5	< 0.5	< 0.5	< 0.5
	Zr	2	2	1	1
µg/g U	Cl	< 20	< 20	< 20	< 20
Elements forming non volatile fluorides (µg/g U)	Mo	<0.5	<0.5	<0.5	<0.5
	Nb	<0.5	<0.5	<0.5	<0.5
	Ta	<0.5	< 0.5	<0.5	<0.5
	Ti	<0.5	<0.5	<0.5	<0.5
	V	<0.5	<0.5	<0.5	<0.5
	W	<0.5	<0.5	<0.5	<0.5
µg/g U	Dy	<0.2	<0.2	<0.2	<0.2
	Gd	<0.2	<0.2	<0.2	<0.2
	Sm	<0.2	<0.2	<0.2	<0.2
	B	<0.5	<0.5	<0.5	<0.5
	P	<15	<15	<15	<15
	Si	< 5	< 5	< 5	< 5
Radio-chemical impurities	Pu dpm/gU	9 120	9 900	<60	<60
	Np dpm/gU	1 560	1 560	<60	<60
	U232 daughters +Am+Cm dpm/gU	105 000	100 080	5 160	5 400
	U 232 (ppm/U)	0.151	0.181	0.155	0.150
	γ PF Bq/kgU	3.44×10^5	3.10×10^5	1 480	1 480

SPECIFICATION FOR NUCLEAR GRADE REPROCESSED URANYL NITRATE SOLUTION

ASTM standard (C 788)	Example of analytical results on uranyl nitrate from La Hague reprocessing plant (burn up : 32260 Mwd/tU) (Cooling time : 1350 days)
Radionuclide content 232 U : $5X10^{-3}$ µg/g U 234 U : 480 µg/g U 236 U : 8400 µg/g U	Radionuclide content 232 U : $1,38X10^{-3}$ µg/g U 234 U : 160 µg/g U 236 U : 3750 µg/gU 235 U : 0,832 % 238 U : 98,777 %
Fission products 99 Tc : 0.5 µg/g U 106 Ru/106 Rh 103 Ru 144 Ce/144 Pr 95 Zr 95 Nb 125 Sb 134 Cs 137 Cs } $4 X 10^5$ MeVBq/kg U	Fission products 103 Ru/103^mRh : 2 363 Bq/kgU 106Ru/106 Rh : $3,626X10^3$ Bq/kg U 144Ce/144Pr: $2,48X10^4$ Bq/kg U 95 Zr: 4440 Bq/kg U 95 Nb : 4810 Bq/kg U 137Cs/137^mBa : 4810 Bq/kg U $4.033 x 10^5$ Bq/kg U } équivalent $8,83X10^4$ MeV/kg U
Transuranies Np + Pu : < 15000 dpm/gU Np : < 7500 dpm/gU	Transuranies Np + Pu : 9120 dpm/gU Np : 1560dpm/gU
Other elements (forming non volatile fluorides) Al - Ba - Bi - Cd - Ca - Cu - Fe - Pb - Li - Mg - Mn - Ni - K - Ag - Na - Sr- Th - Sn - Zn - Zr $\Sigma \leq 500$ µg/g U	Other elements (forming non volatile fluorides) $\Sigma \leq 305$ µg/g U
Total EBC < 4 µg/g U	Total EBC : < 2 µg/g U (without Gd)

2. STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Discussion

The NCI-21PF-1 PSP described herein is essentially a DOT-21PF-1B package with further modifications to address the following concerns with the 21PF-1 and 21PF-1B designs:

1. Questionable protection of the cylinder valve if the package is subjected to the 1-meter puncture test with the center-of-gravity over and in vertical alignment with the valve and target piston.

2. The lack of a convenient closure system which would eliminate the loose nuts, bolts, and washers.

3. The lack of a means to stack these packages for storage or for shipment with an empty cylinder.

The NCI-21PF-1 package design is described in NCI Drawing No. DED-206-B, Sheets 1 through 11, Rev. 4 (see Appendix 1.3.1). The major changes from the DOT-21PF-1B, as delineated in Union Carbide Drawing Numbers E-S-31536-J, Rev. P, and S1E-31536-J2, Rev. B, are as follows:

1. The inner and outer ends have been changed from 14 Gage (2.1mm) sheet metal to 1/4" (6.4mm) plate.

2. The fourteen 3/4" (19.0mm) carbon steel closure bolts have been replaced by ten 1" (25.4mm) stainless steel toggle closures which are quick-opening and have no loose parts.

3. All stiffeners have been eliminated from the ends reducing the overall length from 96" (243.8cm) to 93" (233.7cm).

4. The center angle stiffener ring has been changed to a band made of 1/4" x 3" (6.4mm x 7.6cm) Flat Bar.

5. The other angle stiffener rings, which were 3-1/2" x 3-1/2" x 3/8" (8.9cm x 8.9cm x 9.5mm) on the bottom and 3" x 2" x 1/4" (7.6cm x 5.1cm x 6.4mm) on the top, have been changed to 3" x 3" x 3/8" (7.6cm x 7.6cm x 9.5mm) top and bottom.

6. A set of inverted tie-down bases has been added to the top to facilitate stacking.

7. The four lifting shackles have been eliminated and replaced with four 3/4" (19.0mm) U-bolts in the inverted stacking frame; when packages are stacked, these U-bolts may be used to bolt the packages together. The four lifting shackles were often improperly used for tie-down; the location of the new lifting U-bolts makes their use for tie-down very unlikely.

8. All attachments to the outer shell of the package are now joined by continuous welds thus eliminating pockets where water and corrosive materials might gather.

9. Material specifications have been changed to allow the use of straight grade Type 304 stainless steel in place of Type 304L stainless steel, which is much more difficult to obtain and which is unnecessary for this application.

10. Wood specifications have been changed to allow the use of red or white oak and to allow the use of No. 2 Common Grade lumber in the wooden laminations. At the same time, the wood specifications have been tightened to disallow specific defects and to eliminate end splicing. Also, the use of essentially clear lumber is specified for the wooden rails and cap boards, and these must be single boards with no splicing or lamination allowed. The corner blocks and plywood end rings have been eliminated as unnecessary.

11. Quality Assurance requirements for the NCI-21PF-1 are essentially the same as for the DOT-21PF-1B package. Specific Quality Control requirements regarding material specifications including the requirements for test reports and certifications, tolerances, weld specifications, heat treating specifications, and inspections are specified in NCI Drawing No DED-206-B, Sheets 9 through 11, Rev. 4 (see Appendix 1.3.1).

2.1.2 Design Criteria

The NCI-21PF-1 package was designed to meet all of the performance requirements of 10CFR71, Subpart E. The primary containment vessel is the Model 30B UF_6 cylinder, such that the performance requirements specified in 10CFR71, Subpart E are satisfied when the cylinder and its valve are protected from unacceptable impact damage, from failure of package components due to cold (-40°F), from accidental or inadvertent opening of the package, or from over-pressurization due to over-heating. There is certainly no danger of over-pressurization if the triple point (1.5 atm absolute pressure @ 147.3°F) of the UF_6 is not exceeded when the package is subjected to Normal Conditions of Transport or Hypothetical Accident Conditions as specified in 10CFR71.71 and 10CFR71.73, respectively.

The overriding design criteria for the NCI-21PF-1 package was to correct the remaining design deficiencies of the DOT-21PF-1B package as described in 2.1.1 above, without changing the basic package design of the DOT-21PF-1B. If this could be successfully accomplished, most of the safety evaluations of the DOT-21PF-1B package would still be valid, and testing of the NCI-21PF-1 could be limited to evaluation of the changes only.

This criteria was successfully employed in that the NCI-21PF-1 PSP described herein is essentially a DOT-21PF-1B package with improvements which provide the following:

1. complete protection of the cylinder and cylinder valve when subjected to the hypothetical accident 9-meter drop test and 1-meter puncture test, both conducted with the center-of-gravity in vertical alignment over the valve and, in the puncture test, over the target piston.

2. a convenient closure system which eliminates the use of loose nuts, bolts, and washers.

3. a means of stacking the packages for storage or for shipment with an empty cylinder.

These improvements were incorporated in the package design without changing the basic package structure from that of the DOT-21PF-1B package, ie. the inner and outer shells are the same size and shape and are still made of 14 gage sheet metal, the phenolic foam insulation is unchanged, the wooden ends and rails are unchanged, the wood cover plates are unchanged, and the tie-down bases are unchanged. Assuming the integrity of the package closure is maintained

when the package is subjected to hypothetical accident conditions, then its containment and nuclear safety capabilities should also be equivalent to those of the other 21PF-1 packages.

Since the original 21PF-1 and all the stainless steel versions of the 21PF-1 package have been thoroughly tested and evaluated, it is therefore reasonable to limit the safety evaluation of the NCI-21PF-1 PSP to the following considerations:

1. To evaluate the new lifting and stacking design.

2. To evaluate the design modifications for the effects of vibration incident to normal conditions of transportation.

3. To test the ability of the package to protect the cylinder and cylinder valve when subjected to a 9-meter drop test and a 1-meter puncture test, both conducted with the center-of-gravity in vertical alignment over the valve and, in the puncture test, over the target piston.

4. To test the ability of the closure devices to withstand 9-meter drop testing and 1-meter puncture testing without failure of the closures to maintain secure closure and without developing larger openings between the package halves at the closure plane than previously experienced in similar tests of 21PF-1 packages.

5. To evaluate the containment capabilities of the package and cylinder regarding Type B packaging requirements.

A half-scale test model of the NCI-21PF-1 package was subjected to the Hypothetical Accident Conditions specified in 10CFR71.73 as described in detail in Appendix 2.10.9; drawings for the half-scale model are included in Appendix 2.10.10. A full-scale NCI-21PF-1 package which had been in regular use for over one year was also subjected to the Hypothetical Accident Conditions specified in 10CFR71.73 as described in detail in Appendix 2.10.11. The following acceptance criteria was used to judge performance capabilities of the test packages.

(a) No cylinder damage which breaches or threatens to breach the containment integrity of the cylinder or cylinder valve. Shallow dents in the cylinder walls were considered to be acceptable damage.

(b) Although some toggle closures may be damaged or lost during drop and puncture testing, the remaining toggle closures must maintain secure closure of the package and no openings shall develop between the package halves at the closure plane which are larger than previously experienced in similar tests of 21PF-1 packages (as reported in K-1686).

(c) In the full scale test with a Model 30B cylinder filled with a dummy load, leak-testing of the cylinder before the drop tests must demonstrate compliance with allowable leak-rate standards for Normal Conditions of Transport per 10CFR71.51(a)(1), and leak-testing after the drop tests must demonstrate compliance with allowable leak-rate standards for Hypothetical Accident Conditions per 10CFR71.51(a)(2).

Evaluation of the package for compliance with 10CFR71, Subpart E Standards for Normal Conditions of Transport, as defined in 10CFR71.71, are based on the following criteria:

(a) Analytical evaluations must demonstrate stresses below the yield strength in base metals and below 70% of yield strengths in weld affected zones per values listed in Section 2.3 below.

(b) Yield strength for Type 304 Stainless Steel is based on minimum values given in Table UHA-23, ASME Boiler and Pressure Vessel Code, Section VIII.

(c) Yield strength for Type 17-4PH Stainless Steel is based on values listed in pages 6 through 13, "Republic Precipitation Hardenable Stainless Steels" (See Appendix 2.10.1).

(d) Thermal properties for stainless steel materials are based on Table 23-5, Perry's Chemical Engineers' Handbook.

(e) Thermal and physical properties of wood are based on Table 23-12, Perry's Chemical Engineers' Handbook.

(f) Low temperature (-40°F) toughness is required of all metals per Section 3, Cask Designers' Guide, ORNL-NSIC-68.

(g) All stainless steel materials must be certified and identified per Section 4.1, Cask Designers' Guide, ORNL-NSIC-68.

(h) Heat treat records must be maintained for all cast

components and for all Type 17-4PH stainless steel components (See Notes 1(d) and 1(e) on Sheet 9, DED-206-B, Appendix 1.3.1)..

(i) All Type 17-4PH stainless steel castings shall be evaluated and identified per Section VIII, ASME Boiler and Pressure Vessel Code (See Note 3 on Sheet 9, DED-206-B, Appendix 1.3.1).

(j) All Type 304 stainless steel castings shall be evaluated and identified per Section VIII, ASME Boiler and Pressure Vessel Code (See Note 3 on Sheet 9, DED-206-B, Appendix 1.3.1).

(k) Welders and weld procedures shall be qualified per Section IX, ASME Boiler and Pressure Vessel Code (See Note 4 on Sheet 9, DED-206-B, Appendix 1.3.1).

(l) Model 30B cylinders must be fabricated, inspected, tested, and maintained in accordance with ANSI Standard No. N14.1 which requires fabrication in accordance with Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code and requires the cylinder to be ASME Code "U" stamped.

(m) The main pressure vessel portion of the 30B cylinders must be made of ASTM A-516, Grade 50, 60, or 70 steel which is normalized and meets ASTM A-20 Charpy V-notch testing at temperatures down to -50°F. As stated in ASTM A-516, this steel is specifically intended for low temperature service in welded pressure vessels where improved notch toughness is important.

Additionally, design provisions were included to preclude the accidental or inadvertent loosening or opening of the toggle closure clamps. Also, provisions were retained for security seals meeting the requirement of 10CFR71.43(b)

2.2 Weights and Centers of Gravity

The weights and centers of gravity of the NCI-21PF-1 package, its cylinder, and its UF_6 contents are tabulated below. Centers of gravity are determined from the geometric center of the package with vertical distances (y) shown as positive for centers of gravity above the center line. Longitudinal distances (x) are shown as positive for centers of gravity nearer the plug end of the cylinder and negative for centers of gravity nearer the valve end of the cylinder (see Figure 2.2 below).

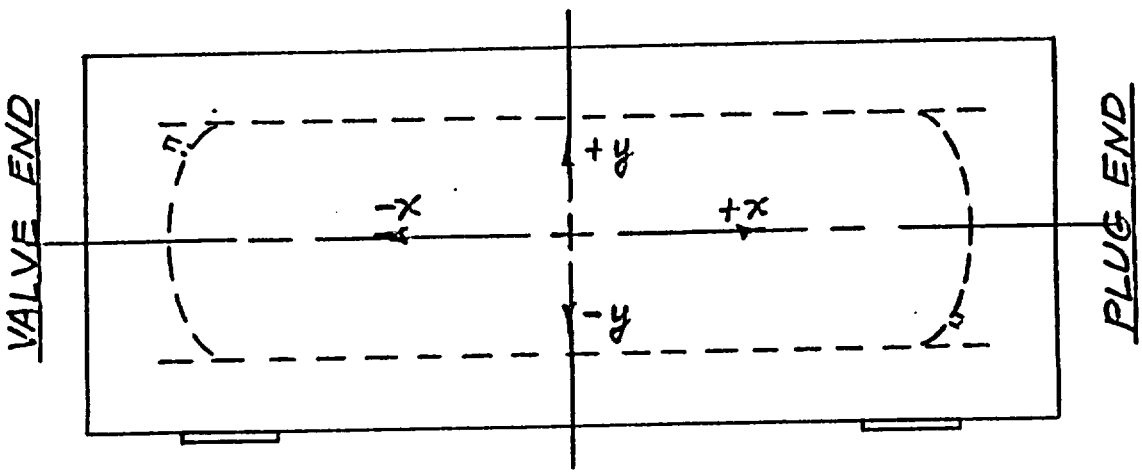


FIGURE 2.2

Component	W	x	Wx	y	Wy
Empty package	2,280	0.0	0	-0.7	-1,596
Empty Cylinder	1,400	0.5	700	0.0	0
UF_6	5,020	2.3	11,546	-4.9	-24,598
Loaded Package	8,700	1.4	12,246	-3.0	-26,194

2.3 Design Properties of Materials

2.3.1 Metals Properties

Property/Material	304 SS	17-4PH SS
Min Yield Strength (psi x 1,000)	30 (1)	115 (2)
Min Tensile Strength (psi x 1,000)	75 (1)	140 (2)
Mod of Elasticity (psi x 10^6)	28 (3)	28.5 (2)
Elongation in 2" (%)	62 (3)	14 (2)
Density (lb/cu-in)	0.29 (3)	0.283 (2)
Thermal Cond. (Btu/hr sq-ft °F/in)	113 (3)	120 (2)
Heat Capacity (Btu/lb °F)	0.12 (3)	0.11 (2)
Coef Thermal Expan (in/10^6 in °F)	9.6 (3)	6.0 (2)

NOTE: Minimum Yield Strength in shear is calculated at 75% of the Minimum Yield Strength in tension.

2.3.2 Insulation Properties

Property/Material	Oak Wood	SP-9 Foam
Moisture (%)	<12 (4)	0 (7)
Density (lb/cu-ft)	41-44 (4)	7-8 (7)
Tensile Strgth (psi)	770-820 (4)	------
Shear Strength (psi)	1830-1890 (4)	------
Comp Strength (psi)		
Across Grain	1260-1410 (4)	------
Parallel to Grain	6920-7040 (4)	------
Mod of Elasticity (psi x 10^6)	1.6-1.8 (4)	1.2-1.6 (4)
Thermal Conductivity (Btu/hr sq-ft °F/in)	0.6-0.9 (5)	0.2-0.8 (6)
Heat Cap (Btu/lb °F)	0.45-0.65 (5)	0.27 (6)
Coef Thermal Expan (in/in °F 10^6)	3 (5)	2-3 (5)

2.3.3 References

(1) ASME Boiler & Pressure Vessel Code (1974 Ed), Section VIII, Table UHA-23.
(2) Republic Precipitation Hardenable Stainless Steels (1969), pages 6-13 (See Appendix 2.10.1).
(3) Perry's Chemical Engineers' Handbook (4th Ed), Table 23.5.
(4) Perry's Chemical Engineers' Handbook (4th Ed), Table 23.12.
(5) Perry's Engineering Manual (2nd Ed), Tables 3-4, 3-12, and 3-30.
(6) J. L. Fraizer, "Thermal Properties Evaluation of UF_6 Cylinder Overpack Insulation", pp 161-162, CONF-880558, 5/24/88.
(7) DED-206-B Bill of Materials and Note 9.

2.4 General Standards for All Packages

The NCI-21PF-1 package meets the General Standards for All Packages per 10CFR71.43 in that it easily meets the minimum size requirement, it is equipped with provisions for security seals, the package and its Model 30B cylinder provide complete containment under Normal Conditions of Transport, the cylinder valve is well protected against accidental or unauthorized operation, and there is no pressure relief valve nor any provision for continuous venting. Since there is essentially no source of internal heat, ie. decay heat is negligible as shown in Appendix 2.10.5, the external surfaces will not exceed 38°C in still air in the shade at 38°C. Other General Standard provisions are also met as described below:

2.4.1 Chemical and Galvanic Reactions

The NCI-21PF-1 package is covered inside and out with Type 304 Stainless Steel which is continuously welded with Type 308L Stainless Steel weld wire. The only other metals in contact with the 304 Stainless Steel are the 17-4PH Stainless Steel used in the closure clamps and the steel in the UF_6 cylinders. These are essentially similar metals such that no chemical, galvanic, or other reaction should take place between them under normal conditions of transport. These stainless steels are resistant to corrosion from contact with the wood and foam insulation when the foam is made with low chloride components, and they are resistant to corrosion from environmental elements. However, painting is recommended to provide added protection from chloride attack which can result from road salts and/or ocean spray. Dry UF_6, as contained in the Model 30B cylinder, has been shown to be essentially non-corrosive to the steel cylinder.

2.4.2 Positive Closures

The NCI-21PF-1 Package is closed by ten (10) one-inch toggle closures which are made of Type 17-4PH Stainless Steel. Each closure is prevented from opening accidentally by a ball-lock pin on its handle. The ball-lock pins have 1/2" diameter shanks made of 17-4PH Stainless Steel. The ball-lock pin is designed such that a button must be depressed in order to remove the pin. This system was proven during the accident condition testing done on these packages as described in Section 2.7.

2.4.3 Lifting Devices

The NCI-21PF-1 package can be lifted by fork-truck tines in which case it is supported on angle reinforcements under its belly or by a lifting harness or slings using the four lifting U-bolts which are bolted into its stacking frames. These lifting attachments meet the requirements of 10CFR71.45(a) as follows:

The stacking frames on the NCI-21PF-1 package are identical to its tie-down bases which are identical to the tie-down bases on the original 21PF-1 and the new 21PF-1B packages. The lifting U-bolts in the stacking frames are each rated for 5,200-pound working loads with a safety factor of 5 such that the four lifting U-bolts can lift a loaded NCI-21PF-1 package weighing 8,700 pounds with a safety factor of about 12. The lifting U-bolts are bolted into the 1/2" thick base plates which are comparably stronger than the 3/8" thick angle to which the lifting shackles are attached on the other 21PF-1 packages. As shown in Appendix 2.10.2, the stresses induced in the base plates at the bolt holes do not exceed the yield strength of the metal if used to lift three times the loaded weight of the package.

2.4.4 Tie-Down Devices

The NCI-21PF-1 PSP is fitted with tie-down bases which are identical to the tie-down bases on the original 21PF-1 and the new 21PF-1B packages. The package is bolted to the bed of its carrier with eight 3/4" bolts on a bolt pattern which is identical to that of the older DOT 21PF-1 PSP. As shown in Appendix 2.10.3, this tie-down system meets the requirements of IOCFR71.45(b) and was designed to ultimately fail at the bolt holes so as not to damage any structural part of the package.

2.5 Additional Requirements for Type B Packages

2.5.1 Normal Conditions of Transport

Per the requirements of 10CFR71.51(a)(1), when subjected to Normal Conditions Of Transport as specified in 10CFR71.71, a package shall not release more than 1×10^{-6} A_2 values of radioactive materials per hour as determined per 10CFR71, Appendix A. As shown in Appendix 2.10.4, this maximum release rate of contents is equivalent to a cylinder leak rate of 5.48×10^{-7} g UF_6/sec when the cylinder contents are limited as described above in Section 1.2.3. As shown in Appendix 2.10.4, this UF_6 leak rate is equivalent to a helium leak rate of 4.0×10^{-8} atm cc/sec. As shown in Section 2.6 below, the NCI-21PF-1 package is capable of withstanding Normal Conditions of Transport as defined in 10CFR71.71 without any adverse effects on the containment capabilities of its Model 30B UF_6 cylinder.

The following leak test procedures are prescribed herein to assure that the 30B cylinder and its valve meet the above criteria in normal operations:

1. When new and after each 5-year cleaning and inspection, each 30B cylinder is hydrostatic tested at 400 psig internal pressure and soap bubble leak tested at 100 psig internal pressure as required in ANSI N14.1.

2. Whenever a new or cleaned and reconditioned valve or plug is installed, the cylinder and valve are soap bubble leak tested at 100 psig internal pressure as required in ANSI N14.1.

3. If the cylinder is to be used for Type B shipments, within the 12-month period preceding any Type B shipment of a 30B cylinder and every time the valve or plug is replaced, the cylinder, with its valve and plug installed, is leak tested at 1300 mBar internal pressure to demonstrate no leakage in excess of 4×10^{-8} atm cc/sec. A helium leak test procedure with a sensitivity of 10^{-8} atm cc/sec, such as the one described in Appendix 2.10.14, shall be used.

4. Before each Type B shipment, after the cylinder is loaded with UF_6, the cylinder, with its valve and plug installed, is leak tested using a pressure drop/rise procedure with a sensitivity of 1×10^{-3} atm cc/sec. A procedure such as the one described in Appendix 4.4.1 is satisfactory for this test.

5. Before each Type B shipment, after the cylinder is loaded with UF_6 and leak-tested per 4 above, the cylinder valve is leak tested using a pressure drop/rise procedure with a sensitivity of 1×10^{-3} atm cc/sec. A procedure such as the one described in Appendix 4.4.2 is satisfactory for this test.

Compliance with 10CFR51.51(a)(1) is further enhanced by the fact that the UF_6 is shipped in solid form only and that the cylinder is maintained under a negative pressure. Under Normal Conditions of Transport the UF_6 temperature will not exceed 118°F as shown in Appendix 2.10.6; this corresponds to a vapor pressure of about 10 psia which means that the cylinder will remain under a partial vacuum. Under these conditions any leakage will be inward such that there will be no loss of radioactive materials under normal conditions of transport. Also, as reported in K-D-1987, leakage of UF_6 is minimized by inherent self-plugging of leakage paths due to the formation of insoluble materials which occurs immediately when the UF_6 reacts with the water in the air. These plugs also form and effectively minimize in-leakage of water when the cylinder is immersed in water.

Based on all of the above reasons, the NCI-21PF-1 meets the requirements of 10CFR71.51(a)(1).

2.5.2 Hypothetical Accident Conditions

Per the requirements of 10CFR71.51(a)(2), when subjected to Hypothetical Accident Conditions as specified in 10CFR71.73, a package shall not release more than one A_2 value of radioactive materials per week as determined per 10CFR71, Appendix A. This maximum release rate of contents is equivalent to a cylinder leak rate of 3.26×10^{-3} g UF_6/sec when the cylinder contents are limited as described above in Section 1.2.3. As shown in Appendix 2.10.4, this UF_6 leak rate is equivalent to a helium leak rate of 0.14 atm cc/sec.

As shown in Section 2.7 below, when the NCI-21PF-1 package is subjected to Hypothetical Accident Conditions as defined in 10CFR71.73, the 30B cylinder easily meets this leak-tightness criteria having demonstrated a maximum leak-rate of 5.7×10^{-3} atm cc/sec at an absolute internal pressure of 2.3 atm. As shown in Appendix 2.10.4, under Hypothetical Accident Conditions the temperature of the UF_6 will not exceed 147.3°F (its triple point) such that the absolute internal pressure will not exceed 1.5 atm.

As shown in Section 4.3.1, there is no likelihood of releasing Krypton-85 at a rate approaching 10,000 Ci/week. Also, as shown in Section 2.7 below, there is no damage to the package or its cylinder which would cause an increase in external dose rates above that allowed under normal conditions of transport.

Based on the above reasons plus the fact that UF_6 leaks are inherently self-plugging as described in Section 2.5.1 above, the NCI-21PF-1 meets the requirements of 10CFR71.51(a)(2).

2.5.3 Filters and Mechanical Cooling

Compliance with 10CFR71.51(a)(1) & (2) as described above is not dependent on filters or mechanical cooling.

2.6 Normal Conditions of Transport

As demonstrated in the following paragraphs, the NCI-21PF-1 package meets the standards specified in 10CFR71, Subpart E when subjected to the Normal Conditions of Transport as specified in 10CFR71.71.

2.6.1 Heat

2.6.1.1 Summary of Pressures and Temperatures

The following pressures and temperatures will be used in evaluating the NCI-21PF-1 package below in Sections 2.6.1.2, 2.6.1.3, and 2.6.1.4; these pressures and temperatures were derived from the minimal decay heat generation calculated in Appendix 2.10.5 and from the heat evaluation in Appendix 2.10.6:

Steady state conditions at 100°F in the shade:

Temperature in outer stainless skin ---------- 100°F
Temperature in insulation ---------- 100°F
Temperature in inner stainless shell---------- 100°F
Temperature in UF_6 cylinder wall ---------- 100°F
Temperature in UF_6 ---------- 100°F

UF_6 vapor pressure ---------- 6 psia.

Steady state conditions at 100°F with specified insolation (see Appendix 2.10.6):

Temperature in outer stainless skin ---------- 118°F
Temperature in insulation ---------- 118°F
Temperature in inner stainless shell---------- 118°F
Temperature in UF_6 cylinder wall ---------- 118°F
Temperature in UF_6 ---------- 118°F

UF_6 vapor pressure ---------- 10 psia.

Transient conditions at 100°F in the shade or with specified insolation present no particular problems as shown below in 2.6.1.2, 2.6.1.3, and 2.6.1.4.

2.6.1.2 Differential Thermal Expansion

As shown in 2.3 above, the thermal expansion coefficient for wood is about 25% that for stainless steel. As the package is heated under transient conditions, the wood will be no warmer than the outer stainless steel skin; under steady state conditions the wood and the stainless steel outer skin will assume the same temperature. Since the stainless steel expands faster than the wood, heating will only cause the stainless steel skin to loosen on the wood such that no thermal stresses are developed.

Similarly, the wood will be no cooler than the inner stainless steel shell when subjected to heating conditions. Assuming a tight fit of the wood to the inner shell at 70°F during fabrication, the wood and inner shell in the NCI-21PF-1 package would expand as follows:

$$e(\text{stainless}) = 9.6 \times 10^{-6} \times 92(118 - 70) = 0.042''$$

$$e(\text{wood}) = 2 \times 10^{-6} \times 92(118 - 70) = 0.009''$$

$$e(\text{difference}) = 0.042 - 0.009 = 0.033''$$

Assuming no strain in either the wood or the stainless steel, this difference would only cause a separation of about 1/64" at the joint where the side boards butt against the end boards at each end of the package; such small gaps would be of no consequence.

2.6.1.3 Stress Calculations

If the differential thermal expansion calculated above were all absorbed by compressive strain of the stainless steel shell, the compressive stress generated in the stainless steel shell would be as follows:

$$S(\text{stainless steel}) = 2.8 \times 10^{7} \times 0.033/92 = 10{,}043 \text{ psi.}$$

Conversely, if the entire differential thermal expansion load were absorbed by tensile strain of the wood, the tensile stress generated in the wood would be as follows:

$$S(\text{wood}) = 1.5 \times 10^{6} \times 0.033/92 = 538 \text{ psi.}$$

Of course, the differential thermal expansion would be absorbed by a combination of compressive strain in the stainless steel, tensile strain in the wood, and minor separations at the wood joints as discussed above in 2.6.1.2 such that the actual stresses in the stainless steel and wood would be somewhat less than those calculated here.

2.6.1.4 Comparison with Allowable Stresses

The compressive stress of 10,043 psi in the stainless steel as calculated above is only about 1/3 of its minimum specified yield strength of 30,000 psi. Also, the tensile stress of 538 psi in the wood as calculated above is only about 2/3 of its specified tensile strength. Therefore, there would be no detrimental effects from heating the packages to 118°F.

2.6.2 Cold

The metals used in the NCI-21PF-1 package are Types 304 and 17-4PH stainless steels, both of which retain their ductilities and mechanical strengths well at -40°F. Type 304 stainless steel is recommended for -40°F in the ORNL-NSIC 68, Cask Designers' Guide, Section 3. Type 17-4PH stainless steel is also recommended for such low temperature applications by Republic Steel Corporation (See Appendix 2.10.1). The design temperature for the Model 30B cylinder as specified in ANSI Standard N14.1, Section 6.10.1 is -40°F, and the normalized ASTM A-516, Grade 70 steel used in the Model 30B UF_6 cylinder is recommended for low temperature applications and meets ASTM A-20 Charpy V-notch testing at -50°F.

There is no reason to suspect that the dry wooden insulation would not also perform well at -40°F; in fact, one would expect that its strength and toughness would increase because of its fibrous composition. The phenolic foam has been tested at -40°F as reported in K-2060 (Strunk, et al, UF_6 Cylinder Overpack Phenolic Foam Drop Testing) and has demonstrated about a 25% stiffening and corresponding decrease in impact absorption capability, all of which was considered to be inconsequential regarding its use as an insulator and impact absorber. Of course, both the foam and the wood have been used in the DOT-21PF-1 package for nearly 25 years with no detrimental effects from heat or cold.

The stainless steel outer skin will contract more than the wooden insulation due to being cooled to -40°F. As shown in Appendix 2.10.7, the maximum differential thermal

contraction for the NCI-21PF-1 package would be about 3/32" which would probably be absorbed by compressing the wood and by closing small gaps which exist after fabrication between the wood and the stainless steel skin. However, assuming no compression of other materials and no gaps between the wood and the stainless steel, the stress generated in the stainless steel skin would not exceed the minimum yield strength of 30,000 psi.

2.6.3 Reduced External Pressure

The NCI-21PF-1 package is not completely leak-tight from the outside to the cylinder cavity; therefore, an external pressure of 3.5 psia would soon be felt inside the package on the UF_6 cylinder. Since the UF_6 cylinder is capable of containing internal pressures of several hundred pounds per square inch, an external pressure of 3.5 psia would be of no consequence structurally. This reduction in external pressure may result in the internal pressure being slightly higher than the external pressure but by somewhat less than 1000 mBar. As shown in Appendix 2.10.4, the UF_6 cylinder exhibits a leak rate of less than 10^{-8} atm cc/sec when pressurized to an internal pressure of 1300 mBar.

The air in the voids and gaps in the insulation cavity between the inner and outer shells would exert an internal pressure of 11.2 psig. As shown in Appendix 2.10.8, this would develop an inconsequential tensile stress of 3,254 psi in the outer skin of the package.

2.6.4 Increased External Pressure

The containment vessel of the NCI-21PF-1 package is the Model 30B cylinder which is designed to withstand many times the external pressure of 20 psia required in 10CFR71.71(c)(4), without any loss of contents. Since the package is close-fitting around the cylinder so as to be supported by the cylinder if subjected to external pressure, these packages would not sustain any damage from 20 psia external pressure. Also, since this package is not airtight with regard to leakage of pressure from outside to the inside cavity, an external pressure of 20 psia would quickly equalize with the inside cavity. The net effect of such external pressure would be to tighten the stainless steel skin on the wood and foam insulation and to apply such external pressure on the UF_6 cylinder; the wood and foam insulation and the UF_6 cylinder would be unaffected by such pressure.

2.6.5 Vibration

Among package components which might be adversely affected by vibration, the lifting U-bolts and the closure devices on the NCI-21PF-1 package are the only components which are different from those on all the other DOT-21PF-1 packages; these packages have shown no adverse effects from vibration incidental to transportation during the more than twenty years they have been in service.

The lifting U-bolts of the NCI-21PF-1 package are secured to the stacking frames with heavy hex nuts which are tightened down on lock washers to prevent them from vibrating loose. The toggle closures are protected from adverse effects of vibration as follows:

1. The adjusting collars are locked by three self-locking set screws in each collar so that neither the collars nor the set screws can vibrate loose.

2. The toggle pivots (shoulder bolts) are tack welded after installation to prevent them from vibrating loose.

3. The toggle mechanisms are under tension when closed, and the handles are locked down by self-locking ball-lock pins which cannot vibrate loose.

No other parts of the NCI-21PF-1 package or of its closure devices are subject to loosening or other damage by vibration.

Otherwise, vibrations normally incident to transport will have no adverse affect on these solidly built packages or on the UF_6 cylinders they house. The UF_6 cylinders are firmly clamped between Neoprene pads in these packages to prevent their movement during transport, and all parts which could loosen because of vibration, have been secured by some special means as described above.

2.6.6 Water Spray

The wood and foam insulation in the NCI-21PF-1 package is totally encased in a welded stainless steel jacket with no penetrations other than the vents which are sealed closed. The lids and bodies join at a closure joint which is stepped down to the outside with a soft gasket on the in-board side to keep water out of the cylinder cavity. Therefore, a water spray would have no adverse effect on

these packages, but it should be noted that there would be no adverse effects even if the UF_6 cylinder were totally immersed in water.

2.6.7 Free Drop

Due to the abilities of this package to withstand accident conditions as described in 2.7, no serious consequences would be suffered in a one-foot drop test.

2.6.8 Corner Drop

N.A.

2.6.9 Compression

As shown in Figures 2.6.9.1 and 2.6.9.2 below, the half-scale NCI-21PF-1 test model was uniformly loaded with 6,000 pounds (more than 5 times its loaded weight of 1200 pounds) for a period of 24 hours with no visible effects, thus meeting the requirements of 10CFR71.71(c)(9).

2.6.10 Penetration

As reported in K-1686, a drop test was performed in which a 13-pound, 1-1/4" diameter steel rod was dropped 4 feet onto the shell of the DOT-21PF-1 prototype. The rod did not penetrate but caused a "barely discernable" indentation in the steel. The effects of a similar penetration test on the NCI-21PF-1 package would be of a similar nature and would be of no consequence.

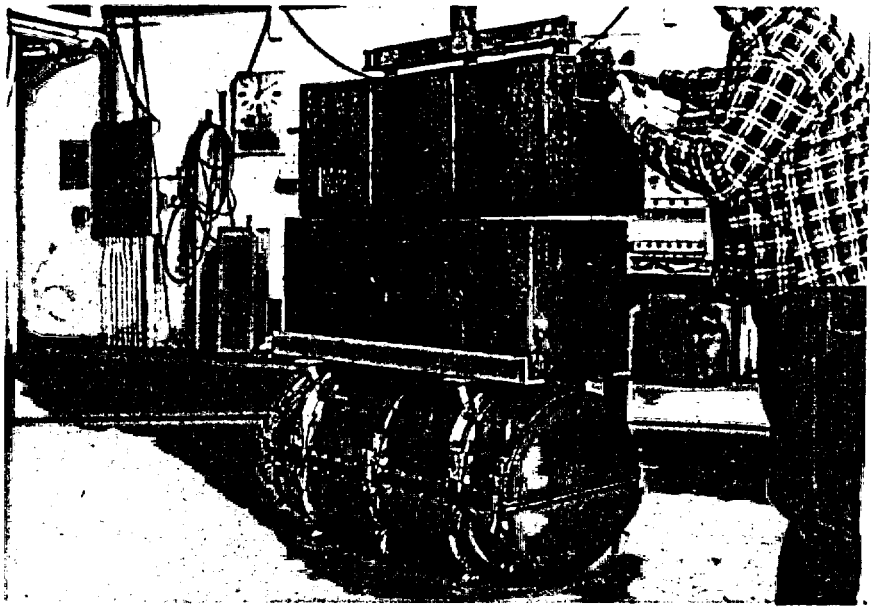


FIGURE 2.6.9.1--6,000 LB LOAD ON HALF-SCALE MODEL

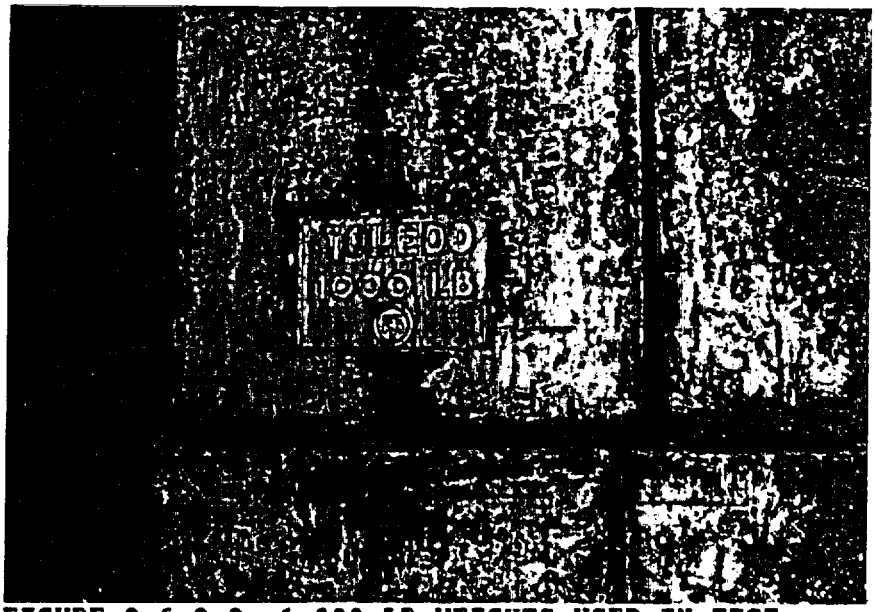


FIGURE 2.6.9.2--1,000 LB WEIGHTS USED IN TEST

2.7 Hypothetical Accident Conditions

A half-scale model of the NCI-21PF-1 package with a dummy cylinder was built and subjected to hypothetical accident drop testing as delineated in 2.7.1 and 2.7.2 below and as described in detail in Appendix 2.10.9. Drawings for the half-scale model are included in Appendix 2.10.10.

A full-scale NCI-21PF-1 package and a Model 30B cylinder were removed from regular service of more than a year and were subjected to similar drop testing as delineated in 2.7.3 and 2.7.4 below. The proposed test procedure is included in Appendix 2.10.11. The actual test procedures are included in Appendices 2.10.12 and 2.10.13. The 30B cylinder used in the full-scale testing was helium leak-tested before and after each series of tests to demonstrate leak-tightness as required for Type B packages as determined in Appendix 2.10.4. The helium leak test procedure is included in Appendix 2.10.14, and the test results are included in Appendix 2.10.15.

2.7.1 Free Drop

The half-scale model was subjected to free drop tests from a height of 9 meters impacting a steel reinforced concrete drop pad as follows:

2.7.1.1 End Drop

The half-scale model was subjected to two end drops, once with the center-of-gravity over the top end corner of the package and once with the center-of-gravity over the bottom end corner of the package. In both drops the dummy cylinder was oriented such that the valve was in line with the center-of-gravity and the impact point. The dummy cylinder used in the first drop suffered unacceptable damage, but it was replaced for subsequent testing when it was discovered that it had been fabricated from metal which was not up to half-scale thickness.

Damage to the package involved crushing of the corners at the points of impact and some deformation of the end toggle closures, but all toggle closures were in working order and continued to hold the package firmly closed. Small gaps which developed at the closure plane were not as great as those described in similar testing of the DOT-21PF-1 package per K-1686. The second test with a cylinder made of 1/4" metal (half-scale thickness for 30B cylinder) resulted in no damage to the cylinder valve or cylinder other than a slightly deformed end skirt.

2.7.1.2 Side Drop

The same half-scale model was subjected to a side drop such that it impacted flat on its side so as to do the most damage to the toggle closures. The closures were deformed and were partially pushed into the side of the package, but they all held firm. The gaps which developed at the closure plane were only open at the surface and were not as great as those suffered in similar testing of the DOT-21PF-1 package per K-1686. This test resulted in no damage to the cylinder or cylinder valve.

2.7.1.3 Corner Drop

See 2.7.1.1 above.

2.7.1.4 Bottom Drop

The same half-scale model was subjected to a bottom drop such that it impacted flat on its bottom so as to impart the most stress on the toggle closures; similar testing of the DOT-21PF-1 prototype resulted in broken bolts and 1" gaps at the closure plane. The NCI-21PF-1 half-scale model survived this test with expected damage to the tie-down bases and minor damage to the toggle closures. However, the toggles all held firm, no gaps developed at the closure plane, and no broken welds developed. A small tear developed in the outer skin but it was in the area of severely deformed metal from previous drop tests. This test resulted in no damage to the cylinder or cylinder valve.

2.7.1.5 Summary of Results

(a) After the 9-meter drop tests described above, the toggle closures were all still intact and still held the package tightly closed. None of the toggle lock-down pins had failed.

(b) Two 1.5-cm wide gaps had developed at the external closure plane of the package, but these gaps did not penetrate far into the package, tapering to nothing at the closure plane step joint such that the inboard gasket was not exposed.

(c) A narrow 4.5-cm rip developed in the outer skin in an area which was already badly deformed from previous drop testing. Otherwise, there were no openings or penetrations in the outer skin, and there were no broken welds on the exterior of the package.

(d) Several of the impacted toggle closures were badly deformed and jammed such that they had to be destroyed in order to open the package; however, they all held the package firmly closed.

(e) Except for a slightly bent end skirt, the dummy cylinder and cylinder valve were undamaged. The inner liners and wood cover plates all suffered some breaks, especially at weld joints, but it is known from interim inspections that these breaks in the inner liner occurred only after the 3rd or 4th 9-meter drop test. No breaks were noted after the first two such tests.

2.7.2 Puncture

The same half-scale test model used in the 9-meter drop tests described in 2.7.1 was subjected to three 1-meter puncture tests. Two of these tests were made with the center-of gravity over and in vertical alignment with the cylinder valve and target piston. These tests resulted in shallow indentations in the ends of the package with no tears or penetration and no damage to the cylinder or cylinder valve. The third test was made such that the package impacted the target piston flat on its side directly over the center toggle closure. The closure was driven into the side of the package but held fast; there was no other damage from this test.

Puncture testing was conducted on the DOT-21PF-1 prototype as described in K-1686 where the impact point was on the sheet metal skin in an area backed only by insulating foam. This test resulted in partial penetration and tearing of the outer skin, severe crushing of the foam under the impact point, and minor denting of the cylinder.

More recent puncture testing of DOT-21PF-1 packages were described in CONF-880558, Conference Proceedings, Uranium Hexafluoride--Safe Handling, Processing, and Transporting, May 24-26, 1988; specifically in reports by Warniez, et al, pages 133-140, and by Andreuccetti, et al, pages 147-156. These test produced similar results when the point of impact was over the foam insulation. However, the later report describes a puncture test in which the center-of-gravity is over and in vertical alignment with the cylinder valve similar to the NCI puncture test described above. This test resulted in penetration on the wood end of the package and internal impact on the cylinder valve which subsequently leaked at the rate of 19.8 atm l/sec at 1 atm internal gage pressure.

The fact that the NCI-21PF-1 can withstand such puncture testing without damage to the cylinder valve is attributed to its much thicker internal and external end plates. In the tests reported by Andreuccetti, leak-tightness of the cylinder valves was unaffected if the valve survived the drop and puncture testing undamaged. Since such testing of the NCI-21PF-1 half- scale model resulted in no valve damage, it is reasonable to expect the cylinder valve involved in such testing of a full size NCI-21PF-1 package would be leak-tight.

2.7.3 Full Scale Test Sequence No. 1

2.7.3.1 First Nine-meter Drop

The first sequence of tests on a full size NCI-21PF-1 package with a 30B cylinder involved a 9-meter drop with the overpack suspended from the end opposite the valve end with the axis of the package at an angle of about 13' from vertical such that the center-of-gravity was over and in line with the valve. In this attitude the impact point on the overpack was the top end coincident with the cylinder valve.

2.7.3.2 First One-meter Puncture Test

Following the 9-meter drop test the package was subjected to a 1-meter puncture test in which the package was suspended from the end opposite the valve end with the axis of the package at an angle of about 13' from vertical such that the center-of-gravity was over and in line with the valve and target piston. In this attitude the impact point on the overpack was the damaged end of the overpack coincident with and in line with the cylinder valve and the center of the target piston.

2.7.3.3 Damage Resulting From the First Sequence of Tests

Damage to the package from the 9-meter drop involved crushing of the corners at the points of impact and the failure of two of the toggle closures as described in Appendix 2.10.12. The 1-meter puncture test resulted in a shallow dent (about 1/2" deep) in the end of the package at the area impacted by the target piston but no further loss of toggle closures. The remaining eight toggle closures were in working order and continued to hold the package firmly closed. No discernable gaps developed between the overpack halves at the closure plane, but the top half was displaced approximately 1/2" longitudinally with respect to the bottom half. There were no tears of any significance in the interior or exterior skin of the package. There was no apparent damage to the cylinder or cylinder valve; the cylinder was helium leak tested before and after this sequence of drop tests as described below in Section 2.7.5.

NOTE: A similar sequence of tests was performed earlier on a similar package except that the Model 30B cylinder was equipped with the standard valve protector, which caused the valve to be slightly bent. Subsequent leak-testing demonstrated an excessive leak rate. As a result of this unacceptable series of tests, it was concluded that for Type B shipments, the valve protector must <u>not</u> be used.

2.7.4 Full Scale Test Sequence No. 2

2.7.4.1 Second Nine-meter Drop

After the first sequence of drop tests, the 30B cylinder valve was re-tightened and the cylinder was helium leak tested again as described below in Section 2.7.5. The same full-scale NCI-21PF-1 package with the 30B cylinder installed was then subjected to a second sequence of drop tests. The first test in this second sequence was a 9-meter drop with the overpack suspended with its axis at an angle of 30° from the horizontal and rotated 85° such that the impact point on the overpack was 5° up on the corner toggle closure on the opposite end from the cylinder valve. At this attitude, the package rotated on impact causing the valve end of the overpack to strike the target in a secondary impact at increased velocity due to rotational acceleration. This secondary impact was 5° up on the toggle closure on the opposite end coincident with the valve.

2.7.4.2 Second One-meter Puncture Test

Following the 9-meter drop test the package was subjected to a 1-meter puncture test in which the package was suspended with its axis horizontal such that the center-of-gravity was over and in line with the target piston and center toggle closure on the side which impacted in the previous 9-meter drop test. In this attitude the overpack impacted on the center toggle closure on the side which was damaged in the previous 9-meter drop test.

2.7.4.3 Damage Resulting From the Second Sequence of Tests

Damage to the package from the 9-meter drop involved crushing of the toggle brackets into the side of the overpack at the impacted areas on each end of the overpack. This resulted in the loss of two non-adjacent toggle closures on the impacted side of the overpack and the loss of one toggle closure on the opposite side. The 1-meter puncture test impacted on and broke the center toggle closure, but the remaining six toggle closures were in working order and continued to hold the package firmly closed (see Appendix 2.10.15). Gaps up to 48 cm wide developed between the overpack halves at the closure plane; the gaps were measured at the surface of the package, but they diminished toward the interior of the package. There were no tears of any significance in the interior or exterior skin of the package. There was no apparent damage to the cylinder or cylinder valve; the cylinder was helium leak tested before and after this sequence of drop tests as described below in Section 2.7.5.

2.7.5 Leak-tightness Before and After Each Test Sequence

Prior to the each sequence of tests, the 30B cylinder with a dummy load of steel shot and paraffin was filled with 100% helium to an internal gage pressure of 1300 mBar. The cylinder was then leak tested in a vacuum chamber using the vacuum global method. After each sequence of drop tests, the cylinder was again leak tested using the same procedure. Between the 9-meter drop and the 1-meter puncture test in each test sequence, the overpack was not opened, but a helium sniff test was performed on the overpack.

The maximum acceptable leak rate of radioactive materials under normal conditions of transport is $A_1 \times 10^{-6}$/hour; this applies to the cylinder before drop testing. For a cylinder containing 1150 A_1 values of radioactive materials is as described in Section 1.2.3., this is equivalent to a leak rate of 5.48×10^{-7} g UF_6/sec; for the test conditions described herein, this is equivalent to a maximum acceptable helium leak rate of 4.0×10^{-8} atm cc/sec (see Appendix 2.10.4).

Similarly, the maximum acceptable leak rate of radioactive materials under hypothetical accident conditions is A_2/week; this applies to the cylinder after drop testing. For a cylinder containing 1150 A_1 values of radioactive materials is as described in Section 1.2.3., this is equivalent to a leak rate of 3.26×10^{-3} g UF_6/sec; for the test conditions described herein, this is equivalent to a maximum acceptable helium leak rate of 1.4×10^{-1} atm cc/sec (see Appendix 2.10.4).

Prior to Test Sequences 1 and 2, the helium leak rates were 4.8×10^{-9} atm cc/sec and 8.7×10^{-9} atm cc/sec, respectively. These leak rates were well within the maximum acceptable leak rate of 4.0×10^{-8} atm cc/sec for normal conditions of transport.

The intermediate sniff test performed during each sequence of tests did not reveal the presence of any helium. After the Test Sequences 1 and 2, the helium leak rates were 5.7×10^{-3} atm cc/sec and 6.6×10^{-9} atm cc/sec, respectively. These leak rates were well within the maximum acceptable leak rate of 1.4×10^{-1} atm cc/sec for hypothetical accident conditions.

2.7.6 Thermal

Both the half-scale NCI-21PF-1 model and the full-scale NCI-21PF-1 package suffered less damage from drop and puncture testing than that reported in previous testing of the DOT-21PF-1 prototype and subsequent DOT-21PF-1 packages. Also, the wood and foam insulation in the NCI-21PF-1 package is much better protected from air which causes continued burning in thermal testing of the DOT-21PF-1 package. For these reasons, thermal testing of the NCI-21PF-1 package is unnecessary if results of the DOT-21PF-1 thermal testing are used to estimate thermal testing results for the NCI-21PF-1 package as summarized below.

2.7.6.1 Summary of Pressures and Temperatures

Numerous thermal tests and evaluations of the DOT-21PF-1 (see Appendix 2.10.16, Ref. 2a, d, & e) lead to the conclusion that the triple point of the contained UF_6 will not be exceeded if a DOT-21PF-1 package is subjected to hypothetical accident conditions. The same conclusion should certainly be valid for the NCI-21PF-1 package for the reasons cited above. Therefore, the cylinder's UF_6 contents will experience the following maximum temperature and pressure if an NCI-21PF-1 package is subjected to hypothetical accident conditions:

Maximum UF_6 Temperature----------147.3°F

Maximum UF_6 Pressure----------1.5 atm

2.7.7 Water Immersion

The containment vessel of the NCI-21PF-1 package is the Model 30B UF_6 cylinder which is designed to withstand many times the external pressure of 21 psig required in IOCFR71.73(c)(5), without any lose of contents. Since this package is close-fitting around the UF_6 cylinder so as to be supported by the cylinder if subjected to external pressure, it would not sustain any detrimental damage from 21 psig external pressure. Also, the package is not airtight with regard to leakage of pressure from outside to the inside cavity, such that any 21 psig external pressure would quickly equalize with the inside cavity. The net effect of such external pressure would be to tighten the stainless steel skin on the wood and foam insulation and to apply such external pressure on the UF_6 cylinder; neither the wood, foam, or the UF_6 Cylinder would be affected by such pressure.

2.7.8 Summary of Damage

Based on comparisons of the above described testing of the half-scale NCI-21PF-1 model and the full-scale NCI-21PF-1 package with earlier testing of the DOT-21PF-1 prototype and subsequent DOT-21PF-1 packages, it is concluded that a full size NCI-21PF-1 Protective Shipping Package, if subjected to the testing describe above and other hypothetical accident conditions as specified in 10CFR71.73, would satisfactorily withstand the testing while suffering the following maximum consequences:

1. As a result of 9-meter drop testing the impacted ends of the package would be crushed to a depth of about 13 cm; the tie-down bases would be deformed into the bottom of the package; the toggle closures on the impacted side of the package would be deformed into the side of the package; there would be a loss of as many as two, non-adjacent toggle closures on each side of the package; gaps up to 5 cm would develop at the external closure plane at the impacted areas around the package; and a 9-cm long rip would open to a maximum width of 2 cm in the outer skin. Comparable gaps which developed at the closure plane in the testing of the original 21PF-1 PSP, as reported in K-1686, had more detrimental consequences because such gaps in the 21PF-1 package exposed the wood and both the interior and exterior gaskets.

2. As a result of 1-meter puncture testing, the impacted areas on the ends of the package would receive 6" diameter dents about 1.4 cm deep but would experience no penetration of the end plate. Similarly impacted areas on the shell of the package would result in 6" diameter penetrations which may tear the metal skin, crush the underlying foam, and cause a minor dent in the cylinder wall.

3. Impacted toggle closures would be deformed and may be lost, but the un-impacted toggle closures would still be intact and would continue to hold the package tightly closed; none of the toggle lock-down pins would fail.

4. The inner end plate would be deformed inward toward the cylinder valve leaving a gap of about 1 cm between the deformed end plate and the valve cap. The cylinder skirt would be slightly deformed, but the valve would be undamaged.

5. The inner liners of the cover and bottom portions

of the package might have several long tears near the welds joining the end plates with either the inner shells or the wood cover plates. None of this interior damage would result in exposure of the wood or foam to damage in subsequent thermal testing.

6. The package would suffer other incidental damage such as bent tie-down bases or stacking frames and bent toggle lock-down pins, but would not suffer any significant tears or rips in the outer skin or other broken components.

7. The basic envelop or space occupied by the damaged package would be essentially unchanged from that occupied by the undamaged package.

8. The cylinder and cylinder valve would provide leak-tight containment of its contents, ie. helium leak testing would demonstrate maximum leak rates no greater than 5% of the maximum allowable leak rate for UF_6 contents as described in Section 1.2.3.

9. Similar testing of DOT-21PF-1 packages as described above, resulted in similar, but generally more severe, damage, ie. the gaps at the closure plane exposed unprotected wood and gaskets, there were numerous broken exterior welds, and the puncture testing resulted in tears in the outer shell up to 12 cm in length and damage to the cylinder valve. The DOT-21PF-1 prototype and subsequent DOT-21PF-1 packages, in their damaged condition, have been thermally tested and/or evaluated and found to provide adequate protection to the UF_6 cylinder and its contents.

10. Except for its toggle closures, thicker end plates, stacking frames, and wood cover plates, the NCI-21PF-1 PSP is almost identical to the original 21PF-1 PSP. When compared to the original 21PF-1 PSP, there is no question that the NCI-21PF-1 (a) affords better puncture resistance in the ends of the package, (b) that its wooden structure and foam insulation is better protected, (c) that its toggle closures keep the package tightly closed even during hypothetical accident testing, (d) that its stacking frames do not compromise its capabilities as a protective shipping package, (e) that its gasket provides better thermal protection, (f) that it provides equal or better protection to its UF_6 cylinder and much better protection to the cylinder valve, and consequently, (g) that it provides better containment and at least equal

criticality safety.

11. Based on the above testing of both half-scale and full-scale NCI-21PF-1 packages and on comparisons with tests and evaluations of the DOT-21PF-1 package, it is fair to conclude that the NCI-21PF-1 package in such damaged condition as described above would afford adequate protection to the cylinder and cylinder valve if subjected to subsequent hypothetical accident conditions involving thermal testing and immersion testing as specified in 10CFR71.73 such that it meets the standards specified in 10CFR71, Subpart E.

2.8 Special Form (Not Applicable)

2.9 Fuel Rods (Not Applicable)

APPENDIX 2.10.1

17-4PH STAINLESS STEEL SPECIFICATIONS

STANDARD HEAT TREATMENTS FOR REPUBLIC 17-4 PH and 15-5 PH

Description of Standard Heat Treatments for Republic 17-4 PH and 15-5 PH

There are five standard heat treatments which are coded as: *Condition H 900, Condition H 925, Condition H 1025, Condition H 1075,* and *Condition H 1150.* The numbers *900, 925, 1025, 1075, 1150* indicate the aging or precipitation hardening temperature employed. As this temperature increases, the developed strength level declines but the ductility and the toughness improve. For example, *Condition H 900* exhibits 200,000 psi ultimate tensile strength, 50% reduction-of-area and 20 ft. lbs. impact strength. *Condition H 1075* develops 165,000 psi, 60% reduction-of-area and 40 ft. lbs.

Treatment	Discussion	
STEP No. 1 **Solution treat at 1900° ±25° F**	The customer normally orders 17-4 PH and 15-5 PH to be supplied by the mill in this condition ("Condition A" or "Solution Heat Treated"). When the customer's application requires forging, this grade should be supplied in the overaged condition. Subsequent to forging, the *customer* performs this step as part of the heat treating cycle.	The purposes of this step are: (1) to austenitize the steel so that high strength martensite is developed on cooling. (2) dissolve copper, thereby conditioning the steel for subsequent age hardening or precipitation hardening.
STEP No. 2 **Cool to below 80° F**	Cooling to below 80° F is required to insure full transformation to martensite. This is a critical requirement for this alloy because, although the transformation to martensite starts at about 400° F, it is not finished until a temperature of near 90° F is attained.	The cooling to below 80° F is accomplished by air cooling to room temperature, *then* if necessary, quenching into cold water.
STEP No. 3 **—Cond. H 900—Heat to 900° F, hold 1 hr., air cool.** **—Cond. H 925—Heat to 925° F, hold 4 hrs., air cool.** **—Cond. H 1025—Heat to 1025° F, hold 4 hrs., air cool.** **—Cond. H 1075—Heat to 1075° F, hold 4 hrs., air cool.** **—Cond. H 1100—Heat to 1100° F, hold 4 hrs., air cool.** **—Cond. H 1150—Heat to 1150° F, hold 4 hrs., air cool.**	*Normally, the steel is fabricated prior to this step.* Age hardening or precipitation hardening (due to the precipitation of copper) occurs during this step which further increases the strength and hardness of the martensite which formed during Step No. 1. However, as the aging temperature increases, "overaging" occurs, thereby progressively lowering the strength but improving the ductility of the heat treated product.	

ROOM TEMPERATURE MECHANICAL PROPERTIES

(Acceptable for Material Specifications)

REPUBLIC 17-4 PH AND 15-5 PH

Rounds, Hexagons and Squares (Condition A)

1/8" and Smaller.....175,000 psi max. ultimate tensile
Over 1/8" to 1/2".....RC 38 max.
Over 1/2" to 3".....BHN 341 max.
Over 3".....BHN 363 max.

Sheet and Strip (Condition A)

Up to 0.187" Thick.....RC 38 max.

Plate and Flats (Condition A)

0.1875" to 3" Thick.....BHN 341 max.
Over 3" Thick.....BHN 363 max.

In Tables I and II are listed mechanical properties for the various aging treatments which should be considered for specification requirements and which can be accepted. This does not mean, however, that customers are limited to these temperatures. For their own particular use, it may be desirable to vary slightly from the temperatures shown. Information regarding larger section sizes is available upon request.

TABLE I

MINIMUM PROPERTIES

Longitudinal Direction - - Intermediate Location

Republic 17-4 PH — Up to 8" section
Republic 15-5 PH — Up to 12" section

Condition	H 900	H 925	H 1025	H 1075	H 1100	H 1150	H 1150-M
Ultimate Tensile Strength - psi	190,000	170,000	155,000	145,000	140,000	135,000	115,000
0.2% Yield Strength - psi	170,000	155,000	145,000	125,000	115,000	105,000	75,000
Elongation, % in 2" or 4 x D	10.0(1)	10.0(1)	12.0(1)	13.0(1)	14.0(2)	16.0(2)	18.0(2)
Reduction of Area - %	35.0	38.0	45.0	45.0	45.0	50.0	55.0
Brinell	388/448	375/438	331/401	302/375	311/364	277/352	255/293
Rockwell	C 40/47	C 38/45	C 35/42	C 31/39	C 32/38	C 28/37	C 24/30
Impact, Charpy V-Notch, ft-lbs	*	5	15	20	25	30	55

**Minimum impact properties cannot be accepted in this condition.*
(1) For sheet sizes (under .187" thick) minimum elongation is 5%.
(2) For sheet sizes (under .187" thick) minimum elongation is 8%.

TABLE II

MINIMUM PROPERTIES

Transverse Direction (1)

Republic 15-5 PH — Up to 12" section

Condition	H 900	H 925	H 1025	H 1075	H 1100	H 1150	H 1150-M
Ultimate Tensile Strength - psi	190,000	170,000	155,000	145,000	140,000	135,000	115,000
0.2% Yield Strength - psi	170,000	155,000	145,000	112,000	115,000	105,000	75,000
Elongation, % in 2" or 4 x D	6.0	7.0	8.0	9.0	10.0	11.0	14.0
Reduction of Area - %	15.0	20.0	27.0	28.0	29.0	30.0	35.0
Brinell	388/448	375/438	331/401	302/375	311/364	277/352	255/293
Rockwell	C 40/47	C 38/45	C 35/42	C 31/39	C 32/38	C 28/37	C 24/30
Impact, Charpy V-Notch, ft-lbs Intermediate Location	*	*	10	15	15	20	35

**Minimum impact properties cannot be accepted in this condition.*
(1) Transverse mechanical properties are not guaranteed on grade 17-4 PH unless ordered as VAR quality.

PROPERTIES OF REPUBLIC 17-4 PH and 15-5 PH

TYPICAL ROOM TEMPERATURE LONGITUDINAL MECHANICAL PROPERTIES OF REPUBLIC 17-4 PH AND 15-5 PH

Property	Condition A	Condition H 900	Condition H 925	Condition H 1025	Condition H 1075	Condition H 1100	Condition H 1150	Condition H 1150-M
Ultimate Tensile Strength, psi	150,000	200,000	190,000	170,000	165,000	150,000	145,000	125,000
Yield (0.2%) Strength, psi								
Tension	110,000	185,000	175,000	165,000	150,000	135,000	125,000	85,000
Elongation in 2", %	10	14	14	15	16	17	18	22
Reduction in Area, %	45	53	51	56	58	58	60	68
Hardness								
Rockwell C	—	44	42	38	36	34	33	27
Brinell	332	420	409	352	341	332	311	277
Impact Strength								
Charpy V-Notch, ft. lbs.	—	20	25	35	40	45	50	100
Fatigue Strength, psi								
10 x 10^6 Cycles	—	90,000	85,000	—	80,000	—	75,000	—
100 x 10^6 Cycles	—	80,000	—	—	—	—	—	—
Torsional Ultimate Strength, psi	—	—	—	—	—	—	125,000	—
Torsional Elastic Limit, psi	—	—	—	—	—	—	52,000	—

TYPICAL ROOM TEMPERATURE TRANSVERSE MECHANICAL PROPERTIES OF REPUBLIC 15-5 PH

Property	Condition A	Condition H 900	Condition H 925	Condition H 1025	Condition H 1075	Condition H 1100	Condition H 1150	Condition H 1150-M
Ultimate Tensile Strength, psi	150,000	200,000	190,000	170,000	165,000	150,000	145,000	125,000
Yield (0.2%) Strength, psi								
Tension	110,000	185,000	175,000	165,000	150,000	135,000	125,000	85,000
Elongation in 2", %	10	10	11	12	13	14	15	18
Reduction in Area, %	45	30	35	42	43	44	45	50
Hardness								
Rockwell C	—	44	42	38	36	34	33	27
Brinell	332	420	409	352	341	332	311	277
Impact Strength								
Charpy V-Notch, ft. lbs.*	—	8	12	25	25	25	45	—
Fatigue Strength, psi								
10 x 10^6 Cycles	—	90,000	85,000	—	80,000	—	75,000	—
100 x 10^6 Cycles	—	80,000	—	—	—	—	—	—
Torsional Ultimate Strength, psi	—	—	—	—	—	—	125,000	—
Torsional Elastic Limit, psi	—	—	—	—	—	—	52,000	—

*Notch axis transverse — Intermediate location.

TYPICAL ELEVATED TEMPERATURE LONGITUDINAL MECHANICAL PROPERTIES OF REPUBLIC 17-4 PH AND 15-5 PH

STRESS-RUPTURE PROPERTIES in Conditions H 900 and H 1075

Stress to Rupture in 100 hrs.	Properties at Temperature 625° F H 900	625° F H 1075	700° F H 900	700° F H 1075	800° F H 900	800° F H 1075
Stress, psi	162,000*	137,000	156,000	126,000	[illegible],000	108,000
Elongation, % in 2 in.	3.0	3.5	3.0	4.0	4.0	6.0
Reduction of area, %	7.0	11.5	7.0	15.5	6.0	16.0
Stress to Rupture in 1000 hrs.						
Stress, psi	157,000*	134,000	150,000	123,000	128,000	103,000
Elongation, psi % in 2 in.	2.0	3.0	2.0	3.5	4.0	5.5
Reduction of area, %	6.0	14.0	6.0	15.0	6.0	15.0

*Extrapolated from 600° to 900° F data.

Republic 17-4 PH and 15-5 PH retain a high proportion of their strength at temperatures up to 900° F. Typical short-time properties are shown on Page 10. For service temperatures in excess of 600° F., the creep and stress rupture strength may be a major design factor.

CREEP STRENGTH in Condition H 900

Stress, psi, for creep rate of	Temperature 600° F	700° F	800° F	900° F
0.1% in 1000 hrs.	135,000	105,000	60,000	23,000
0.01% in 1000 hrs.	125,000	100,000	43,000	—

LOW TEMPERATURE PROPERTIES OF REPUBLIC 17-4 PH AND 15-5 PH

Republic 17-4 PH and 15-5 PH maintain good ductility at low temperatures. No general statement can be made regarding preferred heat treatments for low temperature applications because much depends on design requirements. However, the following low temperature limits are suggested:

- **H 900** — If toughness is a design criterion, this heat treatment should be used with caution, regardless of temperature.
- **H 925** — Down to 0° F for general use. For non-impact applications, useful at temperatures as low as −320° F (for example, valve seats).
- **H 1150** — Down to −110° F. Design with caution when bar diameters exceed 1" rd.
- **H 1150-M** — Down to −320° F.

For critical cryogenic applications, Republic 15-5 PH should be given preference over 17-4 PH because its impact toughness is generally higher than the following properties:

Comparison of Low Temperature Impact Strengths of 17-4 PH in Various Conditions

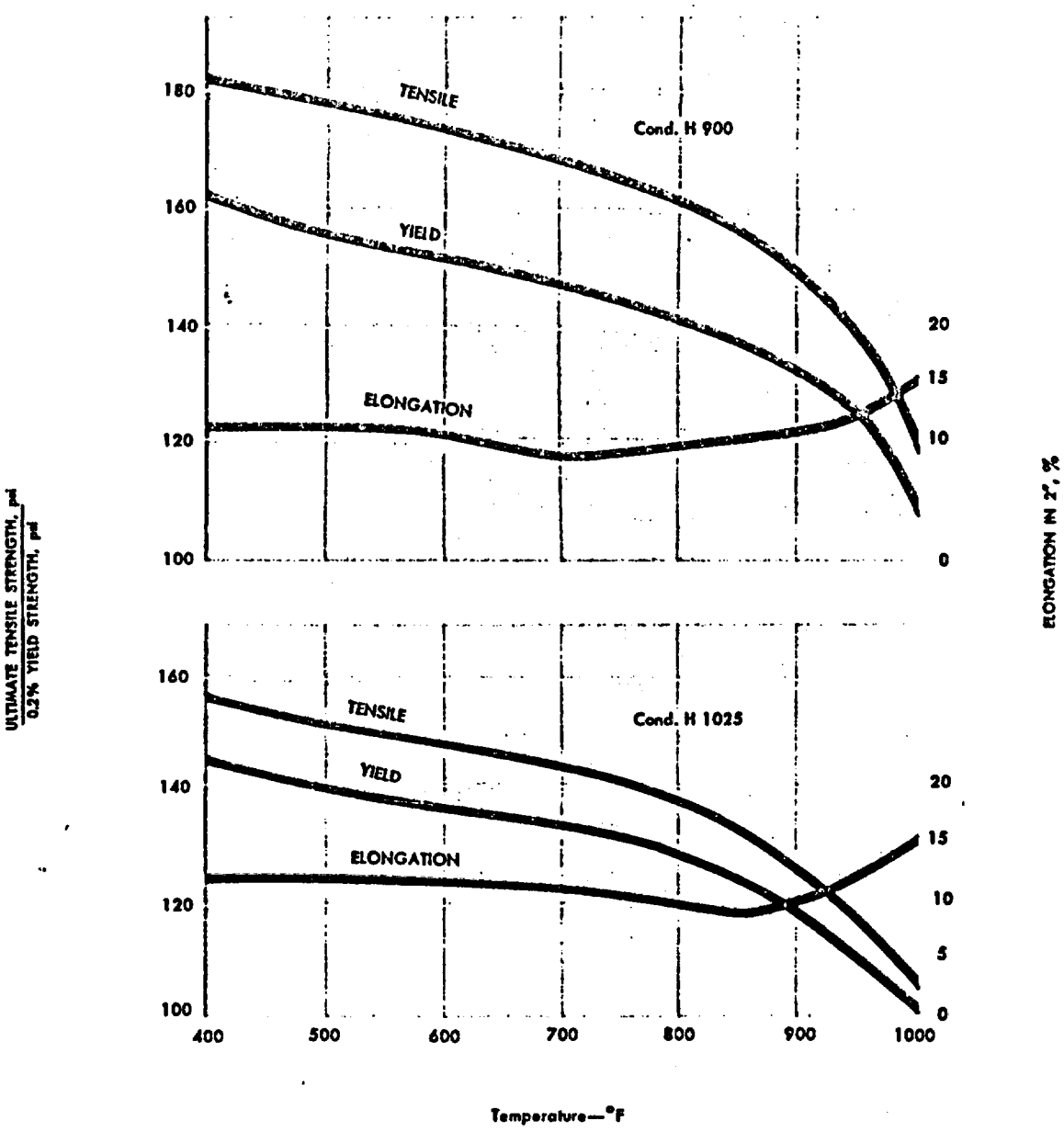
Test Temperature, Degrees F	Impact Strength, ft.-lbs. Condition H 925 *	H 1025 *	H 1150 *	H 1150-M *	H 1150-M **
75	30	75	95	105	95
10	16	58	93	—	85
− 40	9	40	76	—	75
−110	5.5	15	48	—	65
−175	—	—	—	—	35
−250	—	—	—	—	18
−320	3.5	4.5	6.5	28	5

*Test samples from 1" Round Bar—Longitudinal Direction
**Test samples from 4" Round Bar—Longitudinal Direction

Typical Mechanical Properties of 17-4 PH at Low Temperatures (Condition H 1100)

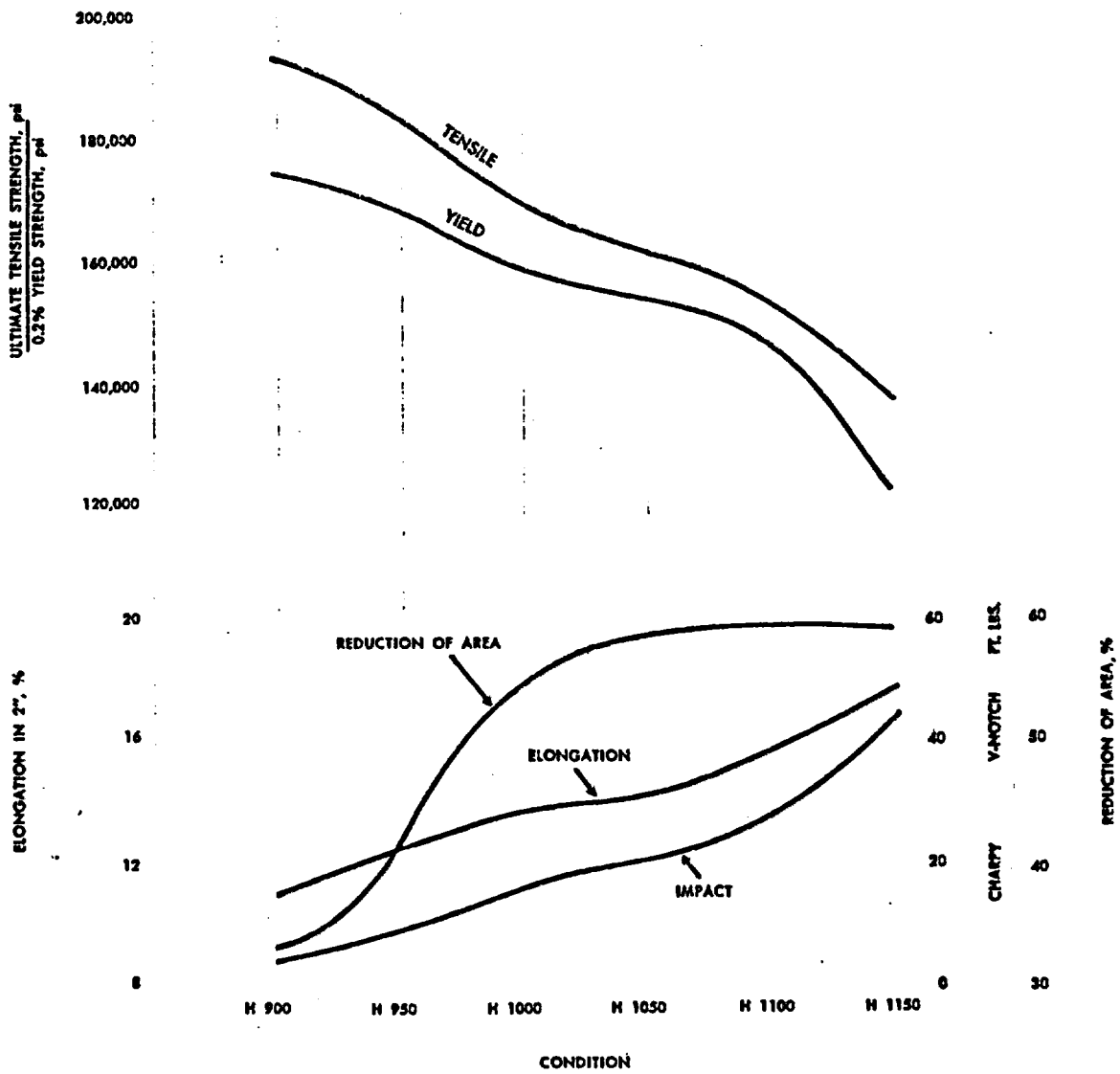
Test Temp F	UTS psi	0.2% YS psi	Elongation % in 2"
75	150,000	135,000	17.0
32	193,000	183,000	16.0
− 40	203,000	189,500	15.5
− 80	209,000	196,000	15.0
−320	248,000	243,000	8.0

TYPICAL ELEVATED TEMPERATURE PROPERTIES
REPUBLIC 17-4 PH AND 15-5 PH
CONDITION H 900* AND H 1025
(Short Time Longitudinal Mechanical Properties)



TYPICAL ROOM TEMPERATURE PROPERTIES
VACUUM ARC REMELTED
REPUBLIC 15-5 PH
VARIOUS CONDITIONS

25 In. Round Full Section Transverse Tests
(Heat Treated as coupons)



PHYSICAL PROPERTIES OF [illegible]

	Condition A (Magnetic)	Condition H 900 (Magnetic)	Condition H 1075 (Magnetic)	Condition H 1150 (Magnetic)
Density, grams per cu. cm	7.78	7.80	7.81	7.82
lbs. per cu. inch	0.280	0.282	0.283	0.284
Electrical Resistivity, microhm-cm	98	77	—	—
Magnetic Permeability at				
100 oersteds	74	90	88	59
at 200 oersteds	48	56	52	38
Maximum	95	135	136	71
Mean Coefficient of Thermal Expansion 10^{-6} inches per inch per °F				
—100 to 70° F	—	5.8	—	6.1
70-200° F	6.0	6.0	6.3	6.6
70-400° F	6.0	6.1	6.5	6.9
70-600° F	6.2	6.3	6.6	7.1
70-800°	6.3	6.5	6.8	7.2
Thermal Conductivity Btu per hr. per sq. ft. per inch per °F at				
300° F	—	124	—	—
500° F	—	135	—	—
860° F	—	156	—	—
900° F	—	157	—	—
Specific Heat Btu per lb. per °F 32-212°	0.11	0.11	—	—
Modulus of Elasticity, psi				
Tension	—	28.5×10^6	—	—
Torsion	—	11.2×10^6	10.0×10^6	10.0×10^6
Poisson's Ratio	—	.272	.272	.272

MAGNETIZATION DATA

(Condition H 900)

Field Strength (H) Oersteds	Induction (B) Gausses
10	430 to 600
25	2000 to 2,900
50	6150 to 7,300
75	7850 to 9,100
100	8900 to 10,000
150	.. to 11,200
200	.. to 12,000

HYSTERESIS DATA (1)

(Condition H 900)

Coercive
Force (Hc).....29 Oersteds

Residual
Induction (Br)..5200 Gausses

(1) Obtained from a maximum induction of 10,000 gausses. Values represent the sample giving the lowest result in magnetization.

ELEVATED TEMPERATURES MODULUS OF ELASTICITY

The modulus of elasticity of 17-4 PH and 15-5 PH at elevated temperatures can be conveniently expressed as a per cent of room temperature modulus. At temperatures ranging from room to 600° F this material showed the following modulus of elasticity.

Temperature °F	Modulus of Elasticity (% of Room Temp. Modulus)
72	100.0
100	99.6
200	97.8
300	96.3
400	94.7
500	93.0
600	91.4

GALLING AND SEIZING

Laboratory tests indicate that 17-4 PH and 15-5 PH of various hardness levels in contact with each other have excellent resistance to galling. This combination has much higher resistance to galling than 18-8 stainless against itself or other hardenable stainless steels. As is usual, the differential of hardness between parts is an advantage as well as employing parts with a smooth finish.

CORROSION RESISTANCE OF 17-4 PH AND 15-5 PH

The general corrosion resistance of these grades is comparable to Type 304 in most media. In boiling 65% HNO_3 and in 1% HCl, 15-5 PH and 17-4 PH exhibit about the same resistance. In salt fog and chloride pitting solutions, 15-5 PH exhibits somewhat superior resistance as shown by these data:

Republic 17-4 PH, 15-5 PH have the greatest degree of resistance to stress-corrosion cracking when heat treated at the highest aging temperature (1100° F being preferred).

Comparative Corrosion Resistance of 15-5 PH and 17-4 PH

Boiling 65% HNO_3—Avg. of 5 48-Hr Periods

Condition	15-5 PH	17-4 PH
H 900	.0083 IPM	.014 IPM
H 1025	.0106 IPM	.007 IPM
H 1150	.0083 IPM	.0065 IPM

1% HCL at 95° F Avg. of 5 48-Hr Periods

Condition	15-5 PH	17-4 PH
H 900	.025 IPY	.035 IPY
H 1025	.085 IPY	.174 IPY
H 1150	.730 IPY	.650 IPY

Commercial Bleach—7 Days at 95° F

Condition	15-5 PH	17-4 PH
H 900	.0016 in.	.03 in.
H 1025	.013 in.	.03 in.
H 1150	.0083 in.	.03 in.

5% Salt Fog at 95° F—10 Days

Condition	15-5 PH	17-4 PH
H 900	0% rust	5-10% rust
H 1025	0-5% rust	10-25% rust
H 1150	0-5% rust	5-10% rust

Comparative Corrosion Rates*—Laboratory Tests (Mils, .001", per year)

Stainless Steel (Bare)	Condition	Corrosion Rate in Specific Media—(mils per year)					
		Sulfuric Acid 1% at 35° C	Hydrochloric Acid 0.5% at 35° C	Nitric Acid 25% Boiling	Acetic Acid 60% Boiling	Sodium Hydroxide 30% Boiling	Phosphoric Acid 20% Boiling
Type 431	Hardened and stress relieved	520-820	500-780	8.4-9.6	5.2-5.8	91-96	6-11.3
Type 304	Annealed	28	33	2	—	68	2
17-4 PH	H 925	0.0-0.3	1.7-3.3	7.1-21.8	0.8-2.0	4.9-9.8	0.8-1.2
	H 1025	0.0-0.1	1.6-2.1	5.8-6.4	0.7-4.2	5.0-10.1	0.5-1.2

**These data were obtained in laboratory tests and only indicate the relative corrosion resistance of the materials tested under specific conditions. They should not be used to evaluate expected performance in service.*

APPENDIX 2.10.2

EVALUATION OF LIFTING DEVICES

The lifting system must be capable of supporting 3 times the weight of the 8,700-pound loaded package, a total of 26,100 pounds, without exceeding the yield strength of the metal. The lifting load is distributed equally among the four 3/4" lifting U-bolts such that:

Shear stress under nut at each bolt hole:

$$S = \frac{26{,}100\ /8}{1.25'' \times 3.14 \times 0.5''} = 1{,}662 \text{ psi (OK yield strength in shear is 22,500 psi)}$$

Bearing stress at each bolt hole:

$$S = \frac{26{,}100/8}{(1.25''^2 - 0.875''^2) \times 3.14/4} = 5{,}213 \text{ psi (OK; yield strength is 30,000 psi)}$$

Tensile stress in leg:

$$S = \frac{26{,}100/8}{4'' \times 1/4''} = 3{,}268 \text{ psi (OK; yield strength is 30,000 psi)}$$

APPENDIX 2.10.3

EVALUATION OF TIE-DOWN SYSTEM ON NCI-21PF-1 Package

Longitudinal Load at 10 g = 10 x 8,700 lb = 87,000 lb

Transverse Load at 5 g = 5 x 8,700 lb = 43,500 lb

Combined Horizontal Load = $(10^2 + 5^2)^{1/2}$ x 8,700 lb

= 97,269 lb

Shearing Stress on the 8 bolts:

$$S = \frac{97{,}269 \times 4}{8 \times 0.75''^2 \times 3.14} = 27{,}521 \text{ psi}$$ (OK; yield strength of B-7 bolt is >>>30,000 psi)

With the package loaded side ways on a carrier, the 10 g longitudinal load creates a coupling moment through the center of gravity placing a vertical load (V_l) on 4 bolts on one side of the package to counteract the moment; the 5 g transverse load creates a similar vertical load (V_t) on 4 bolts on one end of the package as follows:

V_l = 10 x 8,700 lb x 22"/40" = 47,850 lb

V_t = 5 x 8,700 lb x 22"/58" = 16,500 lb

The maximum total vertical load on a bolt (V) due to the forces calculated above plus that due to a 2g vertical load is:

V = (2 x 8,700/8) + (47,850/4) + (16,500/4)

= 18,263 lb/bolt

The maximum Tensile Stress on a Bolt is:

$$S = \frac{18{,}263 \text{ lb}}{0.75''^2 \times 3.14/4} = 29{,}180 \text{ psi}$$ (OK; yield strength of a B-7 bolt >>>30,000 psi)

Shear Stress under the Bolt Head is:

$$S = \frac{18{,}263 \text{ lb}}{1.25'' \times 3.14 \times 0.5''} = 9{,}301 \text{ psi}$$ (OK; yield strength in shear is 22,500 psi)

APPENDIX 2.10.4

CYLINDER LEAKAGE OF RADIOACTIVE MATERIALS

UF_6 cylinders are leak tested when new and when cleaned by pressurizing with air at 100 psig. When new and after each cleaning and inspection (required a minimum of every 5 years), each Model 30B UF_6 cylinder is hydrostatic tested at 400 psig internal pressure and soap bubble leak tested at 100 psig internal pressure as required in ANSI N14.1. Cylinder valves are also leak tested at 400 psig air pressure when new and when cleaned. The cylinder and its valve are soap tested again whenever a valve is installed. However, the most significant leak test of the cylinder and valve occur when the cylinder is filled with liquid UF_6; at this point even the smallest leak is readily visible. All of these factors assure that the cylinder and valve do not leak at a rate exceeding 10^{-1} atm cc/sec at approximately 1 atm internal gage pressure (ANSI N14.5), and this is adequate assurance for the shipment of Type A quantities of UF_6 as is the case with uranium which has not been recycled.

Model 30B cylinders which are used to ship Type B quantities of UF_6, as may be the case with recycled uranium, must be leak-tested as follows to assure that no radioactivity is released under Normal Conditions of Transport or under Hypothetical Accident Conditions in excess of limits set in 10CFR71.51(a)(1) and (2), respectively:

1. Within the 12-month period preceding any Type B shipment of a 30B cylinder and every time the valve or plug is replaced, the cylinder, with its valve and plug installed, is helium leak tested at 1300 mBar internal pressure to demonstrate no leakage in excess of 4×10^{-8} atm cc/sec.

2. Before each Type B shipment, after the cylinder is loaded with UF_6, the cylinder is tested for no detectable leak using a pressure drop/rise procedure with a sensitivity of 1×10^{-3} atm cc/sec.

3. Before each Type B shipment, after the cylinder is loaded with UF_6 and leak-tested per Step 2 above, the cylinder valve is tested for no detectable leak using a pressure drop/rise procedure with a sensitivity of 1×10^{-3} atm cc/sec.

Maximum release rates of UF_6 and leak-test criteria are determined in the following calculations by COGEMA personnel:

4 - LEAK TEST CHARACTERISTICS

4.1 - Maximum permissible release rate :

Two different transport conditions have to be considered to determine the maximum permissible release rate of UF6. They are identified as follows :

- the accidental conditions of transport (ATC) : RA = A2/week
- the normal conditions of transport (NTC) : RN = A2 x 10^{-6}/hour

Substituting the following values :

A2 = 0.824 x 10^{-3} TBq
M (molecular weight) : (M_U = 237.78
(M_{UF6} = 351.79
Activity of uranium : 6.17 x 10^{-7} TBq/gU
Activity of UF6 : 4.17 x 10^{-7} TBq/gUF6

yields the maximum permissible values of RA and RN :

RA = 3.26 x 10^{-3} g UF6/second
RN = 5.48 x 10^{-7} g UF6/second

4.2 - Leak test procedure for the UF6 transport packages :

4.2 -1 Qualification test :

The ability of the cylinder to meet the post accident leak rate criterion has to be demonstrated by physical tests (full scale impact and puncture tests of the package).

The associated leak rate measurement has to be performed before and after the tests, applying the NTC criterion before the tests and the ATC criterion after the tests. To perform these tests, the cylinder will be filled with helium at 1,300 mbars and the leak rate measured by MSLD, after calibration, in an evacuated envelope at 0,1 mbar.

That rate is derived from the calculation of the maximum admissible leak rate of UF6 in both normal and accident transport conditions, defined as follows :

NTC : Pd = 0.245 atm
T_{UF6} = 55 °C

ATC : Pd = 1 atm
T_{UF6} = 200 °C

4.2 - 2 Procedure for shipment :

A leak test on the whole package will be done to the most limiting allowable leak rate (NTC) when the valve is replaced, prior to each filling up with UF6.

For this test, the cylinder may be containing a gas mixture (80 % N2 + 20 % He) at 1,300 mbars and the procedure used will be that of MSLD in an evacuated envelope, as previously described. After filling up, the sealness of the valve will be tested, using a pressure rise method, on the same leak rate basis as for the MSLD test (NTC with UF6).

Description of the pressure rise test :

The pressure rise test consists in measuring a pressure variation in a calibrated piping tightly connected to the valve outlet.

A differential measurement method will be used, enabling to get rid of variations of atmospheric pressure and temperature.

The operating instructions to perform the test can be synthetized as follows :

- placing the UF6 cylinder after cooling down in a temperature - controlled area (25 °C),
- controlling the testing equipment,
- connecting the calibrated piping to the valve outlet,
- evacuating it with a pump at 0.1 mbar,
- waiting for pressure stabilization,
- closing the on-off valves of the system to isolate the cylinder-piping assembly,
- measuring the pressure rise, if any, with a differential sensor for one hour.

It must be noted that the sensitivity of all the leakage test procedures shall be equal to or less one-half the maximum admissible leakage rate of the tracer fluid or the fluid itself.

4.3 - Calculation of the maximum admissible release rate in leak test conditions :

4.3.1 - A.T.C. :

The maximum admissible leak rate is 3.26×10^{-3}g UF6 s^{-1}. At constant volume, the physical characteristics of UF6 in A.T.C. are the following :

Pu	=	28.6 atm (29 bar)	
Tu	=	473 °K	
As Pd	=	1 atm,	$\frac{Pd}{Pu} = 0.035$

Calculation of rc value for UF6 in A.T.C. :

k is the ratio of the specific heat at constant pressure to specific heat at constant volume.

It is defined as follows :

$$\frac{1}{k} = 1 - \frac{T\,(23.62 + P\,\frac{44.88}{T^2} + \frac{1.1073 \times 10^5}{T^4}\,2}{Cp\,(23.62\,T - 4.9 \times 10^6\,p^2)}$$

with $Cp = 395.989 + 0.07036\,T - \frac{4.253 \times 10^6}{T2} + \frac{89.76}{T2} + \frac{44.372 \times 10^6}{T2}\,P$

(P in mbar - T in °K)

In these conditions : $Cp = 447.60$ J Kg^{-1} $°K^{-1}$
$k = 1.15$

The critical pressure ratio (r_c) is defined by equation :

$$rc = \frac{2}{k+1}^{\frac{k}{k-1}}$$

Substituting k = 1.15 yields rc = 0.574

Calculation of r f value :
The pressure ratio, $\frac{Pd}{Pu}$, is less than the critical pressure ratio, introducing the possibility of choked flow.

rf must be calculated to determine whether the flow is in the continium regime. To make this determination, equation B2 has to be solved to calculate D (by iteration) :

$$L = (2.49 \times 10^6 D^4/a\mu + 3.81 \times 10^3 D^3 \sqrt{\frac{T}{M}} / aPa)\ (Pu - Pd)$$

μ is calculated from the following equation :

* $$\mu = \mu_{273\,°K} \sqrt{\frac{T}{273}} \times \frac{1 + \frac{Cs}{273}}{1 + \frac{Cs}{T}}$$

with : $\mu_{273°K}$ = 0.0175 Cp
T = 473°K
Cs (Sutherland's constant) = 170.2
Solving the equation leads to $\mu_{473\,°K}$ = 0.0275 Cp

* a (leak hole length) corresponds to the thickness of the cylinder (1.27 cm)

* $Pa = \frac{Pu + Pd}{2}$ = 14.8 atm

* M = 351.79 g

* L is the maximum admissible UF6 leak rate. It can be calculated from the following equation :

$$\frac{P}{\rho} = 0.2362\ T - (2.1373 \times 10^{-5} + \frac{0.4488}{T} + \frac{3.691 \times 10^4}{T3})\ P + 4.9 \times 10^{-8}\ p2$$

Substituting : p = 29,000 mbar
T= 473°K

yields : ρ = 252.87 Kg m^{-3}

$L = \frac{Ra}{\rho} = 1.29 \times 10^{-2}$ cm3 s^{-1}

Solving equation B2 yields $D = 1.60 \times 10^{-3}$ cm

$Rf = \frac{654\ DPa}{\mu\sqrt{\frac{T}{M}}}$ = 486 (in A.T.C.), assuming flow is choked.

Calculation of the maximum admissible leak hole diameter :

Because rf > 1 and $\frac{Pd}{Pu}$ < rc , equation B7 is used to determine D.

$$L = \frac{\pi D^2}{4} \sqrt{\frac{2k\,Ro\,T}{M\,(k+1)}} \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$ with Ro = 8.31 x 10^7 erg/g mole °K.

Solving this equation leads to the determination of the maximum admissible leak hole diameter in A.T.C. :

$D = 1.56 \times 10^{-3}$cm

Determination of the equivalent leakage rate in test conditions :

Drop tests are performed with a helium containing cylinder (P = 1,300 mbar, T = 298°K).

The pressure in the envelope (Pd) when performing the helium test is 0.1 mbar.

Calculating rf, with k = 1.66, Pa = 0.64 atm, μ = 0.0198 cp, leads to rf = 3.87

Because rf > 1 and $\frac{Pd}{Pu}$ < rc, choked flow is assumed.

Solving eq. B7 for L yields :

$L = 1.09 \times 10^{-1}$cm3 s^{-1}

$Q = LPu = 1.09 \times 10^{-1} \times 1.283 = 1.398 \times 10^{-1}$ atm cm3 s^{-1}

4.3.2 - N.T.C. :

The maximum admissible leak rate in normal transport conditions is 5.48 x 10^{-7}g UF6 s^{-1}

N.T.C. is defined by the following parameters :

Tu = 328 °K (55 °C)

Pd = 0.245 atm

At that temperature, the UF6 vapor pressure is 0.935 atm, i.e. 947 mbar.

The pressure ratio $\frac{Pd}{Pu}$ is 0.262

Calculation of rc value for UF6 in A.T.C.

The calculation is made as for A.T.C., and the following values are successively determined :

Cp = 383.95 J Kg^{-1} K^{-1}

k = 1.068

$$rc = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} = 0.59$$

The pressure ratio is less than rc.

Calculation of rf value

D is determined from eq. B2

* μ 328°K = 0.0205 cp
* a = 1,27 cm
* Pa = $\frac{Pu + Pd}{2}$ = 0.59 atm
* M = 351.79 kg m^{-3}
* ρ = 12.59 kg m^{-3}
* L = 4.35×10^{-5} cm3 s^{-1}

Solving equation B2 yields D = 8.89×10^{-4} cm.
rf = 17.3, assuming flow is choked.

Calculation of the maximum admissible leak hole diameter

Because rf > 1 and ($\frac{Pd}{Pu}$) < rc, eq. B7 is used to determine D.

Solving this equation leads to D = 1.00×10^{-4} cm

4.3.3. - Calculation of the maximum admissible leak rate in qualification test conditions :

Drop tests are performed with a helium containing cylinder (P = 1,300 mbar, T = 298 °K). The pressure in the enveloppe (Pd) when performing the helium test is 0.1 mbar. Calculating rf, with k = 1.66, Pa = 0,64 atm, μ = 0.0198 cp, leads to rf = 0.245.

Because rf < 1, the flow is found to be free molecular, and eq. B2 is the appropriate model.

$$L = (2.49 \times 10^6 D^4/a\mu + 3.81 \times 10^3 D^3 \sqrt{\frac{T}{M}} / a\, Pa)(Pu - Pd)$$

It yields for L : L = 6.27×10^{-8} cm3 s^{-1}

$$Q = L\, Pa = 4.01 \times 10^{-8} \text{atm cm3 s}^{-1}$$

3.2.2. Calculation of the maximum admissible leak rate for shipment :

The leak test conditions are the same as precedently, but He may be replaced on some occasions by a mixture of He (20 %) and N2 (80 %), called "Hemixal".

The characteristics of that mixture are calculated from the following equations :

$$Pm = \sum_{i=1}^{n} Pi$$

$$Mn = \sum_{i=1}^{n} \frac{Pi\, Mi}{Pm}$$

$$\mu m = \sum_{i=1}^{n} \frac{Pi\,\mu i}{Pm}$$

$$k\,m = \sum_{i=1}^{n} (Pi\ Mi\ Cp,\ i) \Big/ \sum_{i=1}^{n} (Pi\ Mi\ Cv,\ i)$$

<u>Substituting</u> :

M_{N2}	=	28 g	M_{He}	=	4 g
μ_{N2}	=	0.0176 cp	μ_{He}	=	0.0198 cp
Cp_{N2}	=	0.2486 kcal kg^{-1} C^{-1}	Cp_{He}	=	1.24 kcal kg^{-1} $°C^{-1}$
Cv_{N2}	=	0.1774 kcal kg^{-1} C^{-1}	C_{VHe}	=	0.75 Kcal Kg^{-1} $°C^{-1}$
P_{N2}	=	1.026 atm	P_{He}	=	0.256 atm

yields for Pm, Mm, μm and km :

Pm	=	1,283 mbar
Mm	=	23.2 g
μm	=	0.0180 Cp
k m	=	1.43

Calculating rf with k = 1.43, Pa = 0.64 atm, μ = 0.0180 cp, leads to rf = 0.649

Because rf < 1, the flow is found to be free molecular, and eq. B2 is the appropriate model.

In these conditions, L = 3.46 x 10^{-8} cm3 s^{-1}

$$Q = L\ Pa = \underline{2.21 \times 10^{-8} atm\ cm3\ s^{-1}}$$

The helium flow corresponding to the maximum admissible leak rate is 0.44 x 10^{-8} cm3 s^{-1}

<u>Testing of the valve</u> :
The test is performed on UF6 containing cylinders after cooling to 25 °C (298 °K). At that temperature, Pu = 110 mm Hg = 0.145 atm = 146.6 mbar.

The calibrated piping connected to the valve outlet is evacuated through a pump at 10^{-3} mbar.

The CNT criterion which has to be met is 5.48 x 10^{-7} g UF6 s^{-1}, as for the helium test.

In these conditions
ρ = 2.095 kg m^{-3} and, subsequently :
L = 2.61 x 10^{-4} cm3 s^{-1}

The leakage condition occurs at a pressure ratio,
$\frac{Pd}{Pu} = \frac{0.001}{146.6} = 6.8 \times 10^{-6}$, which is less than the critical pressure for UF6, introducing the possibility of choked flow.

The second condition that must be met for choked flow is that rf ≥ 1, meaning that the flow is in the continuum regime.

Solving eq. B2 allows to determine D (by iteration) :

$$2.61 \times 10^{-4} = \left(\frac{2.49 \times 10^{6}\, D^{4}}{1.27 \times 0.0188} + \frac{3.81 \times 10^{3}\, D^{3} \times 0.92}{0.0725 \times 1.27}\right) \times 0.145$$

$D = 1.97 \times 10^{-3}$ cm

The ratio rf is found from equation : $rf = \frac{654\ DPa}{\mu\sqrt{\frac{T}{M}}}$

rf = 5.40

Because rf > 1 and $\frac{Pd}{Pu}$ < rc, choked flow is assumed.

The leakage rate in atm cm3 s^{-1} is :

$Q = L\ Pu = 3.78 \times 10^{-5}$ atm $cm3^{-1}$, i-e 3.87×10^{-5} mbar l s^{-1}

The total volume of the calibrated piping (including the sensor connection) is 2×10^{-2} liters.

In these conditions, the maximum admissible leak in a one hour period is :

$Q = V\ \frac{\Delta P}{\Delta t}$, inferring $\Delta P = \frac{3.83 \times 10^{-5} \times 3600}{2 \times 10^{-2}} = 6.9$ mbar

References :

- American National Standard for Radioactive Materials. Leak tests on packages for shipment.

  ANSIN 14.5 - 1987

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- Thermodynamic properties of gaseous uranium hexafluoride report K - 1458 by B.M. PARKS, D.W. BURTON (Union Carbide Nuclear Company sept 1960).

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APPENDIX 2.10.5

DETERMINATION OF DECAY HEAT FOR UF_6 CYLINDER CONTAINING TYPICAL RECYCLED URANIUM

If we assume the maximum 1,150 A_2 values per cylinder (see Appendix 1.3.3) at an average of 0.1 Ci/A_2 and an average disintegration energy of 5 Mev/d, the corresponding decay heat load in the cylinder is calculated as follows:

$$1{,}150\ A^2/\text{cyl} \times 0.1\ \text{Ci}/A^2 = 115\ \text{Ci/cyl}$$

$$1.33 \times 10^{14}\ \text{d/hr/Ci} \times \frac{5\ \text{Mev/d}}{6.58 \times 10^{15}\ \text{Btu/Mev}} = 0.10\ \text{Btu/hr/Ci}$$

$$0.10\ \text{Btu/hr/Ci} \times 115\ \text{Ci/cyl} = 12\ \text{Btu/hr per cyl.}$$

Compared with the solar heat loads under Normal Conditions of Transport (see Appendix 2.10.6) and the larger heat loads under Hypothetical Accident Thermal Conditions, a decay heat load of 12 Btu/hr per cylinder is insignificant.

APPENDIX 2.10.6

HEAT EVALUATION
UNDER NORMAL CONDITIONS OF TRANSPORT

The total solar heat load on the package as specified in 10CFR71.71(c) is:

400 g cal/cm^2 for 12 hr/day for curved surfaces.

200 g cal/cm^2 for 12 hr/day for flat vertical surfaces.

The areas of the NCI-21PF-1 package which are exposed to solar heat are as follows:

A (shell) = 3.14 x (43-1/8"/2) x 92" x 2.54^2

= 40,207 cm^2

A (ends) = 3.14 x 43-1/8"^{2}/4 x 2.54^2 = 9,424 cm^2

Since the UF_6 cylinder represents a large heat sink and the NCI-21PF-1 package provides substantial insulation, the total solar heat load may be averaged over a 24-hr day as follows:

Q_t = (400 x 40,207) + (200 x 9,424)

= 1.8 x 10^7 g cal/day = 2,970 Btu/hr

Using the procedure given in Section 5.3.1, ORNL-NSIC-68, Cask Designers Guide, the surface temperature at which heat removal from the package will equal the solar heat load is calculated as follows:

$Q_t = h_t A_t (T_s - T_a)$ = Btu/hr where $T_a = 100°F$

$A_t = 3.14[(43\text{-}1/8" \times 92") + 43\text{-}1/8"^2/2]/12^2 = 107\ ft^2$

$h_t = h_c + h_r$ = Btu/hr ft^2 °F

$h_c = C(T_s - T_a)$ where $C = 0.18$

$h_r = 0.173\ F_{12}\ [(T_s + 460)/100]^4$

$- [(T_a + 460)/100]^4/(T_s - T_a)$

At a surface temperature, T_s, of 118°F, we find the following values:

$h_c = 0.47$ Btu/hr ft^2 °F

$h_r = 1.09$ Btu/hr ft^2 °F

$h_t = 1.56$ Btu/hr ft^2 °F

$Q_t = 3{,}005$ Btu/hr

Since this is sufficient to remove the solar heat load calculated above, it means that the average surface temperature will not exceed 118°F and that the entire package and its contents will eventually reach the same temperature.

APPENDIX 2.10.7

EVALUATION OF DIFFERENTIAL THERMAL EXPANSION

Assume that the outer stainless steel shell is cooled to -40°F, the wood insulation remains at 70°F, and the stainless steel shell is fitted tightly to the insulation on each end such that there is no room for free contraction. Also assume that the resulting stress is borne entirely by the stainless steel with no compression of the insulation. Under these conditions the tensile stress developed in the stainless steel shell would be:

$$S = CE(T_1 - T_2) \quad \text{where } C = 9.6 \times 10^{-6}/°F$$

$$E = 28 \times 10^6 \text{ psi}$$

$$T_1 = 70°F \text{ and } T_2 = -40°F$$

$$S = 9.6 \times 10^{-6} \times 28 \times 10^6 \times (70 + 40) = 29{,}568 \text{ psi}$$

This is less than its yield strength of 30,000 psi such that the stainless steel could bear the entire stress from such differential contraction due to rapid cooling of the outer shell to -40°F. Of course, much of the differential contraction would be absorbed by closing gaps between the insulation and the shell left from fabrication, and much would be absorbed by compressing the wood in each end of the package to lessen the stress on the stainless steel shell. The total difference to be absorbed would be:

$$L = 9.6 \times 10^{-6} \times 92" \times 110°F = 0.097"$$

This represents fabrication gaps at each end of only 3/64".

APPENDIX 2.10.8

SHELL LOADING 3.5 PSIA

The tensile stress induced in the shell of a cylinder is:

$S = Pd/2t$ where P = pressure, psi.

d = shell diameter, in.

t = shell wall thickness, in.

Under the pressure of 3.5 psia the air trapped inside the insulation cavity of a NCI-21PF-1 Package would act as in internal pressure of 11.2 psig such that the stress induced in the skin would be:

$S = Pd/2t = (11.2 \times 43)/(2 \times 0.074) = 3{,}254$ psi

This is much less than the yield strength of 30,000 psi for the stainless steel shell.

APPENDIX 2.10.9

HALF-SCALE MODEL ACCIDENT TESTING

A. Half-Scale Model

The ability of the NCI-21PF-1 design to protect the cylinder and cylinder valve when subjected to hypothetical accident conditions was tested by subjecting a half-scale model to the drop tests proposed above. The model was fabricated in accordance with NCI Drawing No. DED-206-B, Sheets 1 through 8, Rev. 1 (see Appendix 2.10.10), except that all dimensions, including thicknesses and tolerances, were reduced by one-half. Wood and foam thicknesses were easily reduced to one-half, but metal thicknesses are dependent on standard items available from the steel mills. The half-scale model was built using metal thicknesses which were equal to or less than one-half their full-scale counterparts as shown below:

FULL-SCALE (thickness, mm)	HALF-SCALE (thickness, mm)
16 Gage Sheet (1.524)	22 Gage Sheet (0.762)
14 Gage Sheet (1.905)	20 Gage Sheet (0.914)
1/4" Plate (6.35)	11 Gage Sheet (3.05)
1/4" x 3" Bar (6.35)	11 Gage x 1.5" Strip (3.05)
1/2" x 6" Bar (12.70)	1/4" x 3" Bar (6.35)
2" x 2" x 1/4" Angle (6.35)	1" x 1" x 1/8" Angle (3.18)
3" x 3" x 1/4" Angle (6.35)	1.5" x 1.5" x 1/8" Angle (3.18)
3" x 3" x 3/8" Angle (9.53)	1.5" x 1.5" x 3/16" Angle(4.76)

All parts of the closure toggles, except for the brackets, were cast and were exactly one-half the size of their full-scale counterparts. Threaded parts, including those in the closure toggles, were National Coarse threads which do not scale exactly. However, as can be seen below, the minor thread diameters of the half-scale threads are equal to or less than one-half that of the full-scale threads such that the scaling was conservative:

MINOR THREAD DIAMETERS (mm)

Full-Scale Threads	Half-Scale Threads
1/4"-20NC (4.79)	No. 5-40NC (2.395)
3/4"-10NC (15.93)	3/8"-16NC (7.58)
1"-8NC (21.50)	1/2"-13NC (10.30)
1-1/4"-7NC (27.30)	5/8"-11NC (13.04)

There were some minor differences in the half-scale model. Since it was not being subjected to thermal testing the vent holes were sealed with silicone RTV caulking only,

and the gasket was made of sponge rubber. Also, the toggle lock-down pins were simple 1/4" diameter pins instead of 1/4" ball-lock pins, and the seal lugs were omitted. None of these differences would affect the outcome of the drop and puncture tests.

All Quality Assurance requirements for the manufacture of NCI-21PF-1 PSP's as specified in Drawing No. DED-206-B, Sheets 1 through 8, Rev. 1, were applied to the manufacture of the half-scale model. Due to the thinness of the metal only the GTAW welding process was employed, and the stiffener rings were not continuously welded. Otherwise, requirements for materials and material test reports, welding, tolerances, heat treating, and inspections were strictly followed.

With its inverted stacking frame, the NCI-21PF-1 PSP should weigh approximately 2250 pounds (1023 kg); this is about 15% heavier than the 21PF-1B PSP but is about the same as the GE-21PF-1, the W-21PF-1, and the UX-30 packages. At 1/8 the weight of the full size package, the half-scale model NCI-21PF-1 should have weighed about 281 pounds (128 kg); it actually weighed 302 pounds (137 kg), but this extra weight was attributed to 20 pounds of extra foam which was needed to fill the insulation cavity. This was not surprising because smaller pours do not foam as well as those used in full size packages and result in somewhat higher density foam in small packages. The drop tests being performed did not involve the foamed portions of the package such that this higher density foam was of little significance except that it made the package weigh heavy.

A half-scale dummy cylinder was fabricated with its shell made of 1/4"(6.35mm) thick steel plate and with flat end plates made of 1/2" thick steel plate instead of dished ends of 1/4" (6.35mm) thick steel. The dummy cylinder was loaded with a mixture of steel slugs and sand to give a gross weight of 809 pounds (367 kg), simulating a full scale UF_6 cylinder weighing 6472 pounds (2936 kg), somewhat heavier than the nominal gross weight of 6420 pounds (2912 kg) given in ORO-651 for a 30B cylinder. A capped brass pipe nipple was installed in the end of the half-scale cylinder in the correct position and angle to simulate the 30B cylinder valve.

B. Test Facilities

Drop and puncture testing of the half-scale model NCI-21PF-1 PSP took place at Nuclear Containers, Inc., Elizabethton, TN. The drop test target was an 8' x 8' x 1" thick steel plate lying on a 12' x 12' x 18" thick concrete pad which was poured on a 6" thick crushed stone base and reinforced with four layers of *4 steel rebar wired in 4" grids. This pad weighs approximately 32,000 pounds (29 times the weight of the loaded half-scale test model) and has been used several times during the past ten years for 9-meter drop tests of packages weighing up to 2000 pounds without any cracking or other visible damage. The puncture test piston was a 3" diameter x 12" long solid steel rod welded to a 1/2"thick steel base; the penetrating edge has a machined 1/8" corner radius. Therefore, the piston was exactly a half-scale model of the piston specified in 10CFR71.73.

Each drop was effected by means of a fusible link which was used to attach the package to the lifting hook of the crane hoist; the fusible link was connected to a 400 amp weld machine. A pre-measured plumb line taped to the bottom edge of the package was used to determine that the package was hoisted to the correct height for each drop and to determine exact alignment with the puncture piston for the puncture test. When the package was at the correct height and properly aligned, the plumb line was pulled loose, and the package was released by applying current to the fusible link causing it to part. This simple mechanism effects a clean drop without imparting any turning or twisting motion to the package such that it impacts in exactly the same angle as it is suspended.

The testing and test results were documented by still 35mm photography. Impact deformations were measured and recorded after each drop, and the package was opened between drops to assess damage to the cylinder and to the dummy cylinder valve.

C. Test Sequence

1. The dummy cylinder was installed inside the half-scale model PSP (see Figure 1), and the package was closed and secured with the toggle lock-down pins (see Figure 2).

2. The package was attached to the fusible link from which it was suspended from the crane hook in such an attitude that it would impact the drop pad on the valve end of the package with the package center-of-gravity over and in alignment with the dummy cylinder valve (see Figure 3). The package was hoisted until a 9-meter plumb line taped to the bottom-most portion of the package swung free.

3. The plumb line was pulled free, and the package was dropped by applying current to the fusible link (see Figure 4).

4. Damage to the package consisted of crushing the impacted area of the package to a depth of 7 cm (see Figures 5 and 6); there were no tears or rips in the outer skin of the package and there were no broken welds. The toggle closures on the deformed end of the package were bent, but all toggle closures were still tight and proved to be operable even though the lock-down pins were severely bent on the impacted end of the package. A small gap of about 0.5 cm had developed between the upper and lower portions of the package on the impacted end only.

5. Upon opening the package, the end of the inner liner was deformed into the end of the cylinder skirt and bulged inward toward the cylinder valve leaving a gap between the end of the valve and the deformed end plate of about 0.6 cm. The dummy valve was undamaged. Later assessment, after all testing was complete and the cylinder was removed from the package, showed that the cylinder skirt had suffered some deformation but still offered adequate protection to the valve.

6. The package was re-closed as before with no correction of damaged conditions such as re-adjusting the toggle closures except that the bent lock-down pins were straightened.

7. The package was attached to a new fusible link suspended from the crane hook in such an attitude that it would impact the puncture piston on the valve end of the package with the package center-of-gravity over and in vertical alignment with the dummy cylinder valve and the piston. A 1-meter plumb line taped to the bottom-most portion of the package was used to determine the height of the package and the

position of the target piston (Fig 7).
8. The plumb line was pulled free, and the package was dropped by applying current to the fusible link (Fig 8).

9. Damage to the package consisted of a shallow 3-inch diameter dent about 0.7 cm deep in the area of impact with the piston (see Figure 9). The end plate was not penetrated, and there were no broken welds or tears in the outer skin. One of the tie-down bases was bent when the package fell off the puncture piston. The toggle closures were all still tight and were not damaged at all by the puncture drop test; the gap at the closure plane on the impacted end of the package was actually reduced about 1 mm.

10. Upon opening the package, the gap between the cylinder valve and the inner end was slightly reduced to about 0.5 cm (see Figure 10), but no further damage was found. In order to remove the cylinder from the package, it was necessary to pry the deformed inner end plate away from the dummy valve and disengage it from the cylinder skirt. After the cylinder was removed, the cylinder skirt was found to be slightly deformed, but it still provided a space of about 1.8 cm between the end of the dummy valve and the plane at the end of the skirt (see Figure 11). The inner liner was deformed in the area of impact, primarily from the 9-meter drop (see Figure 12), but there was no evidence of broken welds or tears in the inner skin. Some very small, tight cracks had developed in the miter joints of the wood cover plates, but these were considered insignificant compared to the tears that occurred during earlier 21PF-1 testing.

NOTE: Figures 3, 7, and 8 show evidence of previous damage to the test package; this damage resulted from earlier similar testing which employed a lighter walled dummy cylinder. The lighter cylinder end skirt had collapsed on impact allowing the valve to impact with the bulging inner end plate.

Those earlier tests resulted in damage to the end of the package cover. Some internal straightening was necessary in order to load the cylinder for the later tests. The cylinder was loaded with the valve down, and impacts were on the bottom end of the package opposite the previously damaged end. This difference in loading is considered inconsequential since the top and bottom halves of the NCI-21PF-1 package are nearly identical including the tie-down (stacking) bases.

The significance of the earlier testing is that the damage to the package bottom in the tests described above was virtually identical to the earlier damage to the cover.

Also, the same toggle closures were used in both tests; no repairs were made to the toggle closures between the two test series.

11. NRC concern about the new toggle closures on the NCI-21PF-1 PSP resulted in further structural evaluation by way of additional drop and puncture testing. These tests were accomplished using the same half-scale model, half-scale dummy cylinder, and test procedures as reported above. The dummy cylinder was re-installed inside the half-scale model PSP, and the package was closed and secured with the toggle lock-down pins just as described in the 9/1/88 SARP. No repairs had been made to either the dummy cylinder or the test package since the drop and puncture tests described in the 9/1/88 SARP.

12. The package was attached to the fusible link from which it was suspended from the crane hook in such an attitude that it would impact the drop pad flat on its bottom. The package was hoisted until a 9-meter plumb line taped to the bottom-most portion of the package swung free (see Figure 13).

13. The plumb line was pulled free, and the package was dropped by applying current to the fusible link (see Figure 14).

14. Damage to the package consisted of deforming the tie-down bases and slightly flattening the bottom of the package (see Figure 17). A narrow rip developed in the outer skin near the bottom valve end of the package in the area of severe deformation from previous 9-meter drop testing (see Figure 18); this rip was about 4.5 cm long with a maximum opening less than 1 cm wide. There were no broken welds. The toggle closures were all intact and still held the package tightly closed; no gaps developed between the cover and bottom portions of the package.

15. The package was attached to a new fusible link and suspended from the crane hook in such an attitude that it would impact the drop pad flat on its side. A 9-meter plumb line was taped to the bottom-most portion of the package and was used to determine the height of the package (see Figure 15).

16. The plumb line was pulled free, and the package was dropped by applying current to the fusible link (see Figure 16).

17. Damage to the package consisted of slight additional deformation of the toggle closures on the impacted side of the package as well as slight flattening to that side of the package (see Figure 19). The toggle closures remained intact and continued to hold the package tightly closed; however gaps between the cover and bottom portions of the package developed at the closure plane on the impacted side (see Figure 20). These gaps opened to a maximum width of about 1.5 cm at the surface and

closed to nearly nothing at the step joint (see sketch). The tie-down bases and stacking frames were all somewhat deformed by this time, but there were no further rips or tears in the outer skin, and there were no broken welds.

18. The package was attached to a new fusible link and suspended from the crane hook in such an attitude that it would impact the puncture piston flat on the coupling nut of the center toggle closure on the undamaged side of the package. A 1-meter plumb line was suspended from the coupling nut and was used to determine the height of the package and the position of the target piston (see Figure 21).

19. The plumb line was pulled free, and the package was dropped by applying current to the fusible link (see Figure 22).

20. Damage to the package consisted of driving the toggle closure coupling nut and swing bolts into the side of the package (see Figure 23); there was no other damage from this drop.

D. Results

1. After the 9-meter drop tests and 1-meter puncture tests described above, the toggle closures were all still intact and still held the package tightly closed. None of the toggle lock-down pins had failed.

2. Even though two 1.5-cm wide gaps had developed at the external closure plane of the package, these gaps did not penetrate far into the package but tapered to nothing at the closure plane step joint such that the inboard gasket was not exposed.

3. Except for the 4.5-cm rip in the previously deformed outer skin described above, there were no openings or penetrations in the outer skin, and there were no broken welds on the exterior of the package.

4. Several of the impacted toggle closures were badly deformed and jammed such that they had to be destroyed in order to open the package for inspection. The upper T-bolt of the toggle closure which had impacted on the puncture piston was easily broken indicating it had been cracked during the test; the other four closures on that side were in sound condition. The five toggle closures which had been impacted in the last 9-meter drop test were all sound and yielded only after an hours hard labor by three men working with pry bars, chisels, and sledge hammers.

5. Upon opening the package, the dummy cylinder was undamaged (see Figure 24). The inner liners in the cover and bottom portions of the package were badly damaged with long breaks near the welds joining the end plates with the inner shells (see Figure 25). The wood cover plate in one end of the cover had broken along most of its length near the weld joining it with the inner end plate (see Figure 26). A few small cracks had also developed in the miter joints of the wood cover plates (see Figure 27). Based on the interim inspection described in Test Sequence 10 above, it is known that these breaks in the inner liner occurred only after 3 or 4 9-meter drop tests in succession. In any case, however, none of the cracks and tears in the inner liners and wood cover plates would expose wood or foam to damage during any subsequent thermal testing.

E. Conclusions

Based on the above test results, it is concluded that a full size NCI-21PF-1 Protective Shipping Package, if subjected to the four 9-meter drop tests and three 1-meter puncture tests as described above, would satisfactorily withstand the testing while suffering the following consequences:

1. As a result of the 9-meter drop tests the impacted ends of the package would be crushed to a depth of about 13 cm; the tie-down base would be deformed into the bottom of the package; the toggle closures on the impacted side of the package would be deformed into the side of the package; a 1.2-cm gap would develop at the external closure plane on each of the impacted ends of the package; a 9-cm long rip would open to a maximum width of 2 cm in the outer skin; and 3-cm gaps would develop at the external closure plane on the impacted side of the package. Such gaps at the closure plane are comparable to those developed in the original 21PF-1 PSP as reported in K-1686; however, these gaps did not penetrate far into the package and were nearly closed at the step-joint of the closure plane.

2. As a result of the 1-meter puncture tests, the impacted areas on the ends of the package would receive 6" diameter dents about 1.4 cm deep but would experience no penetration of the end plate.

3. Impacted toggle closures would be deformed, but all of the toggle closures would still be intact and would continue to hold the package tightly closed; none of the toggle lock-down pins would fail; and the un-impacted toggle closures would still be operable.

4. The inner end plate would be deformed inward toward the cylinder valve leaving a gap of about 1 cm between the deformed end plate and the valve cap. The cylinder skirt would be slightly deformed, but the valve would be undamaged.

5. The inner liners of the cover and bottom portions of the package would have several long tears near the welds joining the end plates with either the inner shells or the wood cover plates. None of this interior damage would result in exposure of the wood or foam to damage in subsequent thermal testing.

6. The package would suffer other incidental damage such as bent tie-down bases or stacking frames and bent toggle lock-down pins, but would not suffer any significant tears or rips in the outer skin or other broken components.

7. The basic envelop or space occupied by the damaged package would be essentially unchanged from that occupied by the

undamaged package.

8. Similar testing of the original 21PF-1 package as reported in K-1686, resulted in similar, but generally more severe, damage, ie. the gaps at the closure plane exposed unprotected wood, there were numerous broken exterior welds, and the puncture testing resulted in tears in the outer shell up to 12 cm in length. The damaged 21PF-1 prototype was subjected to a 1-hr diesel oil fire and 24-hr water immersion test with satisfactory results.

9. Except for its toggle closures, thicker end plates, stacking frames, and wood cover plates, the NCI-21PF-1 PSP is almost identical to the original 21PF-1 PSP. When compared to the original 21PF-1 PSP, there is no question that the NCI-21PF-1 (a) affords better puncture resistance in the ends of the package, (b) that its wooden structure is better protected, (c) that its toggle closures keep the package tightly closed even during hypothetical accident testing, (d) that its stacking frames do not compromise its capabilities as a protective shipping package, (e) that its gasket provides better thermal protection, (f) that it provides equal or better protection to its UF_6 cylinder and much better protection to the cylinder valve, and consequently, (g) that it provides better containment and at least equal criticality safety.

10. Based on the above comparison with the original 21PF-1 PSP, it is fair to conclude that the NCI-21PF-1 package in such damaged condition as described above would afford adequate protection to the cylinder and cylinder valve if subjected to subsequent hypothetical accident conditions involving thermal testing and immersion testing as specified in 10CFR71.73 such that it meets the standards specified in 10CFR71, Subpart E.

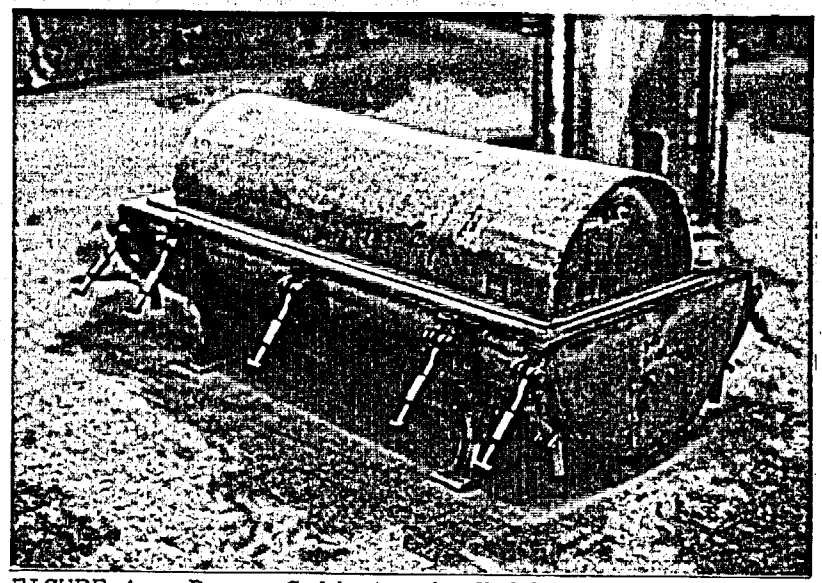


FIGURE 1. Dummy Cylinder in Half Scale NCI-21PF-1

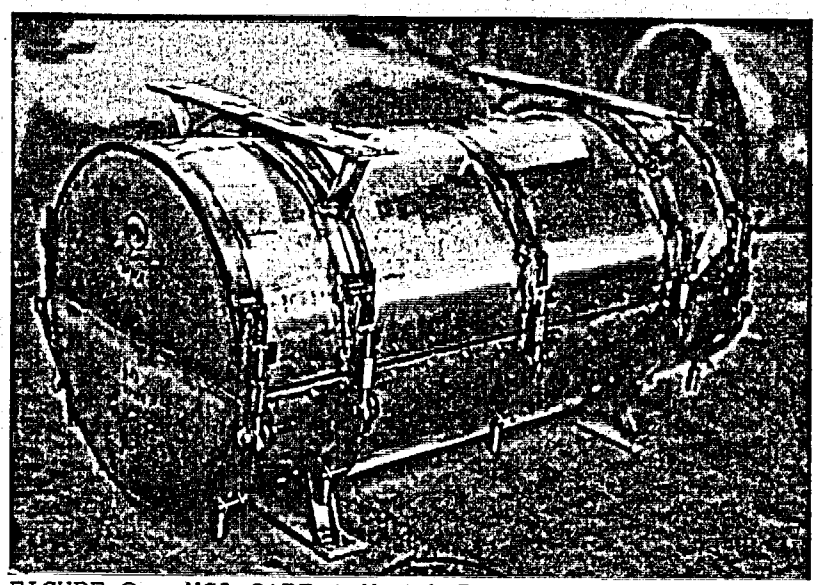
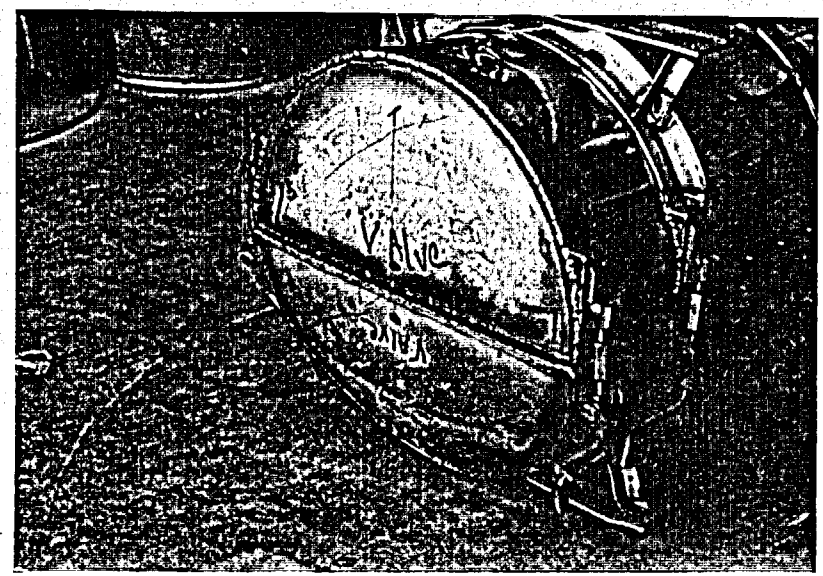
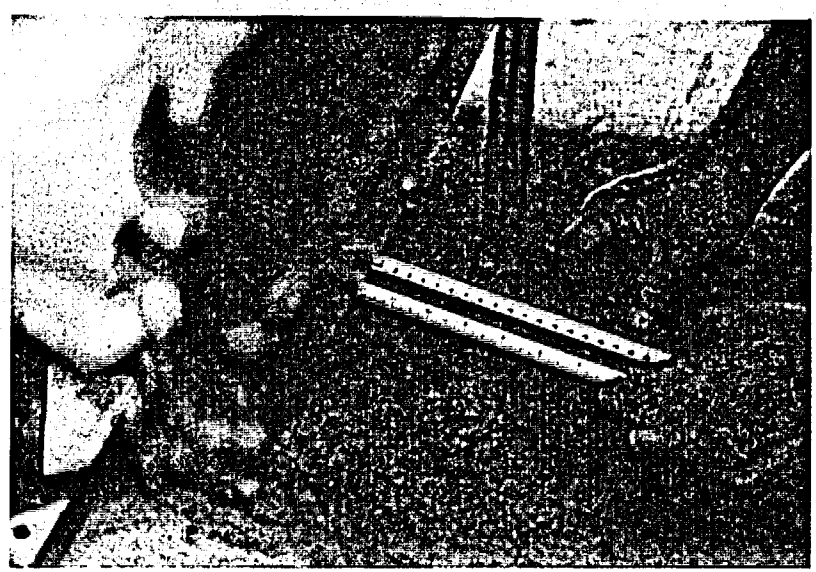


FIGURE 2. NCI-21PF-1 Model Ready for Drop Tests





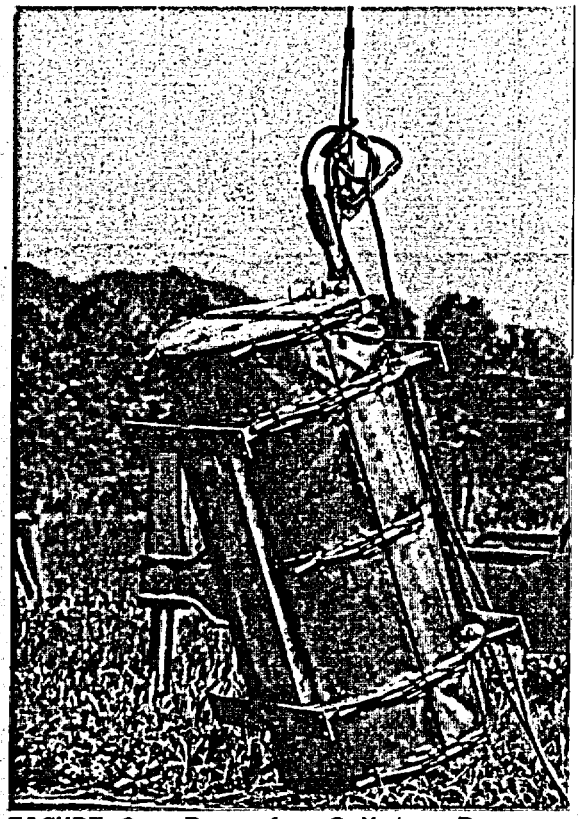


FIGURE 3. Prep for 9-Meter Drop

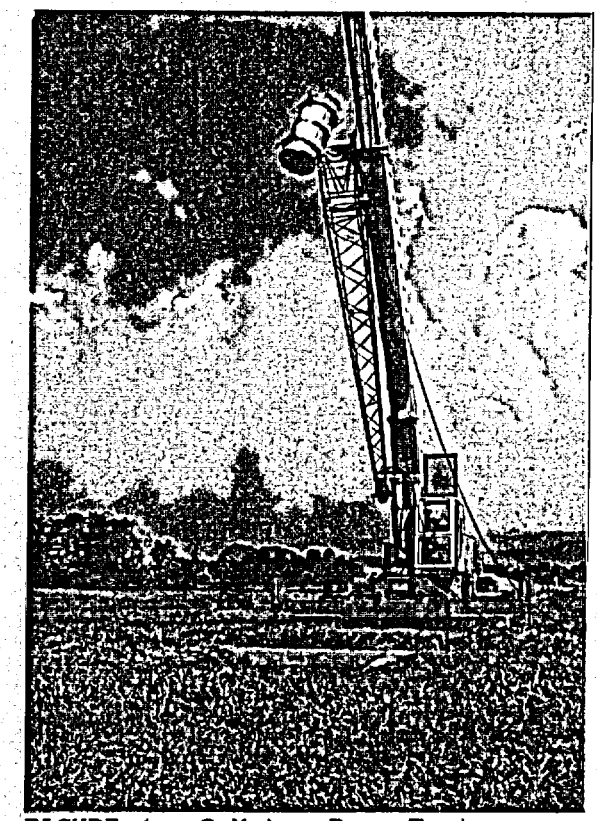


FIGURE 4. 9-Meter Drop Test

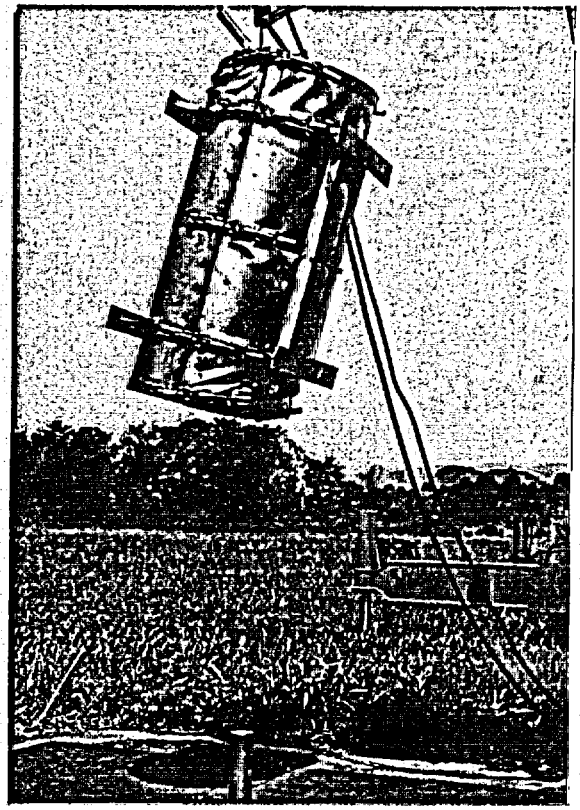


FIGURE 7. Prep for Puncture Test

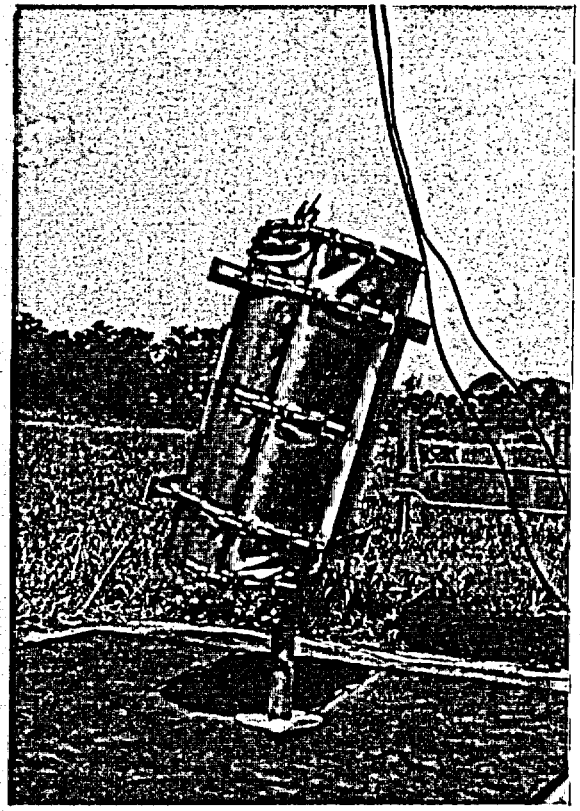


FIGURE 8. 1-Meter Puncture Test

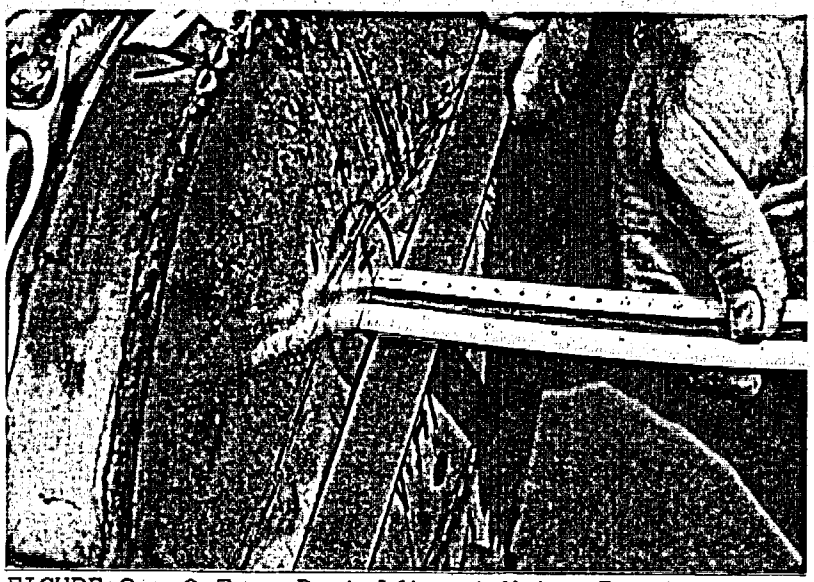


FIGURE 9. 0.7-cm Dent After 1-Meter Puncture Test

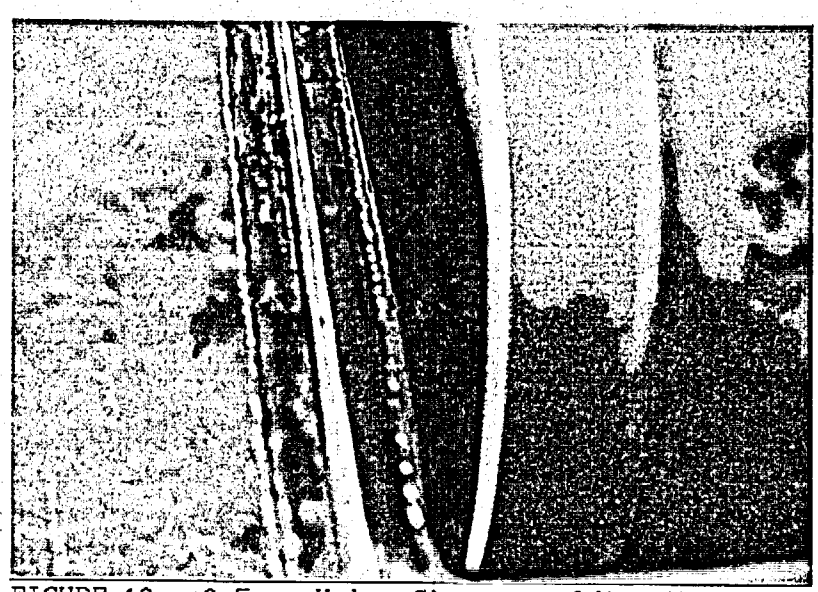


FIGURE 10. 0.5-cm Valve Clearance After Testing

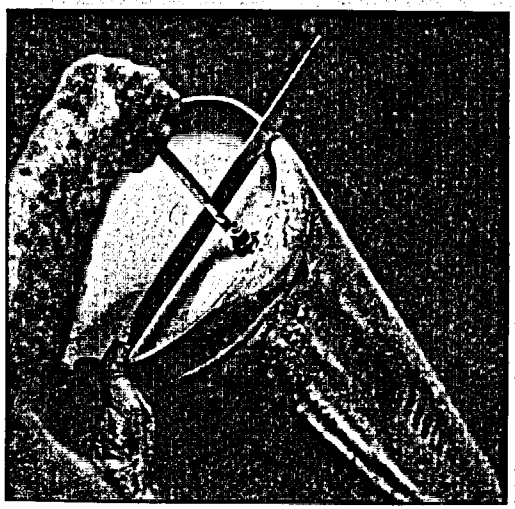


FIGURE 11. Condition of Dummy Valve After Tests

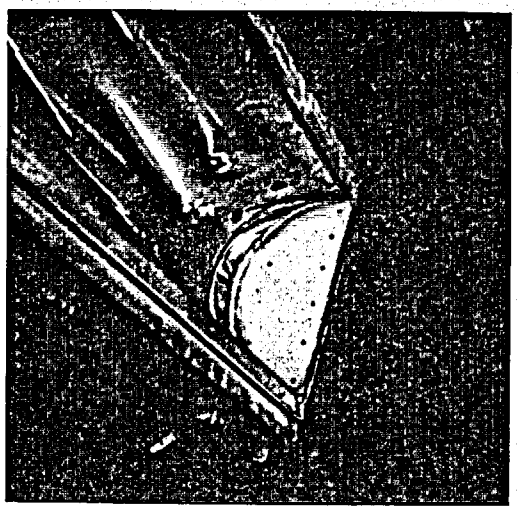


FIGURE 12. Condition of Inner Liner After Tests

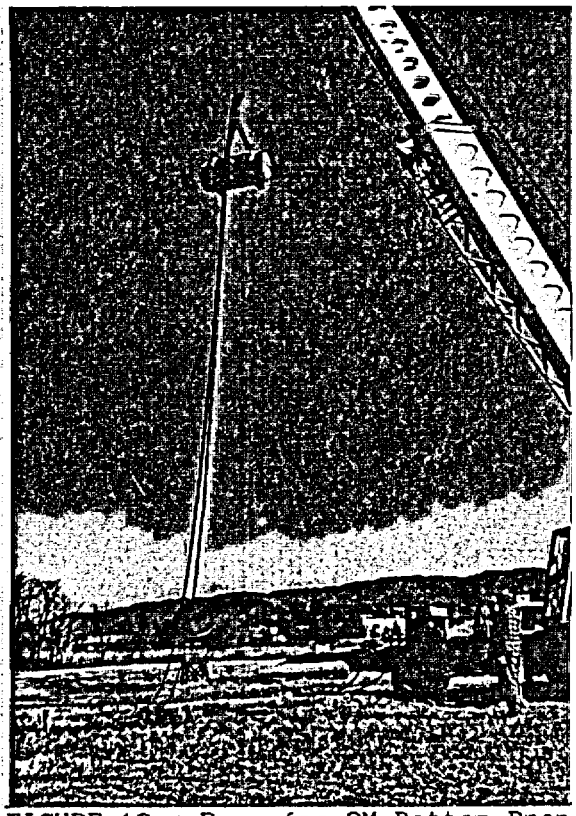


FIGURE 13. Prep for 9M Bottom Drop

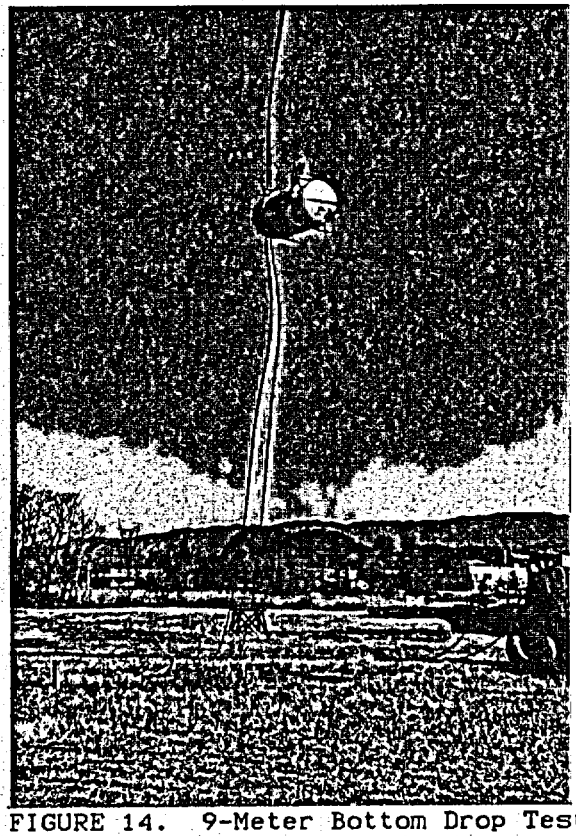


FIGURE 14. 9-Meter Bottom Drop Test

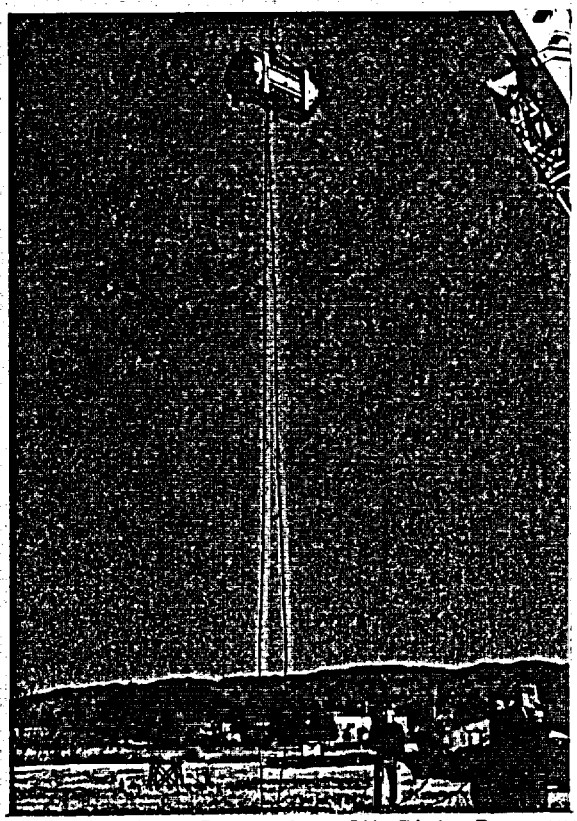


FIGURE 15. Prep for 9M Side Drop

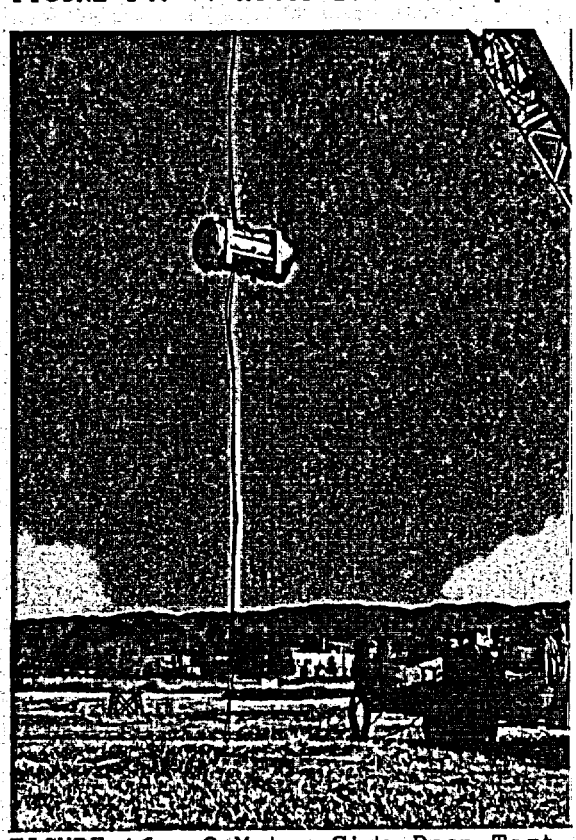


FIGURE 16. 9-Meter Side Drop Test

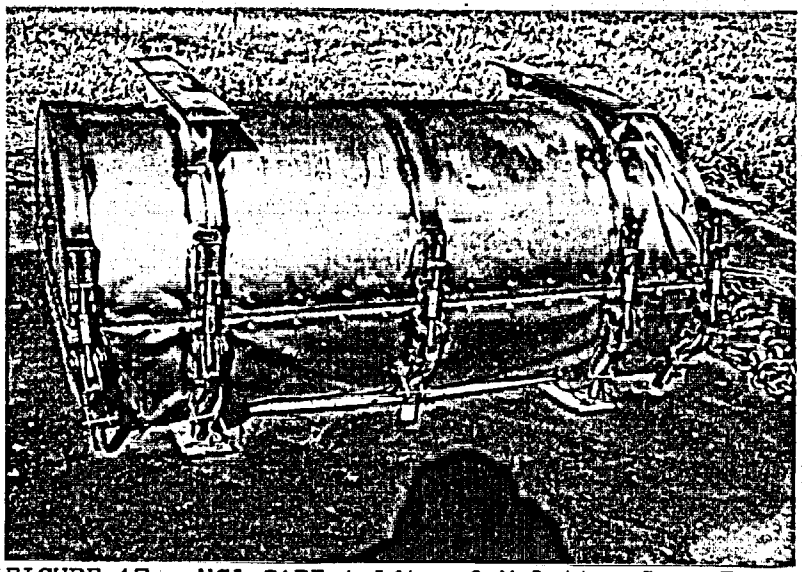


FIGURE 17. NCI-21PF-1 After 9-M Bottom Drop Test

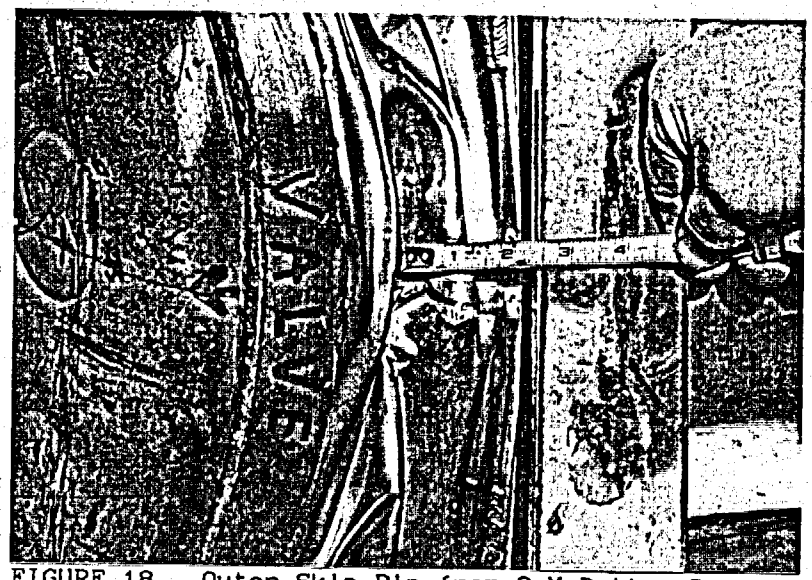


FIGURE 18. Outer Skin Rip from 9-M Bottom Drop

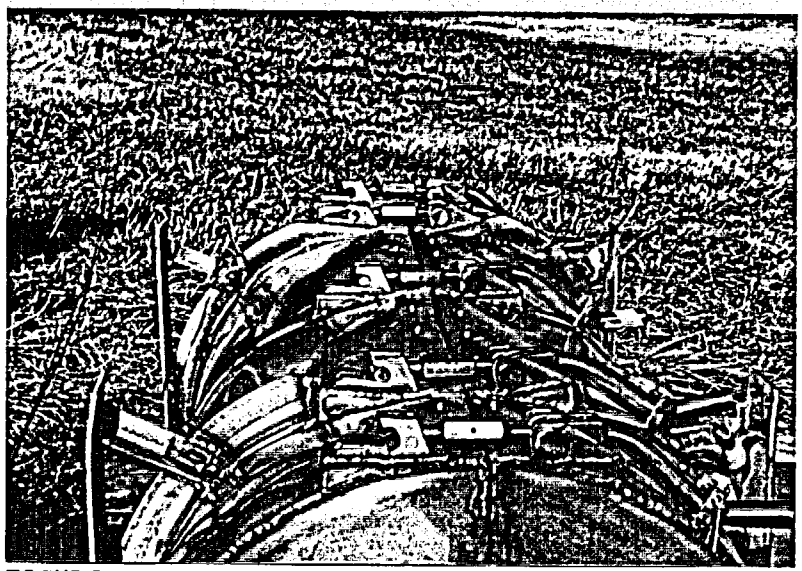


FIGURE 19. NCI-21PF-1 After 9-M Side Drop Test

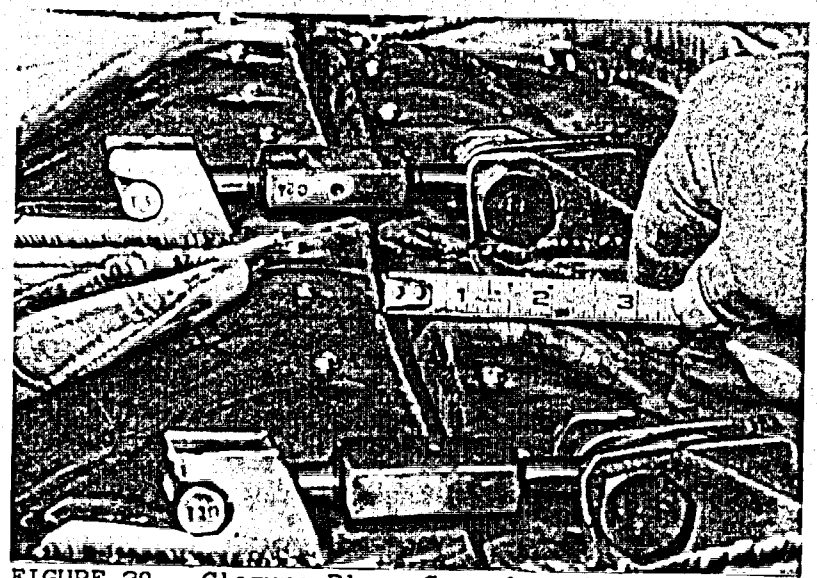


FIGURE 20. Closure Plane Gaps from 9-M Side Drop

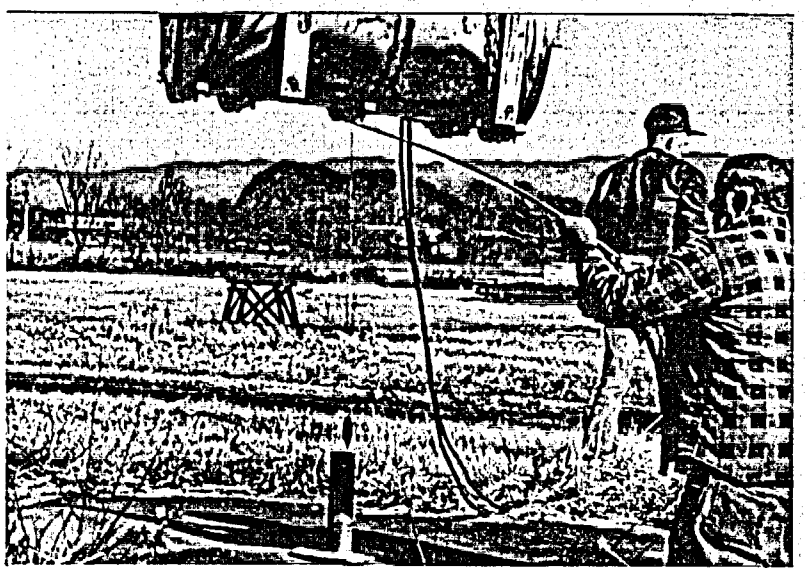


FIGURE 21. Prep for 1-M Puncture Drop on Closure

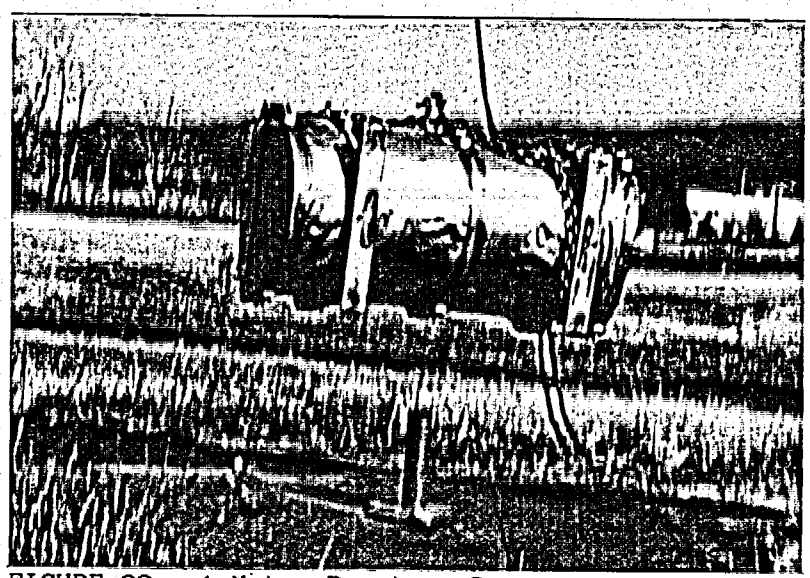


FIGURE 22. 1-Meter Puncture Drop on Closure

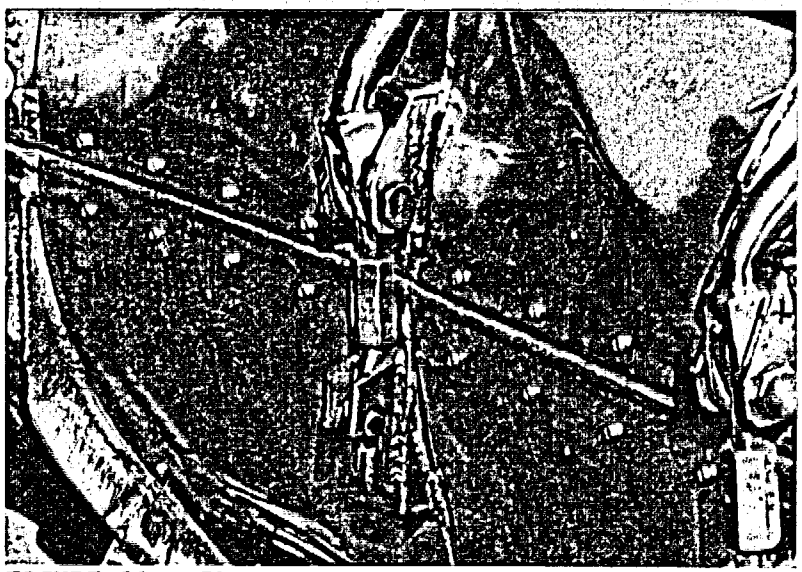


FIGURE 23. Closure Damage from 1-M Puncture Drop

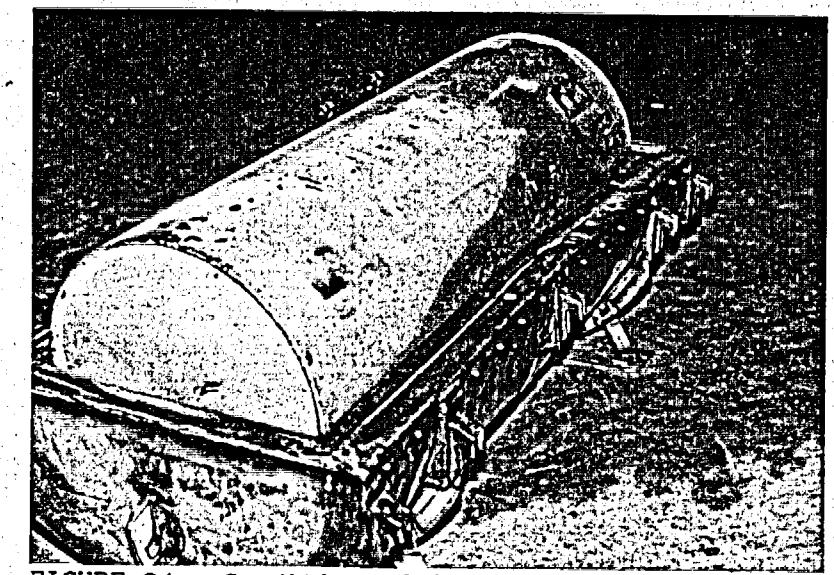


FIGURE 24. Condition of Cylinder After All Tests

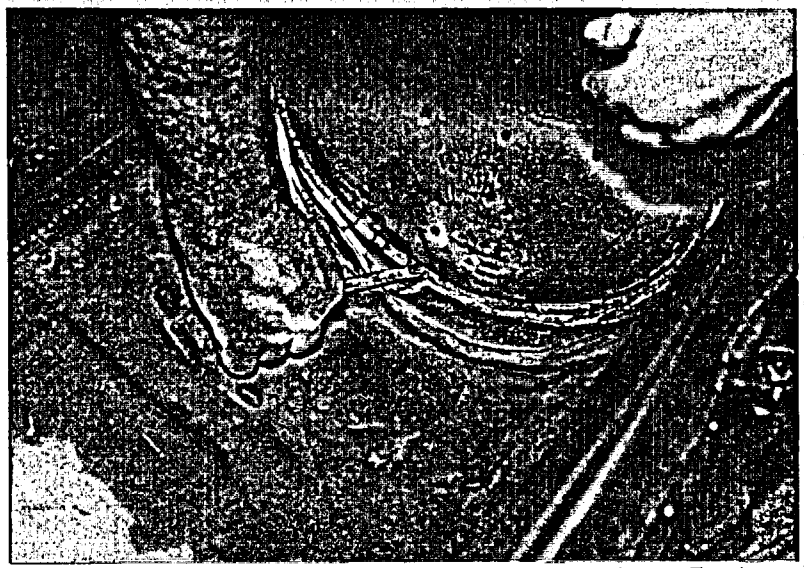


FIGURE 25. Condition of Inner Liner After Tests

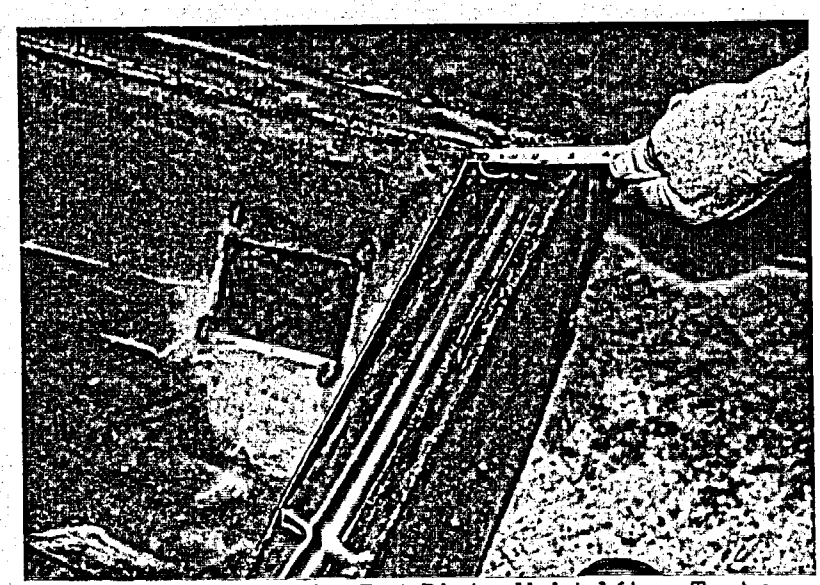
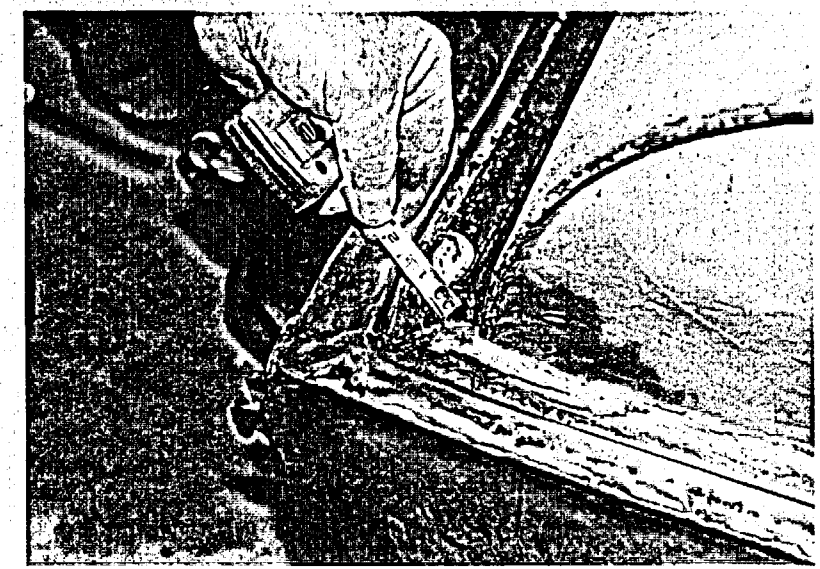


FIGURE 26. Break In End Plate Weld After Tests



APPENDIX 2.10.10

DRAWINGS USED TO BUILD HALF-SCALE NCI-21PF-1 TEST PACKAGE

NCI Drawing No. DED-206-B, Sheets 1 through 8, Rev. 1, were the initial drawings used to build 1/2-Scale Test Package. Subsequent drawing changes have not included any design or fabrication changes which would affect the outcome of Hypothetical Accident Testing. Revision 2 did not introduce any changes in the design, but included details such that DED-206-B could be used alone without reference to the DOT-21PF-1 drawings. Likewise, Revision 3 included no design changes, but corrected some minor drawing errors and provides for toggle bases and brackets to be investment castings of Type 304 stainless steel. Revision 4 (see Appendix 1.3.1) provides for lifting U-bolts instead of eye-bolts and for 5/8" thick gaskets instead of 1/2" thick gaskets. Revisions 3 and 4 also more fully specify the heat treatment, inspection, and testing requirements for all cast components.

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
	NO	DATE	BY			
DECIMAL ±	1	7/1/88	WRH	MODEL NCI-21PF-1 PACKAGE		
	2					
FRACTIONAL ± NOTE 6	3			DRAWN BY WRH	SCALE 1/2 = 12	MATERIAL 304 SS
	4			CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
ANGULAR ±	5			TRACED	APP'D WRH	SHEET 1 OF 8

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
UNLESS OTHERWISE SPECIFIED	NO	DATE	BY			
DECIMAL ±	1	7/1/88	WRH	TYPICAL WELD DETAILS MODEL NCI-21PF-1 PACKAGE		
	2					
FRACTIONAL ±NOTE 6	3			DRAWN BY WRH	SCALE HALF	MATERIAL 304 SS
	4			CHK'D WRH	DATE 6-1-88	DRAWING NO DED-206-E
ANGULAR ±	5			TRACED	APP'D WRH	SHEET 2 OF

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
DECIMAL ± 0.002	NO	DATE	BY	TOGGLE BRACKETS MODEL NCI-21PF-1 PACKAGE		
FRACTIONAL ± NOTE 6	1	7/1/88	WRH	DRAWN BY WRH	SCALE 1/2	MATERIAL 304 SS
ANGULAR	2			CHK'D WRH	DATE 6-1-88	DRAWING NO. PED-206-E
	3			TRACED	APP'D WRH	SHEET 3 OF
	4					
	5					

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
UNLESS OTHERWISE SPECIFIED	NO.	DATE	BY			
DECIMAL .XX ± .02 .XXX ± .002	1	7/1/88	WRA	TOGGLE DETAILS MODEL NCI-21PF-1 PACKAGE		
FRACTIONAL ± 1/32	2			DRAWN BY WRA	SCALE HALF	MATERIAL 17-4PH SS
	3			CHK'D WRA	DATE 6-1-88	DRAWING NO. DED-206-B
ANGULAR ±	4			TRACED	APP'D WRA	SHEET 4 OF 8
	5					

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
UNLESS OTHERWISE NOTED	NO.	DATE	BY			
DECIMAL ± 0.02	1	7/1/88	WRH	TOGGLE CLOSURE DETAILS MODEL NCI-21PF-1 PACKAGE		
	2					
FRACTIONAL ±NOTE 6	3			DRAWN BY WRH	SCALE HALF	MATERIAL 304 SS
	4			CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-E
ANGULAR ±	5			TRACED	APP'D WRH	SHEET 5 OF

AF 124698

BILL OF MATERIALS

Quantities for one Model NCI-21PF-1 Protective Shipping Package; see Note 2 (Sheet 7) for material specifications. Items specified hereon by trade name provide minimum requirements only; equivalent or better items may be substituted.

ITEM	DESCRIPTION (QUANTITY REQUIRED)
Outer Shell	Sheet, 14 Ga x 72" x 91-3/4" (2 ea).
Outer Ends	Plate, 1/4" x 22" x 44" (4 ea).
Inner Shell	Sheet, 16 Ga x 60" x 82-5/8" (2 ea).
Inner Ends	Plate, 1/4" x 16" x 32" (4 ea).
Inner Angles	Angle, 2" x 2" x 1/4" by 91-1/2" length (2 ea).
Support Block Angles	Formed Angle, 1-1/2" x 1-1/2" x 16 Ga Sheet by 7" lengths (16 ea).
Wood Covers (Sides)	Sheet, 14 Ga x 7" x 92" (4 ea).
Wood Covers (Ends)	Sheet, 14 Ga x 5" x 43" (4 ea).
Closure Bands	Flat Bar, 1/4" x 3" by 72" length (6 ea).
Stiffener Rings	Angle, 3" x 3" x 3/8" by 80" length (4 ea).
Bottom Lift Angles	Angle, 3" x 3" x 1/4" by 56" length (2 ea).
Base Plates	Flat Bar, 1/2" x 6" by 43" length (4 ea).
Base Angle Legs	Angle, 2" x 2" x 1/4" by 12" length (8 ea).
Base Gussets	Plate, 1/2" x 2-1/8" x 3-1/8" (2 ea).
Lifting Eyes	Eye Bolt, 3/4"-10NC-2A x 2" long, with shoulder, galvanized carbon steel, 5200 lb. working load rating, McMaster Carr No. 3014T53 (4 ea).
Lifting Eye Nuts	Nuts, 3/4"-10NC-2B, ASTM A-194, Grade 8A Stainless Steel, ANSI B18.2.2.SF, Heavy Hex, with proper marking and material certification (4 ea).
Lifting Eye Washers	Lock Washer, 3/4" US Standard (4 ea).
Toggle Assemblies:	See Shts 3, 4, & 5 and Notes 2d, 4, & 14 (10 ea).
Upper Base	Plate, 1/4" x 7" x 10" (10 ea).
Upper Bracket	Flat Bar, 1/2" x 2-1/2" by 6" length (20 ea).
Lower Base	Plate, 1/4" x 7" x 9" (10 ea).
Lower Bracket	Flat Bar, 1/2" x 2-1/2" by 5-1/4" lgth (20 ea).
Arm Handle	Pipe, 1-1/4" Sch. 80 x 14" length (10 ea).
Arm Base	Flat Bar, 1/2" x 2" by 2-3/32" length (10 ea).
Arm Bracket	Flat Bar, 1/2" x 2" by 4" length (20 ea).
Upper T-Bolt	Casting, 1"-8NC-2A (10 ea).
Lower Swing-bolt	Casting, 1"-8NC-2A (10 ea).
Swing-bolt Pin	Rod, 1" dia. x 2" long (10 ea).
Pivot Bolts	Casting, 1-1/4"-7NC Hex Shoulder Bolt (20 ea).
Coupling Nut	Casting, 1-1/2" Hex x 1"-8NC (10 ea).
Set Screws	Hex Socket Set Screw, 1/4"-20NC-2A x 1/4", Self-Locking Stainless Steel, McMaster Carr No. 90251A533 (30 ea).
Lock-down Pin	Ball Lock Pin, 1/2" dia. x 2-1/2" long, Stainless Steel with attaching cable, Carr-Lane No. CL-8-BLP-T-2.SS (10 ea).
Lock-down Bracket	Flat Bar, 1/4" x 1-1/2" by 3-1/4" lgth (20 ea).
Attaching Screw	1/4" Hex Head, Self Tapping SS Screw (10 ea).
Seal Lug	Pad Eye, 3/4", Stainless Steel, McMaster Carr No. 8892T12 (4 ea).

ITEM	DESCRIPTION (QUANTITY REQUIRED)
Lag Screws	1/4" x 2" Hex Head (140 ea).
Boat Nails	Plain Flat Head, #10 x 2-1/2" (100 ea).
Wooden Components:	Oak, moisture content less than 15%. Rails and Cap Boards--Select Grade; laminated components--No. 1 Common or better, see Notes 1 & 7.
End Block	Cross-lamination 4-3/16" thick using 1-3/8" thick boards (4 ea, 150 board-feet).
End Rail	Board, 1-1/2" tk x 4-1/2" x 43" (4 ea, 16 brd-ft).
Upper End Cap	Board, 1" tk x 2-1/2" x 43" (2 ea, 4 board-feet).
Lower End Cap	Board, 5/8" tk x 2-1/2" x 43" (2 ea, 3 board-feet).
Side Rail	Board, 1-1/2" tk x 6-1/2" x 92" (4 ea, 45 brd-ft).
Upper Side Cap	Board, 1" tk x 3-1/2" x 92" (2 ea, 12 board-feet).
Lower Side Cap	Board, 5/8" tk x 3-1/2" x 92" (2 ea, 8 board-feet).
Support Block	Lamination, 6" thick x 5-1/2" x 9" made of 5 boards 1-3/8" thick boards, (8 ea, 25 board-feet).
Dowel Rod	Hardwood, 3/4" x 6" long (16 ea).
Wood Glue	Weldwood Waterproof Plastic Resin Adhesive (10 lb).
Concrete Nails	No. 10 x 2" and No. 10 x 3" (about 10 lb).
Phenolic Foam	Raw Materials for Fire Resistant Phenolic Foam Insulation per AEC Material and Equipment Specification No. SP-9, Rev. 1 and Supplement K/TL-729, see Notes 9 & 10 (about 260 lb total).
Upper Pad	Neoprene Sponge, 1/2" thick x 6" x 9", medium density, closed cell (4 ea).
Lower Pad	Neoprene, 3/16" thick x 6" x 9", 50 to 60 Durometer A (4 ea).
Rubber Adhesive	Rubber to Metal Cement, 3M No. 051135-08004 (2 oz) or Silicone Adhesive/Caulking described below.
Gasket	Silicone Sponge, 1/2" thick x 1-1/2" wide, medium density, closed cell, rated for continuous use at 400°F (21 feet).
Gasket Primer	Metal Primer, Clear, Albi 487S (1 pint).
Silicone Caulking	Silicone RTV Adhesive/Caulking, rated for continuous use at 400°F, Dow Silastic 732 (about 2 ea 10-oz tubes).
Paint, Fire	Fire Retardant Paint, White, Intumescent, Albi 107A (1 quart).
Vent Seals	Plastic Plugs for 1/4" holes, Caplug No. BPF-1/4 Polyethylene By Protective Closures Co., Buffalo, NY (40 ea).

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTOWN, TENN.		
	NO	DATE	BY	BILL OF MATERIALS MODEL NCI-21PF-1 PACKAGE		
DECIMAL ±	1	7/1/88	WKH			
FRACTIONAL ± NOTE 6	2			DRAWN BY WKH	SCALE	MATERIAL NOTE 2
ANGULAR ±	3			CHK'D WKH	DATE 6-1-88	DRAWING NO. DED-206-E
	4			TRACED	APP'D WKH	SHEET 6 OF

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NOTES

1. Work this drawing with UCC-ND Drawing Numbers E-S-31536-J, Rev. P and S1E-31536-J2, Rev. B for the following details:

   (a) Location of vent holes, boat nails, and lag screws.

   (b) Location of gaskets and rubber pads.

   (c) Fabrication and installation of wooden components and cover plates at the wooden step joints, except note that corner blocks and plywood end rings have been deleted.

2. Unless otherwise specified, all metal items shall be as follows:

   (a) Sheet--ASTM A-240, Type 304 or 304L Stainless Steel, #2B Finish.

   (b) Plate--ASTM A-240, Type 304 or 304L Stainless Steel, #1 Finish.

   (c) Angle & Flat Bar--ASTM A276, Type 304 or 304L Stainless Steel, Hot Rolled, Annealed, and Pickled. It is acceptable for flat bar to be fabricated from sheet or plate meeting above specifications.

   (d) Toggle Castings and Swing Pins--Type 17-4PH Stainless Steel, solution heat treated at 1900 ± 25°F for 30 minutes in vacuum and nitrogen cooled to put material in Condition A; then hardened to Condition H1100 by heat treating at 1100°F for 4 hours and air cooling. Machining operations may be done in either Condition A or H1100.

   (e) Pipe--ASTM A-312, Type 304 or 304L Stainless Steel, seamless or welded, cold drawn, annealed, and pickled. Fittings shall be ASTM A-403, Type 304 or 304L Stainless Steel.

   (f) Boat Nails, Lag Screws, Set Screws, Pad Eyes, & Washers--300 Series, 18-8, or 17-4PH Stainless Steel.

3. Certifications and Test Reports:

   (a) Mill test reports must be obtained and maintained on file for all stainless steel raw materials including sheet, plate, angles, flat bar, pipe and pipe fittings, and casting metal for cast toggle components.

   (b) Manufacturer's certifications must be obtained and maintained on file for gasket materials and for lifting eye-bolts and nuts.

   (c) All other commercially available items may be purchased without certification, but copies of written purchase orders which stipulate the appropriate specifications must be maintained on file for each such item.

4. All cast toggle components shall be Investment Castings of Type 17-4PH Stainless Steel in the H1100 Condition as specified in Note 2(d) above; these castings shall meet the requirements of Section VIII, Articles UG-24(a)(1) & (5) and UG-24(b) & (c), ASME Boiler and Pressure Vessel Code. After heat treating, all castings shall be examined per ASME Code, Section VIII, Appendix VII, Articles UA-80; UA-81(b) & (c); UA-82(a)(1), (2), (4), & (5); UA-83; and UA-84. All items must be re-examined after any repairs and/or reheat treating required by UA-83.

5. Welds:

   (a) Unless otherwise specified, all welds shall be continuous and shall develop the full strength of the weakest member being joined; butt welds shall be full penetration welds. All welds shall be free from cracks, excessive undercutting, pits, or spatter, and shall not be oxidized beyond normal discoloration which can easily be removed by wire brushing.

   (b) Welds shall only be by GTAW or GMAW processes using welders and welding procedures qualified on P8 materials in accordance with Section IX, ASME Boiler and Pressure Vessel Code. Use only Type 308L weld rod and filler materials for welding.

   (c) Do not weld over foam materials; weld over wood only when it has been coated with fire retardant intumescent paint and then use appropriate means to reduce heat to a minimum to protect the wood.

   (d) All stainless steel wire brushes, grinding wheels, and cutting discs which are used for stainless steel shall be used for stainless steel only and shall be so marked. Carbon steel wire brushes shall not be used on stainless steel.

   (e) Welds shall be inspected in accordance with Section V, Article 9 of the ASME Code; the inner liner, outer shell, and wood cover seams shall be inspected visually--linear defects over 1/16" shall be ground out and repaired, other welds shall meet the minimum requirements indicated.

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	1	7/1/88	WRH			
FRACTIONAL ±NOTE 6	2			DRAWN BY WRH	SCALE	MATERIAL NOTE 2
	3			CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
ANGULAR ±	4			TRACED	APP'D WRH	SHEET 7 OF 8
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NOTES--continued:

6. Tolerances: unless otherwise specified:

   (a) Dimensions up to 24" shall be ± 1/16".

   (b) Dimensions greater than 24" shall be ± 1/8".

   (c) Gasket sealing surfaces shall be flat ± 1/16" per 3 feet.

   (d) Overall diagonal lengths shall be within 1/8" of each other.

7. All wood shall be inspected to ensure that it is free of rot, end splitting, loose knots, etc. prior to use; Select Grade lumber for rails and cap boards shall essentially be clear lumber with no knots greater than 1/2". Unacceptable portions may be cut off and discarded, but all boards shall be full length and shall not be spliced lengthwise; each rail or cap board must be a single board. All wood assemblies shall be glued with waterproof plastic resin glue and nailed with No. 10 concrete nails spaced no more than 6" apart.

8. Paint all wood with two coats of fire retardant intumescent paint prior to installation. Seal all screw and nail penetrations through the inner liner or outer shell with silicone RTV caulking when inserting the screw or nail; wipe off excess RTV caulking.

9. Insulation shall be Fire Retardant Phenolic Foam fabricated in accordance with US AEC Material and Equipment Specification SP-9, Rev. 1 and Supplement K/TL-729. Foam each package in place using 2 or 3 equal pours each for the cover half and the bottom half; weight of finished insulation shall be a minimum of 100 pounds in each half. Install and secure the wooden end block in each half immediately after the last pour has been made. After foaming is complete, inspect all vent holes to ensure that the foam has completely filled all void space; if any voids are found, the end blocks must be removed and foam must be added as needed to fill all voids.

10. After foam has cured, drill out all vent holes to a depth of 1/4" to 1/2" and seal each with a plastic cap-plug set in silicone RTV caulking; wipe away excess caulking and allow to cure.

11. Prior to installation of gaskets or rubber pads, use acetone or MEK solvent to thoroughly clean and degrease the metal in the areas to which the rubber is to adhere. Then apply one coat of clear metal primer to the cleaned area and allow to air dry for one hour at room temperature. Install the silicone sponge gaskets by applying a uniform layer (15 to 30 mils) of silicone RTV caulking to the metal surface and applying the gasket using only enough pressure to displace the air but not the adhesive. Seal all joints in the gasket using silicone RTV caulking; wipe away excess caulking and allow to cure. Install the rubber pads using rubber to metal cement per the manufacturer's instructions or use silicone RTV caulking as described above.

12. Items specified hereon by trade name provide minimum requirements only; equivalent or better items may be substituted.

13. Obtain weights of cover, of bottom, and of assembled package without a cylinder; these weights (in pounds and kilograms) must be recorded and included in package labeling and in marking package identification plates.

14. After assembly of finished package, adjust all toggle closures to securely close the package giving a metal-to-metal seat without requiring excessive closing force; then tighten all set screws in each toggle coupling nut. Lock down each toggle handle using a ball-lock pin.

15. Attach the cable of each ball-lock pin to the lower toggle bracket just above it using a 1/4" self-tapping screw set in silicone caulking.

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	1	7/1/88	WRH			
FRACTIONAL ±NOTE 6	2			DRAWN BY WRH	SCALE	MATERIAL NOTE 2
	3			CHK'D WRH	DATE 6-1-88	DRAWING NO. DED-206-B
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