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MARTIN MARIETTA

SAFETY ANALYSIS REPORT FOR PACKAGING: THE UNIRRADIATED FUEL SHIPPING CONTAINER USA/9853/AF

Research Reactors Division

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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SAFETY ANALYSIS REPORT FOR PACKAGING: THE UNIRRADIATED FUEL SHIPPING CONTAINER USA/9853/AF

Research Reactors Division

Issue Date — October 18, 1991

Prepared for
Office of Energy Research
ERKCR01

Prepared by the
Research Reactors Division
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

MASTER

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SAFETY ANALYSIS REPORT FOR PACKAGING:
HFBR UNIRRADIATED FUEL SHIPPING CONTAINER
USA/9853/AF (DOE)

ABSTRACT

The HFBR Unirradiated Fuel Shipping Container was designed and fabricated at the Oak Ridge National Laboratory in 1978 for the transport of fuel for the High Flux Beam Reactor (HFBR) for Brookhaven National Laboratory. The package has been evaluated analytically, as well as by comparison to tests on similar packages, to demonstrate compliance with the applicable regulations governing packages in which radioactive and fissile materials are transported. The contents of this Safety Analysis Report for Packaging (SARP) are based on Regulatory Guide 7.9 (proposed Revision 2 - May 1986), 10 CFR Part 71, DOE Order 1540.2, DOE Order 5480.3, and 49 CFR Part 173.

1.0 GENERAL INFORMATION

1.1 Introduction

The Brookhaven National Laboratory (BNL) High-Flux Beam Reactor (HFBR) Unirradiated Fuel Shipping Container hereinafter referred to as the package was designed at the Oak Ridge National Laboratory (ORNL) for the transport of unirradiated fuel assemblies. The package is evaluated analytically and by comparison to other packages, to determine its compliance with the applicable regulations governing packages in which radioactive and fissile materials are transported, and the initial evaluation was reported in 1979 in the original Safety Analysis Report for Packaging (SARP) for the Unirradiated Fuel Shipping Container[1]. This revised SARP contains computational procedures used to determine the structural integrity, thermal, radiation, nuclear criticality, and shielding (by comparison to other packages) behavior of the package relative to the General Standards (§ 71.43), Lifting and Tie-down Standards (§ 71.45), External Radiation Standards (§ 71.47), General Fissile Requirements (§ 71.55), and Specific Fissile Class III Standards (§ 71.61) of 10 CFR Part 71. Results of the evaluation demonstrated that the package is in compliance with the applicable requirements of 10 CFR Part 71 as an AF package.

The use of the packaging is to ship two unirradiated fuel assemblies from the fuel fabricator to BNL and ORNL, and from ORNL to BNL for use in the HFBR.

The packaging and contents are classified as a Fissile Class III package with a Type A quantity of fissile material as defined in 10 CFR Part 71. The unirradiated fuel assemblies are considered normal form radioactive material. The quantity of material in the package is less than the A_2 value for radionuclides allowed in Table A-1 of Appendix A, 10 CFR Part 71, for ^{235}U of 20 percent or greater enrichment. The fuel assembly plates contain U_3O_8 - Al cores with a maximum ^{235}U enrichment of 95 wt %. The cores are clad with aluminum alloy ASTM Spec. B-209, ASA-6061-T0 or T6. The cladding is considered the containment boundary for the fuel.

The package is currently approved under US Nuclear Regulatory Commission (NRC) Certificate of Compliance No. 9853, Rev. 7, and US Department of Energy (DOE) Certificate of Compliance No. 9853, Rev. 7. This renewal request is for a USA/9853/AF designation. Both the NRC and DOE certificates expire October 31, 1991. Both certificates were issued in response to ORNL applications that included the original SARP[1].

This revised SARP has been prepared using NRC Regulatory Guide 7.9[2] and replaces the original SARP for the package. The SARP has been prepared to support renewal of the Certificate of Compliance and addresses applicable DOE, NRC and Department of Transportation (DOT) rules and regulations regarding packaging and shipment of Type A and fissile radioactive material.[3-6] The succeeding chapters of this SARP are intended to show that the package is in compliance with these rules and regulations for packaging and transporting the unirradiated HFBR fuel assemblies identified herein.

The packaging provides confinement, shielding, impact and thermal resistance for the fuel assemblies and maintains subcriticality of the contents for Normal Conditions of Transport. The subcriticality requirements of 10 CFR §§ 71.55(e) and 71.61 for when the package is subjected to the Hypothetical Accident Conditions of 10 CFR § 71.73 are met because the total mass (710 g) of ^{235}U to be transported is 110 g less than the minimum mass of 820 g required for criticality (see Sect 6.4.1). The package will be transported as exclusive use by rail, highway, or water. The packaging is fabricated from stainless steel, alloy steel, carbon steel plate, an aluminum alloy inner basket lid, wooden basket support, Neoprene gaskets and cushioning, and is filled with borated phenolic foam in the region between the outer container and the inner fuel basket. Specific materials are delineated below.

1.2 Package Description

1.2.1 Packaging

The main features of the packaging are shown in Figure 1.1 and fabrication drawings for the packaging are included in the Appendix A. The packaging consists of an inner basket with seven fuel assembly cavities and an outer cylindrical container. The package outside diameter is 24-1/2 inches and a base 29 x 29 inches with an overall length of 75-1/2 inches.

The fuel basket is 58-3/4 inches long and is seated on crossed 2 x 6-inch (nominal) Douglas fir or Southern pine timbers that rest on edge on the bottom of the outer container. The bottom of the basket is secured by four threaded stainless steel rods welded to the bottom of the outer housing. The basket is held in place at the upper end by four, 2 x 1/2-inch radial phenolic spacers 4-1/4 inches long that are bolted to the basket and to stainless steel ASTM 276 or A479, Type 304L or 347 clip angles welded to the outer housing, by 1/4-20UNC alloy steel ASTM A449, SAE 5, 105,000 psi min. tensile bolts and stainless steel ASTM A194, Type 303 Grade 8F nuts and stainless steel lock washers.

The basket shell is fabricated from 16-gauge (0.063-inch) stainless steel ASTM A167 or A240, Type 304, 304L or 347 to form seven, 4-inch square fuel assembly cavities. All but the two outermost cavities in the three cavity row are blocked against use by stainless steel bars welded across the upper section of the cavities. The basket top and bottom plates are 11-gauge (0.125-inch) stainless steel ASTM A167 or A240, Type 304, 304L or 347. One-half-inch thick Neoprene spacers are placed in the bottom of each fuel assembly cavity to cushion the fuel assemblies. The basket lid is fabricated from 1/8-inch aluminum alloy AA2024-T4 or 6061-T6 ASTM B209, which has a 1/2-inch thick Neoprene spacer glued to its inner face. The Neoprene is slotted to vent the basket and prevent any pressure buildup. The lid is secured to the upper rim of the basket with eight, 3/8-16UNC alloy steel ASTM A449 or SAE J429 Grade 5, 105,000 psi min. tensile hex-head bolts and stainless steel ASTM A194, Type 303 Grade 8F nuts and stainless steel lock washers.

The shipping package outer housing is a right cylindrical drum fabricated from stainless steel ASTM A240, Type 304, 304L or 347. The outer shell thickness is 11-gauge (0.125-inch). The bottom plate is 1/4-inch stainless steel ASTM A240, Type 304 or 347 welded to the cylindrical shell. The top of the cylinder is rimmed with a 1-1/2 x 1-1/2 x 1/8-inch stainless steel ASTM 276 or A479, Type 304L or 347 angle to provide a flange to which the lid is attached with six, 5/8-11UNC stainless steel ASTM A193, Grade B8 Class 2 bolts with carbon steel A516 Grade 60 hex nuts and stainless steel lock washers. Two, 4 x 1-3/4 x 29-inch stainless steel ASTM 276 or A479, Type 304L or 347 channels are welded to the underside of the base to support the package and provide for handling by fork-lift truck.

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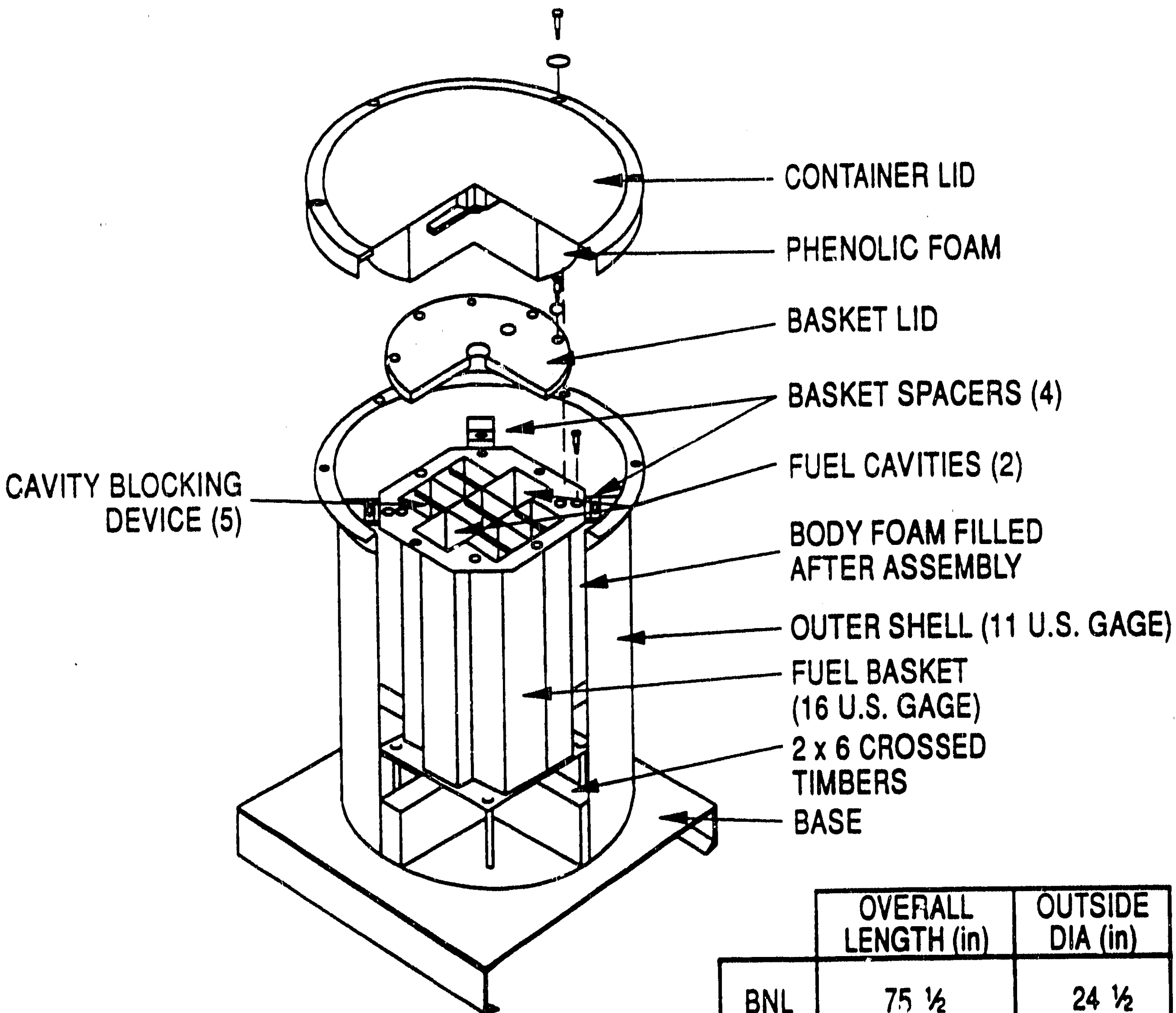


	OVERALL LENGTH (in)	OUTSIDE DIA (in)
BNL	75 ½	24 ½

Figure 1.1 - HFBR Unirradiated Fuel Shipping Container

The outer container lid is fabricated from 11-gauge (0.125-inch) stainless steel ASTM A240 or A167, Type 304, 304L or 347 and a 2 x 2 x 1/8-inch stainless steel ASTM 276 or A479, Type 304L or 347 angle welded around the periphery. The lid has a 1/4-inch thick Neoprene gasket glued to its underside to fit between the lid and the outer shell top flange. There are two, 1/4-inch holes 180° apart drilled through the lip of the lid and outer shell flange for the placement of sealing wire during shipment. A stainless steel 6 x 6 x 1/8-inch shipping label is welded to the lid and to the shell. A stainless steel 6 x 6 x 1/8-inch identification plate is welded to the shell 180° from the shipping label.

The area between the basket and outer container is filled with phenolic foam (Union Carbide Corporation Specification No. JS-31536-1, Rev. 1). The phenolic foam provides some structural support and is an effective thermal insulator. Forty-eight, 3/16-inch vent holes located in the sides of the outer container to provide for release of gas pressure that may be generated by decomposition of the phenolic foam in a fire. After the package is filled with foam, these vent holes are sealed against the weather by two coats of an epoxy paint that does not react with the phenolic foam. The epoxy seals are designed to vent in a fire, since the epoxy paint will decompose at temperatures well below 1000°F. This ability has been demonstrated by Mallet and Newlon on very similar epoxy seals.[7] A 5-3/4-inch thick phenolic foam plug is attached to the underside of the package lid to complete the enclosure of the fuel basket in phenolic foam. The foam is fire resistant and its boron (B_2O_3) content incidentally provides criticality protection as well as fire resistance. The specifications for preparation and application of the foam are included in the Appendix C. The stainless steel and aluminum materials of construction meet ASTM specifications. The welding procedures are in accordance with ASME Boiler and Pressure Vessel Code Sect. IX. Welding and weld inspection procedures are specified in ORNL Drawing No. M-11518-OH-003-D, Rev. 0.

The weight of the empty fuel basket is 92 lb for the package. The net weight of the complete package is 560 lb. The gross weight is 590 lb.

The fuel basket and the outer container have gasketed lids. The outer container has 48 vents that are closed with two coats of epoxy paint for weather proofing as mentioned above.

1.2.2 Operational Features

The packaging is designed to house up to seven fuel assemblies. However, the fuel basket has been limited to a maximum of two fuel assemblies by blocking.

The package is designed to be lifted by fork-lift truck. The basket and outer container lids can be removed after removing the securing bolts. Both lids can be removed manually without the use of hooks, lifting devices, etc. The outer container lid has provisions for two sealing wires, which preclude undetected tampering during transport. The packaging is designed for transport of unirradiated fuel assemblies and, therefore, is not provided with heat removal capability nor designed as a containment or a pressure boundary.

1.2.3 Contents of Packaging

The packaging has been restricted to transport two unirradiated HFBR fuel assemblies. The HFBR fuel assembly is composed of curved plates with U_3O_8-Al cores clad with aluminum alloy ASTM Spec. B-209, ASA-6061-T0 or T6. The maximum ^{235}U enrichment is 95 wt % and the maximum ^{235}U per assembly is 355 grams. Drawings of the assembly are in the Appendix A. The concept of the cladding as containment for the fuel is discussed in Sects. 2.9 and 4.1. The heat content of the two HFBR fuel assemblies is less than one watt. Each fuel assembly weighs about 13 pounds and is sized 2.82 x 3.22 x 57.25 inches. The fuel assemblies are shipped dry and may be wrapped in a small amount of plastic bagging (tubing). The assembly ends may be taped to provide dunnage.

The manufacturing and inspection processes for aluminum clad fuel plates where the fuel form is U_3O_8 enriched, dispersed in an aluminum powder (MIL-A-81335(WP)), are described in Chapter 4 Appendix A.

1.3 References

1. ORNL Report, Safety Analysis Report for Packaging: The Unirradiated Fuel Shipping Container, ORNL/ENG/TM-15, dated September 1979.

2. US Nuclear Regulatory Commission, Regulatory Guide 7.9, Proposed Rev. 2, Standard Format and Content of Part 71 Applications for Approval of Packaging for Radioactive Material, dated May 1986.

3. Office of the Federal Register, 10 CFR Part 71, Packaging and Transportation of Radioactive Material, Washington, DC, dated January 1, 1991.

4. US Department of Energy, DOE 1540.2, Hazardous Material Packaging for Transport - Administrative Procedures, US Department of Energy, Washington, DC, September 30, 1986.

5. US Department of Energy, DOE 5480.3, Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substance, and Hazardous Wastes, US Department of Energy, Washington, DC, July 9, 1985, and Notice DOE N 5480.3, effective March 1988.

6. Office of the Federal Register, 10 CFR 49, Parts 100-199, Transportation of Hazardous Materials, Washington, DC, dated October 1, 1991.

7. A.J. Mallett and C.E. Newlon, Protective Shipping packages for 8- and 12-Inch Diameter UF_6 Cylinders, ORGDP K-1714, April 1967.

1.4 Appendix

A **Drawings**

B **Minimum Edge Cladding**

Brookhaven National Laboratory letter dated October 17, 1991 (C. Wennes to R.H. Odegaarden) modifying minimum edge cladding specified on B&W Drawing No. 4-8002, Rev. F.

C **Specification - Phenolic Foam**

This appendix includes Union Carbide Specification No. JS-31536-1 for the unirradiated fuel assembly shipping package fire resistant phenolic foam.

Appendix A

The following drawings are included in this Appendix:

Shipping Packaging

Drawing Number	Title
ORNL M-11518-OH-001-E, Rev. 0	Unirradiated Fuel Element Shipping Container Assembly Brookhaven National Laboratory USA/9853/AF
ORNL M-11518-OH-002-E, Rev. 0	Unirradiated Fuel Element Shipping Container Details Brookhaven National Laboratory USA/9853/AF
ORNL M-11518-OH-003-D, Rev. 0	Unirradiated Fuel Element Shipping Container Notes Brookhaven National Laboratory USA/9853/AF

Fuel Plate

Drawing Number	Title
B&W 4-8002-D, Rev. F*	HFBR "FLAT" TYPE 2 FUEL PLATE

Fuel Assembly

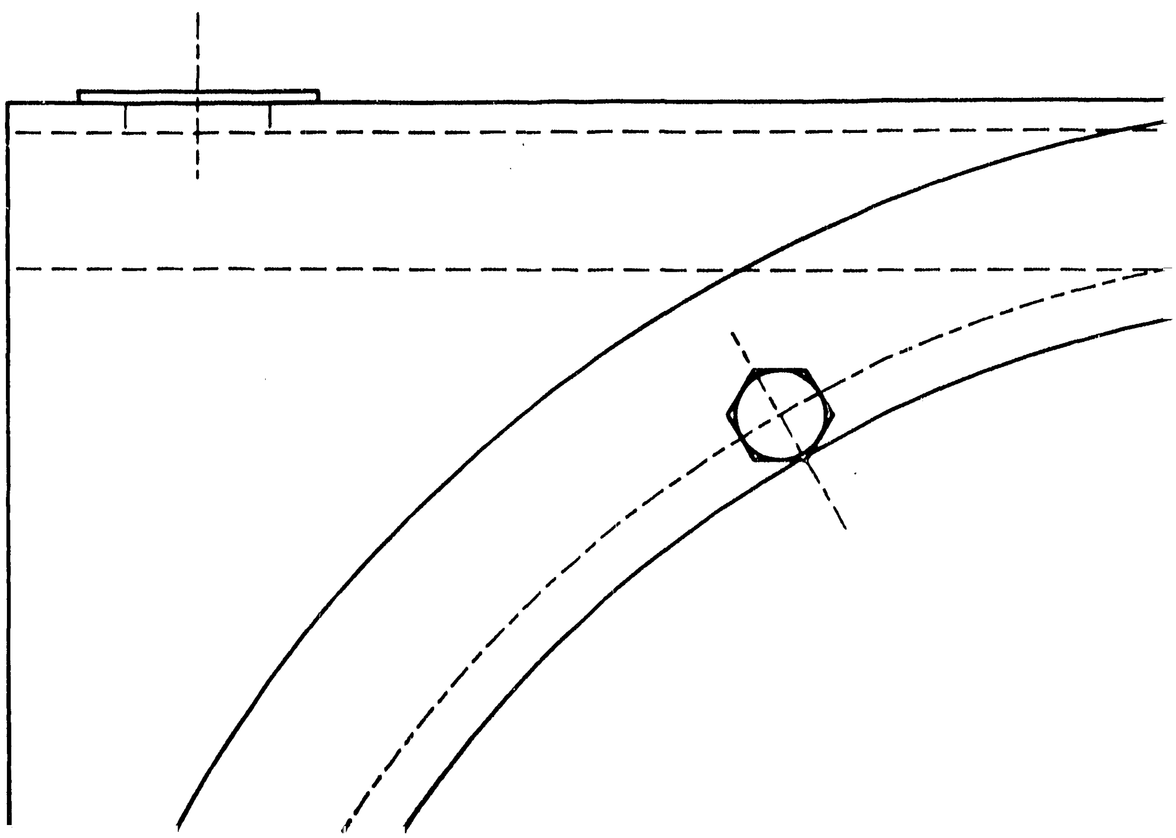
Drawing Number	Title
B&W 9-8025E, Rev. M**	HFBR FUEL ELEMENT TYPE KM ASSEMBLY

*As modified by BNL letter dated October 17, 1991 (C. Wennes to R.H. Odegaarden).

**Plate cladding thickness shall be a minimum of 10 mils following the pickling operation of the individual fuel plates. This determination shall be made by measuring the total plate thickness. The maximum ^{235}U contamination level of the fuel plates shall not exceed 5 $\mu g/ft^2$.

NOTE:

SEE DRAWING M-11518-ØH
FOR NOTES AND EXACT MA



-003-D, REV. 0,
TERIAL DESIGNATIONS.

QUALITY VE

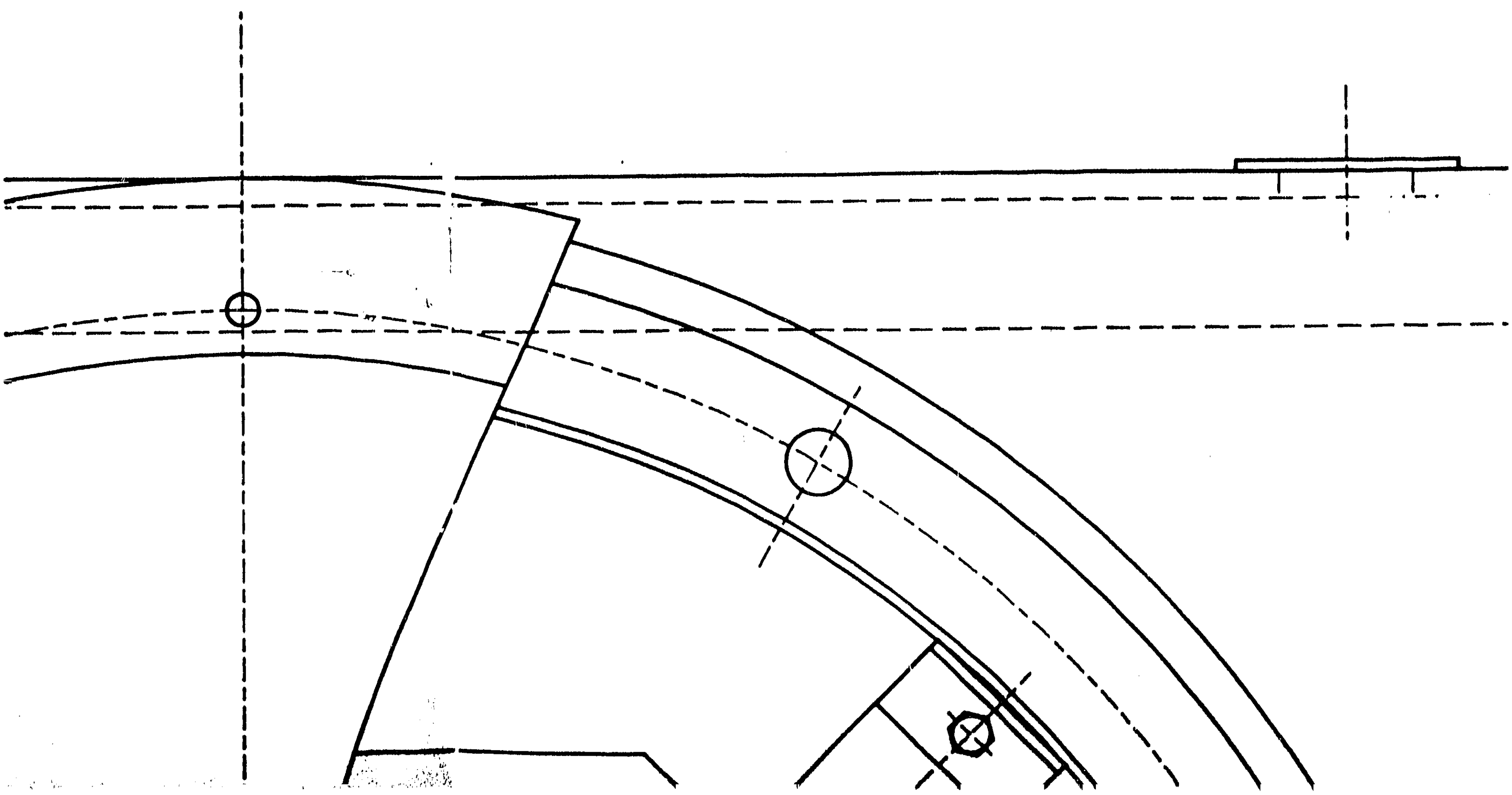
MECHANICAL AN
REFERENCE C

QV CLAUSE	DOCUMENTS REQUIR
303	MATERIAL MILL TEST REPO
325	MATERIAL SELLER CERT
326	SPECIAL MATERIAL INSP RE
205	MFG INSP AND TEST PLAN
312	FIELD INSP & TEST PLAN
321	WELD AND BRAZE INSP REP
322	HEAT TREAT REPRT/CHAR
310	LEAK TEST REPORT
315	CLEANING CERT
318	DEVIATION REQUEST
319	NONCONFORMANCE REPORT
323	DIMENSIONAL REPORT
330	FUNCTIONAL TEST REPORT
100	DOCUMENTATION

• SYMBOL √ INDICATES APPLICABLE T

D L Shutter

QA COORDINATOR



VERIFICATION

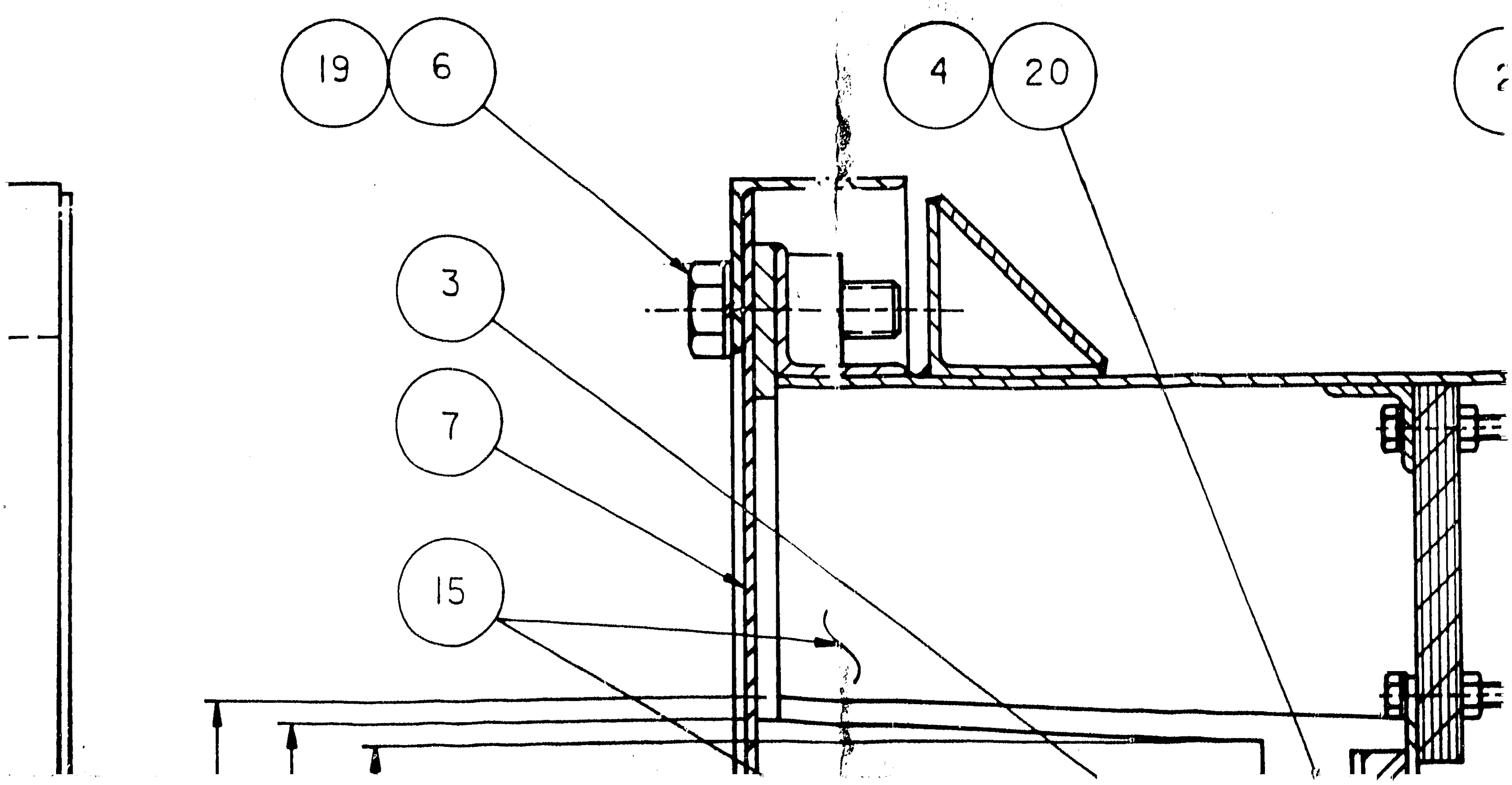
.L AND STRUCTURAL
:CE ORNL QV-001

EQUIRED	APPLICABLE TO SPEC NO.*
T REPORT(CERT)	
ERT	✓ SEE NOTE 5
MSP REPORT	
PLAN	
PLAN	
SP REPORT	✓ SEE NOTE 8
/CHART)	
	✓
EPORT	✓
T	✓ SEE NOTE 8
EPORT	✓ SEE NOTE 1
	✓

.BLE TO ALL PARTS OR ITEMS

10-25-91
DATE

PART	DWG. NO.	REQD.	
1	THIS DWG.	1	UNIRRADI SHIPPING
2	M-11518-ØH-002-E	1	FUEL ELE
3	M-11518-ØH-002-E	1	FUEL ELE
4	THIS DWG.	8	HEX HD C
5	THIS DWG.	9	HEX NUT,
6	THIS DWG.	6	LOCK WA
7	M-11518-ØH-002-E	1	UNIRRA.
8	M-11518-ØH-002-E	1	UNIRRA.
9	THIS DWG.	1	2 X 2 X 3
10	THIS DWG.	4	BASKET



PARTS LIST

DESCRIPTION	MATERIAL
RADIATED FUEL ELEMENT PING CONTAINER ASSEMBLY	
ELEMENT BASKET	
ELEMENT BASKET LID	
HD CAP SCR, 3/8-16UNC-2A X 1 1/4 LG, ALLOY STEEL	
NUT, 3/8-16UNC-2B, 300 SER. SST	
WASHER, 5/8 NOM., 300 SER. SST	
RA. FUEL ELEMENT SHIPP. CONTAINER LID	
RA. FUEL ELEMENT SHIPP. CONTAINER BODY	
2 X 3 WOOD	
KET SPACER, 2 X 1/2 X 4 1/4 LG (PHENOLIC)	

PART	DWG. NO
11	THIS DW
12	THIS DW
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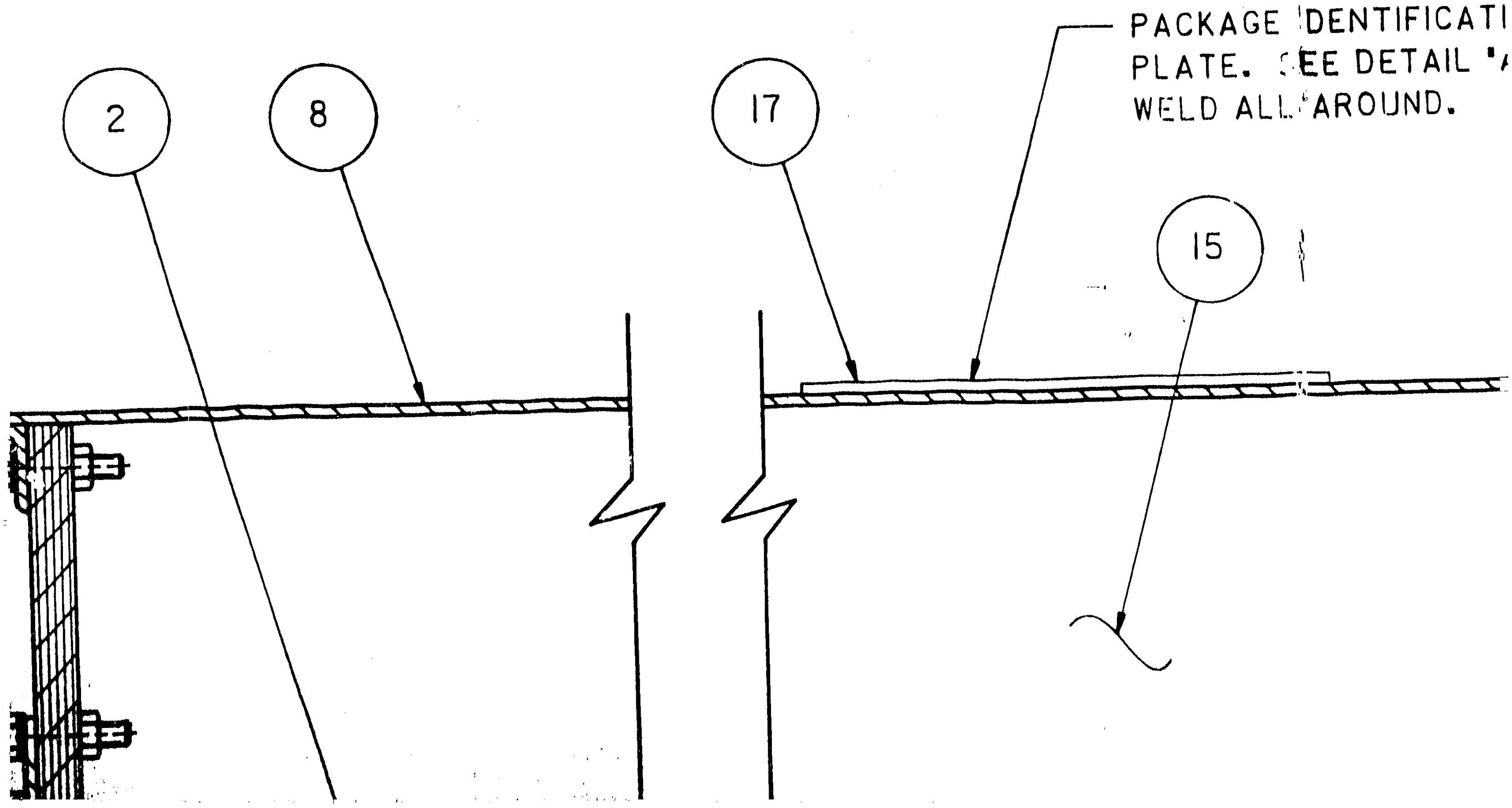
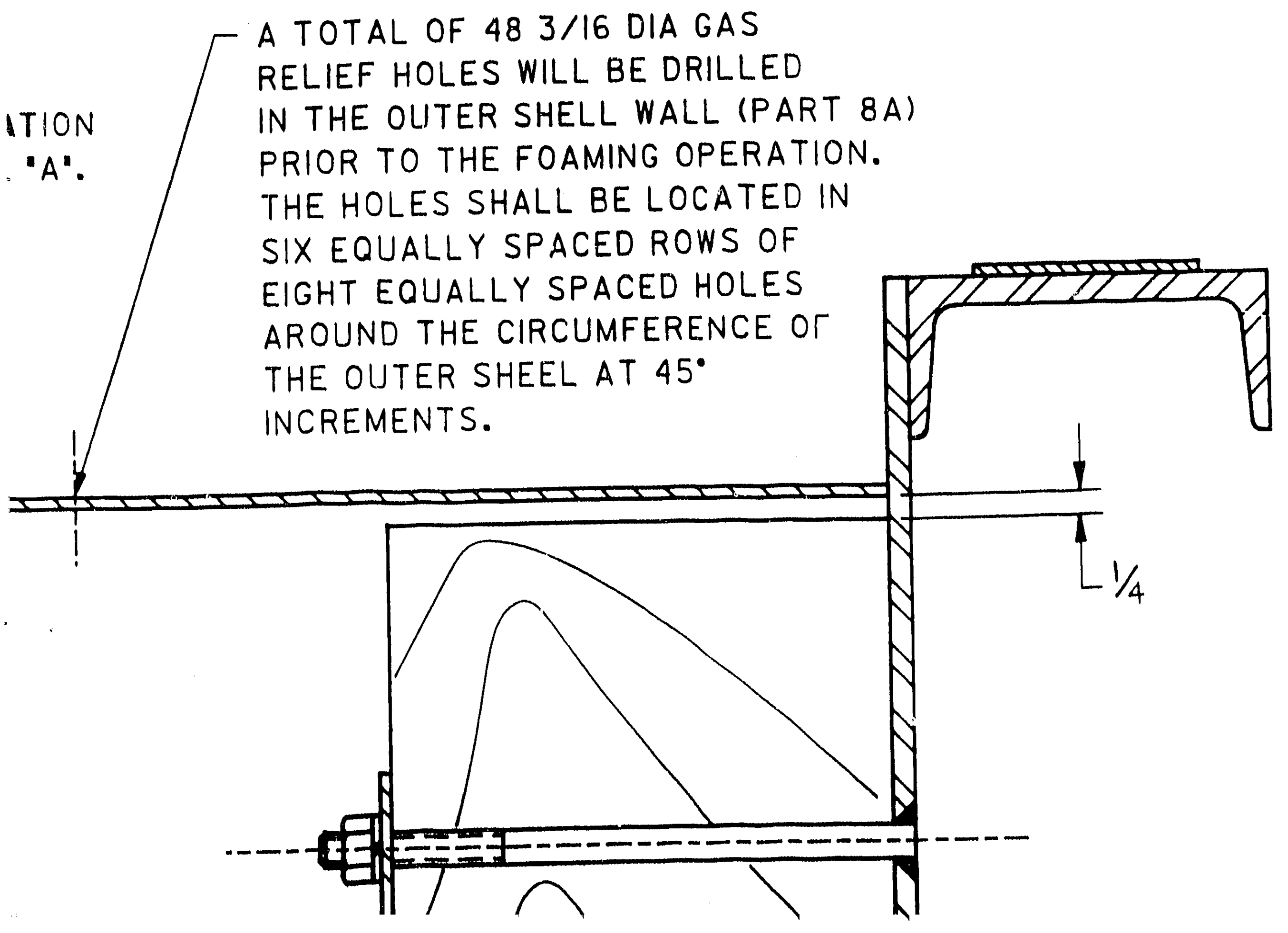
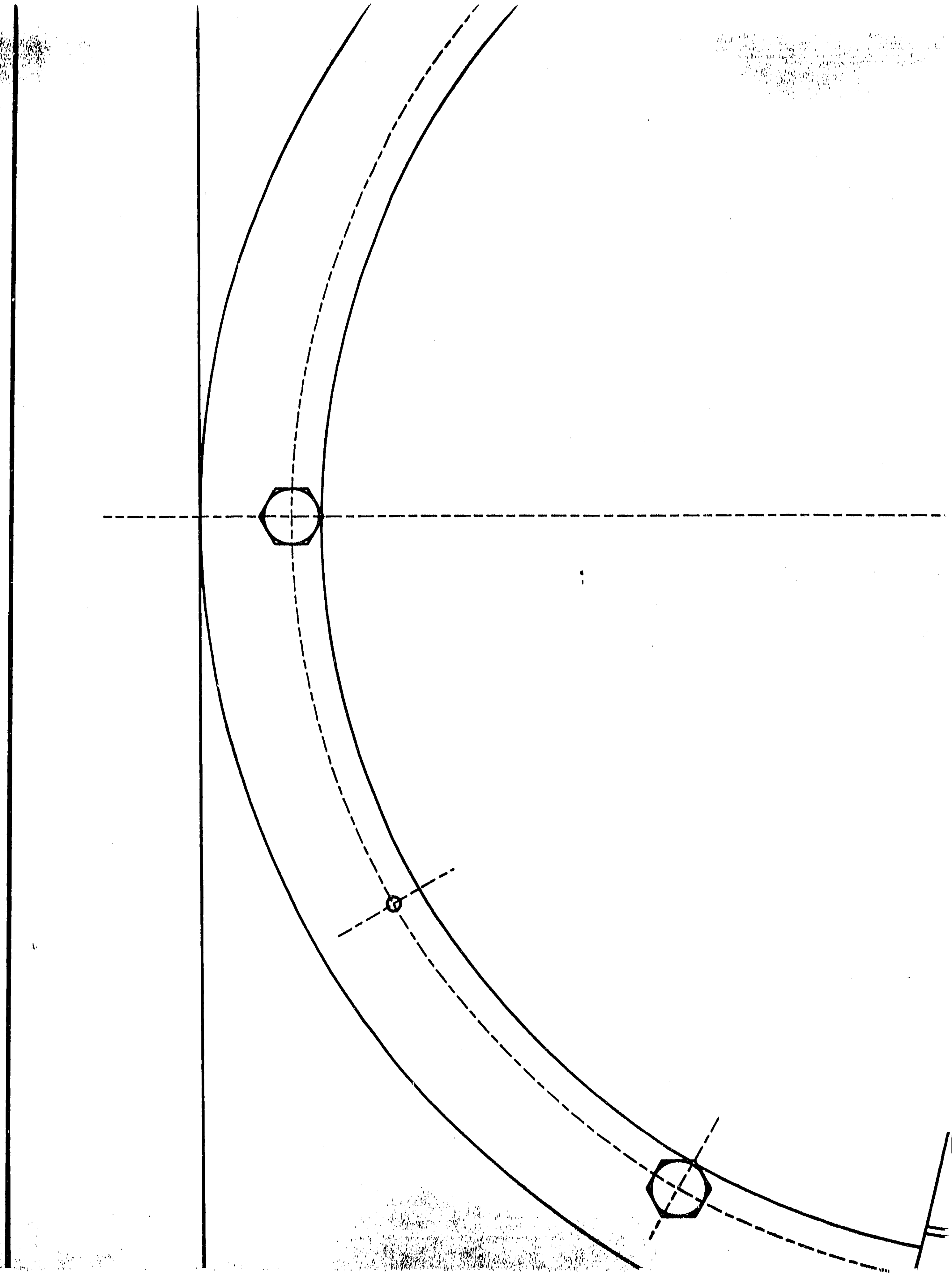
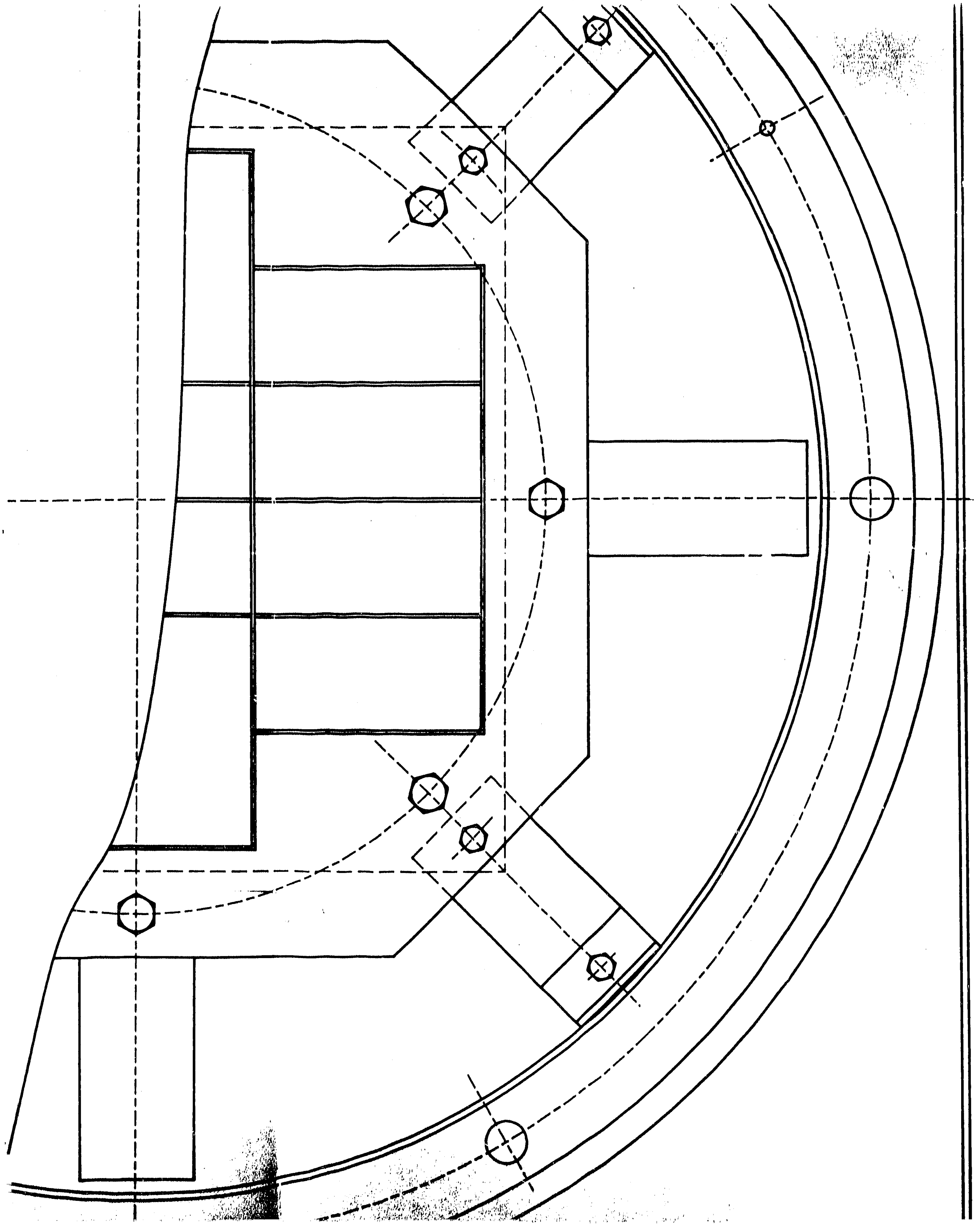
16	THIS DW
17	THIS DW
18	THIS DW
19	THIS DW
20	THIS DW

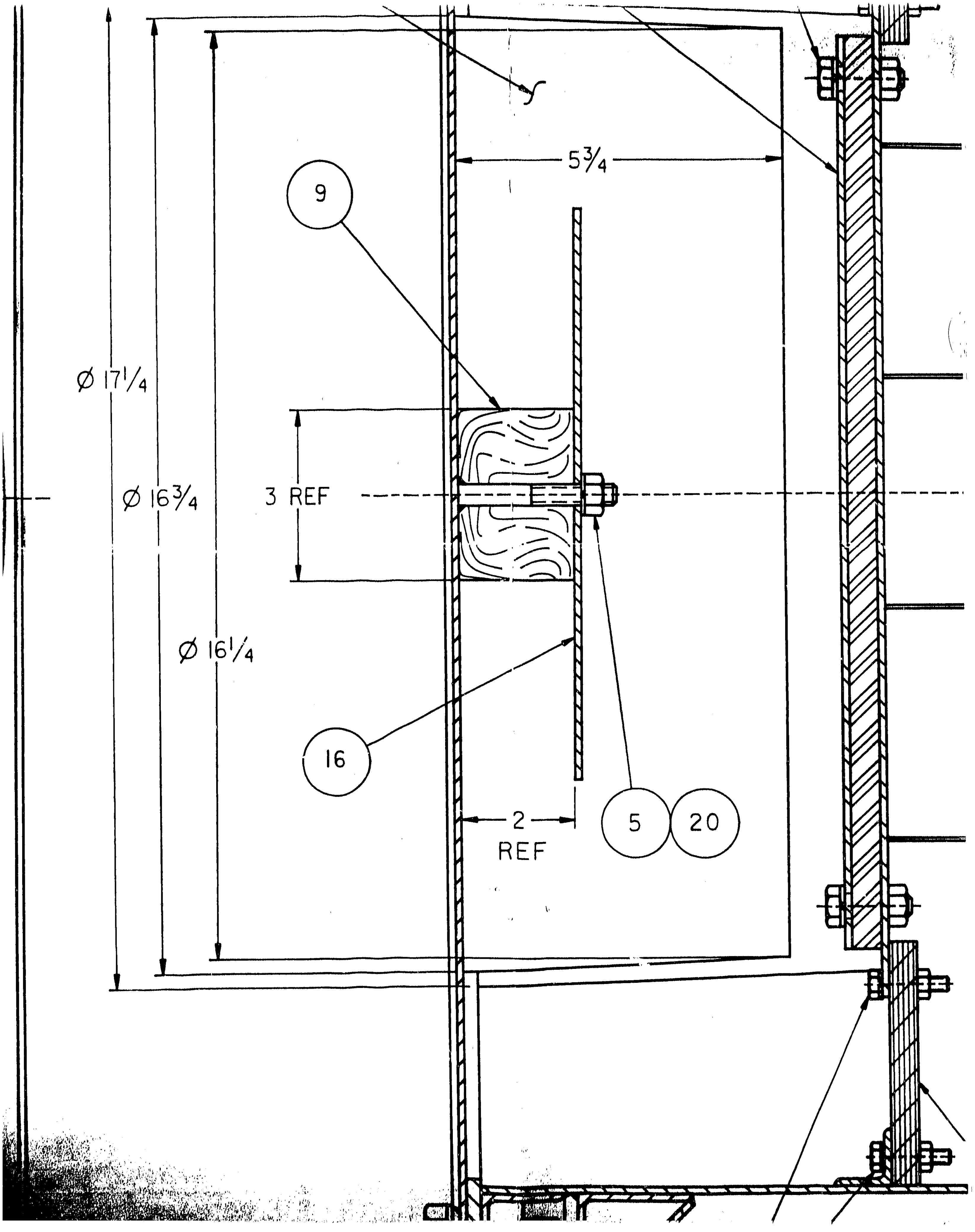


	PARTS LIST		
NO.	REQD.	DESCRIPTION	MATERIAL
DWG.	8	HEX HD CAP SCR, 1/4-20UNC-2A X 1 1/4 LG, ALLOY STEEL	
DWG.	8	HEX NUT, 1/4-20UNC-2B, 300 SER. SST	
DWG.	8	LOCK WASHER, 1/4 NOM., 300 SER. SST	
DWG.	2	CROSS TIMBER, 2 X 6	
DWG.	AS REQD	PHENOLIC FOAM	
DWG.	1	10 X 2 X 1/8 PLYWOOD	
DWG.	1	PACKAGE IDENTIFICATION PLATE, 11 GA SHT., 300 SER. SST	
DWG.	1	SHIPPING LABEL, 11 GA SHT., 300 SER. SST	
DWG.	6	HEX BOLT, 5/8-11UNC-2A X 2 LG, ASTM-A193 GRADE B8 CLASS 2	
DWG.	13	LOCK WASHER, 3/8 NOM., 300 SER. SST	









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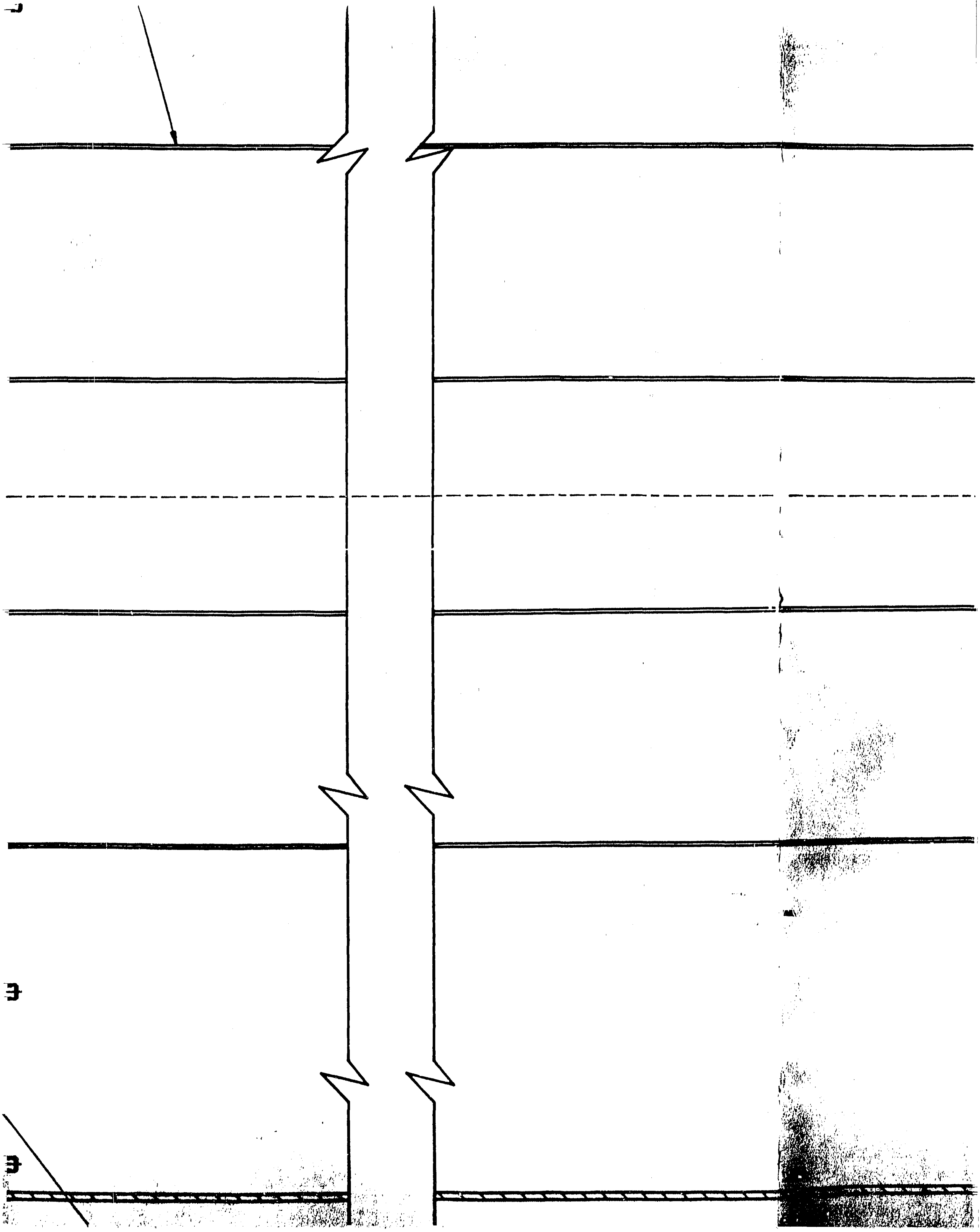

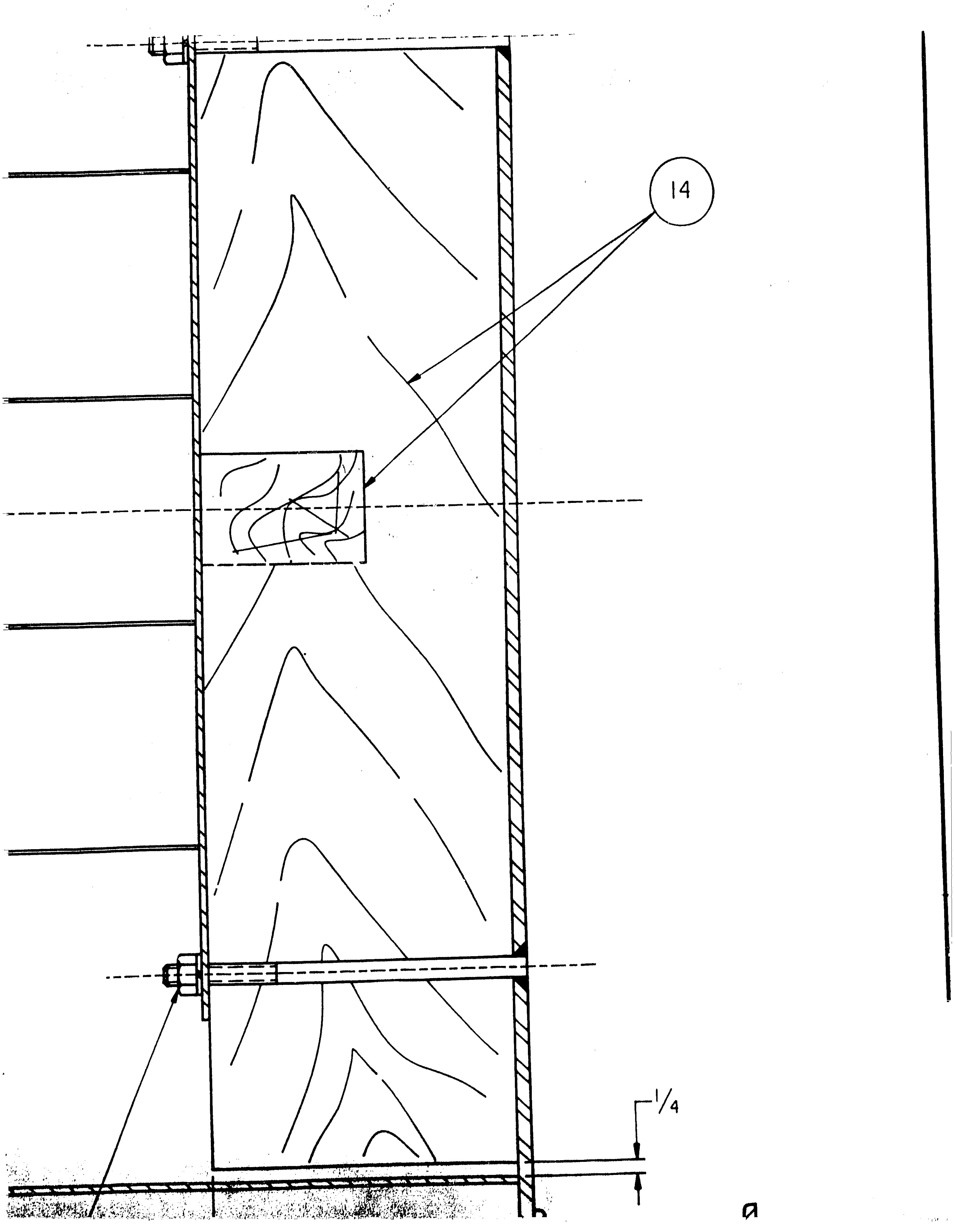
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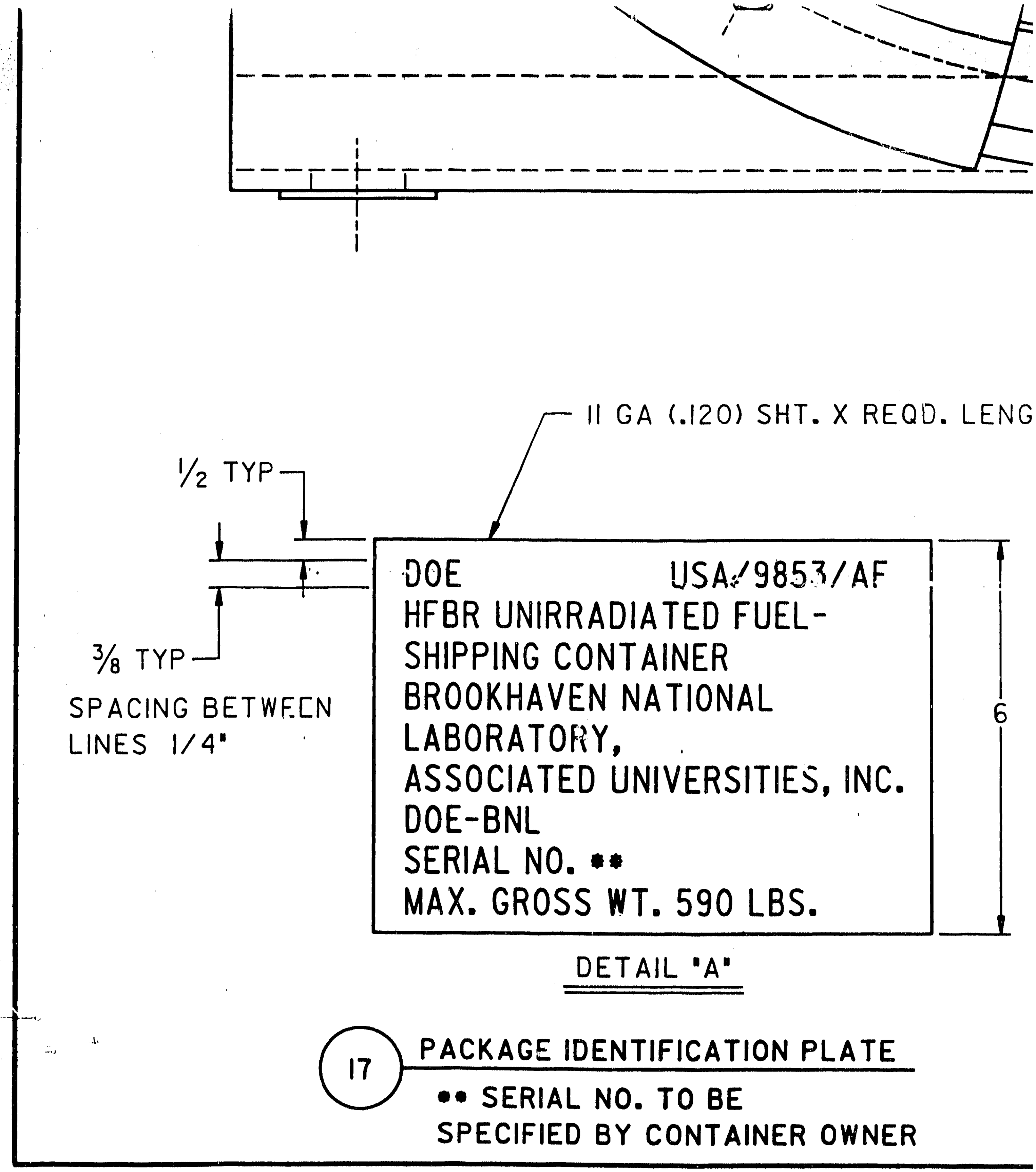
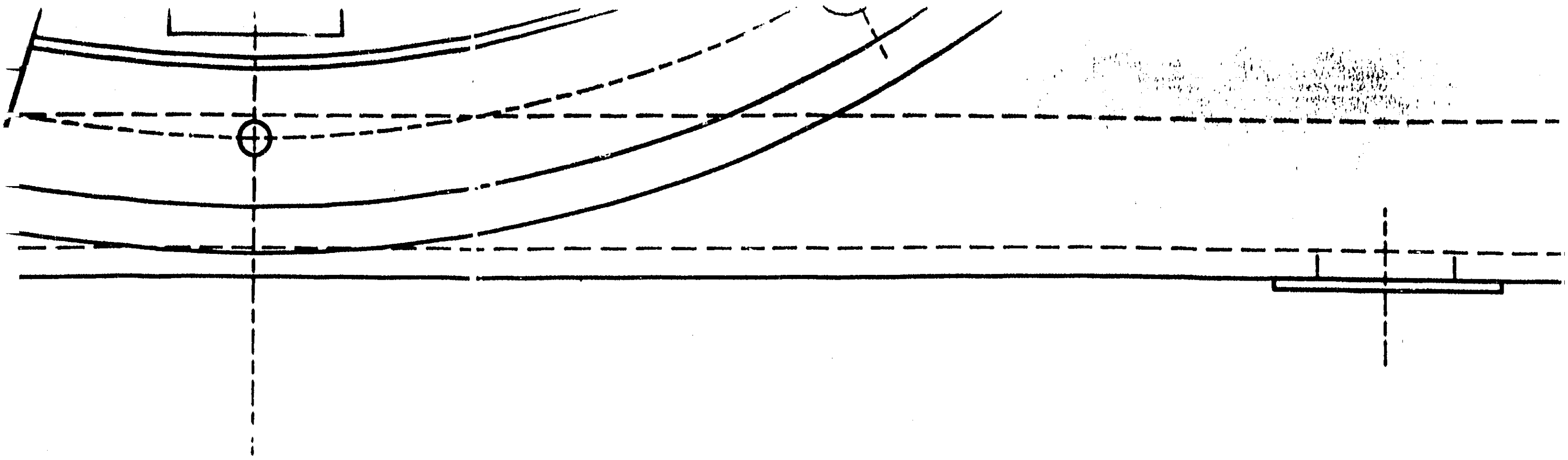
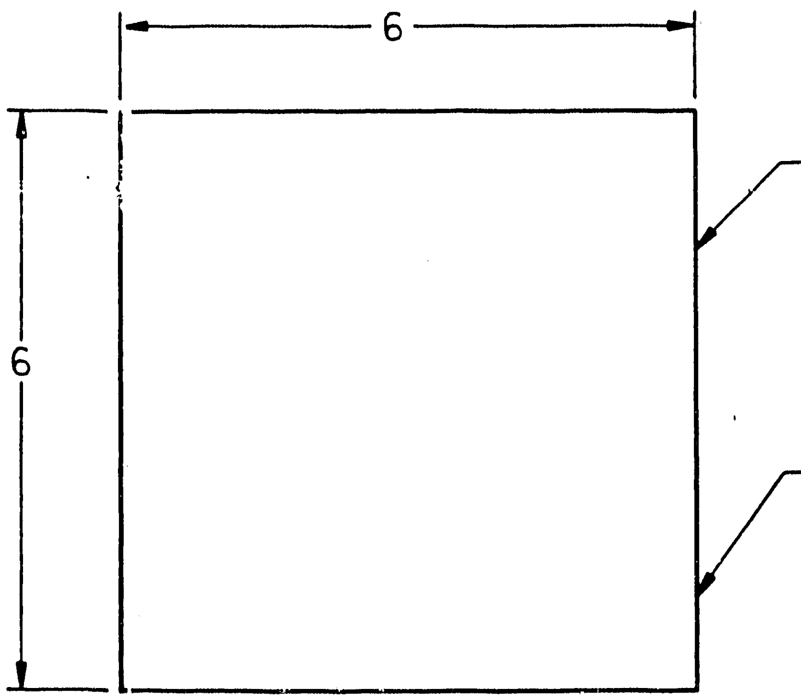

11 GA (.120) SHT. X REQD. LENG
1/2 TYP
3/8 TYP
SPACING BETWEEN LINES 1/4"
DOE USA/9853/AF
HFBR UNIRRADIATED FUEL-
SHIPPING CONTAINER
BROOKHAVEN NATIONAL
LABORATORY,
ASSOCIATED UNIVERSITIES, INC.
DOE-BNL
SERIAL NO. **
MAX. GROSS WT. 590 LBS.
6
DETAIL "A"
17
PACKAGE IDENTIFICATION PLATE
** SERIAL NO. TO BE
SPECIFIED BY CONTAINER OWNER



NGTH



18 SHIPPING LABEL

AV
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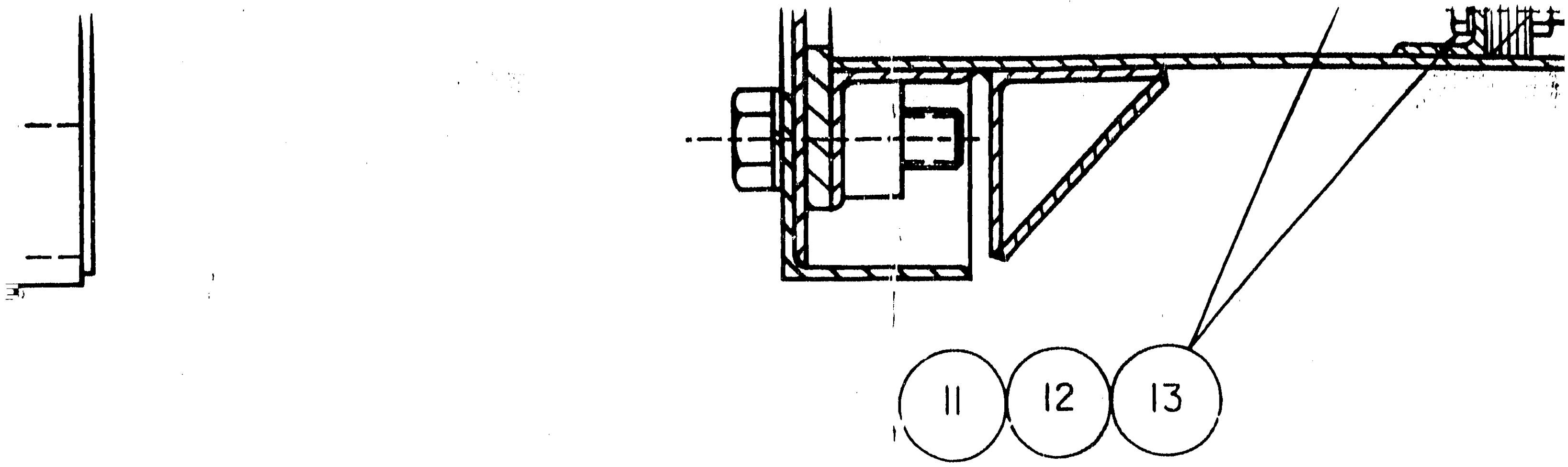


1 UNIRRADIATED FUEL

SCAI

ɪNTAINER BODY, ITEM 8.
ɪUND, 180° FROM
ɪTIFICATION TAG, ITEM 17.

SHEET

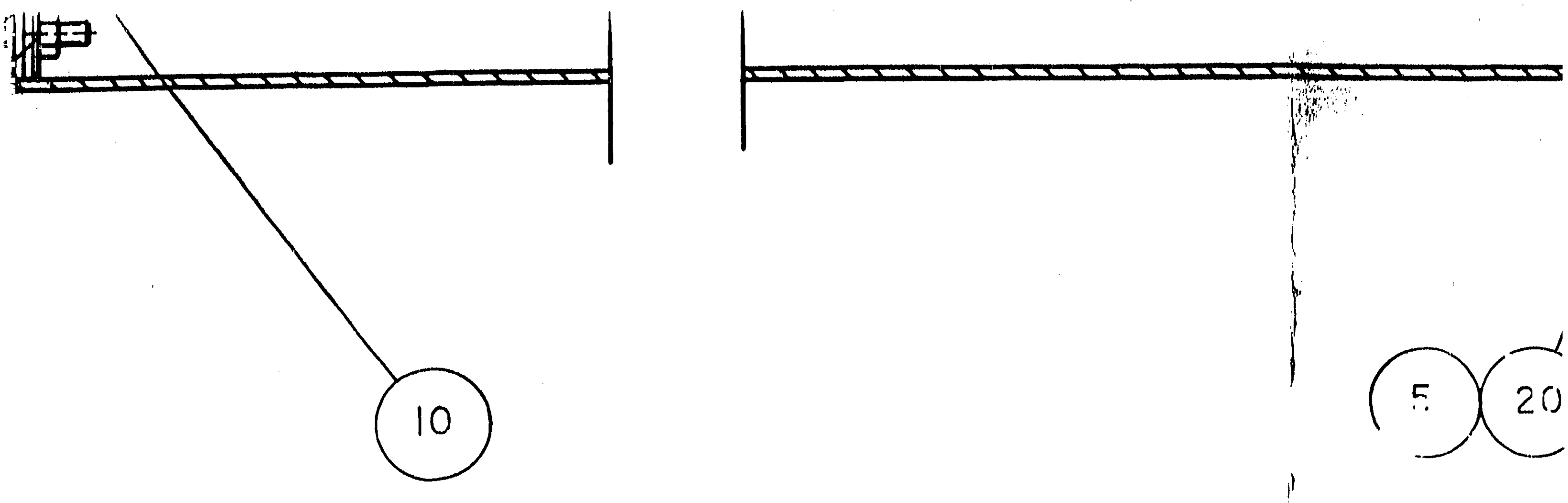
CAUTION

NUCLEAR EQUIPMENT

AVOID CONTACT AND/OR CONTAMINATION WITH MATERIALS CONTAINING: COPPER, SILVER, LEAD, (ALL SOLDERS), MERCURY, THORIUM, URANIUM, CHLORINE, FLUORINE, GRAPHITE, ______________

____

ANY SUCH CONTAMINATION MUST BE REMOVED.



:L ELEMENT SHIPPING CONTAINER

:ALE: 1/2" = 1"

NOTE: LICEN
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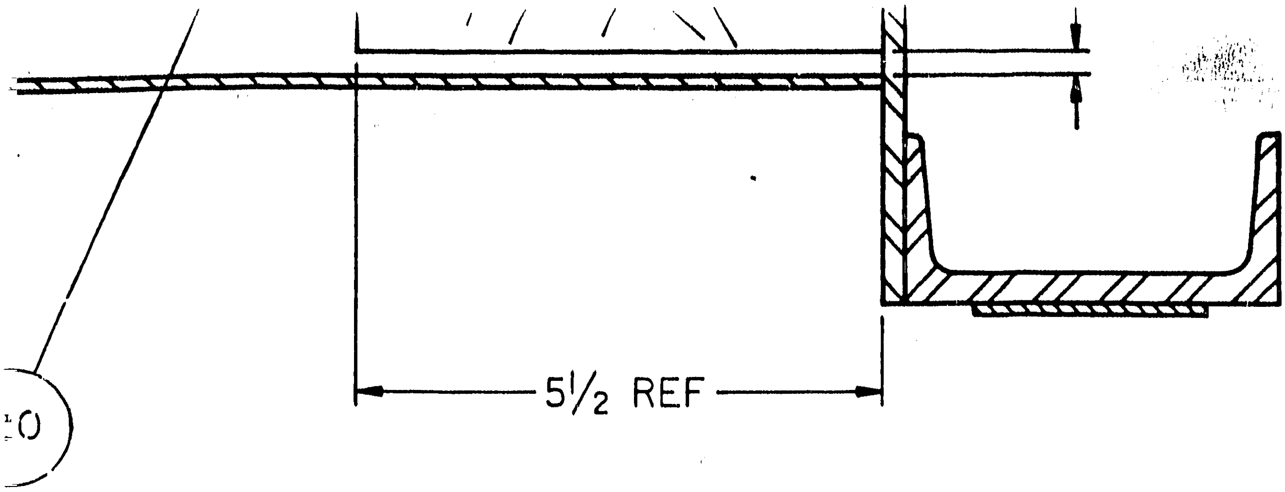
NO.		REVISIONS

SECTION-

	GENERAL SPECIFICATIONS	TOLERANCES UNLESS OTHERWISE SPECIFIED
:DE ARATUS, :RINGE :T TO :Y : IN THESE :RMA- :D ARE ACTOR.	UNLESS OTHERWISE SPECIFIED 1. BREAK ALL SHARP EDGES. 2. FILLETS TO BE — MAX. 3. MACHINED SURFACE FINISH SHALL NOT EXCEED: —√ (ANSI Y14.5M - 1982)	FRACTIONS ± 1/8 DECIMALS — ANGLES — SCALE: 1/2" = 1".

DRAWN	DATE	DETAIL DESIGN	D
B.T. LAWRENCE	10-3-91		
CONCEPT DES	DATE	APPROVED	D
		R Horne	10/
CHECKED	DATE	APPROVED	D
C.E. Dinkins	10/23/91		



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REFERENCE DRAWINGS	NUMBER
UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER NOTES - BNL	M-11518-ØH-003-D
UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER DETAILS - BNL	M-11518-ØH-002-E

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA — MARTIN MARIETTA ENERGY SYSTEMS, INC.

operated for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC-05-84OR21 400 eng 26
Oak Ridge, Tennessee • Paducah, Kentucky

FACILITY B.N.L. BLDG. NO.

DRAWN	APPD.	APPD.
BTL	JTM	JTM
CED	SEB	10-24-91
CHECKED	APPD.	DATE

UNIRRADIATED FUEL ELEMENT
SHIPPING CONTAINER ASSEMBLY
BROOKHAVEN NATIONAL LABORATORY
USA/9853/AF

DATE		DATE
DATE 7/24/91		DATE
DATE	EXP. REVIEW	DATE

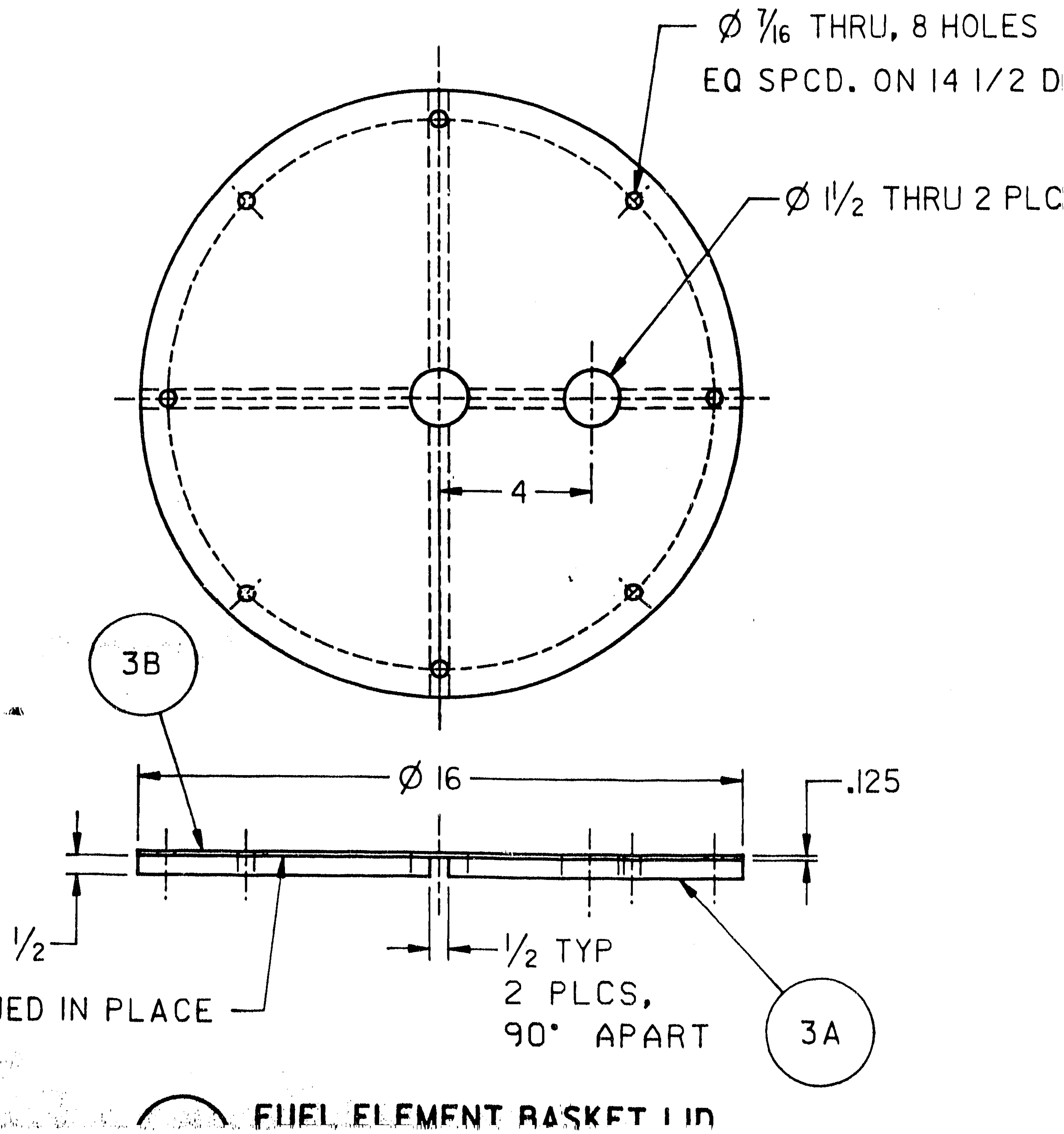
SUBMITTED	REQUESTOR	FACILITY APPROVAL
J. T. Muecke	Larry B. Proctor	J. T. Muecke for BNL

SEBurnett 10/24/91 | M | 11518 | ØH | 001 | E | REV. 0

PARTS LIST

PART	REQD.	DESCRIPTION
3	1	FUEL ELEMENT BASKET LID
3A	1	NEOPRENE SPACER, 16 DIA X 1/2 THK.
3B	1	SHEET, 6061-T6 AL, 16 DIA X .125 THK.

NOTE:
NEOPRENE SPACER SLOTTED 1/2 WIDE SO THAT THE BASKET CAN NOT BECOME PRESSURIZED.



FUEL ELEMENT BASKET LID

S

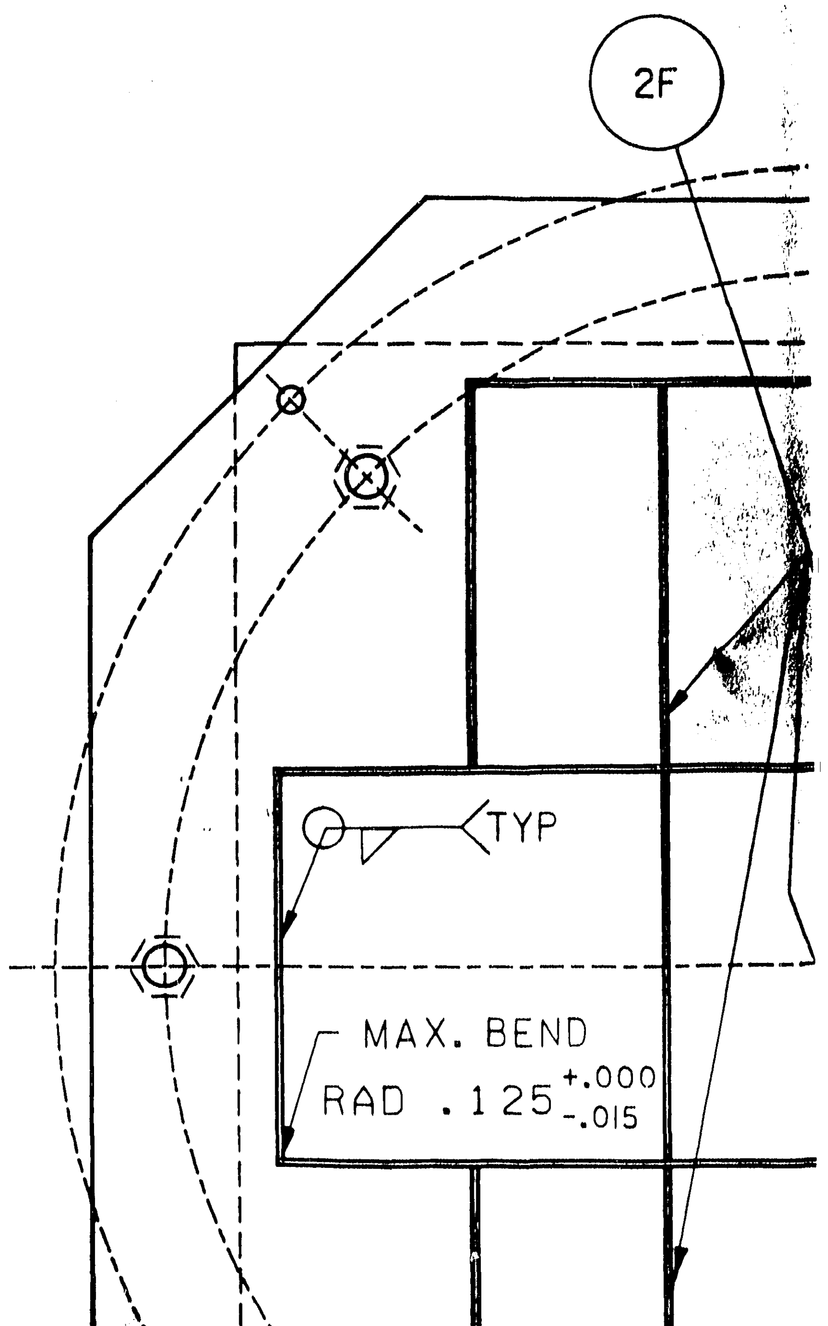
: DIA B.C.

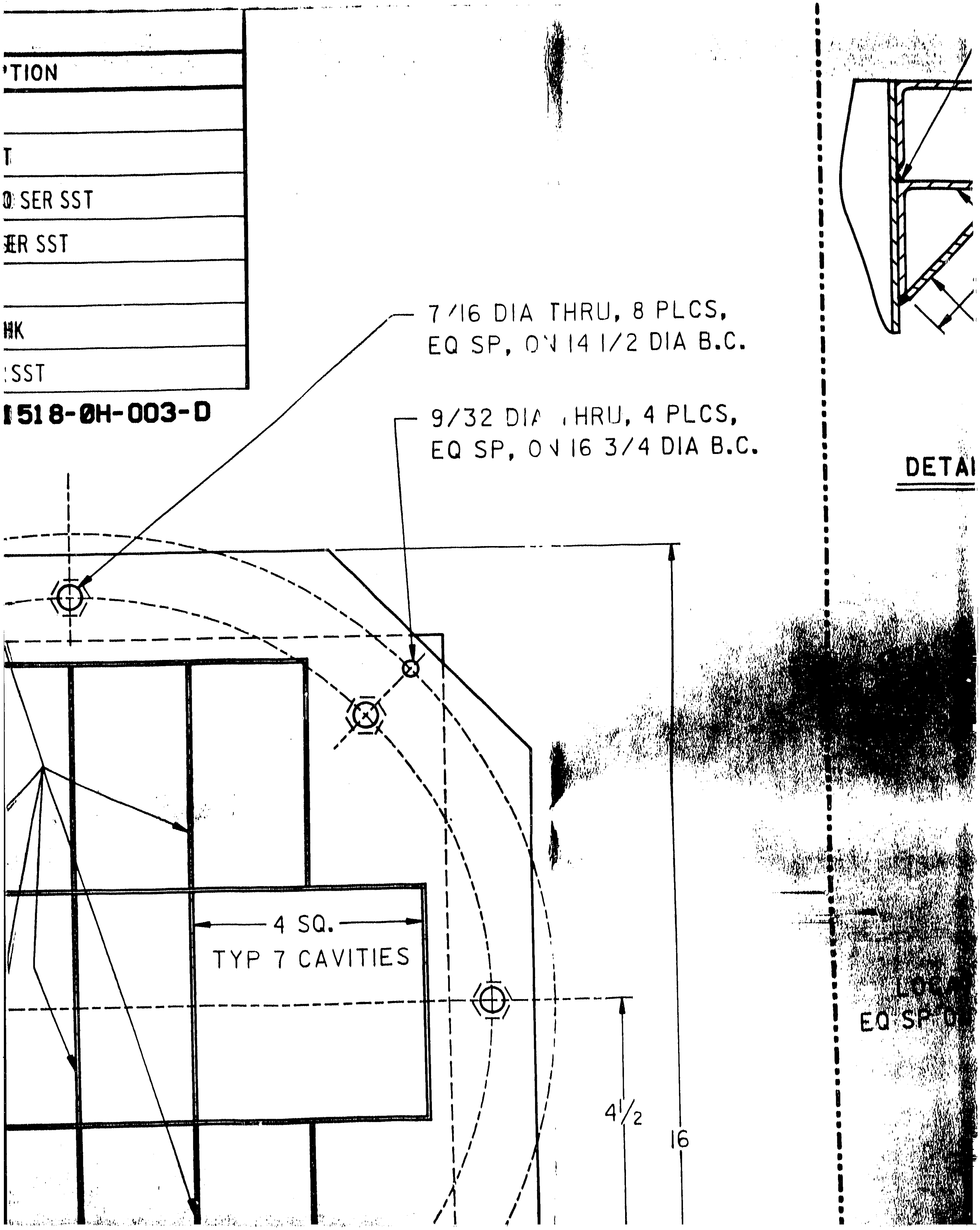
LCS

PARTS LIST

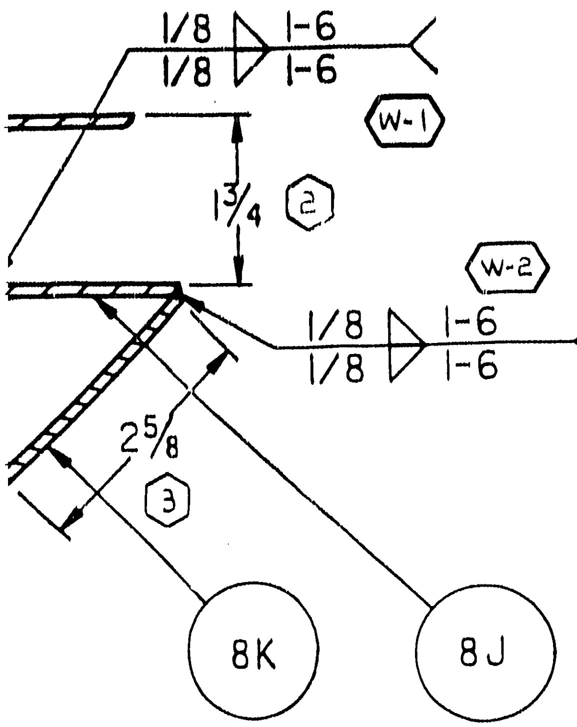
PART	REQD.	DESCRIPTI(
2	1	FUEL ELEMENT BASKET
2A	AS REQD	BASKET SHELL, 16 GA, 300 SER SST
2B	1	BOTTOM PLATE, 13" SQ. X 11 GA, 300 SE
2C	1	TOP PLATE, 16" X 16" X 11 GA, 300 SER
2D	8	NUT, 3/8-16UNC-2B, 300 SER SST
2E	7	NEOPRENE SPACERS, 4 X 4 X 1/2 THK
2F	5	BARRIER, 4 X 1/2 X 16 GA, 300 SER SST

SEE NOTES 1 & 2, DWG. NO. M-1151

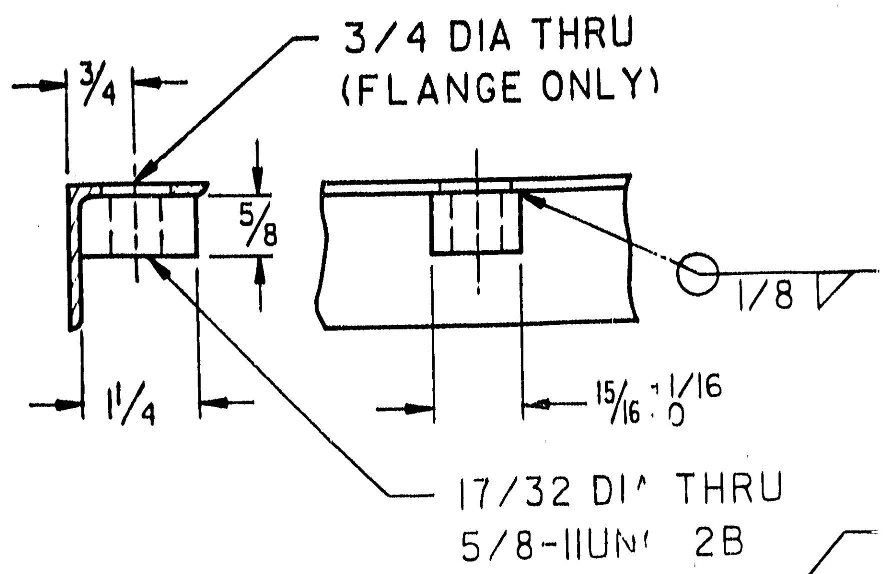




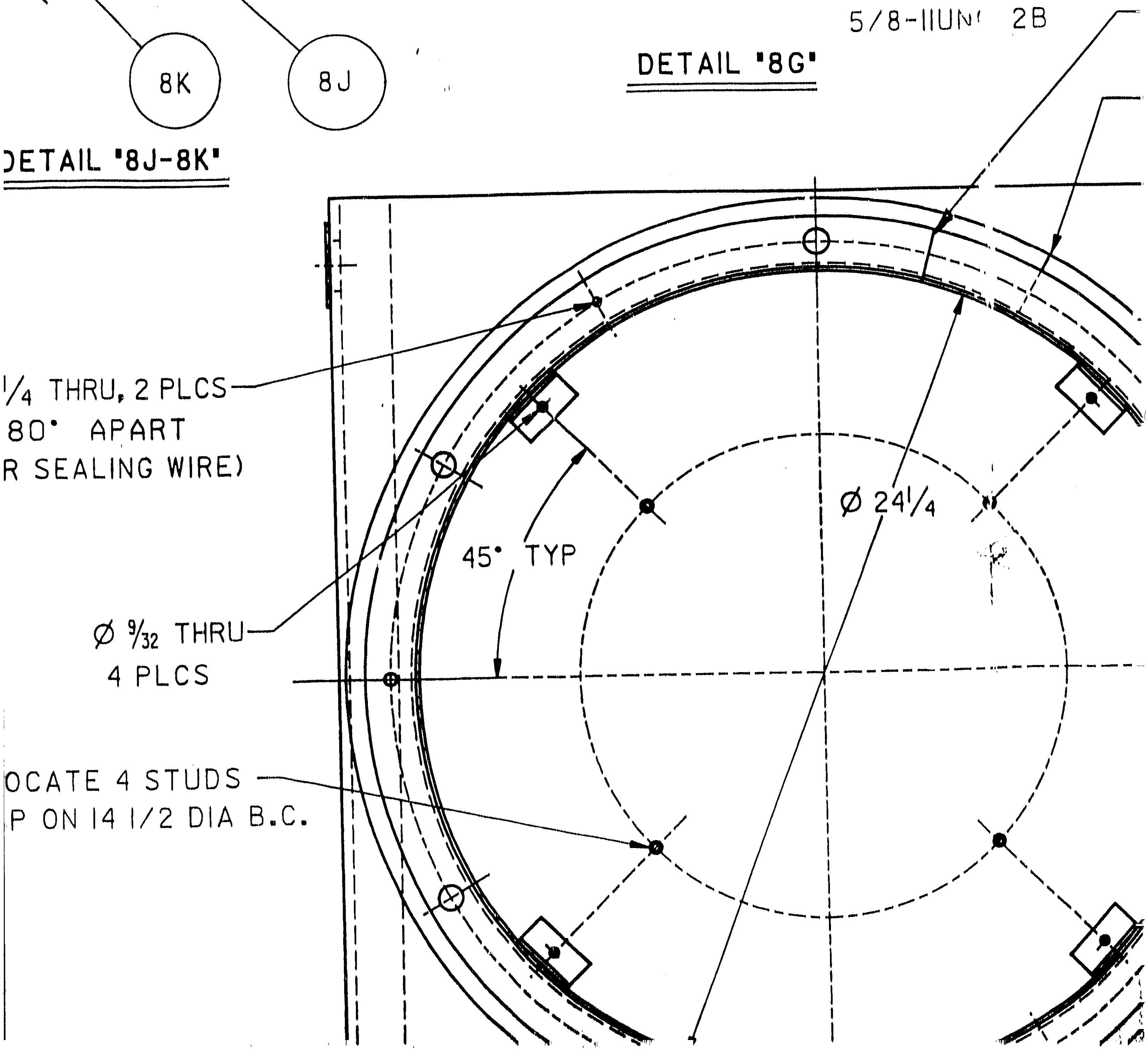
TION
SER SST
ER SST
SST
518-0H-003-D
7/16 DIA THRU, 8 PLCS, EQ SP, ON 14 1/2 DIA B.C.
9/32 DIA THRU, 4 PLCS, EQ SP, ON 16 3/4 DIA B.C.
4 SQ.
TYP 7 CAVITIES
4½
16



DETAIL "8J-8K"

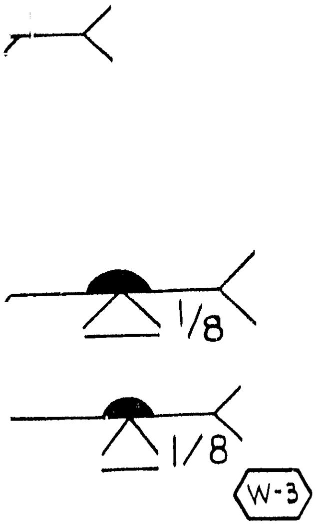


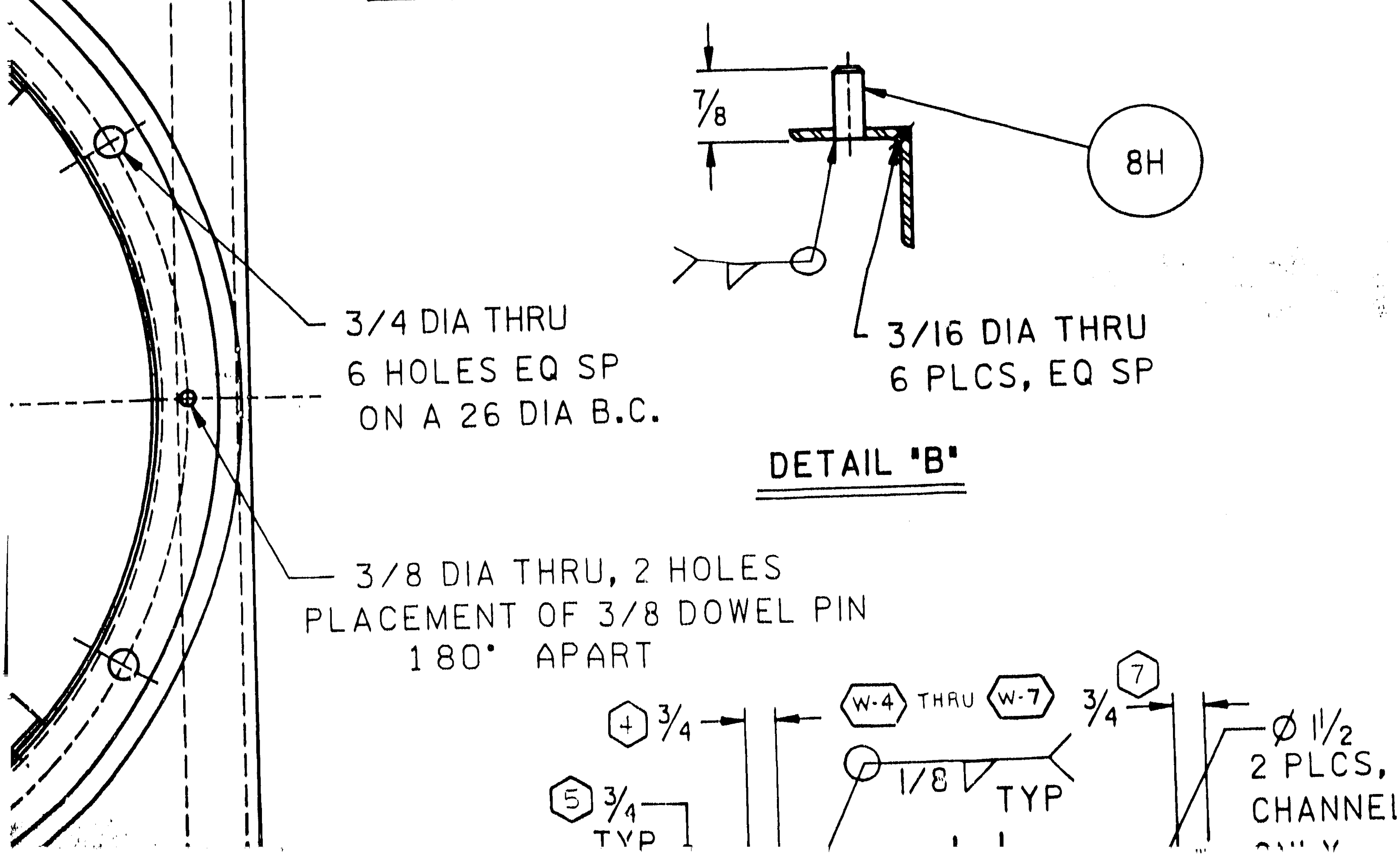
DETAIL "8G"



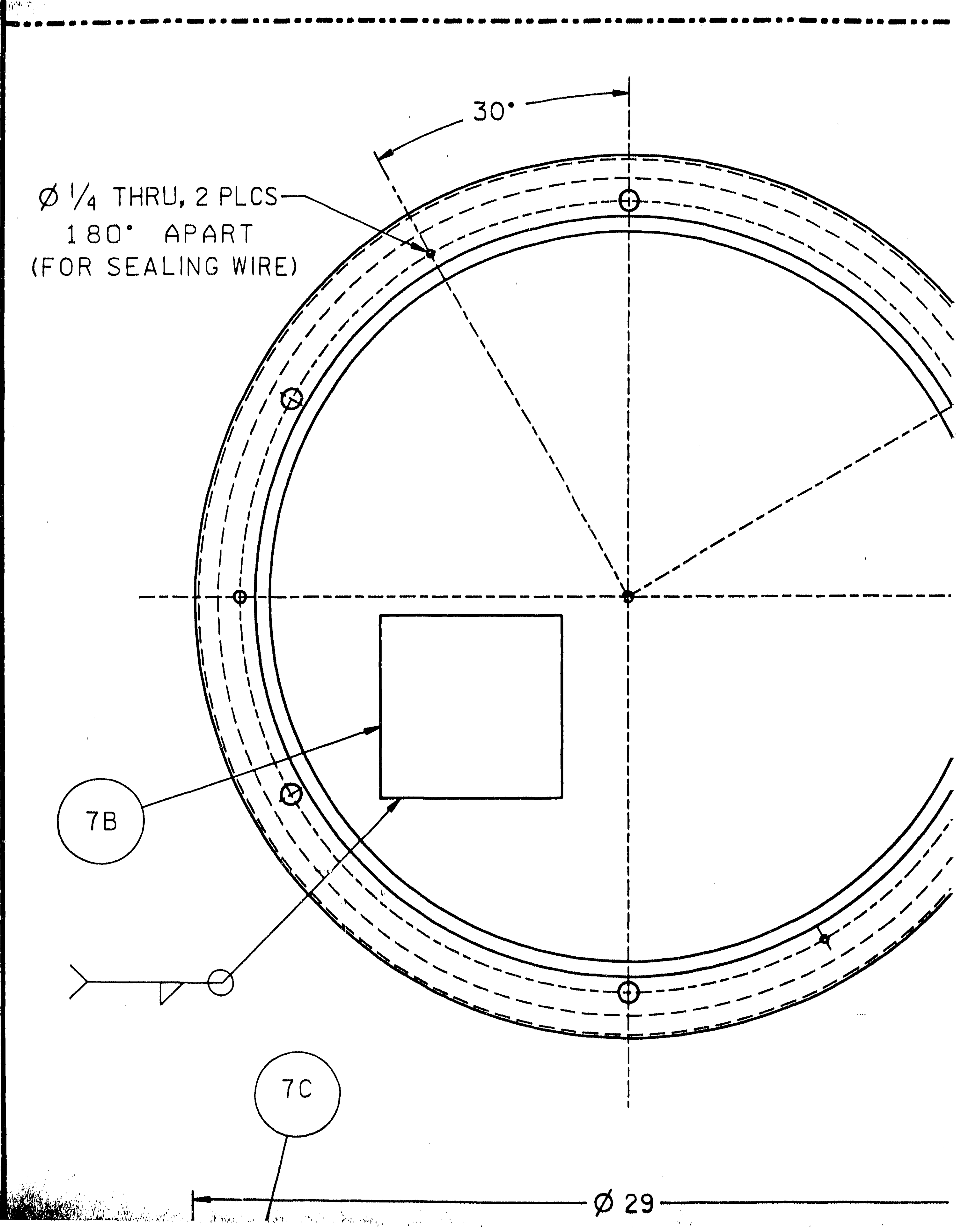
PARTS LIST

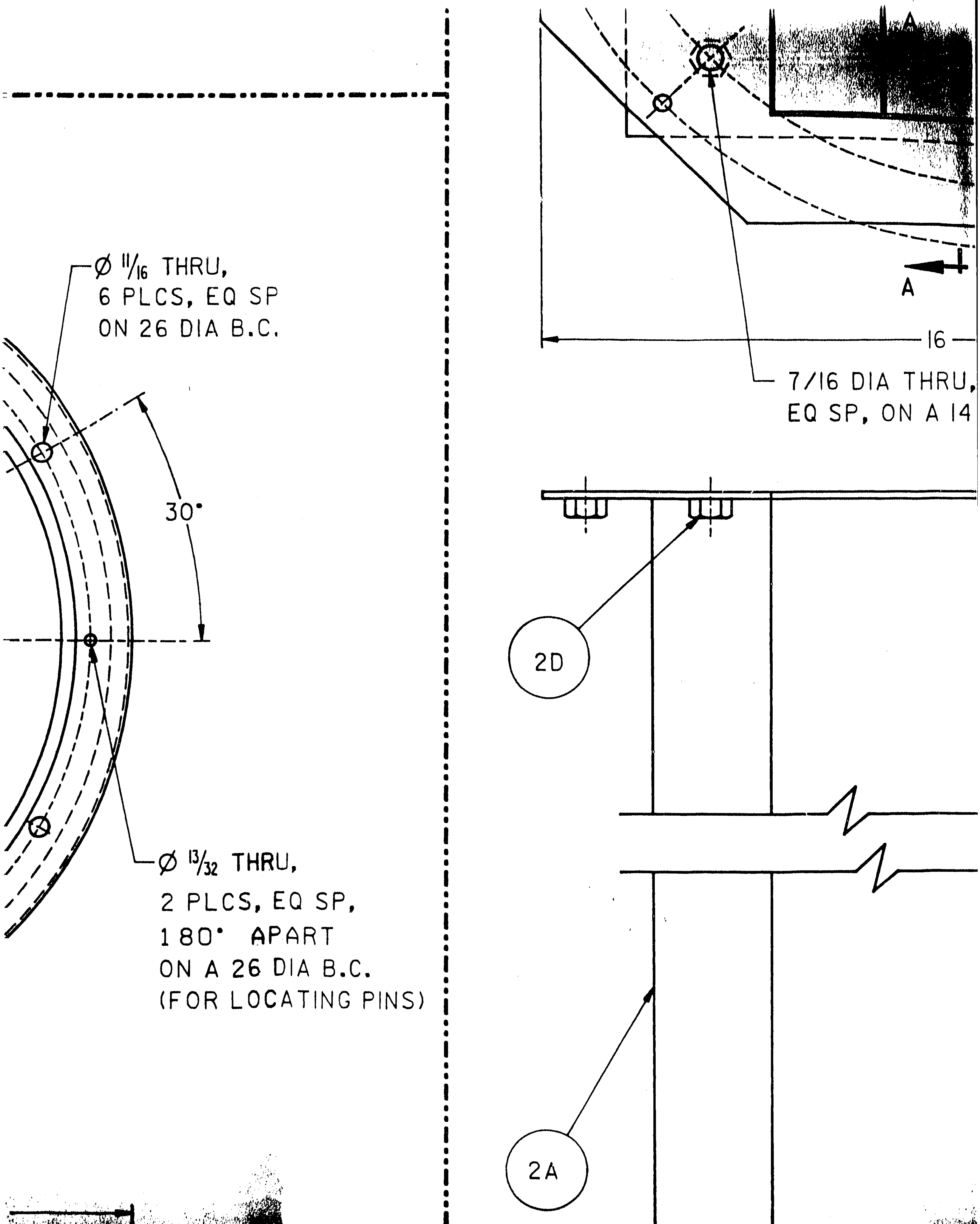
PART	REQD.	DESCRIPTION
8	1	UNIRRADIATED SHIPPING CONTAINER BODY
8A	1	OUTER SHELL, 71 X 80 X 11 GA, 300 SER SST
8B	1	CLOSURE LIP, ∠ 1 1/2 X 1 1/2 X 1/8 X 80, 300 SER SST
8C	1	BOTTOM PLATE, 29 X 29 X 1/4, 300 SER SST
8D	2	CHANNELS, 4 X 1 3/4 X 29 LG @ 7.25, 300 SER SST
8E	4	SPACER CLIPS, ∠ 1 X 1 X 1/8 X 2 LG, 300 SER SST
8F	4	THREADED STUDS, 3/8-16UNC-2A X 11 1/2 LG, 300 SER SST
8G	6	NUT, 5/8 THK CARBON STL PLATE, ASTM A516 GRADE 60
8H	2	DOWEL PIN, 3/8 X 7/8 LG, 300 SER SST
8J	1	ANGLE, 2 X 2 X 1/8 X 83 1/4 LG, 300 SER SST
8K	1	SHEET, 11 GA X 2 5/8 X 89 1/2, 300 SER SST
8L	4	SHEET, 11 GA X 2 1/2 SQ., 300 SER SST
8M	1	SHEET, 11 GA X 4 X 28 3/4, 300 SER SST



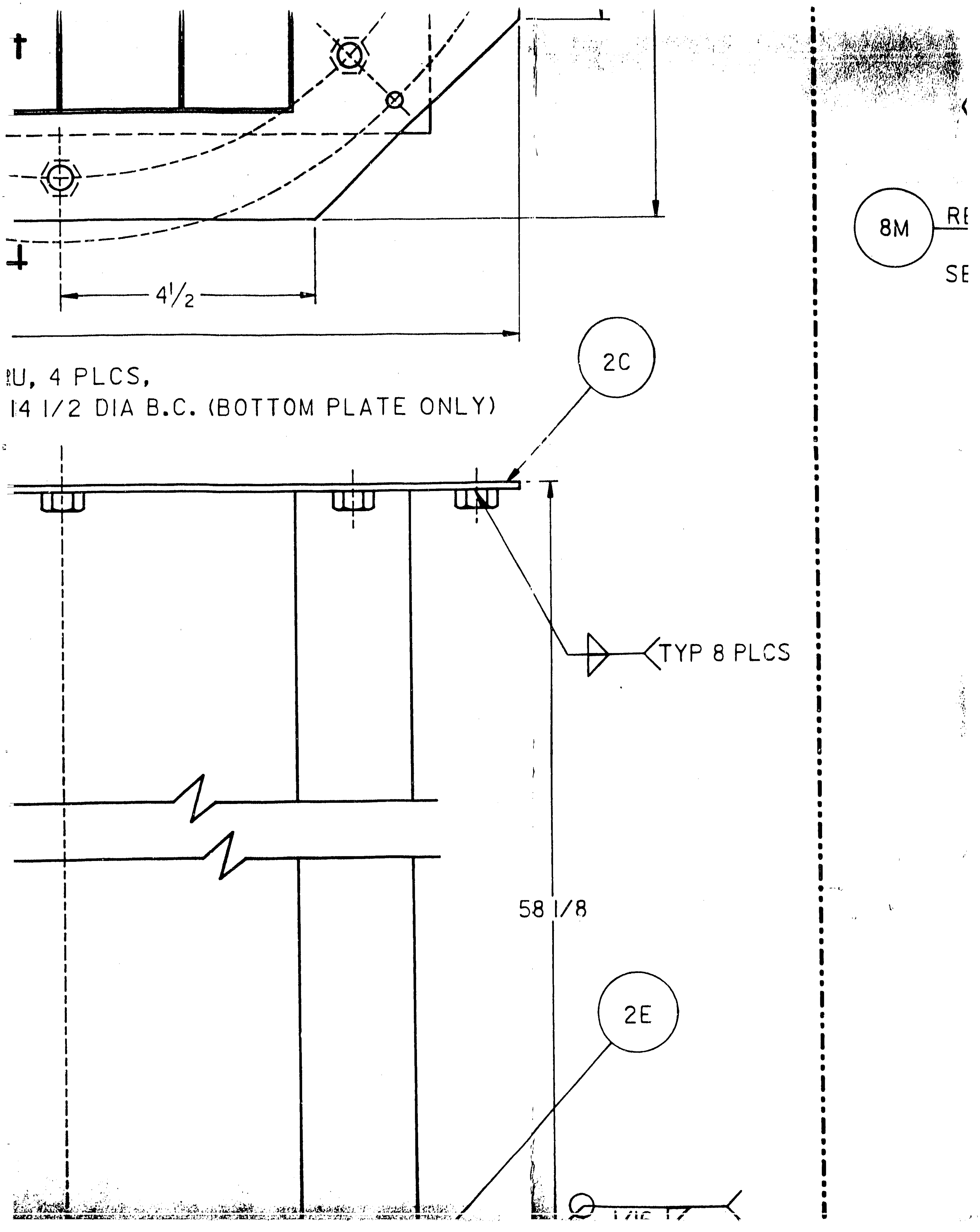


SCALE: 1/4" = 1"

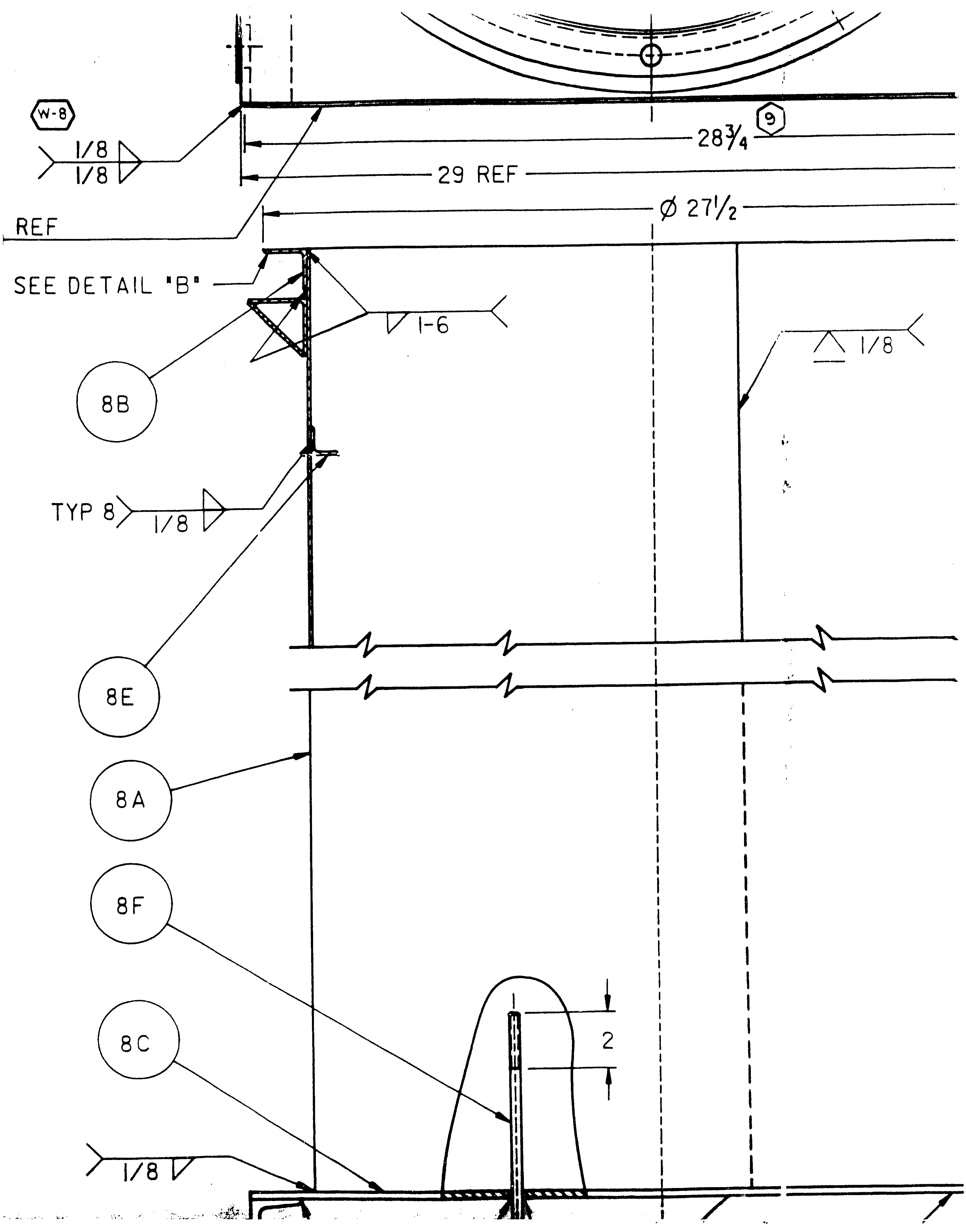




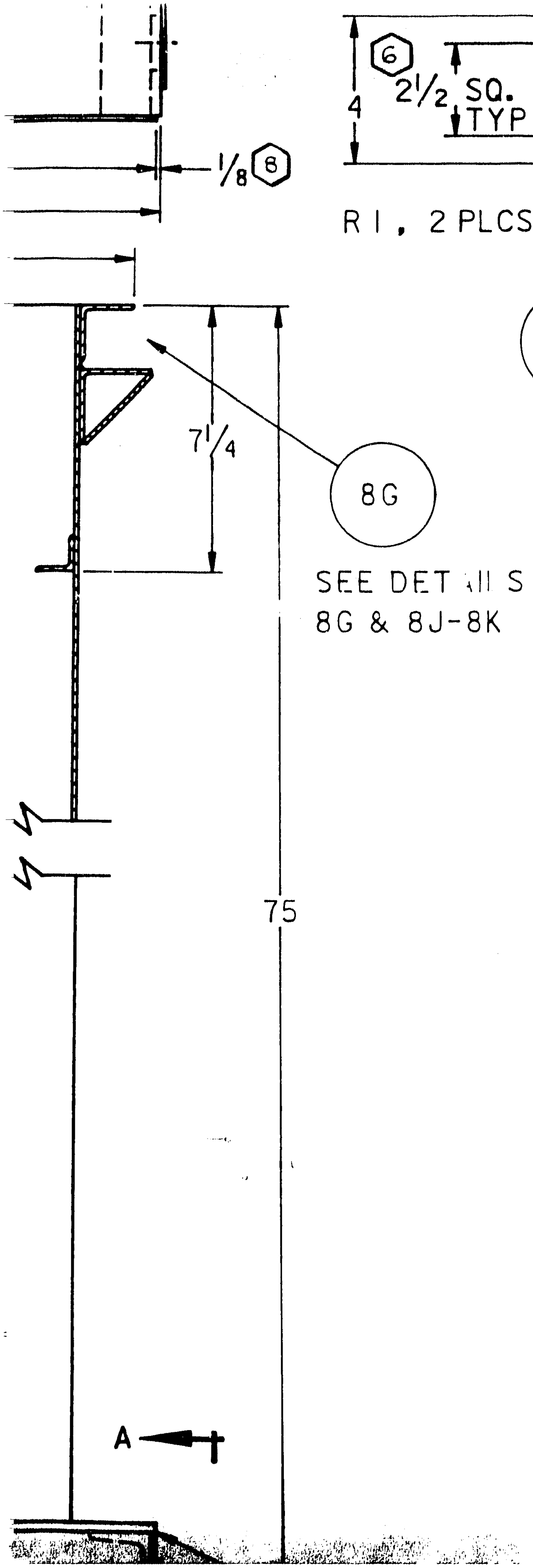
Ø 11/16 THRU,
6 PLCS, EQ SP
ON 26 DIA B.C.
30°
Ø 13/32 THRU,
2 PLCS, EQ SP,
180° APART
ON A 26 DIA B.C.
(FOR LOCATING PINS)
A
A
16
7/16 DIA THRU,
EQ SP, ON A 14
2D
2A

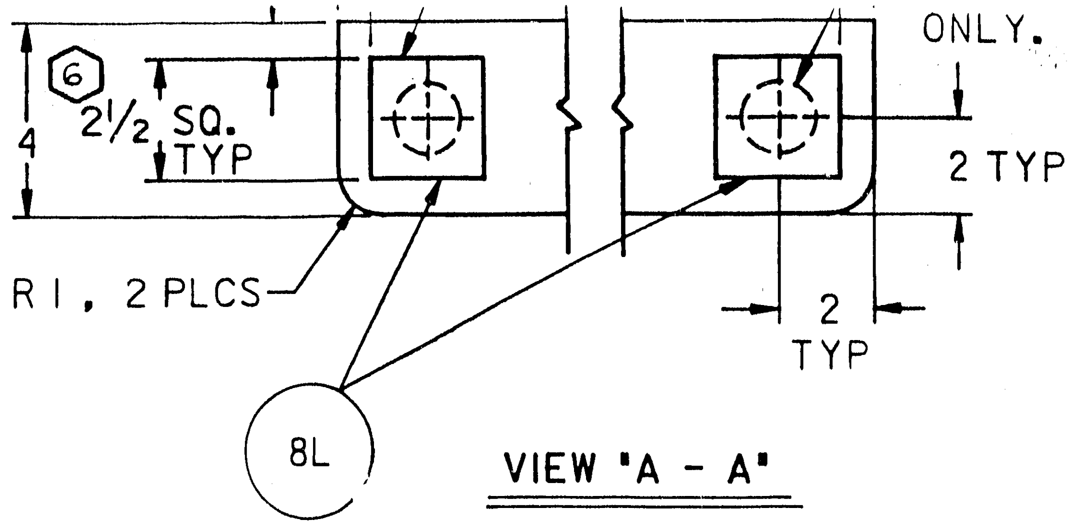


!U, 4 PLCS,
14 1/2 DIA B.C. (BOTTOM PLATE ONLY)



W-8
1/8
1/8
9
28 3/4
29 REF
Ø 27 1/2
REF
SEE DETAIL "B"
1-6
1/8
8B
TYP 8
1/8
8E
8A
8F
2
8C
1/8





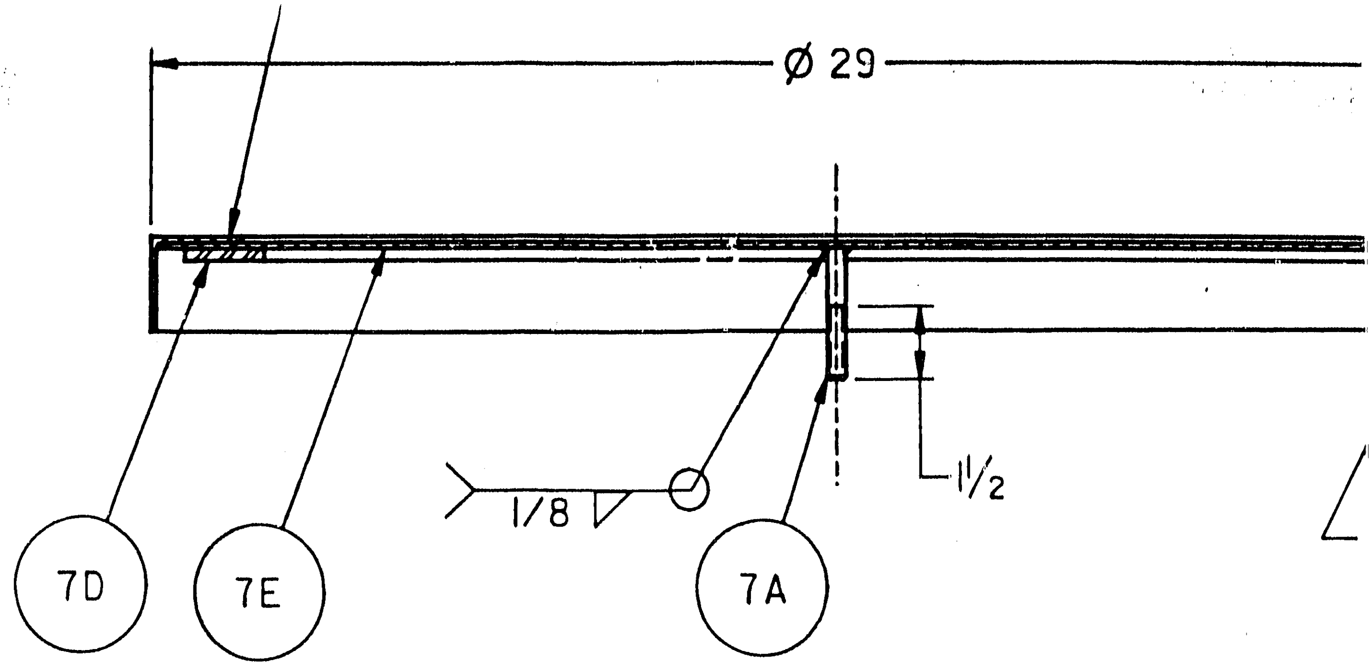
NOTE: LICENSING RESTRICTIONS APPLY

SEE DRAWING M-11518-ØH-003-D, REV. 0, FOR NOTES AND EXACT MATERIAL DESIGNATIONS

QUALITY VERIFICATION

MECHANICAL AND STRUCTURAL
REFERENCE ORNL QV-001

QV CLAUSE	DOCUMENTS REQUIRED	APPLICABLE TO SPEC NO.*
303	MATERIAL MILL TEST REPORT(CERT)	
325	MATERIAL SELLER CERT	✓ SEE NOTE 5
326	SPECIAL MATERIAL INSP REPORT	
205	MFG INSP AND TEST PLAN	
312	FIELD INSP & TEST PLAN	
321	WELD AND BRAZE INSP REPORT	✓ SEE NOTE 8
322	HEAT TREAT REPR(W/CHART)	
310	LEAK TEST REPORT	
315	CLEANING CERT	
318	DEVIATION REQUEST	✓
319	NONCONFORMANCE REPORT	✓
323	DIMENSIONAL REPORT	✓ SEE NOTE 8
330	FUNCTIONAL TEST REPORT	✓ SEE NOTE 1

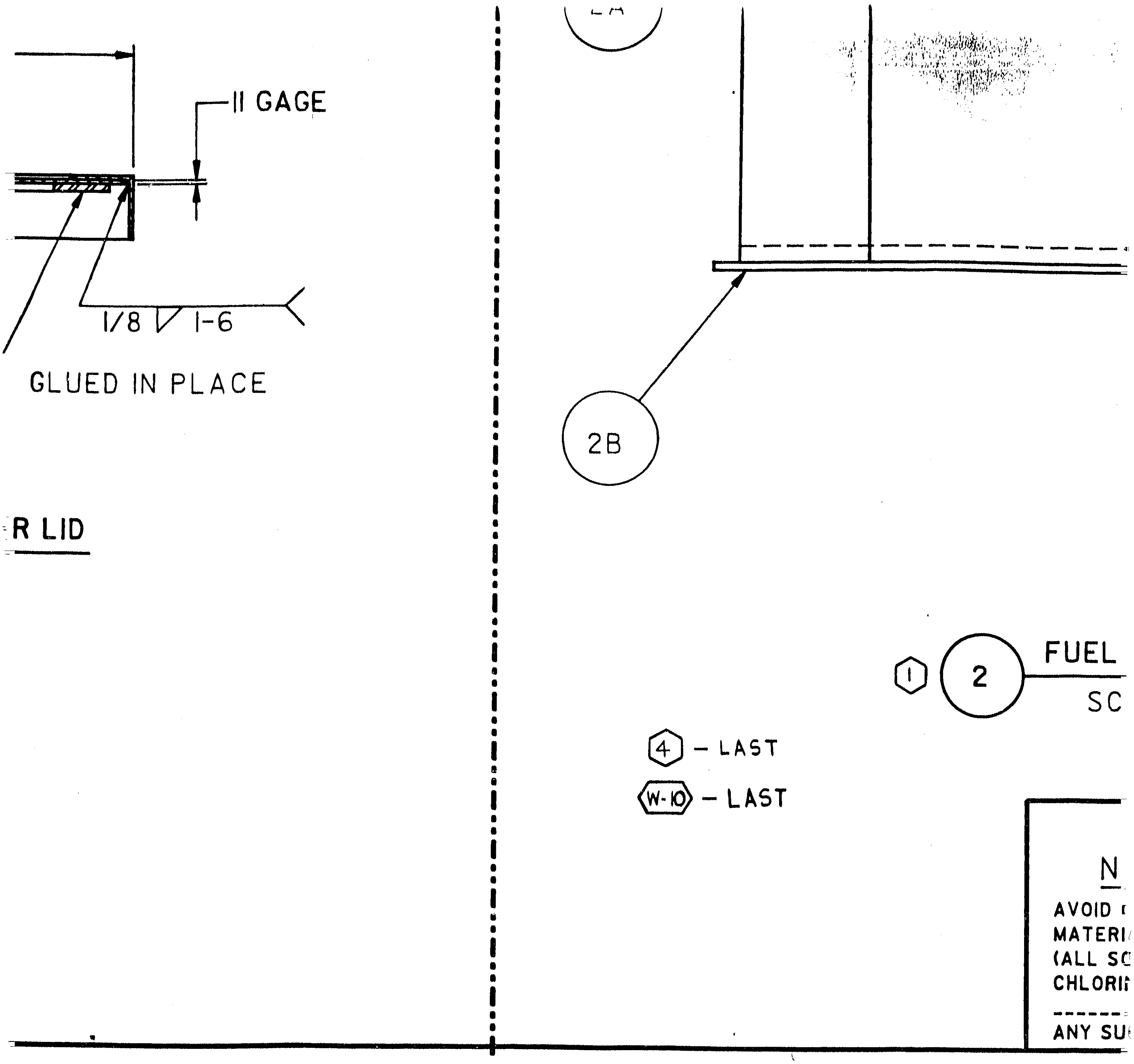


UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINE

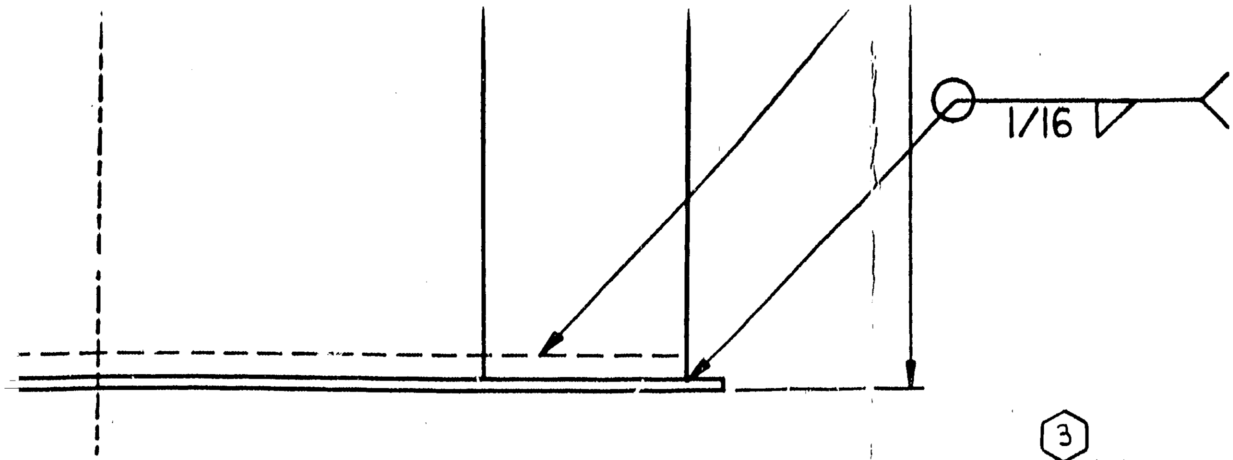
7

SCALE: 1/4" = 1"

PARTS LIST		
PART	REQD.	DESCRIPTION
7	1	UNIRRADIATED FUEL ELEMENT SHIP. CONTAINER LID
7A	1	STUD, 3/8-16UNC-2A X 2 3/4 LG, 300 SER. SST
7B	1	SHIPPING LABEL, 6 X 6 X 11 GA SHT., 300 SER. SST
7C	2	LID LIP, ∠ 2 X 2 X 1/8 THK, 300 SER. SST
7D	2	GASKET, 27 1/2 O.D. X 24 I.D. X 1/4 THK, NEOPRENE
7E	1	SHEET STEEL, 11 GA X 28 3/4 DIA, 300 SER. SST

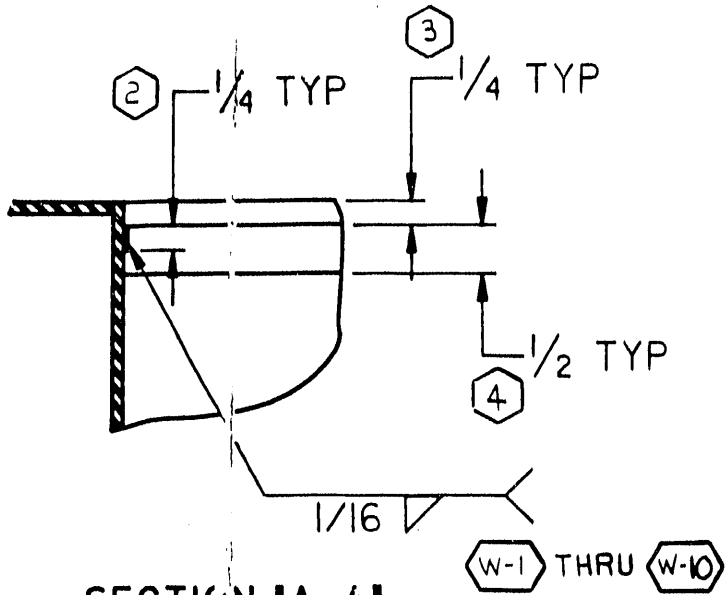


11 GAGE
1/8 1-6
GLUED IN PLACE
R LID
2B
FUEL
SC
1
2
4 – LAST
W-10 – LAST
N
AVOID
MATERI
(ALL SC
CHLORI
ANY SU



EL ELEMENT BASKET

SCALE: 1/2" = 1"



SECTION "A-A"
TYP

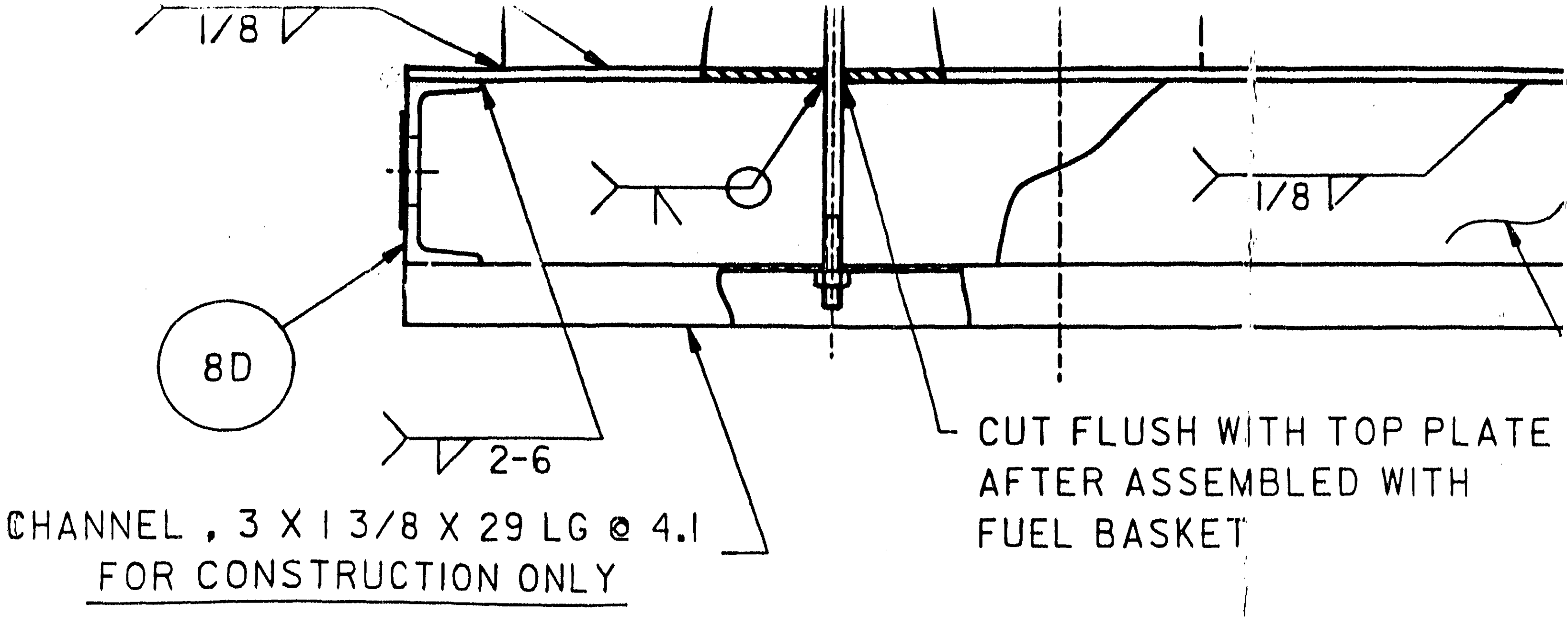
CHA

*BOLT &
BE 1/6

CAUTION
NUCLEAR EQUIPMENT

OID CONTACT AND/OR CONTAMINATION WITH
TERIALS CONTAINING: COPPER, SILVER, LEAD,
L SOLDERS), MERCURY, THORIUM, URANIUM,
.ORINE, FLUORINE, GRAPHITE, ______________
____
Y SUCH CONTAMINATION MUST BE REMOVED.

NO REPRESENTATION OR WARRANTY, EXPRESSED OR IMPLIED, IS MADE THAT THE USE OR DISCLOSURE OF ANY INFORMATION, APPARATUS, METHOD OR PROCESS DISCLOSED IN THESE DRAWINGS MAY NOT INFRINGE PRIVATE RIGHTS OF OTHERS. NO LIABILITY IS ASSUMED WITH RESPECT TO THE USE OF, OR FOR DAMAGES RESULTING FROM THE USE OF, ANY INFORMATION, APPARATUS, METHOD OR PROCESS DISCLOSED IN THES DRAWINGS. THE DRAWINGS ARE BEING MADE AVAILABLE FOR INFORMATION TO BIDDER AND ARE NOT TO BE USED FOR OTHER PURPOSES, AND ARE TO BE RETURNED UPON REQUEST OF THE FORWARDING CONTRACTOR.



(1) (8) UNIRRADIATED SHIPPING CONTAINER BODY

SCALE: 1/4" = 1"

(9) - LAST

(W-8) - LAST

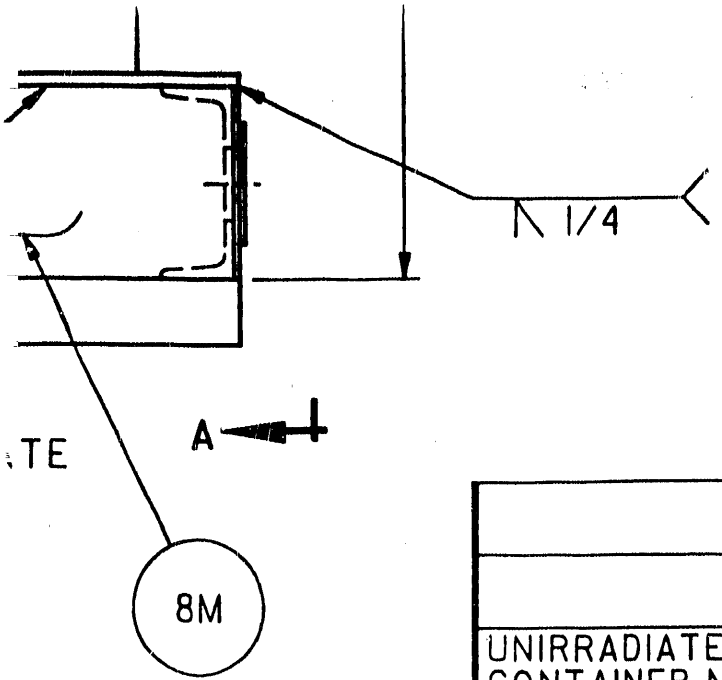
T & DOWEL HOLES SHALL
/64 OF SPECIFIED LOCATION

SECTION-

ATUS, GE IO THESE A- RE TOR.	GENERAL SPECIFICATIONS UNLESS OTHERWISE SPECIFIED 1. BREAK ALL SHARP EDGES. ~~2. FILLETS TO BE MAX.~~ ~~3. MACHINED SURFACE FINISH SHALL NOT EXCEED:~~ ~~(ANSI Y14.5M - 1982)~~	TOLERANCES UNLESS OTHERWISE SPECIFIED FRACTIONS ±1/16 DECIMALS — ANGLES — SCALE: AS NOTED

NO.	REVISIONS
0	SEE DCN #4754

DRAWN	DATE	DETAIL DESIGN	DATE
B.T.LAWRENCE			
CONCEPT DES.	DATE	APPROVED	DATE
		[signature]	10/24/
CHECKED	DATE	APPROVED	DATE
C.E. DINKINS	10/23/91		



319	NONCONFORMANCE REPORT	✓
323	DIMENSIONAL REPORT	✓ SEE NOTE 8
330	FUNCTIONAL TEST REPORT	✓ SEE NOTE 1
100	DOCUMENTATION	✓

• SYMBOL ✓ INDICATES APPLICABLE TO ALL PARTS OR ITEMS

QA COORDINATOR — DATE 10-25-91

REFERENCE DRAWINGS	NUMBER
UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER NOTES - BNL	M-11518-ØH-003-D
UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER ASSEMBLY - BNL	M-11518-ØH-001-E

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA — MARTIN MARIETTA ENERGY SYSTEMS, INC.

operated for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC-05-840R21 400 eng 26

Oak Ridge, Tennessee • Paducah, Kentucky

FACILITY B.N.L. BLDG. NO.

UNIRRADIATED FUEL ELEMENT
SHIPPING CONTAINER DETAILS
BROOKHAVEN NATIONAL LABORATORY
USA/9853/AF

BTL	JTM	JTM
CED	SEB	10-24-91
DRAWN	APPD.	APPD.
CHECKED	APPD.	DATE

DATE		DATE	
DATE 10/24/91		DATE	
DATE	EXP. REVIEW	DATE	

SUBMITTED	REQUESTOR	FACILITY APPROVAL
J. T. Muecke	Larry D. Proctor	J. T. Muecke for BNL

S.E. Barnett	M	11518	ØH	002	E	REV.	0

NOTE:

1. FUNCTIONAL ACCEPTANCE CRITERION
THE FUEL ELEMENT BASKET ASSEMBLY (PART NUMBER 2) W
ASSEMBLED AND CENTERED IN THE SHIPPING CONTAINER BO
TION BAR 3 15/16±1/16 INCHES SQUARE AND A STRAIGHTNE
FULL LENGTH OF 40 IN. CAN BE FREELY INSERTED AND W
ONE OF THE 7 FUEL CAVITIES. THE INSPECTION BAR MAY
IUS OF 0.125±.015 IN. DOCUMENTATION IS NOT REQUIRED E

2. FUEL ELEMENT BASKET ASSEMBLY FABRICATION
THE FUEL ELEMENT BASKET ASSEMBLY (PART NUMBER 2) M
BINATION OF FORMED (BENT) SHAPES AND WELDED JOINTS
THE SEAMS SHALL BE JOINED BY WELDS OF 1/2 IN. LONG
THE FUNCTIONAL ACCEPTANCE CRITERION SHALL BE PER NO

3. SUGGESTED FUEL BASKET ASSEMBLY PROCEDURE
   A. CROSS TIMBERS (PART NUMBER 14) INSTALLED IN THE (PART NUMBER 8).
   B. THE THREADED RODS, NUTS AND LOCKWASHERS (PART LED AND TIGHTENED ON THE FUEL BASKET ASSEMBLY 2B).
   C. THE FUEL ELEMENT BASKET ASSEMBLY (PART NUMBER PING CONTAINER BODY (PART NUMBER 8) WITH THE TH 8F) PASSING THROUGH THE HOLES IN THE SHIPPING C (PART NUMBER 8C).
   D. THE PHENOLIC SPACERS (PART NUMBER 10) WILL BE I ELEMENT BASKET UPPER PLATE (PART NUMBER 2C) AN ON THE INNER SURFACE OF THE CONTAINER. THE HOL WILL BE ADJUSTED TO LOCATE THE FUEL ELEMENT B CONTAINER BODY WITHIN ±1/16 IN.
   E. THE THREADED ROD (PART NUMBER 8F) AT THE BOTTO BE TENSIONED THROUGH THE CHANNEL FIXTURE (SEE I ING A 10 FT/LB TORQUE. THE THREADED RODS WILL NEL FIXTURE REMOVED, THE WELDS COMPLETED AND F BE REMOVED AND THE BOTTOM PLATE GROUND SMOOTH

4. WELDS
   A. WELDING AND INSPECTION OF WELD JOINING STAINLES
   ALL WELDS SHALL BE PERFORMED ACCORDING TO THE PROCEDURE AND IN ACCORDANCE WITH THE WELD SYM DRAWINGS. THE FABRICATOR SHALL QUALIFY ALL WEL ... WITH SECTION IX OF THE AMERICAN SOCIET

WILL BE ACCEPTABLE IF, WHEN
BODY (PART NUMBER 8) AN INSPEC-
NESS OF 1/32 IN. OVER ITS
WITHDRAWN FROM EACH AND EVERY
Y HAVE A MAXIMUM CORNER RAD-
EXCEPT AS NOTED IN NOTE NO. 8.

MAY BE FABRICATED BY A COM-
S AT THE FABRICATOR'S OPTION.
5 ON 4 IN. CENTERS OR EQUAL.
NOTE 1.

E SHIPPING CONTAINER BODY

NUMBERS 8F, 5 AND 20) INSTAL-
BOTTOM PLATE (PART NUMBER

R 2) LOWERED INTO THE SHIP-
THREADED RODS (PART NUMBER
CONTAINER'S BOTTOM PLATE

INSTALLED BETWEEN THE FUEL
ND THE CLIP (PART NUMBER 8E)
ILES IN THE PHENOLIC SPACERS
BASKET IN THE CENTER OF THE

OM OF THE CONTAINER BODY WILL
DWG. M-11518-0H-002-E) BY APPLY-
BE TACK-WELDED, THE CHAN-
FINALLY THE EXCESS RODS WILL
H.

SS STEEL TO STAINLESS STEEL
E PROVISIONS OF A QUALIFIED
MBOLS ON THE FABRICATION
[illegible] PROCEDURES USED IN AC-
[illegible]F MECHANICAL ENGINEERS

5. MATERIALS
   A. LUMBER SHALL BE D
      LESS, NO. 2 OR BET
   B. STAINLESS SHEET P
      ANNEALED. (PART NO
   C. STAINLESS PLATE P
   D. ALUMINUM SHEET, AA
   E. STAINLESS STEEL B
      ROLLED, ANNEALED A
   F. SCREW, ALLOY STEE
      (PART NO.'S 4 & 11)
   G. NUT, STAINLESS STE
   H. SHEET, PHENOLIC LA
      WOVENGLASS, FABRI
      (PART NO. 10)
   I. SHEET NEOPRENE, 50
   J. SCREW, STAINLESS S
   K. CARBON STEEL PLAT
      (PART NO. 8G)

6. FOAM FILLING
   FOAM FILLING SHALL BE
   IFICATION JS-31536-1 A
   A. FILL THE TOP SECTI
      USING A MOLD OF SP
      LB ± 10%.
   B. FILL THE BOTTOM S
      TWO APPROXIMATELY
      SHAPED BY FOAMING
      TION SHALL BE 45 L
      TION OF MATERIALS
      R.R. WRIGHT, MARCH

JS-31536-1
ORIGINAL

DOUGLAS FIR OR SOUTHERN PINE, WITH MOISTURE CONTENT 18% OR
TTER GRADE. THE PLYWOOD MAY BE ANY GRADE. (PART NO.'S 9. 14 & 16)

PER ASTM A240 OR A167, TYPE 304, 304L, OR 347 HOT FINISHED AND
NO.'S 2A, 2B, 2C, 2F, 7B, 7E, 8A, 8K, 8L, 8M, 17 & 18)

PER ASTM A240, TYPE 304 OR 347 HOT ROLLED. (PART NO. 8C)

AA2024-T4 OR 6061-T6 ASTM B209. (PART NO. 3B)

BAR AND STRUCTURAL SHAPES TYPE 304L OR 347, ASTM 276 OR A479, HOT
AND PICKLED. (PART NO.'S 7A, 7C, 8B, 8D, 8E, 8F, 8H & 8J)

EL ASTM A449, SAE 5, 105,000 PSI MIN. TENSILE.
1)

TEEL TYPE 303, ASTM A194, GRADE 8F. (PART NO.'S 2D, 5 & 12)

AMINATED BROWN OR NATURAL FINE WEAVE CONTINUOUS FILAMENT
IC LAMINATE MELAMINE RESIN BASE NEMA GRADE GB-112M.

50 TO 60 DURAMETER HARDNESS. (PART NO.'S 2E, 3A & 7D)

STEEL, ASTM-A193 GRADE B8 CLASS 2 (PART NO. 19)

ATE PER ASTM A-516 GRADE 60 HOT ROLLED AND ANNEALED.

E FIRE RESISTANT PHENOLIC FOAM AND WATER PROOFED PER JOB SPEC-
AND AS FOLLOWS.
TION BY FOAMING IN ONE POUR INTO TOP SHELL (CONTAINER LID) AND
SPECIFIED FINISHED SHAPE. WEIGHT OF FOAM FILLING SHALL BE 2 1/2

SECTION BETWEEN THE FUEL ELEMENT BASKET AND CONTAINER BODY IN
EQUAL WEIGHT POURS WITH THE EXPOSED FINISH SURFACE BEING
INTO A MOLD. WEIGHT OF FINISHED FOAM FILLING THE BOTTOM SEC-
LB ± 10%. MATERIALS MAY BE SUBSTITUTED PER K/TL-729, EVALUA-
IN FIRE-RESISTANT PHENOLIC FOAM, C.E DAUGHERTY, G.E. HARRIS, AND
1, 1978.

K/TL-729
SUBSTITUTE

V-6663

COLD LAPS, POROSITY AND UNDERCUTS SHALL BE REMO
OR BY GRINDING AND REWELDING. THE REPAIRED WELD
REQUIREMENTS OF THE ORIGINAL WELD. WRITTEN INSP
REQUIRED EXCEPT AS NOTED IN NOTE NO. 8.

B. WELDING AND INSPECTION OF WELD JOINING CARBON ST
THE WELDING PROCESS IS DC GAS TUNGSTEN-ARC, ARGO
MATERIAL SHALL BE ERNICR-3 (INCONEL 82T). THE PR
60-300°F. A 100% VISUAL INSPECTION IS REQUIRED FOR
SHALL COMPLY WITH PARAGRAPH 8.15 OF AWS D1.1-1975
CRACKS, PINHOLES, INCOMPLETE FUSION, COLD LAPS, PO
BE REMOVED AND REPAIRED BY GRINDING, OR BY GRIND
PAIRED WELD SHALL MEET THE QUALITY REQUIREMENTS
TEN INSPECTION REPORTS ARE NOT REQUIRED EXCEPT A

1DVE) AND REPAIRED BY GRINDING,
LD SHALL MEET THE QUALITY
SPECTION REPORTS ARE NOT

STEEL TO STAINLESS STEEL
GON SHIELDED. THE FILLER
PREHEAT TEMPERATURE SHALL BE
OR ALL WELDS AND THE WELDS
75. VISIBLE DEFECTS SUCH AS
POROSITY AND UNDERCUTS SHALL
IDING AND REWELDING. THE RE-
'S OF THE ORIGINAL WELD. WRIT-
AS NOTED IN NOTE NO. 8.

MATERIAL 4

MATERIAL 5

7. DIMENSIONAL INSPECTI
ALL DIMENSIONS, ANGLE
WITHIN THE SPECIFIED
WILL BE ISSUED BY TH

8. DRAWINGS M-11518-ØH-
MODIFICATION TO THE
X3E10191011 REV. B AN
BE INSPECTED AND DO
DOCUMENTED. REFERE

⬡ - INDICATES DIM

⬭ - INDICATES WE

CAUTION

NUCLEAR EQUIPMENT

AVOID CONTACT AND/OR CONTAMINATION WITH MATERIALS CONTAINING: COPPER, SILVER, LEAD, (ALL SOLDERS), MERCURY, THORIUM, URANIUM, CHLORINE, FLUORINE, GRAPHITE, ________

ANY SUCH CONTAMINATION MUST BE REMOVED.

PO-2685 EASTMAN

TECHNICAL GRADE OXALIC ACID, $H_2C_2O_4$

:TION AND INSPECTION OF FINISHES
GLES AND FINISHES SHALL BE SHOP INSPECTED TO INSURE THEY ARE
ED TOLERANCE. A CERTIFICATION OF COMPLIANCE WITH THE DRAWINGS
THE FABRICATOR TO THE OWNER.

H-001-E, M-11518-ØH-002-E AND M-11518-ØH-003-D REPRESENT A
IE EXISTING CONTAINER SHOWN ON DRAWINGS X3E10191010 REV. B,
AND DATA SHEET DS-XDE-10191-2 REV. A. ALL MODIFICATIONS WILL
DOCUMENTED. FUNCTIONAL FIT INSPECTION SHALL BE INSPECTED AND
RENCE DCN NO. 4754 FOR DETAILED DESCRIPTIONS OF MODIFICATIONS.

IMENSIONS REQUIRING INSPECTION AND DOCUMENTATION.

VELDS REQUIRING INSPECTION AND DOCUMENTATION.

NOTE: LICEN
RESTR
APPLY

0	SEE DCN #4754
NO.	REVISIONS

MPLIED, IS MADE
ON, APPARATUS,
AY NOT INFRINGE
WITH RESPECT TO
IE USE OF, ANY
LOSED IN THESE
FOR INFORMATION
POSES, AND ARE
NG CONTRA

GENERAL SPECIFICATIONS

UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES.
2. FILLETS TO BE __ MAX.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: -- (ANSI Y14.5M – 1982)

TOLERANCES UNLESS OTHERWISE SPECIFIED

FRACTIONS ± ----

DECIMALS ± ----

ANGLES ± ----

SCALE: ----

DRAWN	DATE	DETAIL DESIGN
S.T. BELL	10/4/91	
CONCEPT DES.	DATE	APPROVED
		R. Boerne
CHECKED	DATE	APPROVED
C.E. Dinkins	10/24/91	

MECHANICAL AND STRUCT...

REFERENCE ORNL QV-...

QV CLAUSE	DOCUMENTS REQUIRED	APPLIC...
303	MATERIAL MILL TEST REPORT(CERT)	
325	MATERIAL SELLER CERT	
326	SPECIAL MATERIAL INSP REPORT	
205	MFG INSP AND TEST PLAN	
312	FIELD INSP & TEST PLAN	
321	WELD AND BRAZE INSP REPORT	✓ S
322	HEAT TREAT REPR(W/CHART)	
310	LEAK TEST REPORT	
315	CLEANING CERT	
318	DEVIATION REQUEST	
319	NONCONFORMANCE REPORT	
323	DIMENSIONAL REPORT	✓ S
330	FUNCTIONAL TEST REPORT	✓ S
100	DOCUMENTATION	

■ SYMBOL ✓ INDICATES APPLICABLE TO ALL PARTS OR ITEMS

QA COORDINATOR

...ENSING
...TRICTIONS
...LY

REFERENCE DRAWINGS	NUMB...
UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER DETAILS-BNL	M-11518-Ø...
UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER ASSY. - BNL	M-11518-Ø...

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA — MARTIN MARIETTA ENERGY SYS...

operated for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC-05-840R...
Oak Ridge, Tennessee • Paducah, Kentucky

FACILITY B.N.L. BLDG. NO.

UNIRRADIATED FUEL ELEMENT
SHIPPING CONTAINER NOTES
BROOKHAVEN NATIONAL LABORATOR...
USA/9853/AF

BTL	JTM	JTM
CED	SSB	10-24-91
DRAWN	APPD.	APPD.
CHECKED	APPD.	DATE

4

...SIONS

...TAIL DESIGN — DATE — DATE

APPROVED — DATE 10/24/91 — DATE

APPROVED — DATE — EXP. REVIEW — DATE

SUBMITTED: J I Muecke — REQUESTOR: Larry L. Proctor — FACILITY AP...: J I Muecke

M 11518 ØH 003

REFERENCE ORNL QV-001

QV CLAUSE	DOCUMENTS REQUIRED	APPLICABLE TO SPEC NO.*
303	MATERIAL MILL TEST REPORT(CERT)	
325	MATERIAL SELLER CERT	✓ See Note 5
3?8	SPECIAL MATERIAL INSP REPORT	
205	MFG INSP AND TEST PLAN	
312	FIELD INSP & TEST PLAN	
321	WELD AND BRAZE INSP REPORT	✓ SEE NOTE 8
322	HEAT TREAT REPR(W/CHART)	
310	LEAK TEST REPORT	
315	CLEANING CERT	
318	DEVIATION REQUEST	✓
319	NONCONFORMANCE REPORT	✓
323	DIMENSIONAL REPORT	✓ SEE NOTE 8
330	FUNCTIONAL TEST REPORT	✓ SEE NOTE 1
100	DOCUMENTATION	✓

* SYMBOL ✓ INDICATES APPLICABLE TO ALL PARTS OR ITEMS

[signature] QA COORDINATOR — DATE 10-25-91

NG
TIONS

REFERENCE DRAWINGS	NUMBER
UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER DETAILS-BNL	M-11518-ØH-002-E
UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER ASSY. - BNL	M-11518-ØH-001-E

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA — MARTIN MARIETTA ENERGY SYSTEMS, INC.

operated for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC-05-840R21 400 eng 26

Oak Ridge, Tennessee • Paducah, Kentucky

FACILITY B.N.L. BLDG. NO.

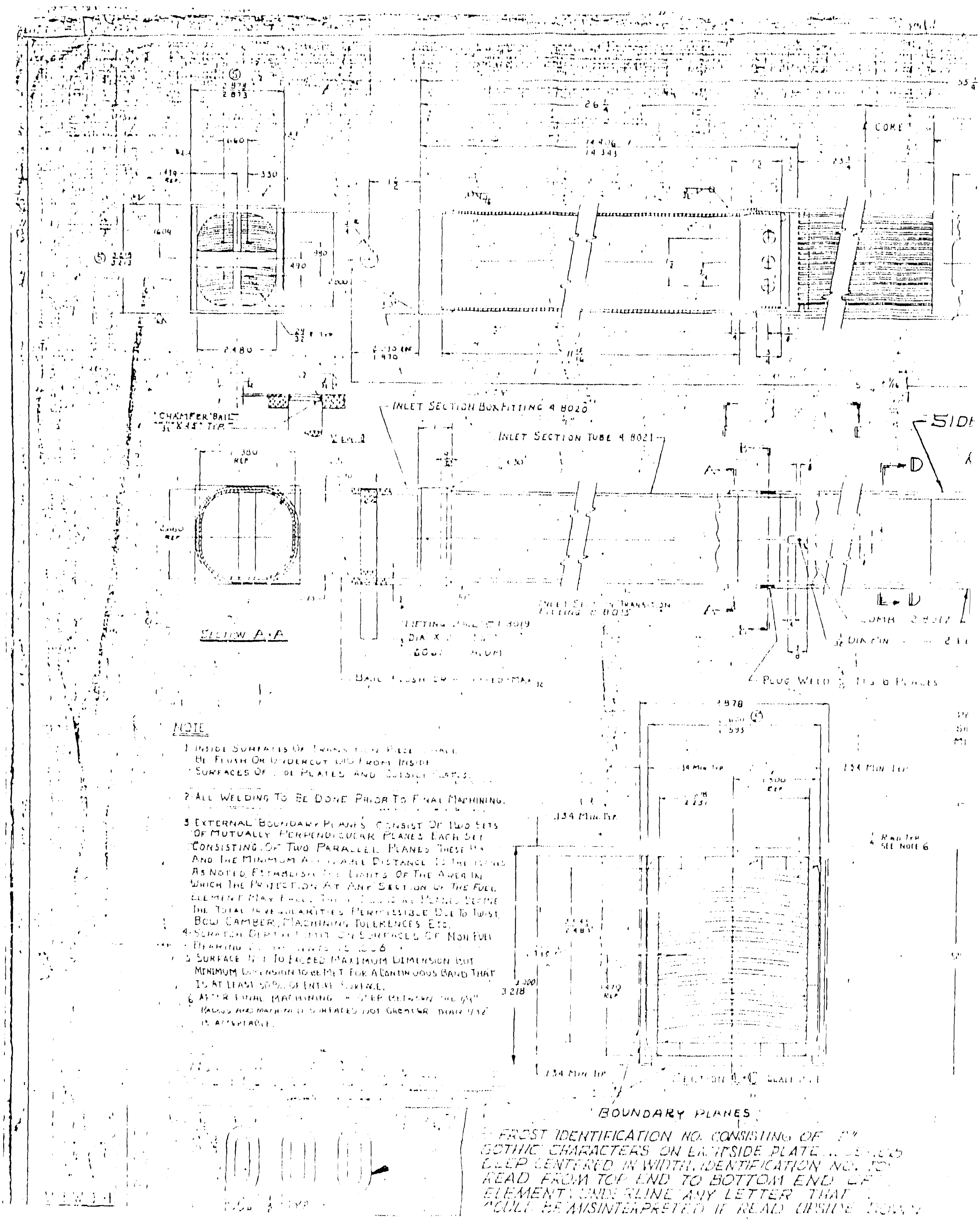
BTL	JTM	JTM
CED	SSB	10-24-91
DRAWN	APPD.	APPD.
CHECKED	APPD.	DATE

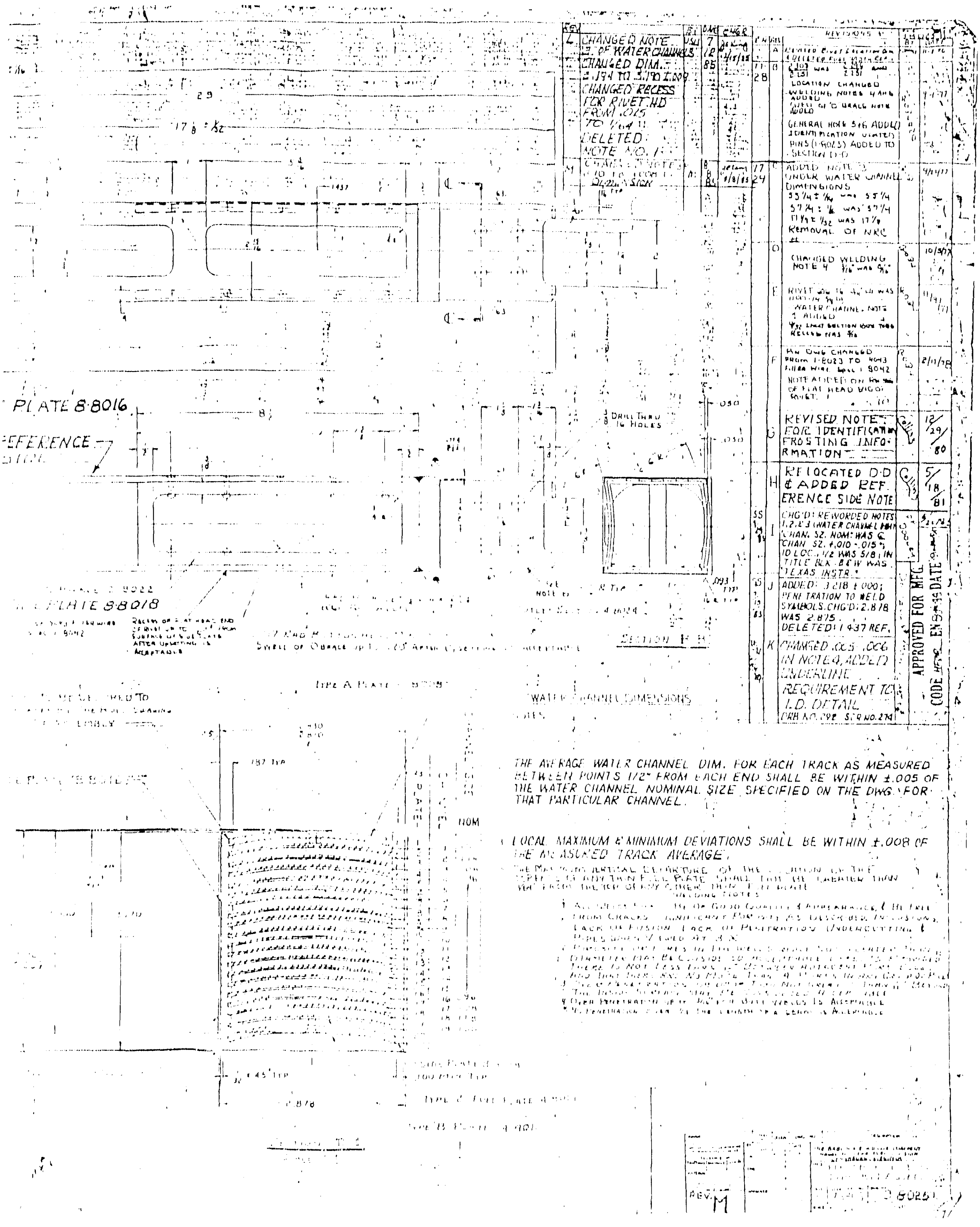
UNIRRADIATED FUEL ELEMENT
SHIPPING CONTAINER NOTES
BROOKHAVEN NATIONAL LABORATORY
USA/9853/AF

SUBMITTED	REQUESTOR	FACILITY APPROVAL
J I Muecke	Larry G. Proctor	J I Muecke for BNL

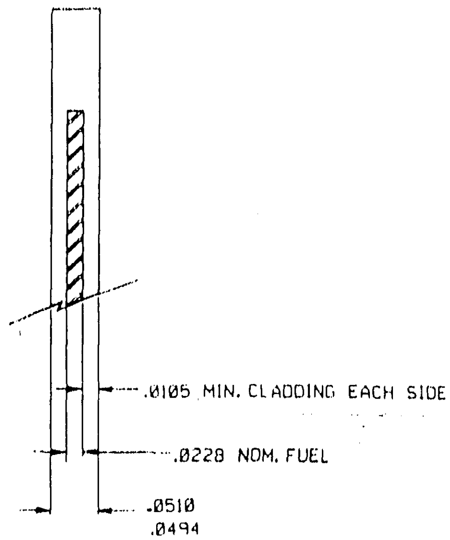
DATE — DATE — EXP. REVIEW — DATE

M 11518 ØH 003 D REV. C

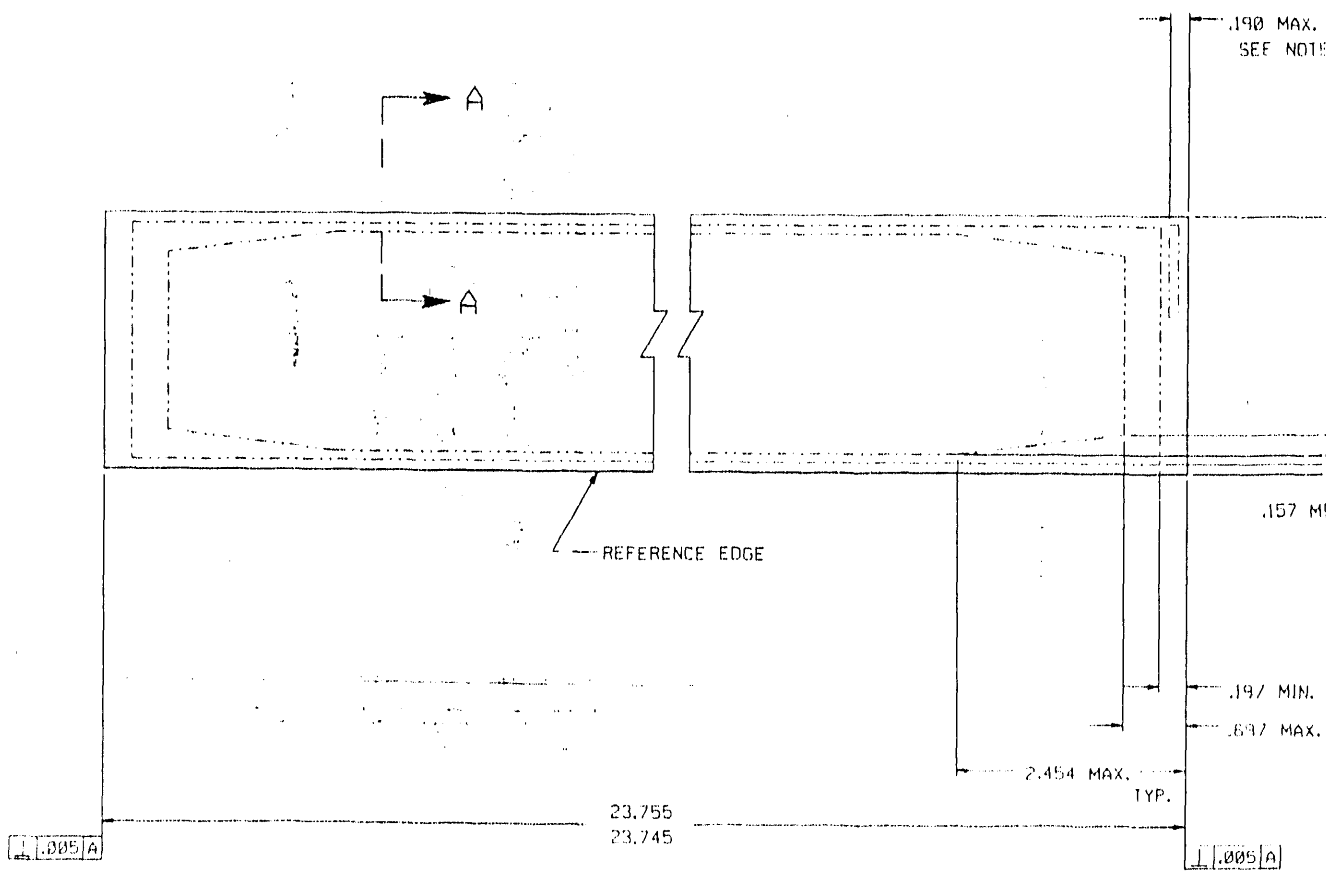

CORE
INLET SECTION BOX FITTING 4 8020
INLET SECTION TUBE 4 8021
CHAMFER BAIL
SECTION A-A
PLUG WELD
SIDE
NOTE
1 INSIDE SURFACES OF TRANSITION PIECE [illegible] BE FLUSH OR UNDERCUT [illegible] FROM INSIDE SURFACES OF [illegible] PLATES AND OUTSIDE [illegible].
2 ALL WELDING TO BE DONE PRIOR TO FINAL MACHINING.
3 EXTERNAL BOUNDARY PLANES CONSIST OF TWO SETS OF MUTUALLY PERPENDICULAR PLANES EACH SET CONSISTING OF TWO PARALLEL PLANES THESE [illegible] AND THE MINIMUM A[illegible]ABLE DISTANCE TO THE [illegible] AS NOTED ESTABLISH THE LIMITS OF THE AREA IN WHICH THE PROTECTION AT ANY SECTION OF THE FUEL ELEMENT MAY FALL. [illegible] DEFINE THE TOTAL IRREGULARITIES PERMISSIBLE DUE TO TWIST, BOW CAMBER, MACHINING TOLERENCES ETC.
4 SCRATCH DEPTH LIMIT ON SURFACES OF NON FUEL BEARING [illegible] .006
5 SURFACE NOT TO EXCEED MAXIMUM DIMENSION BUT MINIMUM DIMENSION TO BE MET FOR A CONTINUOUS BAND THAT IS AT LEAST 50% OF ENTIRE SURFACE.
6 AFTER FINAL MACHINING A STEP BETWEEN THE [illegible] RADIUS AND MACHINED SURFACES NOT GREATER THAN 1/32" IS ACCEPTABLE.
BOUNDARY PLANES
FROST IDENTIFICATION NO. CONSISTING OF [illegible] GOTHIC CHARACTERS ON EACH SIDE PLATE [illegible] DEEP CENTERED IN WIDTH. IDENTIFICATION NO. TO READ FROM TOP END TO BOTTOM END OF ELEMENT; UNDERLINE ANY LETTER THAT COULD BE MISINTERPRETED IF READ UPSIDE DOWN
VIEW B-B



CHANGED NOTE
OF WATER CHANNELS
CHANGED DIM.
2.194 TO 3.190 ±.009
CHANGED RECESS
FOR RIVET HD
FROM .025
TO 1/64
DELETED
NOTE NO. 1
REVISIONS
LOCATION CHANGED
WELDING NOTES 4 AND 6 ADDED
GENERAL NOTE 5 & 6 ADDED
IDENTIFICATION UPDATED
PINS (1-8023) ADDED TO SECTION D-D
ADDED NOTE 3 UNDER WATER CHANNEL DIMENSIONS
REMOVAL OF NRC
CHANGED WELDING NOTE 4
WATER CHANNEL NOTE 1 ADDED
DWG CHANGED FROM 1-8023 TO 4043 FILLER WIRE SPEC 1-8042
REVISED NOTE FOR IDENTIFICATION FROSTING INFORMATION
12/29/80
RELOCATED D-D & ADDED REFERENCE SIDE NOTE
5/18/81
CHG'D: REWORDED NOTES 1, 2, & 3 WATER CHANNEL
CHAN. SZ. NOM. WAS
ID LOC. 1/2 WAS 5/8 IN TITLE BLK.
TEXAS INSTR.
ADDED: 3.218 ±.000; PENETRATION TO WELD SYMBOLS. CHG'D: 2.878 WAS 2.875. DELETED: 1.437 REF.
IN NOTE 4, ADDED UNDERLINE REQUIREMENT TO I.D. DETAIL
APPROVED FOR MFG
CODE
EN
DATE
PLATE 8-8016
REFERENCE SIDE
PLATE 8-8018
DRILL THRU 16 HOLES
.050
.093 TYP
SECTION B-B
TYPE A PLATE
WATER CHANNEL DIMENSIONS
NOTES
THE AVERAGE WATER CHANNEL DIM. FOR EACH TRACK AS MEASURED BETWEEN POINTS 1/2" FROM EACH END SHALL BE WITHIN ±.005 OF THE WATER CHANNEL NOMINAL SIZE SPECIFIED ON THE DWG. FOR THAT PARTICULAR CHANNEL.
LOCAL MAXIMUM & MINIMUM DEVIATIONS SHALL BE WITHIN ±.008 OF THE MEASURED TRACK AVERAGE.
WELDING NOTES
NOM
45° TYP
2.878
TYPE B PLATE
REV. M
8025


.0105 MIN. CLADDING EACH SIDE
.0228 NOM. FUEL
.0510
.0494

SECTION A-A


.190 MAX.
SEE NOTE
A
A
REFERENCE EDGE
.157 M
.197 MIN.
.697 MAX.
2.454 MAX.
TYP.
23.755
23.745
.005 A
.005 A

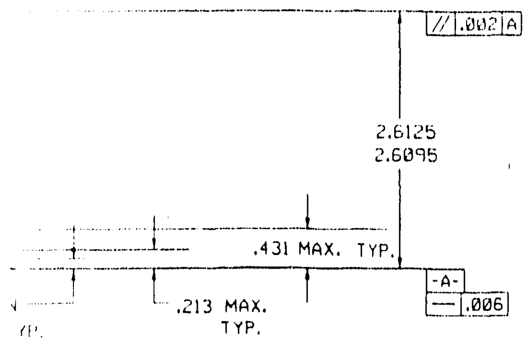
4 | 3 | 2 | 1

REVISIONS						
CAB NO.	REV NO.	DWN. BY	CHK'D. BY	PASSED BY	APPV'D. BY	DESCRIPTION
1878	F	SS 1/17/89	S [illegible] 2/13/89	[illegible] 2/1/89	[illegible] 2/13/89	CAD REDRAWN--ADMINISTRATIVE REV. SEE MANUAL DWG. IN VOID FILE FOR REV. HISTORY

NOTES:

1. FUEL PLATE SURFACE CONTAINING ANY PITS, SCRATCHES GREATER THAN 0.005", OR DENTS LARGER THAN 0.250" IN DIAMETER SHALL BE CAUSE FOR REJECTION.
2. URANIUM SHALL NOT EXTEND BEYOND THE MAXIMUM CORE OUTLINE.
3. NO FUEL PLATE SHALL HAVE VISUAL EVIDENCE OF A BLISTER.
4. EACH FUEL PLATE SHALL BE ULTRASONIC TESTED WITH SUFFICIENT SENSITIVITY TO DETECT A 0.062" DIA. NON-BOND OR BLISTER LOCATED WITHIN THE FUEL CORE OUTLINE. THE SENSITIVITY AND REPRODUCIBILITY OF THE TECHNIQUE SHALL BE ESTABLISHED WITH A CALIBRATION PLATE CONTAINING FUEL CORES AND REFERENCE DISCONTINUITIES. ANY RESPONSE LARGER THAN THAT WHICH IS RECEIVED FROM THE REFERENCE DISCONTINUITY SHALL BE CAUSE FOR REJECTION OF THE PLATE.
5. FUEL PLATES SHALL BE FREE OF EMBEDDED FOREIGN MATERIAL.
6. VIBRATOOL IDENTIFICATION NO. 1/8" HIGH BY 0.005" -0.010" DEEP-- BOTTOM OF DIGITS TO BE TOWARDS CENTER OF PLATE. ID TO BE ON CONVEX SIDE OF PLATE.
7. THE FUEL CORE LOCATION IS BASED ON THE FOLLOWING RADIOGRAPH BIASES:
   PLATE EDGE TO EDGE OF FUEL +.001"
   END OF PLATE TO END OF FUEL +.005"
8. ALL COMPONENTS MUST BE BONDED WITH AT LEAST 40% GRAIN GROWTH ACROSS INTERFACE.
9. ACCEPTANCE LIMITS FOR URANIUM LOADING ARE AS FOLLOWS:
   I. ACCEPTANCE LIMITS FOR ELEMENT PLATE POSITIONS 2-19
      A. AVERAGE LOADING LESS THAN +9%
      B. LOCAL LOADING LESS THAN +15%
   II. ACCEPTANCE LIMITS FOR ELEMENT PLATE POSITIONS 6-15
      A. AVERAGE LOADING LESS THAN +12%
      B. LOCAL LOADING LESS THAN +17%

6



TYP.

TYP.

D | C | B | A

TOLERANCES UNLESS OTHERWISE SPECIFIED	
DEC.DIM.	±
FRAC.DIM.	±
ANG.DIM.	±
MACH.SURF.	✓

IN CONFORMANCE WITH ANSI-Y14.5M 1982

DWN.BY S. SIMMONS DATE 1/18/89	HFBR "FLAT" TYPE 2 FUEL PLATE	THE BABCOCK & WILCOX COMPANY A McDERMOTT COMPANY NNFD RTRFE
CHKD.BY DATE		
PASSED BY DATE		
APPV'D.BY DATE		
SUBMITTAL 225 (ORIG.) CAB NO.		DWG. NO. 4-8002
DO NOT SCALE USE DIMENSIONS ONLY	SCALE NTS	DWG. SIZE D · REV. F

Appendix B

Brookhaven National Laboratory letter dated Octover 17, 1991 from C. Wennes to R. Odegaarden regarding acceptable deviations from clad requirements shown on BNL Drawing No. 4-8002, Rev. F, HFBR Flat Type 2 Fuel Plate

List of Effective Pages

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Upton, Long Island, New York 11973

516 282
FTS 666 X4701

Reactor Division

October 17, 1991

Mr. Richard H. Odegaarden
6048 East Star Valley Street
Mesa, AZ 85205

Dear Mr. Odegaarden,

This letter is in reference to our telephone conversations of October 3rd and 4th regarding the minimum and maximum fuel core outlines as shown on drawing 4-8002, Rev. F, HFBR Flat Type 2 Fuel Plate. The deviations from the requirements on this drawing that have been accepted during past production are listed below.

This list of items is provided in order to describe as accurately as feasible the fuel plates now in inventory that remain to be shipped and the possible characteristics of fuel plates that may be accepted from the contractor in the future. Its intent is to preclude one possible way in which the future "2-element" Safety Analysis Report for Packaging (SARP) and the resultant DOE and NRC Certificates of Compliance for the "9853" container might be written so as to unintentionally exclude presently existing and future HFBR fresh fuel from the authorized package contents.

(1) 0.150 inch minimum edge clad is acceptable. (See ".157 MIN. TYP." on dwg. 4-8002)

(2) 0.800 inch maximum end clad is acceptable. (See ".697 MAX. TYP." on dwg. 4-8002)

(3) 0.060 inch minimum end clad is acceptable in specific locations only. The fuel core is never permitted to extend under the vibratooled fuel plate identification number. (See ".197 MIN. TYP." and ".190 MAX." on dwg. 4-8002)

Please call me if you have any questions.

Yours truly,

Christopher Wennes,
Project Engineer

Paul Tichler,
Safety Evaluation Group Leader

cc: G. Popper, ANL
C. Scarlett, BNL
File 12.9.1

TELEX: 6852516 BNL DOE FACSIMILE: (516)282-3000, FTS 666-3000 CABLE: BROOKLAB UPTONNY

Appendix C

Fire Resistant Phenolic Foam

Publication

Union Carbide Specification Number JS-31536-1

List of Effective Pages

1 through 5 Rev. 1

JOB SPECIFICATION

STANDARD REFERENCE INFORMATION

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
ORGDP, OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY

NUMBER	JS-31576-1 Rev. 1
DATE	3-28-68
REVISED	3-28-68
PAGE	1 of 5

SUBJECT

FIRE RESISTANT PHENOLIC FOAM

SCOPE

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

MATERIALS AND PROPORTIONS

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

Material	Vendor - Trade Name	Component Weight per 100 Lb. of Matl. (Lbs.)
Liquid Components		
Phenolic Resin	UCC Plastics Division BRL-2760 (Foam Density 1.8-2.0 Lbs./ft.^{3})*	65.8 ± 0.2
Surfactant	UCC Plastics Division Silicone Surfactant L-530, or equal	2.0 ± 0.1
Refrigerant 113	DuPont Freon 113, or equal	6.6 ± 0.1
Powder Components		
Boric Anhydride (B_2O_3), Powder, Reagent Grade, -100 + 200 Mesh	Varlaccoid Chemical Company No. 1136, or equal	4.1 ± 0.1

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

UCN-474

APPROVED BY: Ben? Zimmerman

Material	Vendor - Trade Name	Component Weight per 100 Lb. of Matl. (Lbs.)
Powder Components (Contd)		
Boric Anhydride (B_2O_3) Powder, Reagent Grade, -200 Mesh	Varlacoid Chemical Company No. 1137, or equal.	4.1 ± 0.1
Oxalic Acid, $H_2C_2O_4$, Anhydrous Powder, Reagent Grade	Baker and Adamson No. 1135, or equal	8.2 ± 0.1
Reinforcing Component		
Fiberglass Rovings 1/4" Chopped Lengths	Owens-Corning Fiberglas No. 805 (HSI), or equal	9.2 ± 0.1

MATERIAL STORAGE REQUIREMENTS

Phenolic Resin

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

   or

   Maximum shelf life is six months from date of manufacture if stored at a temperature of 40° ± 5°F.

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

Pre-blended Liquid Components

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

Powder Components

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

APPROVED BY: ______

UCN-4768 (1 3-63)

All Other Materials

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

PREPARATION OF RECEIVER CONTAINER AND ACCESSORIES

Container

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

Molds

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

Cleaning Before Foaming

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

MIXING PROCEDURES

Pre-Blending

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

Powder Components

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

Final Blending

1. Add liquid components or pre-blended liquid components to mixer tub and stir to a uniform consistency, about 2 minutes for pre-blended components. Temperature of the phenolic resin or pre-blended liquid components shall be $60^\circ \pm 5^\circ F$ when it is added to the mix.

2. Add fiberglass and mix to a uniform consistency.

3. Add the pre-blended powder components rapidly and mix to a uniform consistency, 30 to 60 seconds.

4. Quickly transfer the mixed raw material to the receiver container so that the foaming action takes place within the container.

PLACING AND CURING FOAM MATERIAL

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

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

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

REMOVAL OF BRACING, MOLDS, AND ACCESSORIES AND FINISHING WORK

General

All bracing, molds, and any accessories not part of the finished container, as defined on the drawings, shall be removed after foaming and curing operations are completed. Any extruded foam material (e.g. extrusions through air vent holes) shall be carefully trimmed and removed to provide a smooth surface over the exterior and interior surface of the container. Foam material splashed onto exposed surfaces of the container shall be removed.

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

Patching Voids in Finished Foamed Surface Material

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

Waterproofing

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

CLEANING AGENTS

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

OTHER

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

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

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

UCN-4748 (2 3-63)

APPROVED BY. ____________

2.0 STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Discussion

The HFBR Unirradiated Fuel Shipping Container is described in detail in Section 1.2.1. The principal structural members and closure devices are an inner stainless steel basket and an aluminum alloy lid with seven fuel assembly cavities, an outer stainless steel cylindrical container and lid with the volume between the basket and outer container filled with phenolic foam, and a wooden basket support, as can be seen in Figure 1.1. The package outside diameter is 24-1/2" and a base 29 x 29 inches with an overall length of 75-1/2 inches including two, stainless steel 4 x 1-3/4 x 29-inch channels welded to the base to facilitate lifting with a fork-lift truck. Fabrication drawings for the packaging are included in Chapter 1 Appendix A.

For Normal Conditions of Transport, the outer shell provides the confinement boundary for the package and the fuel plates provide the containment. The adequacy of the containment boundary is demonstrated in Sections 2.9 and 4.1.4. No shielding other than normal packaging materials is required for unirradiated ^{235}U enriched fuel assemblies as explained in Section 5.1.

For the Normal Conditions of Transport tests given in 10 CFR § 71.71 governing criteria are the requirements of 10 CFR § 71.43(f) and 10 CFR § 71.55(d). These requirements are that there will be no loss or dispersal of radioactive contents, subcriticality will be maintained taking into account possibility of water inleakage, no significant increase in external radiation levels, and no substantial reduction in the effectiveness of the packaging including maximum of five percent loss of spacing on which criticality is based and the distance between the fuel material and the outer container wall. To meet these criteria, it is demonstrated that the packaging confines the fuel elements, the fuel assembly cladding remains intact, and the contents remain subcritical following the test series required for Normal Conditions of Transport.

For a Fissile Class III shipment, the single package will remain subcritical if it is subjected to the Hypothetical Accident Conditions tests, as required by 10 CFR § 71.55(e), because the package contains a maximum of 710 g ^{235}U which is less than the optimally moderated and reflected critical mass of 820 g.

2.1.2 Design Criteria

The outer container bolts shall not yield when subjected to the Normal Conditions of Transport tests. Localized yielding of the outer container is acceptable when the package is subject to these same tests. In addition, the fuel basket has not been analyzed for the Normal Conditions of Transport because the nuclear criticality safety requirements do not depend upon the spacing provided by the basket.

The containment criteria for the Normal Conditions of Transport is met by the integrity of the individual fuel plates within the fuel assembly. The fuel plate integrity can be maintained by limiting the maximum bending in the fuel plates to the 80° tested value.

Governing criteria for lifting and tie-down are the requirements of 10 CFR § 71.45. In accordance with these criteria, any structural part of the package which can be used to lift will either be rendered inoperable for lifting the package during transport, or will have a minimum safety factor of three against yielding if used for lifting. Tie-down devices and parts of structure which could be used for tie-down, must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, the load combinations specified in 10 CFR § 71.45. The package has no tie-down devices and any lifting loads on the base of the package would not result in additional stress on the package.

Additionally, each lifting device and tie-down device which is a structural part of the package must be designed so that the failure of the device under excessive load would not impair the ability of the package to meet other requirements of 10 CFR Part 71. The package has no tie-down devices. Lifting loads would result in no additional stresses on the package.

Justification is provided for not considering brittle fracture and fatigue failure in Sections 2.6.2 and 2.6.5.

Buckling mode of failure for Normal Conditions of Transport is not possible because the compressive stress levels are shown to be significantly below those calculated for classical buckling loads.

Material properties are obtained from references a) through e) listed in Section 2.3 of the SARP.

Section 2.6.9, Compression, shows that the package is able to withstand a pressure from a load greater than 5 times the weight of the package. The criterion applied for this requirement is that the stresses do not exceed the yield stresses shown in the Table 2.2.

2.2 Weights and Centers of Gravity

Table 2.1 Weights and Centers of Gravity

The weights of the package is given in the table below.

	HFBR
Packaging Weight (lb) (including a maximum lid assembly weight of 45 lb)	560
Fuel Weight (lb)	30
Total Weight (lb)	590

The center of gravity of the 75-1/2-inch high package is about 3-1/2 inches below the geometric center because of the additional weight of the base. See Figure 1.1.

2.3 Mechanical Properties of Materials

Table 2.2 Mechanical Properties of Materials

Mechanical properties of the steel, aluminum, and foam are given in the table below.

Material	Yield Strength (psi)	Ultimate Strength (psi)	Elastic Modulus (psi)	Density (pci)
304L stainless steel	28,000[a]	75,000[a]	28×10^{6} [b]	0.285[a]
6061-T6 aluminum	40,000[c]	45,000[c]	10×10^{6} [b]	0.098[c]
Phenolic foam	-	14[d]	-	0.00191[e]

[a]Carpenter Technology, Carpenter Stainless Steels, 1987, pp. 31, 32.

[b]Higdon, A., E. H. Ohlsen, W. B. Stiles, and J. A. Weese, Mechanics of Materials, Second Edition, 1967, pp. 554, 555.

[c]American Society of Metals, Metals Handbook, Ninth Edition, Vol. 2, 1979, p. 116. Note: Non-heat treated, non-fuel plates and fuel element side plates. Fuel plates are 15% cold worked and may be softer.

[d]Martin Marietta Energy Systems Report K-2057, Rev. 1, Renovation of DOT Specification 21PF-1 Protective Shipping Packages, November 21, 1987, p. 19. Note: Ultimate strength is lower limit crush strength. Actual data shows value may range from 4 to 20 psi rather than the average value of 14 psi.

[e]Calculated value based on weights given in ORNL Drawing No. M-11518-OH-003-D, Rev. 0; and foam volumes calculated from dimensions given in ORNL Drawing Nos.: M-11518-OH-001-E, Rev. 0; and M-11518-OH-002-E, Rev. 0.

2.4 General Standards for all Packages

The general standards for all packaging, specified in 10 CFR § 71.43, are complied with as demonstrated in the following sections.

2.4.1 Minimum Package Size

The smallest overall dimension of the package is 24-1/2 inches, which is the least outside diameter of the package. This exceeds the minimum required overall dimension of 4 inches specified in 10 CFR § 71.43(a).

2.4.2 Tamperproof Feature

The package has two, 1/4-inch holes 180° apart drilled through the lip of the outer container lid and the outer container flange for the placement of sealing wire, which is used during shipment to ensure against undetected unauthorized opening of the package. This complies with 10 CFR § 71.43(b).

2.4.3 Positive Closure

The basket lid and the outer container lid are secured with bolts, nuts, and lock washers that are installed at a specified torque, which ensures that the lids will not be opened unintentionally. The basket lid is secured with eight, 3/8-inch bolts and nuts. The outer container lid is secured with six, 5/8-inch bolts and nuts. This complies with 10 CFR § 71.43(c).

2.4.4 Chemical and Galvanic Reactions

The packaging materials are stainless steel, aluminum alloy, phenolic foam, nominal 2" x 6" inch wooden basket supports, and Neoprene spacers and gaskets. There has been no evidence of any corrosive reactions between these materials and the aluminum clad fuel elements or among the package materials. Therefore, the packaging complies with 10 CFR § 71.43(d).

2.4.5 Valve or Other Device

The packaging is only used to transport dry, aluminum plate-type fuel assemblies and is not provided with either a valve or a pressure relief device.

2.5 Lifting and Tie-down Standards for all Packages

2.5.1 Lifting Devices

10 CFR § 71.45(a) requires that any lifting attachment that is a structural part of a package have a minimum safety factor of three against yielding when used to lift the package and be designed so that failure of the lifting device under excessive load would not impair the ability of the package to meet other requirements of Subpart E to 10 CFR Part 71 . It further requires that any other structural part of the package, which could be used to lift the package, be capable of being rendered

inoperable for lifting the package during transport or be designed with strength equivalent to that required for lifting attachments.

The package is designed for fork lift handling from the bottom of the container. The lifting forces or excessive load requirement would only result in raising the package. The forces would not differ from the package resting on the ground or floor of a vehicle. ORNL Drawing No. M-11518-0H-001-E, Rev. 0 show the attachment of a triangular cross-section band to the wall of the package just below the outer container lid. This band is intended to block the use of a hook or fork lift to lift the package by the top flange of the outer container.

2.5.2 Tie-down Devices

10 CFR § 71.45(b) specifies the requirements for tie-down devices that are a structural part of the package. The tie-down system must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, a static force applied to the center of gravity of the package having a vertical component of two times the gross weight of the package, a horizontal component along the direction of travel of ten times the gross weight of the package, and a horizontal component in the transverse direction of five times the gross weight of the package. Any other structural part of the package that could be used to tie-down the package must be capable of being rendered inoperable for tying down the package during transport, or must be designed with strength equivalent to that required for tie-down devices. Each tie-down device that is a structural part of a package must be designed so that failure of the device under excessive load would not impair the ability of the package to meet other requirements of 10 CFR Part 71.

The package is not provided with tie-down devices which are a structural part of the package. One open end of the base fork lift channels has been provided with a blocking device to prevent use of the channels to tie-down the package.

2.6 Normal Conditions of Transport

The package, when subjected to the conditions and tests (Normal Conditions of Transport) specified in 10 CFR § 71.71, meets the standards specified in 10 CFR §§ 71.43 and 71.55(d) as demonstrated in the following sections. The requirements are that there be no loss or dispersal of radioactive contents, contents would be subcritical considering possible inleakage, contents would not be substantially altered, no significant increase in external radiation levels, and no substantial reduction in the effectiveness of the packaging including no more than five percent reduction in the total effective volume of the packaging on which nuclear safety is assessed and the effective spacing between the fissile content and the outer surface of the packaging.

2.6.1 Heat

10 CFR § 71.43(g) requires that the package be designed, constructed, and prepared for transport so that in still air at 38° C (100° F) and in the shade, no accessible surface of the package would have a temperature exceeding 82° C (180° F) for an exclusive use shipment. The unirradiated fuel assemblies will provide less than one watt of heat input to the package. Thus, the entire package will ultimately achieve a steady state temperature equal to the ambient temperature of 38° C (100° F).

The condition of direct sunlight gives a peak temperature of 108° C (226° F), as discussed in Sect. 3.4.2. Thus the packaging complies with the requirements of 10 CFR § 71.43(g).

2.6.2 Cold

10 CFR § 71.71(c)(2) requires that the shipping package be able to withstand an ambient temperature of -40° C (-40° F) in still air in the shade. Because the package has no significant internal heat load (less than one watt), the temperature of the entire package will be -40° C, and because the package is not sealed, no pressure differential will result. NRC Regulatory Guide 7.6, Part B states, "...these designs were made of austenitic stainless steel which is ductile even at low temperatures. Thus, this guide does not consider brittle fracture." The aluminum alloy fuel basket lid and fuel plates are also unaffected by brittle fracture at low temperature per Structural Alloys Handbook, Vol. 3, Metals and Ceramics Information Center, Battelle, Columbus, OH, 1990. Thus, the container satisfies the 10 CFR § 71.71(c)(2) cold temperature requirement.

2.6.3 Reduced External Pressure

10 CFR § 71.71(c)(3) requires that the package be assessed for the effects of an external pressure of 3.5 psia. The package is not air tight; therefore, the internal pressure will equal the external pressure, there will be no differential pressure across the package boundaries, and the reduced external pressure will have no effect on the package. The effect of reduced pressure on the cladding is negligible.

2.6.4 Increased External Pressure

10 CFR § 71.71(c)(4) requires that the package be assessed for the effects of an external pressure of 20 psia. As in the case of reduced pressure, the pressure differential across the package boundary will be zero and increased external pressure will have no effect on the packaging. The effect of increased pressure on the cladding is negligible.

2.6.5 Vibration

10 CFR § 71.71(c)(5) requires that the package be assessed for the effects of vibration normally incident to transport. The stainless steel package is of welded construction. The welding procedures met ASME Sect. IX requirements and the welds were 100% visually inspected. The bolts that secure the lids are equipped with lock washers to prevent loosening. Transport vibrations will, therefore, not affect the integrity of the package. The phenolic foam will also cushion the basket against vibrations. The packages have been used for the shipment of the fuel assemblies for over 10 years without being adversely affected by vibrations incident to transport. With respect to vibration induced fatigue failure, vibration induced stress is low for these packages. According to test results reported by Sandia National Laboratory (SC-RR-66-677, The Environment Experienced by Cargo on a Flatbed Tractor-Trailer Combination, December, 1966), truck tire and suspension system vibration frequencies are usually between 1 and 20 Hz. Since the packages are supported directly on their stiff integral support channels, rather than flexible impact limiters, there will be no amplification of truck

vibration accelerations. Hence, with no vibration amplification and a relatively light-weight rigid structure, stresses due to transportation loads are small and fatigue failures will not occur. The fuel is cushioned by its polyethylene wrap. The package and fuel satisfies the requirements of 10 CFR § 71.71(c)(5).

2.6.6 Water Spray

10 CFR § 71.71(c)(6) requires that the package be assessed for the effects of a water spray that simulates exposure to rainfall of approximately 5-cm (2-inch) per hour for at least one hour.

The Neoprene lid gasket and epoxy housing vent seals will limit the amount of water entering the package. However, the stainless steel and aluminum package construction materials will not be affected by the water. The phenolic foam will also not be affected by the water. The contents will remain subcritical (see Sect 6.1). Studies[1,2] have shown that the properties of the foam are not impaired by being wet and subsequently dried. Therefore, the water spray test will have no adverse effect on the package.

2.6.7 Free Drop

10 CFR § 71.71(c)(7) requires that the package be assessed for the effects of a four-foot free drop onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected. The free drop test is to be performed between 1-1/2 and 2-1/2 hours after the conclusion of the water spray test above.

The effects of a four-foot free drop of the loaded package onto an unyielding surface are shown to be fully acceptable. Containment is provided by the payload itself (see Sect. 2.9), thus the concern here is only with the ability of the packaging to confine the payload during and subsequent to the drop event. By demonstrating that the closure bolts (i.e., the most vulnerable "confinement" feature) are capable of retaining the outer container lid, and that the 1/4-inch thick lower end plate will remain attached to the container body, confinement of payload can be assured.

The assessment in Chapter 2 Appendix A, Container Lid Retention in a 4 Foot Free Drop onto an Unyielding Surface, conservatively applies flow stress and energy balance approaches to establish worst case tensile and shear loads on the closure bolts. Corresponding stresses are shown to be less than yield, thus the conclusion is reached that the lid will be retained and the payload will be confined as required.

The nuclear criticality analyses (see Sect. 6.1) are independent of the spacing provided by the fuel basket. The crush depth of the drum is about 0.6 inch and, for a c.g. over corner, the small volume change on the corner of the package is localized (see Chapter 2, Appendix A, § 1.1) and would have no effect on nuclear criticality spacing. Thus, the requirements of 10 CFR § 71.55(d)(4) are met.

The assessment in Chapter 2, Appendix A, Lower End Plate Retention in a 4 Foot Free Drop onto an Unyielding Surface, applies flow stress approaches to establish that the end plate will not be sheared from the outer container body in a drop event. Maximum shear stress in the attachment weld is shown to be below the ultimate shear strength of the weld, thus ensuring payload confinement.

2.6.8 Corner Drop

The 10 CFR § 71.71(c)(8) corner drop test applies only to fiberboard or wooden packages. This test does not apply to the stainless steel package.

2.6.9 Compression

The compression test evaluation specified in 10 CFR § 71.71(c)(9) considers the worst case loading of 5 times the weight of the package or 1.85 psig acting on the vertically projected area of the package when in its normal shipping orientation (i.e., with the package axis horizontal). As shown in the assessment in Appendix A, Compression Test, the 1.85 psig loading governs for the HFBR Unirradiated Fuel Shipping Container with fuel. It is shown that the basic cross section of the package will withstand the applied load without yielding the container shell or crushing the phenolic foam within. That assessment also goes on to show that overall bending of the package under the defined compressive loading is of negligible consequence. The analyses are considered to be conservative since the "composite" action inherent in a foamed-in-place steel structure is ignored and no credit is given to the strength of the basket structure itself.

For the package transported in the vertical position, the maximum compressive stress in the outer stainless steel shell is:

$$\sigma = P/A = 5W/\pi Dt = (5)(590)/\pi(24.5)(0.125)$$
$$= 307 \text{ psi}$$

where:

W = gross weight (lb)
D = diameter of shell (in)
t = shell thickness (in)

This stress is significantly below the yield strength of the stainless steel.

Thus, the package can support five times its weight with no loss in effectiveness.

2.6.10 Penetration

10 CFR § 71.71(c)(10) requires that the package be assessed for the effects of the impact of the hemispherical end of a vertical steel cylinder of 1-1/4-inch diameter and 13-lb mass, dropped from a height of 40 inches onto the exposed surface of the package that is expected to be most vulnerable to puncture.

There are two empirical relationships in common use to calculate the required steel plate thickness to prevent puncture, i.e., perforation of the plate by a missile[4]. These are the Stanford Research Institute (SRI) formula[5] and the Ballistic Research Laboratory (BRL) formula[6]. In order to make use of these formulas, a missile is defined as having the diameter of the cylinder (1-1/4" dia.) and the kinetic energy of the 13-lb cylinder at impact upon falling 40 inches.

Using the SRI formula, the required shell thickness, T, is:

$$T = \sqrt{0.045 \ x \ \frac{W_m V^2}{DS} + 0.0022 \ x \ (\frac{W}{W_s})^2} - 0.047 \ x \ \frac{W}{W_s}$$

where

W_m = Weight of missile
= 13-lb

V = missile velocity

= 2gh

= (2)(32.2)(40/12)

= 14.65 fps

D = missile diameter
= 1.25 in.

S = ultimate tensile strength of steel shell
= 75,000 psi

$\frac{W}{W_s}$ = scale factor

= 1.0

Use of a scale factor of 1.0 represents the case of a highly restrained target. This is a conservative assumption for this application since the steel shell is backed by relatively flexible foam. The formula is also based on test data obtained from impact with high strength tool steel missiles having a sharp edge rather than a mild steel punch having a rounded edge. Hence, the formula is conservative for this application and the thickness of plate calculated can be considered to be an upper bound value. The thickness required to prevent perforation is therefore:

$$T = \frac{(0.045)(13)(14.65)^2}{(1.25)(75,000)} + (0.0022) - 0.047$$

$$= 0.0125''$$

Using the BRL formula, the required shell thickness, T, is:

$$T = \frac{\left[\frac{W_m V^2}{2g}\right]^{2/3}}{672D}$$

$$= \frac{\left[\frac{(13)(14.65)^2}{(2)(32.2)}\right]^{2/3}}{(672)(1.25)}$$

$$= 0.0147"$$

With both the SRI and BRL formulas showing the actual shell thickness (0.12") to be ten times greater than the calculated required thickness, it is apparent that the 13-lb, 1-1/4" dia. steel cylinder penetration test will be of little consequence to this package.

It is concluded from the results of the calculation that the dropped cylinder would not reduce the effectiveness of the stainless steel package and would result in no more than a localized dent in the surface of the package.

2.7 Hypothetical Accident Conditions

The subcriticality requirements of 10 CFR §§ 71.55(e) and 71.61 for when the package is subjected to the Hypothetical Accident Conditions of 10 CFR § 71.73 are met because the total mass (710 g) of ^{235}U to be transported is less than the minimum mass of 820 g required for criticality (see Sect. 6.4.1).

2.8 Special Form

The unirradiated fuel assemblies shipped in the package are not qualified as special form. Therefore, this section is not applicable to the package.

2.9 Fuel Assemblies

The fuel plate cladding and fuel matrix as described in Sect. 4.1 provide for the containment of the radioactive material under Normal Conditions of Transport. Each fuel plate during the fabrication process is heated to between 475° C and 493° C and then examined for blisters, delaminations, or cracks. This exceeds the maximum temperature of 108° C (226° F) that the plate would experience under Normal Conditions of Transport. General toughness of irradiated aluminum fuel plates was investigated by Argonne National Laboratory and the results were published in ANL/RERTR/TM-10[3]. In these tests several high burnup plates were bent to determine their ductility and toughness. Typically the plates were bent in excess of 80° and were found to partially straighten out after the force was removed. The fuel plates were shown to have a high degree of toughness and to be able to survive severe physical deformation without release of fissile contents. These plates had been irradiated; therefore, they would behave in a more brittle manner than the unirradiated research reactor fuel plates. Hence, the research reactor fuel plates could experience greater bending before any cracking of the clad would occur. The bending of the fuel plates in excess of 80° will not occur as a result of the drop test prescribed for Normal Conditions of Transport. Therefore, breaching of the cladding will not occur.

The cladding will maintain sufficient mechanical integrity to provide for containment of the fuel after being subjected to the Norman Conditions of Transport specified in 10 CFR § 71.71.

2.10 References

1. J. L. Frazier, Thermal Properties Evaluation of UF_6 Cylinder Overpack Insulation, K/PS-1128, Martin Marietta Energy Systems, Inc., Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, November 29, 1985.
2. C. R. Barlow, et al., Renovation of DOT Specification 21PF-1 Protective Shipping Packages, K-2057, Revision 1, Martin marietta Energy Systems, Inc., Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, November 21, 1986.
3. G. L. Copeland, et al., Performance of Low-Enriched U_3Si_2 - Aluminum Dispersion Fuel Elements in the Oak Ridge Research Reactor, ANL/RERTR/TM-10, Argonne National Laboratory, dated October 1987.
4. USNRC Standard Review Plan, Section 3.5.3, Barrier Design Procedures, NUREG-0800, Rev. 1, July 1981.
5. US Reactor Containment Technology, ORNL-NSIC-5, August 1965.
6. Bechtel Topical Report, Design of Structure for Missile Impact, BC-TOP-9A, Rev. 2, September 1974.

2.11 Appendix

A Lid and Bottom Plate Retention and Compression Test

Container Lid Retention in a 4 Foot Free Drop onto an Unyielding Surface, Lower End Plate Retention in a 4 Foot Free Drop onto an Unyielding Surface, and Compression Test performed by PacTec on 10/15/91.

Appendix A

Lid and Bottom Plate Retention and Compression Test

PacTec
10/15/91

1.0 Container Lid Retention in a 4 Foot Free Drop onto an Unyielding Surface

Design Basics:

Lid assembly weight = 45 lb (upper bound)

Lid retained by 6, 5/8 - 11UNC, A193 Gr B8, Class 2 bolts

Minimum area per bolt = 0.2201 in^2 (shear or tension)

Per ASME Code, Sec II, Part A, bolt material properties are as follows:

σ_y = yield strength = 100,000 psi

σ_u = ultimate strength = 125,000 psi

ε_u = ultimate elongation = 0.12 in/in

Loaded container assembly weight = 590 lb

(560 lb for empty container + 2 HFBR fuel assemblies @ 15 lb each)

Foam crush strength = σ_o = 14 psi (p.19 of Martin Marietta report K-2057, Rev. 1)

300 series stainless steel cylinder (24.25" ID, 11 gage = 0.12" wall) properties are as follows:

(per Carpenter Technology, "Carpenter Stainless Steels", 1987, pp. 31, 32)

σ_y = yield strength = 28,000 psi

σ_u = ultimate strength = 75,000 psi

For dynamic yield, a factor of 1.2 on yield strength will be employed for a dynamic yield strength of 33,600 psi for the container cylinder.

1.1 Tensile loads in lid bolts

The maximum tensile loads which can develop in the lid bolts occur for drops on the lid end of the package. The maximum deceleration will be for the case of a flat end drop where the full cross sectional area of the container becomes mobilized at the instant of impact. Other, oblique impacts involving the top end (center of gravity over impacted corner in particular) will initially mobilize a smaller volume of material, thus will result in greater crush depths and consequently lesser deceleration magnitudes than the flat end drop. Of note, crush depths in these oblique orientations will not be of concern in a 4 foot drop since the package was originally designed to accommodate 30 foot drops. By way of example, it can be shown from the geometries involved that over 1.0 in^3 of material in the wall of the outer stainless steel cylinder would have to "flow" in order to obtain a 1 inch crush depth in a cg over corner drop event. With a "flow" stress equal to 33,600 psi, this small volume of steel would absorb the entire drop energy associated with a 4 foot drop (1.0x33,600 = 33,600 in-lb > 48x590 = 28,320 in-lb). Consequently, it is concluded that container crush depths will remain small.

Although in a flat end drop, bolts will actually be loaded in compression, the flat end drop deceleration will conservatively be used as the upper bound load tending to drive the lid from the body of the container. The following calculation shows that the lid bolt stresses remain below yield even if it is assumed that the bolts must resist the full end drop "g" loading acting on the fuel assemblies, basket lid and container lid (i.e., basket lid bolts are conservatively ignored).

a) <u>End drop deceleration calculation</u>

For this calculation, it is assumed that the container shell flows at its dynamic yield strength of 33,600 psi and the full foam cross section (24.25" dia) crushes at 14 psi. The total force on the container is therefore:

$$F_t = \pi(24.25)(0.12)(33{,}600) + (\pi/4)(24.25)^2(14) = 313{,}638 \text{ lb}$$

With a 590 lb package, deceleration becomes:

$$G = F_t/590 = 532 \text{ g's}$$

b) <u>Force on lid bolts</u>

For this calculation, it is assumed that basket lid bolts fail and the basket lid assembly (10 lb), the 2 fuel assemblies (30 lb total) and the container lid itself (45 lb) act to load the bolts. The resultant force acting on the bolts is:

$$F_b = 532(10 + 30 + 45) = 45{,}220 \text{ lb; or } 7{,}537 \text{ lb per bolt}$$

c) <u>Lid bolt tensile stress</u>

With a minimum area of 0.2201 in^2 per bolt, resultant bolt stress becomes:

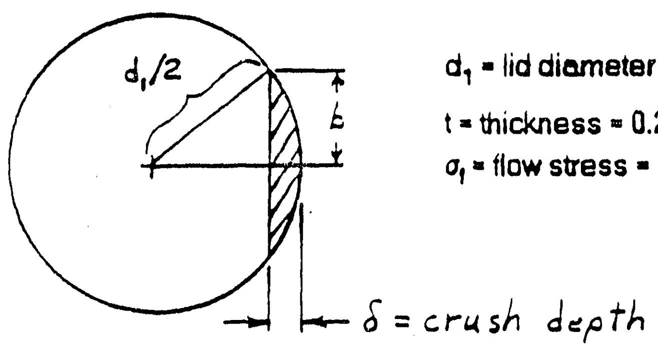
$$\sigma_b = 7{,}537/0.2201 = 34{,}244 \text{ psi} << \sigma_y = 100{,}000 \text{ psi}$$

1.2 Shear loads in lid bolts

The maximum shear loads which can develop in the lid bolts occur for side drops or "slapdowns" which directly load that portion of the lid which extends radially beyond the body of the basic container. The following calculations demonstrate that shear failure of the lid bolts will not occur even if it is assumed that the total package drop energy in a 4 foot drop is absorbed by crushing the edge of the lid. The resultant force is the maximum which can develop and is insufficient to shear off the lid bolts.

a) Deformation of lid lip and resultant force

Considering lid geometry, an energy balance can be employed to establish worst case shear loads acting on the lid bolts. For this assessment the full package drop energy of (590)(48) = 28,320 in-lb will be assumed to "flow" the edge of the lid (29" dia. 0.245" thick {1/8" angle + 0.12" (i.e., 11 gage) sheet}) at a dynamic yield stress of 33,600 psi. Details follow:



d_1 = lid diameter = 29"

t = thickness = 0.245" = 0.125" angle + 0.12" sheet

σ_f = flow stress = 33,600 psi

At a given crush depth, δ, the force acting on the edge of the lid is simply,

$$F = 2bt\sigma_f = 2(b)(0.245)(33{,}600) = 16{,}464(b)$$

From geometry,

$$b = (d_1\delta - \delta^2)^{0.5}$$

or, when $d_1 >> \delta$,

$$b = (d_1\delta)^{0.5}$$

Therefore,

$$F = 16.464(d_1\delta)^{0.5} = 88.661(\delta)^{0.5}$$

From conservation of energy,

$$E = \int_0^{x_m} F d\delta = 28{,}320 \text{ in-lb}$$

x_m = maximum crush depth (inches)

$$\int_0^{x_m} F d\delta = 88.661(2/3)\delta^{1.5}\Big|_0^{x_m} = 59.107(x_m)^{1.5} = 28{,}320 \text{ in-lb}$$

Therefore,

$$x_m = 0.612 \text{ inches}$$

$$F_{max} = 88.661(x_m)^{0.5} = 69{,}360 \text{ lb; or } 11{,}560 \text{ lb per bolt}$$

b) Lid bolt shear stress

With a minimum area of 0.2201 in^2 per bolt, resultant bolt shear stress becomes:

$$\tau_b = 11{,}560/0.2201 = 52{,}522 \text{ psi}$$

Considering a maximum bolt pre-torque of 320 in-lb, tensile force and corresponding tensile stress in each 5/8 inch diameter bolt becomes:

$$F_b = T/(0.2d) = 320/[(0.2)(0.625)] = 2{,}560 \text{ lb}$$

$$\sigma_b = F/A = 2{,}560/0.2201 = 11{,}631 \text{ psi}$$

Combining with the above bolt shear stress, τ_b, the maximum shear stress becomes:

$$\tau_{max} = [(\sigma_b/2)^2 + \tau_b^2]^{0.5} = 52{,}843 \text{ psi}$$

This maximum shear stress is below both shear yield of 60,000 psi ($0.6\sigma_y$) and shear ultimate of 75,000 psi ($0.6\sigma_u$).

1.3 Conclusion

Based on the preceding calculations, it is concluded that the container lid will be retained to the body when subjected to worst case four foot drop events. Although not specifically addressed above, the lid will also be retained in drops involving the bottom end of the package. With a total tensile force required to yield the 6 lid bolts of 132,060 pounds (6x0.2201x100,000 psi), and a maximum lid assembly weight of 45 pounds, an acceleration of 2,935 g's (132,060/45) acting on the lid would be required to yield the bolts. Accelerations of this magnitude obviously will not develop as a result of 4 foot drops on the bottom end of the package.

2.0 Lower End Plate Retention in a 4 Foot Free Drop onto an Unyielding Surface

Design Basics:

Base plate is 29x29x0.25 inch thick stainless steel
Plate is attached to 24.49" OD cylinder with a 1/8" fillet weld
Weld shear area is:

$$A_w = \pi(24.49)(0.125)(0.707) = 6.80 \text{ in}^2$$

2.1 Maximum shear force in end weld

The maximum shear force which can develop in the end weld for any drop orientation can be no larger than the lateral force which can develop on the edge of the 29 inch long, 0.25 inch thick base plate. Using a flow stress of 33,600 psi, the maximum shear force, F_s, becomes:

$$F_s = (29)(0.25)(33{,}600) = 243{,}600 \text{ lb}$$

2.2 Maximum shear stress in end weld

With a weld shear area of 6.80 in^2, the maximum shear stress which can develop is:

$$\tau_{max} = F_s/6.80 = 35{,}824 \text{ psi} < \sigma_{su} = 0.6\sigma_u = 45{,}000 \text{ psi}$$

2.3 Conclusion

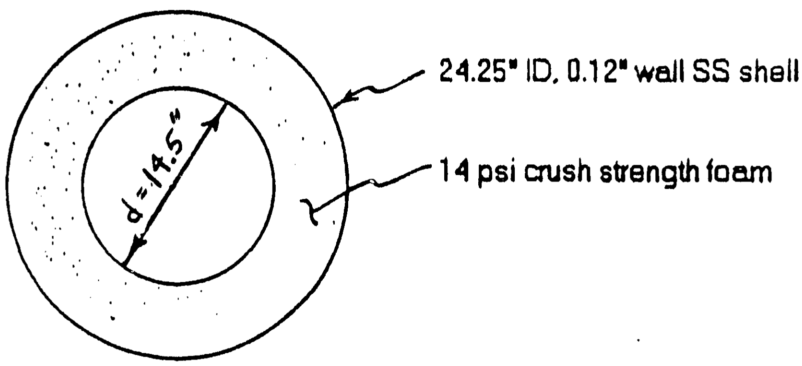
With the maximum weld shear stress being less than its ultimate shear strength, the end plate will be retained and the payload will remain confined within the container as required.

3.0 Compression Test

With a 75 inch length and a 24.5 inch diameter, a 1.85 psi load acting on the projected area is somewhat greater than 5 times the weight of the package [(75)(24.5)(1.85) = 3,399 lb vs. (5)(590) = 2,950 lb]. The 3,399 lb load (or 3,399/75 = 45.32 lb/in) will therefore be applied in accordance with 10CFR71.71(c)(9)(ii). Two cases are considered to demonstrate the capability of the package to withstand this load condition as follows:

3.1 Local flexure of the container cross section

For this assessment, the container cross section will be approximated as follows:



d = "effective" foam diameter assumed for analysis = 14.50" (which envelops the basic geometry of the basket)

The strength of the basket is conservatively ignored. The following calculations show that the outer shell and the foam acting in combination will adequately withstand the 1.85 psi projected load.

a) Steel shell as only structural member

For this assessment, Roark and Young, Fifth Edition, Table 17 case 10 with $\theta = 0$, will be utilized. Per that case, the maximum stress in the shell becomes:

$\sigma = Mc/I + P/A = 28{,}613 + 188 = 28{,}800$ psi

where,

$M = K_{MA}\omega R^2 = 68.67$ in-lb

$c = t/2 = 0.12/2 = 0.06$ inches

$I = (1/12)(1)(0.12)^3 = 0.000144$ in^4

$K_{MA} = 0.25$ (for $\theta = 0$)

$\omega = 1.85$ lb/in (for 1" length of container)

$R = 24.25/2 + 0.06 = 12.185$ inches

$P = T = K_{TA}\omega R = 22.542$ lb

$K_{TA} = 1.00$ (for $\theta = 0$)

$A = (0.12)(1) = 0.12$ in^2

This very conservative assessment, which ignores any basket or foam strength, results in a shell stress less than 3% over the shell yield strength.

b) Foam as only structural member

Roark Table 17, case 10 will again be applied.

$\sigma = Mc/I + P/A = 13.716 + 4.601 = 18.317$ psi

where,

$M = K_{MA}\omega R^2 = 54.320$ in-lb

$R = (14.50 + 24.25)/4 = 9.688$ inches

$\omega = 1.85(24.25/(2\{9.688\})) = 2.315$ lb/in

Note: ω has been adjusted to reflect that loading is applied to OD of foam, whereas formula being used is based on load being applied at average diameter.

$K_{MA} = 0.25$ (for $\theta = 0$)

$t = (24.25 - 14.50)/2 = 4.875$ inches

$c = t/2 = 2.438$ inches

$I = (1/12)(1)(4.875)^3 = 9.655$ in^4

$P = T = K_{TA}\omega R = 22.43$ lb

$K_{TA} = 1.00$ (for $\theta = 0$)

$A = (4.875)(1) = 4.875 \text{ in}^2$

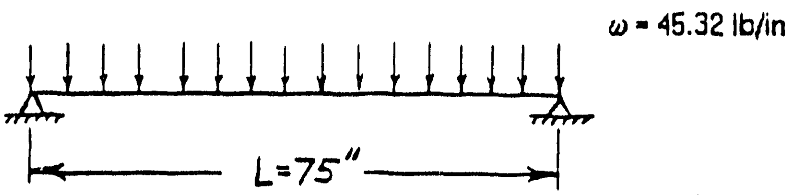
This very conservative assessment which ignores any steel shell or basket strength indicates that the foam alone can support over 76% of the applied load [(14 psi)(100)/(18.317 psi) = 76.4%].

c) Steel shell acting in conjunction with foam

From a) and b) above, the steel acting alone can support 97% of the applied load and the foam can support 76%. It is apparent that when acting together, and with added support from the basket structures, the full 1.85 psig applied load is readily accommodated. Further, the foamed-in-place construction technique will actually result in a "composite" structure capability which will be far superior to the sum of the individual component capabilities. Finally, since the steel alone can support 97% of the applied load, significant deviations in foam strength from the 14 psi value used herein can occur without compromising the ability of the design to withstand the compression test.

3.2 Overall bending response of the container

For this assessment, only the 24.25 inch ID, 0.12 inch thick cylinder will be assumed to resist the 45.32 lb/in lateral loading. A 75 inch long simply supported beam will be assumed.



$M = \omega L^2/8 = 31{,}866 \text{ in-lb}$

$\sigma = Mc/I = 572 \text{ psi} \ll \sigma_y = 28{,}000 \text{ psi}$

where,

$c = 24.49/2 = 12.245$ inches

$I = (\pi/64)(24.49^4 - 24.25^4) = 682.0 \text{ in}^4$

Therefore, overall bending due to the compresion test is easily accommodated by the design.

3.0 THERMAL EVALUATION

This chapter discusses the thermal performance of the HFBR Unirradiated Fuel Shipping Container to comply with the requirements specified in the regulations[1,2,3] of the US Nuclear Regulatory Commission (NRC), the US Department of Energy (DOE), and the US Department of Transportation (DOT).

For Normal Conditions of Transport, the requirements in 10 CFR § 71.71(c) stipulate that the package must be able to withstand an ambient temperature of -40° C (-40° F) in still air and shade, and an ambient temperature of 38° C (100° F) in still air and direct sunlight without the effectiveness of the packaging being reduced. The requirements in 10 CFR § 71.43 and 49 CFR § 173.442 further stipulate that the temperature of any accessible surface of the fully loaded shipping package for an exclusive use shipment shall not exceed 82° C (180° F) when the package is in the shade in still air at an ambient temperature of 38° C (100° F).

3.1 Discussion and Results

The package has a decay heat load of less than one watt and a steady-state analysis shows that the accessible surfaces will reach a maximum temperature of 108° C (226° F) when the package is exposed to an average solar radiation and 38° C (100° F) in the shade during a 38° C (100° F) ambient day. All of the packaging components will perform satisfactorily from -40° C (-40° F) to 108° C (226° F). Furthermore, these temperatures are far below the 475° C (887° F) minimum annealing temperature of the HFBR fuel plates. The package surface temperature in the shade in an ambient temperature of 38° C (100° F) is also less than the 82° C (180° F) specified in the regulations for exclusive use shipments.

The package was not analyzed for the hypothetical accident thermal event since the quantity of fissile material is less than a critical mass and an A_2 value.

3.2 Summary of Thermal Properties

The thermal properties of the packaging materials are not required for the thermal analysis of the package performance.

3.3 Technical Specifications of Components

Detailed specifications of the packaging components are given in Chapter 1.0.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Thermal Model

A thermal test was not performed on this package for Normal Conditions of Transport. The maximum package temperatures are calculated by applying a steady-state energy balance at the package surface as shown in the Appendix A to Chapter 3.0

3.4.2 Maximum Temperatures

For the condition of a constant average solar radiation at 38° C (100° F), the result of the steady-state analysis shows that the surface of the package and the contents will reach a maximum temperature of 108° C (226° F). For the condition where the package is in a 38° C (100° F) ambient temperature and in the shade, the package will not reach a temperature above the ambient since the internal heat load from the unirradiated HFBR fuel is less than one watt.

3.4.3 Minimum Temperatures

Since there is less than a one watt of internal heat load, the package will reach -40° C (-40° F) when exposed to the coldest regulatory environment.

3.4.4 Maximum Internal Pressure

The pressure will not rise in the HFBR Unirradiated Fuel Shipping Container for any heating condition, as explained in Section 2.6.4. A number of weep holes provide for adequate venting of the outer container during all conditions of transport.

3.4.5 Thermal Stress

There are no thermal gradients that could cause thermal stress in the structural members of the packaging.

3.4.6 Evaluation of Package Performance for Normal Conditions of Transport

The HFBR Unirradiated Fuel Shipping Container meets the thermal requirements of 10 CFR Part 71 and 49 CFR Part 173.

3.5 Hypothetical Accident Thermal Evaluation

The HFBR Unirradiated Fuel Shipping Container was not analyzed for the hypothetical accident thermal event because the package meets containment and subcriticality requirements under all circumstances of release by restricting the fissile contents to a subcritical mass and to less than an A_2 value.

3.6 References

1. Code of Federal Regulations, Title 10, Part 71, Packaging and Transportation of Radioactive Material.

2. United States Department of Energy, Order 5480.3, Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes, July 9, 1985 and Notice DOE N 5480.3, effective March 1988.

3. Code of Federal Regulations, Title 49, Part 173, Shippers -General Requirements for Shipments and Packaging.

4. F. Krieth, Principles of Heat Transfer, International Textbook, Scranton, PA, 1965.

5. L.B. Shappert, Cask Designer's Guide, ORNL/NSIC-68 (Feb. 1970).

3.7 Appendix

A Normal Conditions of Transport with Insolation

Appendix A

Normal Conditions of Transport with Insolation

Normal Conditions of Transport with Insolation

The package must be able to withstand direct sunlight at an ambient temperature of 38° C (100°) F in still air without reducing the effectiveness of the packaging. With the cyclic nature of the solar heat load, the large thermal capacity of the package, the less than a one watt internal heat load, and the thick foam insulation surrounding the basket, the temperature variation will only occur in the vicinity of the surface. Therefore, a simplified one-dimensional heat transfer analysis[4] was used to compute the steady-state temperature distribution in the package.

The steady-state energy balance at the packaging surface is

$$q_{out} = q_{in} \quad (1)$$

where

q_{out} = total heat outflow from the package (Btu/h),

q_{in} = total heat inflow to the package (Btu/h).

To determine q_{out} an expression that includes convective and radiative heat transfer effects[5] is used. The expression is of the form

$$q_{out} = q_c + q_r$$

$$= h_c A_c (T_s - T_a) + 0.173\, F_{12} A_r \{[(T_s + 460)/(100)]^4 - [(T_a + 460)/(100)]^4\}, \quad (2)$$

where

q_c = convective heat flow (Btu/h),

q_r = radiative heat flow (Btu/h),

h_c = convective heat transfer coefficient[5] = $0.19(T_s - T_a)^{1/3}$, Btu/h-ft²-°F,

A_c = Convective heat transfer area = 3.27 ft² (3,042 cm²) (see below),

T_s = surface temperature (°F),

T_a = ambient temperature, 100° F (38° C),

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

ϵ = emissivity of the stainless steel shield surface (Table 5.2[5]),

F_{12} = gray body shape factor[5] (0.6), $F_{12} = \epsilon$ (between 0.15 and 0.85).

The heat load, q_{in}, on the package is only the solar heat load.

Since the insolation rate of 800 g•cal/cm^2 for a flat surface is the maximum of the three rates specified in 10 CFR § 71.71(c) for a 12-hour period, the maximum surface temperature will be on the top flat surface of the HFBR package.

The area of the top flat surface is

$$A_r = A_o = \pi r^2$$

$$= \pi (12.25 \times 2.54)^2$$

$$= 3{,}042 \text{ cm}^2. \tag{3}$$

The heat load on the top flat surface of the HFBR package is

$$q_{top} = 800 \times (1/12) \times 3{,}042$$

$$= 2.028 \times 10^5 \text{ g•cal/h} = 804 \text{ Btu/h}. \tag{4}$$

Equation (2) was solved via an iterative process to determine the surface temperature T_s corresponding to $q_{out} = q_{in} = 804$ Btu/h. In this case $T_s = 226°F$ (108° C). Since the internal heat load is less than one watt, the maximum temperatures of all internal components of the HFBR package will be less than 108° C (226° F).

4.0 CONTAINMENT

This chapter discusses the unirradiated fuel plates (assemblies) as providing containment for the Normal Conditions of Transport in the HFBR Unirradiated Fuel Shipping Container. In 10 CFR § 71.43(f) there is no loss or dispersal of radioactive contents when the package is subjected to the tests specified for Normal Conditions of Transport. Because the contents do not exceed an A_2 quantity, the requirements for Type B packages in 10 CFR § 71.51 do not apply.

4.1 Containment Boundary

The radioactive contents of the HFBR research reactor fuel assemblies are contained in a fuel matrix and clad in aluminum, which together provide a containment that withstands the combined effects of the structural and thermal tests for Normal Conditions of Transport when shipped in the HFBR Unirradiated Fuel Shipping Container. Each fuel assembly will contain a maximum of 355 g ^{235}U (maximum 95 wt % enriched U) and the package may contain up to two fuel assemblies. The HFBR unirradiated Fuel Shipping Container contains a maximum of 0.07 Ci well below the A_2 limiting value of 0.1 from Table A-1 of 10 CFR Part 71. The aluminum cladding bonded to the fuel matrix provides the primary boundary or containment. This type of bonded containment would limit any failure to the immediate area of the bond because each section of the containment or cladding is independent of the remaining boundary.

HFBR fuel assemblies are Al plate-type fuel assemblies, which are characterized by fuel meat plates consisting of U_3O_8 fuel particles distributed in an aluminum matrix. Several fuel plates are assembled with aluminum alloy ASTM Spec. B-209, ASA-6061-T0 or T6 hardware to make up a fuel assembly. Plate-type fuel assemblies are illustrated in the fuel assembly drawings listed in Chapter 1 Appendix A.

Fuel meat plates are fabricated by powder metallurgy methods. Fuel plates are clad with aluminum alloy ASTM Spec. B-209, ASA-6061-T0 or T6. A metallurgical bond between the fuel meat matrix and the cladding is formed by hot rolling during the fabrication process. This fabrication method produces a fuel plate with isolated fuel fines ranging in size from 100 to 325 mesh (44 μm to 150 μm) evenly dispersed throughout a metal matrix that has been demonstrated to be essentially impermeable to fission product migration or diffusion below 500 °C (932 °F).

Enrichment values of greater than 93% uranium are representative of the fuel material. A conservative value of 95% will be used to determine the radioactive content (A_2 value) from Table A-4 of 10 CFR Part 71, but a value of 93% will be used to determine the total amount of uranium. The quantities of radionuclides contained within the two unirradiated HFBR fuel assemblies are summarized as follows to determine the worst-case A_2 value.

Table 4.1 HFBR Package Curie Content

Max. ^{235}U	Minimum Enrichment	Max. U	Specify activity of 95 wt% U	Curie Content
710 g	93 w/o	763 g	9.1 x 10^{-5} Ci/g	0.07 Ci

A_2 (Ci) limit per 10 CFR Part 71 (Table A-1)

Isotope	A_2 (Ci)
U (enriched) 20% or greater	0.1

Note: The limit of 0.1 Ci for the A_2 value for enriched uranium (>20%) from Table A-1 of 10 CFR Part 71 is based on the ^{234}U isotope limit.

A secondary boundary is formed by the container cavity, lid, and seal as indicated in Figure 1.1 (HFBR Unirradiated Fuel Shipping Container). This boundary, which surrounds the containment or fuel cladding, is necessary only for ensuring compliance with the requirements of 10 CFR §§ 71.43, 71.45, and 71.55.

4.1.1 Containment Boundary

The containment boundary is the cladding of the HFBR fuel plates together with the fuel matrix. The clad material is aluminum alloy ASTM Spec. B-209, ASA-6061-T0 or T6. The clad thickness is a minimum of 0.010 in.

4.1.2 Containment Penetrations

There are no penetrations into the cladding.

4.1.3 Seals and Welds

Cladding for HFBR fuel is bonded to the fuel matrix by a hot rolling technique. As referenced in Sect. 4.1, the container seal or gasket is part of the container boundary and is not part of the containment.

HFBR fuel plates are roll swaged to the inner and outer side plates of the assembly.

4.1.4 Closure

Initial cladding integrity is verified by ultrasonic inspection and a blister test (non-bond indication) at a temperature between 475° C (887° F) and 493° C (920° F) for every fuel plate.

The integrity of the containment boundary, which is the fuel plate, is verified by means of the following sampling or verification processes:

Item	Verification Process	Frequency
1	Plate inspections	100%
2	Core outline	100%
3	Blister inspection	100%
4	Ultrasonic inspection	100%
5	Delamination test to verify bond quality of fuel plate (clippings)	4 per 24 plates (2 clippings (top & bottom) from each of 2 fuel plates out of each 24 plate batch)

During the initial qualification of the fuel plate fabrication process, a minimum of three plates out of 60 plates per production are destructively tested. Thereafter, the value presented in Item 5 represents a minimum value for maintaining confidence in an established fabrication process. Because inspections or tests performed per Items 1 through 4 are completed on 100% of the fuel plates used in the assembly of fuel assemblies, the results of these tests demonstrate the adequacy of containment. Thus, the containment boundary of each plate shipped has been verified, and the cladding-to-cladding bond and cladding-to-fuel bond have been shown to be acceptable. Item 5 is an overview test that provides physical performance data on the adequacy of the other tests (Items 1 through 4).

The fabrication and inspection process for HFBR unirradiated fuel assemblies contain the special requirements to establish the containment conditions for unirradiated fuel. A complete listing of these requirements is contained in Appendix A of this chapter as specifications for the fabricator of the HFBR fuel assemblies. The Appendix A document shall be maintained as a controlled document.

The destructive and nondestructive tests (Items 3, 4, and 5) provide assurance that the cladding-to-cladding bond and cladding-to-fuel bond are sufficient to provide the containment necessary for HFBR fuel. A description of the manufacturing process and associated quality assurance for fuel is given in Appendix A.

Because containment is established by the integrity of the fuel plates and their associated fuel assemblies specific physical parameters of these components are controlled to ensure that important design/fabrication parameters are maintained. A listing of fuel assembly and fuel plate drawings and their revision numbers together with the fuel fabrication specifications is contained in Chapter 1 Appendix A.

4.2 Requirements for Normal Conditions of Transport

4.2.1 Containment of Radioactive Material

The HFBR fuel plates are considered the containment boundary when maintained in the environment provided by the HFBR Unirradiated Fuel Shipping Container. The secondary boundary formed by the package cavity and lid ensures that no damage to the fuel occurs during normal conditions of transport. The HFBR Unirradiated Fuel Shipping Container and similar packages have been used in over 200 fuel shipments for aluminum-clad-plate-type fuel since 1978 with no release of radioactive material.

Normal fabrication and inspection requirements for the HFBR fuel assemblies limit radioactive contamination of the external surfaces of the fuel plates to less than 5 μg of ^{235}U per square foot (~ 3.5×10^{-7} $\mu Ci/cm^2$) of surface area. This value would not contribute to any significant source term during normal transportation. The contamination level is determined by inspecting three fuel plates per lot of 24 before a fuel assembly is assembled. Additionally, the assembled fuel assemblies are checked for contamination by a smear survey of available surfaces to determine contamination levels before loading the fuel assemblies into the packaging.

This level of non-fixed radioactive contamination is as low as reasonably achievable and within the requirements of 10 CFR § 71.87(i) if it were potentially deposited on the external surfaces of the package.

4.2.2 Pressurization of Containment Boundary

The unirradiated HFBR fuel assemblies contain no fission products. Therefore, no source for internal pressurization of the fuel matrix or cladding exists. The fuel matrix and cladding provide a high margin for containment during operation in a reactor. When the fuel assemblies are irradiated in a reactor, fission products will generate an internal pressure within the fuel matrix and cladding. Actual experiments [1,2] at 500 °C (932 °F) for irradiated fuel plates verify that the 0.010-in. aluminum cladding is sufficient to ensure that the irradiated fuel plate provides containment at a conservative analysis limit of 400 °C (752 °F) for spent fuel. Therefore, this same containment boundary for irradiated fuel plates provides for a very conservative containment boundary for unirradiated fuel plates since unirradiated fuel plates are more ductile than irradiated plates.

4.2.3 Containment Criterion

10 CFR § 71.43 specifies no loss or dispersal of radioactive contents during Normal Conditions of Transport. During normal conditions of transport, no loss of radioactive material from a fuel assembly has ever been detected on receipt of fuel. During the last 13 years, Al plate-type fuel assemblies have been fabricated, shipped for storage, stored for time frames up to one year or more, and then transferred to the reactor for use. This process has demonstrated that no radioactive material from the fuel is lost or dispersed during normal transportation conditions. The evaluation of Normal Conditions of Transport tests on the fuel plates, discussed in Section 2.9, concludes that breaching of the cladding will not occur. The regulatory containment criteria requirement in 10 CFR § 71.43(f) is therefore met.

Because the radioactive material does not exceed an A_2 quantity, the Type B requirements of 10 CFR § 71.51(a)(1) do not apply.

4.3 Containment Requirements for Hypothetical Accident Conditions

Because the radioactive material does not exceed an A_2 quantity, the Type B requirements of 10 CFR § 71.51(a)(2) do not apply.

4.4 Special Requirements

No plutonium shipments are made in this shipping container. Therefore, this section does not apply.

4.5 References

1. Release of Fission Products from Irradiated Aluminide Fuel at High Temperature, T. Shibata, K. Kanda, K. Mishima, T. Tamai, M. Hayshi (Japan), J. L. Snelgrove, D. Stahl, J. Matos, A. Travell (ANL-USA), and F. N. Case and J. C. Posey (ORNL-USA), ANL/RERTR/TM-4, Conf. 821155.

2. Release of Fission Products from Miniature Fuel Plates at Elevated Temperature, John C. Posey, ANL/RERTR/TM-4, Conf. 821155.

4.6 Appendix

A Brookhaven National Laboratory Specifications for HFBR Fuel Type KM

Appendix A

BNL Specifications for HFBR Fuel Element Type KM

List of Effective Pages

Title Page	Approved July 10, 1987
Index	Dated October 1985
Pages 1 through 14 and Drawing List	Dated May 1987

BROOKHAVEN NATIONAL LABORATORY

DESCRIPTION AND GENERAL SPECIFICATIONS FOR

HFBR FUEL ELEMENT TYPE KM

January 12, 1976

February 1, 1979

August 26, 1980

March 13, 1984

April 10, 1984

August 20, 1984

October 15, 1985

May 29, 1987

Approved by Michael Brooks
Michael H. Brooks, Reactor Division Manager

Date 7/10/87

INDEX

1.0 SCOPE

These specifications cover the fabrication of HFBR fuel element assemblies. Each element consists of 18 identical fuel bearing inner plates and two thicker nonfuel bearing outer plates attached to grooved side plates by roll swaging with a water inlet shroud section above the fuel plates and a supporting water outlet structure below the fuel plates.

The manufacturing technology used for the fuel cores should be based on the use of U_3O_8 -Al cermet clad with aluminum.

These specifications are not to be considered as completely covering all aspects of different process technologies but are to be taken as an indication of the level of quality desired in the finished product. It is intended that final details will be completely described after contractor and process selection. Alternate methods of achieving equivalent quality may, therefore, be outlined in proposals.

The term "Buyer", as used in these specifications, means Brookhaven National Laboratory.

2.0 DRAWINGS

The following drawings describe mechanical aspects of the assemblies and are a part of these specifications.

HFBR Fuel Element type KM Assembly Drawing #9-8025-M and the 16 additional detailed drawings listed on page 13.

3.0 GENERAL REQUIREMENTS

3.1 The seller is required to supply fuel elements, each to consist of the following components:

3.1.1 Two (2) nonfuel bearing grooved side plates.

3.1.2 Two (2) nonfuel bearing outside curved plates.

3.1.3 Eighteen (18) fuel bearing inside curved plates.

3.1.4 One (1) plate spacer comb.

3.1.5 Two (2) 3/32" diameter pins or weld rod for attaching comb to top of the fuel plates.

3.1.6 Two (2) "O" brace spacer sections.

3.1.7 One (1) inlet section box fitting.

3.1.8 One (1) inlet section tube.

3.1.9 One (1) inlet section transition fitting.

3.1.10 One (1) outlet section.

3.1.11 One (1) 1/2" diameter lifting bale.

3.1.12 Twenty (20) rivets for joining O-braces to side plates.

3.2 All fuel bearing plates will consist of rolled uranium bearing aluminum cores, enveloped in aluminum covers or cladding. The finished individual plates, both fueled inside and non-fueled outside types, are attached to appropriately grooved side plates to form a multiplate assembly containing twenty (20) carefully positioned curved plates with nineteen (19) cooling water passages between the plates. As delivered by the Seller, the fuel assemblies are to have the inlet tube assembly and outlet box attached, be finish machined, have passed the "Boundary Plane Gauge Test" and be ready for insertion into the reactor.

3.3 Each fuel element generates a large amount of heat during operation. To insure that this heat is adequately removed from each individual plate and assembly, it is mandatory that certain mechanical and metallurgical characteristics be maintained. Cladding continuity and metallurgical bonding in the fuel bearing plates, must be maintained to ensure adequate heat transfer and to ensure against ruptures or fission breaks with release of fission products into the cooling water. Fuel plate spacing, overall assembly dimension, plate thicknesses, etc., are of particular importance in the control and distribution of cooling water flow and heat removal. Material specifications must be adhered to rigorously for, although the operating life of a fuel assembly is measured in weeks, corrosion of the fuel plates must be minimized and foreign elements which may be parasitic to the nuclear chain reaction, must be limited by use of specification materials prescribed in Section 4.0. In facilities fabricating other fuel bearing components containing nuclear fuels or reactor poisons such as boron, cadmium, etc., particular care must be detailed in procedures to prevent contamination of the HFBR components covered by these specifications through carry over of other fuels or reactor poisons from ladles, rolls, and other fabrication equipment.

3.4 The fuel plates are to be attached to the grooved side-plates of the fuel assemblies by the mechanical method known as "roll swaging." The mechanical joint between the fuel plates and side plates must meet the "pull test" requirements as outlined in Section 12.4.3.1. The finished units must be strong, rigid, tight, and capable of withstanding the normal conditions of loading, handling, and reactor operation. The equipment to "roll swage" the HFBR fuel element will be supplied to the fabricator as government owned equipment along with detailed procedures to be followed by the fabricator.

3.5 The maximum overall vertical departure of the location of the top ends of fuel plates in an individual fuel assembly shall not be greater than 1/64" in order to ensure proper distribution of inlet water flow.

3.6 The fuel plate cladding must be bonded metallurgically to the fuel bearing core to ensure adequate heat transfer from the heat generating core outward through the cladding material. A minimum metallurgical bond as represented by 40% grain growth across the bonded interfaces over this core and core frame shall be verified as specified in 8.5. Individual fuel plates, as prepared for assembly into the side plates, must be completely free of dirt, scum, scale, grease, pencil marks, or other foreign materials. Each fuel plate shall be free of pits, dents, scratches, or other blemishes in excess of 0.005" deep and shall be entirely free of blisters and unbonded areas as specified in Sections 8.2 and 8.4.

3.7 During operation of the HFBR, the fuel elements are subjected to the hydraulic forces resulting from water flowing at an average velocity of 40 feet per second through the fuel plate spacings. In addition, the inlet shroud section and the outside curved plates are subjected to pressure differentials between the high core inlet, or channel pressures, on the inside surfaces and the lower reflector pressures on the outside surfaces of the elements. Each fuel element must be capable of continuous operation at full power in the HFBR for extended periods without distortion, or impairing its performance. In order to provide protection against such failure, fuel elements will be hydraulically (simulated service) tested by the Buyer at Brookhaven. This test shall consist of flowing water through the element at a maximum of 700 gpm. The temperature of the water used for this test shall be between 90° and 130°F. The length of time an element is at test condition may be as long as six (6) hours. The frequency of this testing will be determined by the Buyer.

All elements failing the hydraulic test, as evidenced by any cooling channel being outside the specified tolerances, by plate or element distortion, by failure of welds, or by loosening of plates or other components in the assembly, will be unacceptable and shall be replaced by the Seller.

3.8 Each fuel bearing plate shall be identifiable with the material batch and fabrication lot from which it was made. Records shall also be kept which shall allow each plate to be identified with the fuel assembly and position into which it was placed. Identification on fuel plates shall be located at the bottom end of the plate when placed in the fuel assembly. A vibratool shall be used to place the plate identification number on the fuel plate and it shall identify the fabrication sequence. The starting series shall be approved by the Buyer.

3.9 Each fuel element shall have an identifying number placed on the outside of each grooved side plate as shown in the drawings. Two (2) inch block characters using a vibratool frosting technique shall be placed on the side plates from 0.005" to 0.015" deep. These markings must be legible under 10 feet of clear water. Those numbers which could be misinterpreted when read upside down must have a base line inscribed to show correct orientation. No identification is to be used more than once. The starting series shall be specified by the Buyer. If an element is disassembled, any reassembly shall bear a new identification.

3.10 All parts and assemblies are to be fabricated in strict accordance with best existing standards of commercial practice.

3.11 Notwithstanding other provisions these specifications, the Buyer may at his option, when requested in writing, accept minor deviation from requirements of the specifications and drawings where the deviation will not, in the opion of the Buyer, result in a restriction of the use of the element. Acceptance of a fuel element by the Buyer with one or more such deviations from the specifications shall not be construed to mean that the Buyer approves, or will approve, similar deviations in elements not yet completed under the contract.

3.12 The Seller shall submit to the Buyer for his approval, prior to fabrication, copies of the detailed shop drawings of the fuel elements to be manufactured under these specifications, along with written manufacturing procedures and process control variables stressing the inspection and quality control steps in relation to the flow of materials and processes. A limited initial quantity of each component shall be produced strictly in accordance with this submission on which all quality aspects will be verified. Following approval of the initial production by the Buyer, no changes in process or manufacturing details may be made without written approval of the Buyer.

4.0 MATERIALS OF FABRICATION

4.1 Materials to be used for the various parts of the fuel assemblies shall meet the following specifications. All specifications shall be the latest revision. Adjustments may be made in these specifications by the Buyer, if necessary, to accommodate material availability or design/process changes.

4.1.1 Side Plates - Aluminum alloy ASTM Specification B-209, ASA-6061-T6, maximum allowable boron content 10 ppm.

4.1.2 Nonfueled Outer Plates - Aluminum alloy ASTM Specification B-209, ASA-6061-T0 or T6, maximum boron content 10 ppm.

4.1.3 Comb - Aluminum alloy ASTM Specification B-209, ASA-6061-T6, maximum boron content 10 ppm.

4.1.4 Fuel Plate Core Metal - Aluminum powder Military Specification A-81335(WP), maximum boron content 10 ppm or aluminum powder of equivalent purity and quality. 100% of the powder must pass through a 100 mesh U.S. Standard screen and with a minimum of 65% passing through a 325 mesh U.S. Standard Screen.

4.1.5 Fuel alloy Frame - Aluminum alloy ASTM Specification B-209, ASA-6061-T0-T6, maximum boron content 10 ppm.

4.1.6 Fuel Alloy Cladding - Aluminum alloy ASTM Specification B-209, ASA-6061-T0-T6, maximum boron content 10 ppm.

4.1.7 Pins - Aluminum alloy 4043, AWS 5.10, .093 dia. welding wire.

4.1.8 Rivets - Aluminum alloy ASTM Specification B-316, ASA-6061-T6, maximum boron content 10 ppm.

4.1.9 O-Bar - Aluminum alloy ASTM Specification B-209, ASA-6061-T6, maximum boron content 10 ppm.

4.1.10 Inlet Tube Section - Aluminum alloy ASTM Specification B-221, ASA-6061-T6, or Aluminum 6105-T5, either with maximum boron content of 10 ppm.

4.1.11 Welding Rods - 4043 aluminum rod - AWSA 5.10 and MIL-E-16053K.

4.1.12 Inlet Box - Cast aluminum alloy 356 T7 ASTM B-26.

4.1.13 Outlet Box - same as 4.1.12.

4.1.14 Transition Section - same as 4.1.12.

4.1.15 Lifting Bail - Aluminum alloy ASTM Specification B-211, ASA-6061-T6, maximum boron content 10 ppm.

.0 URANIUM CONTENT AND CONTROL

5.1 The uranium in the uranium bearing aluminum cores of all fuel plates shall consist of uranium, enriched to a minimum of 93% in the isotope U-235.

5.2 The Buyer reserves the right to require further analyses and/or to reject the batch of uranium involved if (1) the U-235 isotopic enrichment analysis shows a deviation in excess of 0.2% absolute from the Seller's assigned enrichment, (2) if the chemical impurities total greater than 0.1% based on volumetric analysis, (3) if any of the spectrographic impurities are excessive in terms of high neutron absorption cross section or indicate contamination of the uranium during conversion.

5.3 The total U-235 content of each fuel element shall be 351.0 grams $\pm$ 4.0 gms. The total U-235 content of each individual fuel plate shall be 19.50 $\pm$ 0.30 gms.

5.4 The Buyer reserves the right to establish from time to time, at its option, resident inspection at the Seller's plant. Such inspections may include natural gamma counting of unclad fuel cores and/or natural gamma scanning of some finished flat fuel plates, utilizing the Buyer's equipment, as a procedure for verifying the U-235 contents and distribution.

5.5 Distribution of the uranium in each flat fuel plate shall be onitored using a collimated (.080" dia.) x-ray beam scanner. Procedures for use of this equipment are based on the attenuation of the x-ray beam which is calibrated to measure local uranium loading. The allowable unit loading for all fuel plate positions (2 through 19) will be an average loading less than +9% with local loading less than +15% from nominal. If either of these limits is exceeded, the fuel plate may be used in fuel plate positions 6 through 15 if the average loading is less than +12% and local loading less than +17% from nominal.

5.6 The total U-235 content of each fuel plate will be carefully determined. Prior to fabrication by the Seller under this contract, the Seller shall supply the buyer with a detailed description of the proposed system by which the individual plate U-235 content will be assigned. Included in this description should be the standardization, analytical and quality control procedures; a statement as to the estimated absolute accuracy of the assigned fuel plate and fuel assembly U-235 contents; developmental and/or production data in support of the precision estimate and data showing that the methods to be used are free from any systematic errors (bias) and applicable to the proposed fabrication procedure.

5.7 The enriched uranium contained in any cores, fuel plates or finished elements shall be transferred to the Buyer's accountability station as specified in the contract.

6.0 WELDING REQUIREMENTS

6.1 Basic Requirements.

6.1.1 All welding shall be performed employing the tungsten inert gas process (TIG).

6.2 Welder and Equipment Qualification.

6.2.1 Simulated joints shall be made for each type of weld required on the fuel element, and these samples along with the associated welding procedure sheets shall be forwarded to the Buyer for inspection and approval prior to any production welding. For a series of joints to be qualified by a single simulated joint, all applicable joints must have: (1) the same materials, (2) the same joint preparation, (3) the same geometry, (4) the same welding position, (5) the same filler material, (6) the same welding equipment, and (7) the same procedure.

6.2.2 Radiographic examination is required wherever practical during qualification of process. Porosity standards will be established by the Buyer prior to the start of production. Inclusions, undercutting, icicles, cracks, lack of penetration, and slugging will not be allowed.

6.2.3 For qualification only, liquid penetrant inspection shall be performed on the entire length of each final pass of all welds. When dressing is necessary, the weld shall be examined before removing metal.

6.2.4 After meeting the requirements of paragraph 6.2.1, an inlet shroud assembly welded to a dummy fuel box shall be forwarded to the Buyer for inspection, tests, and approval of the welded joints. This test section must withstand a tensile test pull of 4000 lbs.

6.3 Joint Preparation

6.3.1 Files, saws, milling cutter, brushes, and other tools used in preparation of joints shall be used on aluminum only. Joint preparation by grinding is not permitted.

6.3.2 In no case shall welding be performed if the prepared joint has been exposed to the atmosphere for more than four (4) hours. If a longer time elapses, or if the joint becomes contaminated with dirt or grease, the surfaces shall be cleaned with toluene or a comparable solvent and brushed with a clean brush with stainless steel bristles.

6.3.3 Power driven chipper, wire brushes and milling cutters shall be lubricated with dry lubricant only such as graphite or molybdenum-disulfide. Hand tools are preferred.

6.4 Weld Wire

6.4.1 The recommended filler metal is aluminum alloy ER-4043. Other material may be used, subject to Buyer's approval.

6.4.2 Wire purchased shall be from ingots with a low gas content. High quality weld wire is required.

6.4.3 Certified chemical analysis shall be furnished for each heat or batch number.

6.4.4 Weld wire must be identified by the classification of wire and the certification that the requirements of 4.1.11 have been met. Prior to use, the wire shall be wiped clean with alcohol.

6.5 Shielding Gas

6.5.1 The shielding gas for TIG welding shall be 100% Argon.

6.5.2 Gas cylinders shall not be used when the pressure falls below 50 psi.

6.6 Welding Procedure

6.6.1 Only one welder shall work on any one joint.

6.6.2 All welds shall be of good quality and appearance and be free from cracks, significant porosity, inclusions, lacks of fusion, lack of penetration, under-cutting, angular defects and pipes.

6.6.3 Pores in the weld surface not greater than 1/32 inch diameter may be considered acceptable defects provided there is not less than 1/32 inch between adjacent pore edges and, that there are no more than four pores in any group of pores. Frequency of such defects in any weld will be established with the Seller and will be based on strength requirements of each particular weld in the fuel element.

7.0 DIMENSIONAL TOLERANCES

7.1 To be acceptable for reactor operational requirements, each fuel assembly's dimensional deviations must be held within the limits shown on the listed drawings that are a part of these specifications.

7.2 Plate spacings, as they define the coolant channels of the fuel assembly, must be held within the dimensional limits shown on the drawings and must be measured along three tracks. One track shall be down the centerline of each water channel and the other two tracks shall be halfway between the centerline and each sideplate.

7.3 The Seller will inspect all completed fuel elements in a boundary plane gage provided by the Buyer to ensure that they do not touch or exceed the boundary plane dimensions specified on the assembly drawing which is part of these specifications.

8.0 FUEL PLATES, NONFUEL PLATES

8.1 Each fuel plate shall be rolled by a combination of first hot rolling, and second, cold rolling. The final reduction of the fuel plate thickness shall be accomplished by cold rolling after the plate has been blister-tested (Section 8.2) and shall not be less than 15% nor greater than 25%.

8.2 Each fuel plate shall be heated after hot rolling, but before cold rolling, to 887°F Min., 920°F Max., maintained for a period of at least one (1) hour as a blister test. A visual examination (unaided eyes) by a trained individual with adequate light of all annealed fuel plates shall be made to determine if any blisters, delaminations or cracks are present. If any are found, a determination shall be made as to whether any such defects would remain in the fuel plate after blanking, shearing or machining. There shall be no blisters in the final sheared plate area. Any plates with blisters in the final sheared plate area are unacceptable and shall be rendered unusable by the Seller by placing the word "reject" on the fuel plate with a vibratool over the fueled area.

8.3 Each fuel plate shall be X-rayed or fluoroscoped prior to final shearing to establish the outlines of the fuel core material. It is mandatory that the fuel core material not be exposed as a result of the plate shearing process. Particular care must also be taken to prevent the exposure of core material due to feathering or overriding of the core material on to the window frame. The fuel plate cores shall be of the size specified on the drawings, and shall be within the minimum and maximum end clad and edge clad specifications.

8.4 Each finished fuel plate shall be inspected by means of a recording ultrasonic test to detect any unbond between the core and the aluminum cladding. Any plate showing, by this test, an unbond area 1/16" or larger in diameter shall be rejected. All defect indications on the UT record must be explained in writing on the recording by the Seller's inspector. Standards and test procedures to assure compliance with this specification must be approved by the Buyer.

8.5 All fuel plates shall be .0494-.0510 inches in thickness. A nominal core thickness shall be established between .020 and .023 inches as required by the production process. The thickness of the cladding on either side of the core shall be equal within 0.002 inch. The fuel core thickness and cladding thickness dimensions are to be based on measurements using the average interface between the fuel core and the cladding. Any extension of single fuel core grains into the cladding must not violate a minimum cladding requirement of 0.0105".

8.5.1 In order to ensure that a minimum of 40% grain growth is achieved in the fuel plate bonding and that the thickness specifications of 8.5 are met, the Seller shall make metallographic sections of finished flat fuel plates. These sections shall include a longitudinal cut through each end of the fuel core for at least one inch and a transverse cut through the middle of the fuel core. Percentage grain growth shall be measured over at least a 1/4" length of interface on the metallographic sections taken in accordance with Specification 8.5. Four separate measurements shall be made on each section covering the top and bottom interfaces between the fuel core and cladding. These measurements shall not be averaged together.

8.5.2 For process qualification, every 20th fuel plate at the start of production shall be tested as required by 8.5.1. After three consecutive successful tests, the monitoring of the fuel plate bonding process shall be done by performing a delamination test on at least four of the end clippings as sheared from each lot. A lot shall consist of twenty four plates.

8.5.3 The delamination test of the nonfuel bearing end clippings shall be done using a wedge device provided by the buyer. Each end clipping shall be impacted in three places on the edge which adjoined the fuel plate and these impacts will be examined for evidence of delamination using a low power eye-loop magnifier.

8.5.4 Any deviation from the established plate fabrication procedures may require requalification at the request of the Buyer.

8.6 Acomb spacer is to be attached to the top of the fuel plate assembly. This comb is secured in place by aluminum alloy pins or wire welded to the nonfueled outer plates.

8.7 The nonfueled outer plate stock material should be in the T-O condition and of a thickness which will allow achieving the specified thickness after a cold rolling reduction of about 20%.

9.0 FINISHED FUEL ASSEMBLY

9.1 The finished fuel element shall be completely free of dirt, scum, scale, pencil or graphite marks, grease, or other foreign materials inside and outside. The element shall be free of dents, scratches, slivers, or surface blemishes on all fuel plates. Scratches on the nonfuel bearing outer and side plates are harmless, provided they are not of a severity causing distortion of the plates or cannot be construed to invalidate or lessen the structural integrity of the side plates themselves.

9.2 The requirements of these specifications and the drawings listed herein must be complied with in full. Deviations beyond specified tolerances, faulty or inadequate fabrication procedures or practices, improper handling, inadequate packaging, inadequate quality control, failure to withstand the flow tests as specified, and/or faulty workmanship may render fuel plates or completed elements unacceptable.

10.0 CLEANING

10.1 The Seller shall take all precautions necessary to maintain a high standard of cleanliness during fabrication to ensure that no foreign materials or corrosion products are present in the finished units.

10.2 All metal chips, turnings, dust, abrasives, weld splatter, scale and other particles shall be removed without destroying the continuity of the surface(s).

10.3 All oil and grease shall be removed by use of satisfactory degreasing agent, and all surfaces, including all crevices, shall be thoroughly rinsed with water.

10.4 To ensure against fixed uranium contamination, all surfaces of one fuel plate in each one hundred accepted plates (1% of all accepted plates) shall be counted, by means of a flowing gas proportional counter, for fixed alpha contamination. The alpha count shall be less than the equivalent of 5 Zgm/ft^2 of U-235. Alternate methods of achieving equivalent assurance may be proposed.

10.5 100% of the finished fuel elements shall be smeared just prior to packaging for shipment to detect loose radioactive contamination. There shall be no detectable alpha or beta-gamma contamination.

11.0 PACKAGING AND SHIPPING

11.1 The Buyer will provide suitable shipping containers for the fuel assemblies. The Seller is responsible for loading the elements in the shipping containers in a clean, dry condition, free of grease and other extraneous materials. A Buyer representative will be available to perform final inspection and acceptance of completed fuel elements at the time of packaging.

11.2 The Seller shall take all necessary precautions during packing to protect the finished elements from damage during shipment.

12.0 TESTING, INSPECTION, AND DATA RECORDS

12.1 A certified copy of inspection and test records covering all itmes in Section 12.3 shall be supplied to the Buyer.

12.2 The Seller shall allow the Buyer's inspectors free access to the portion of the plant engaged in fabrication of the fuel elements and parts at all reasonable times when so requested by the Buyer. The Seller shall provide the Buyer's inspectors all reasonable assistance necessary to perform the tests and inspections that may be required.

12.3 The Seller shall supply the Buyer with samples, inspection data, process control data, manufacturing data, and other information specified in other sections of these specifications. The Seller shall inspect all parts, subassemblies, and finished elements to determine conformity to the drawings listed in Section 2. The following shall be supplied to the Buyer along with the delivered fuel elements.

12.3.1 One copy of final inspection records for each element covering the following:

12.3.1.1 Location of outside surfaces with reference to boundary planes and minimum clearances as required in Section 7 and shown on the assembly drawing listed in Section 2.

12.3.1.2 Exterior dimensions of top box section of inlet shroud and bottom section of assembly.

12.3.1.3 Final plate spacing (water-channel) inspection results which demonstrates compliance with the required dimensions shown on the drawings listed in Section 2.

12.3.1.4 General compliance with the dimensional requirements of the specifications and fuel element drawings.

12.3.2 Individual plate uranium date in duplicate for each fuel element showing the following:

12.3.2.1 Fuel element serial number.

12.3.2.2 Serial number of each fuel plate and its position in the fuel element.

12.3.2.3 Uranium weight in grams for each fuel plate.

12.3.2.4 U-235 weight in grams for each fuel plate.

12.3.2.5 Total quantity of uranium and U-235 in the fuel assembly.

12.4 The following records and test results shall be shown to the Buyer for review as generated and will be transferred to the Buyer at or before completion of the contract.

12.4.1 One (1) certified copy of all reports establishing and identifying all materials used in the fabrication of the fuel elements furnished under the contract.

12.4.2 Records of results of beta gamma and alpha counts as required in Sections 10.4 and 10.5. The counting period, counter background and efficiency and type of counter shall also be indicated.

12.4.3 In order to assure a satisfactory roll swaging attachment of fuel plates to the grooved side plates, certain minimum strength requirements must be met. To demonstrate that these requirements have been met, the Seller will perform "pull tests" to be witnessed by the Buyer and will report the results of these tests to the Buyer prior to the assembly of any element. Quality control of the roll swaging, during production as well as for test samples, will be the responsibility of the Seller. Additional test samples may be required if there are changes or interruptions in the process. The following minimum strength requirements must be met in a "pull test."

12.4.3.1 The minimum roll swage joint strength is 150 pounds per linear inch of curved fuel element plate. Using a fuel element section, a minimum of 2 inches long, consisting of twenty (20) dummy plates roll swaged into two (2) side plate sections, a uniform tensile load shall be applied perpendicular to the side plates. No roll swaged joints shall fail at a load less than 150 pounds per plate per linear inch of side plate. The tensile loading shall be increased until joint failure does occur and those load values recorded. Production assembly of fuel plates into fuel elements shall be accomplished in the same manner and by the same operations as used in the fabrication of the satisfactory "pull test" specimen.

12.4.4 Results of Metallographic examinations required by Section 8.5.1.

12.4.5 Ultrasonic inspection records of each fuel plate examined as required in Section 8.4.

REFERENCE SECTION 2.0 DRAWINGS

1.	Fuel Plate - Formed	DWG#4-8001-G
2.	Fuel Plate - Flat	#4-8002-D
3.	Type A Plate-Formed (outer plate-no fuel)	#4-8008-D
4.	Type A Plate-Flat (outer plate-no fuel)	#4-8009-C
5.	Type B Plate-Formed (outer plate-no fuel)	#4-8010-D
6.	Type B Plate-Flat (outer plate-no fuel)	#4-8011-C
7.	Transition Piece	#8-8015-M
8.	Side Plate (left)	#8-8016-J
9.	Comb	#2-8017-B
10.	Side Plate (right)	#8-8018-J
11.	Bail	#1-8019-A
12.	Inlet Section Assembly	#8-8020-F
13.	Inlet Section Tube	#2-8021-G
14.	O-Brace	#2-8022-A
15.	Outlet Box	#8-8024-R
16.	Inlet Section Box	#4-8032-L

NOTES: 1. Drawings are not necessarily to scale because of reduction during reproduction.

5.0 SHIELDING EVALUATION

This chapter discusses the shielding performance of the HFBR Unirradiated Fuel Shipping Container to comply with the requirements specified in the regulations of the US Nuclear Regulatory Commission (NRC)[1], the US Department of Energy (DOE)[2,3], and the US Department of Transportation (DOT)[4].

For Normal Conditions of Transport, the regulations set forth by the NRC in 10 CFR § 71.47[1], External Radiation Standards For All Packages, stipulate that a package transported as exclusive use must be designed and prepared for shipment so that the radiation level does not exceed 200 millirem per hour (or one rem per hour in a closed transport vehicle) on the accessible external surface of the package, 200 millirem per hour at any point on the outer surface of the vehicle, 10 millirem per hour at any point two meters from the vertical planes represented by the outer lateral surfaces of the vehicle, and two millirem per hour in any normally occupied positions of the vehicle.

5.1 Discussion and Results

The HFBR Unirradiated Fuel Shipping Container is designed for shipping fresh fuel assemblies, and as such does not require any shielding in addition to that provided by the package structure itself to meet 10 CFR § 71.47 requirements. This can be seen from a comparison with other packages approved by the NRC and DOT that contain much greater fuel loadings and similar ^{235}U enrichment without additional shielding within the packaging. The container surrounding the fuel basket is filled with phenolic foam, which includes boron in the form of boric anhydride (B_2O_3) powder. The boron is included for its fire retardant qualities and any shielding effect is incidental. In addition, the package loading procedures require package external radiation levels to be measured and to be within allowable limits (see Sect. 7.1).

5.2 Source Specification

Unirradiated aluminum-clad-plate-type fuel assemblies as described in Sect. 1.2.3 will be shipped in the HFBR package. The maximum content of radioactive material that may be shipped in any package is 710 g of ^{235}U at a maximum enrichment of 95 wt % in the form of HFBR fuel assemblies.

5.3 Shielding Comparison

The HFBR package contains a smaller fuel loading (maximum 710 g ^{235}U) than other NRC and DOT approved packages without any internal package shielding. For example Specification 6M package contains up to 32 kg ^{235}U (93.5 wt %)[5], and the Model No. UNC-1484 package contains up to 25.4 kg ^{235}U (fully enriched)[6].

Actual measurements, as required by 10 CFR § 71.87(j), prior to each shipment, remove any uncertainties associated with the comparison to other packages. Table 5.1 contains the results of a health physics container survey for outgoing radioactive and fissile shipments. The two HFBR packages each contain two HFBR fuel assemblies. The results show that from each of the packages, the beta-gamma dose rate was 0.4 mR/hr on contact and 0.2 mR/hr at one meter from the surface of the package. In addition, all neutron dose rates were zero. The measurements were taken from a package within an array of packages. Thus, the recorded dose rates are high because of the radiation background from the other packages.

Compliance with the shielding requirements of 10 CFR § 71.47 has been demonstrated.

5.4 References

1. Code of Federal Regulations, Title 10 - Energy Chapter 1 - Nuclear Regulatory Commission, Part 71 (10 CFR Part 71), Packaging and Transportation of Radioactive Material.

2. US Department of Energy, DOE 1540.2, Hazardous Material Packaging for Transportation - Administrative Procedures, September 30, 1986.

3. US Department of Energy, DOE 5480.3, Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substance, and Hazardous Wastes, August 9, 1985.

4. Code of Federal Regulations, US Department of Transportation, Title 49 - Transportation, Parts 100-199.

5. Code of Federal Regulations, US Department of Transportation, Title 49 - Transportation, 49 CFR § 173.417(b)(2), Table 5.

6. Nuclear Regulatory Commission, Certificate of Compliance No. 4949, USA/4949/AF.

Table 5.1

RESULTS OF HEALTH PHYSICS SURVEY FOR OUTGOING RADIOACTIVE AND FISSILE SHIPMENTS OF HFBR UNIRRADIATED FUEL SHIPPING CONTAINERS LOADED WITH TWO FUEL ASSEMBLIES

	ALPHA (dpm/100 cm²) Removable				BETA GAMMA (dpm/100 cm²) Removable			BETA-GAMMA (mR/hr)		NEUTRON (mR/hr)	
Container Number	Max. Fixed Plus Removable	Top	Side	Bottom	Top	Side	Pottom	Contact	1 m (3.3 ft)	Contact	1 m (3.3 ft)
1. 79-6	600	6	3	3	<250	<250	<250	0.4	0.2	0	0
2. 79-5	400	12	3	6	<250	<250	<250	0.4	0.2	0	0

Survey taken: September 19, 1991

NOTE: HEALTH PHYSICS INSTRUMENTS USED (I.D.): ALPHA 240 M103 BETA/GAMMA B153 C522 NEUTRON N-12

6.0 CRITICALITY EVALUATION

This chapter discusses the performance of the HFBR Unirradiated Fuel Shipping Container to comply with the requirements specified in the regulations of the US Nuclear Regulatory Commission (NRC) 10 CFR §§ 71.55 and 71.61[1].

6.1 Discussions And Results

The HFBR Unirradiated Fuel Shipping Container (package) meets the requirements of 10 CFR Part 71 permitting shipment of one package as Fissile Class III containing up to two HFBR fuel assemblies. The fuel assemblies contain up to a maximum of 355 g ^{235}U (maximum 95 wt % enriched U) per assembly or 710 g ^{235}U per shipment. The fuel assemblies are shipped dry and are wrapped in a small amount of plastic bagging. The packaging is described in Sect. 1.2.1.

It was concluded in Chapter 2.0, Structural Evaluation, that under the Normal Conditions of Transport the geometric form of the packaging contents would not be substantially altered and there would be no substantial reduction in the effectiveness of the packaging. The water spray test for Normal Conditions of Transport will not cause the contents to become moderated. However, because water in-leakage was not ruled out, the criticality analysis assumes moderation of the contents. Chapter 2.0 does demonstrate that the outer lid stays on the drum during Normal Conditions of Transport and, therefore, the contents of the package are contained.

For Normal Conditions of Transport, Appendix A shows that an infinite array of packages containing nine fuel assemblies each containing 326 g ^{235}U (93.2 wt %) with water in the fuel region would have a maximum k_{eff} of 0.819 which is well below the acceptable limit of 0.95. Since HFBR package has only two fuel assemblies each containing a maximum of 355 g ^{235}U, this configuration will be subcritical. For the Hypothetical Accident Conditions, a single package will remain subcritical since the contents are less than a critical mass.

6.2 Package Fuel Loading

The HFBR shipping container was originally designed to carry seven fuel assemblies of aluminum-clad-plate-type design. The package drawing has been revised by the addition of a blocking device to prevent the loading of more than two fuel assemblies into the HFBR package (see Figure 1.1).

The physical dimensions of the HFBR fuel assembly are 2.82" x 3.22" x 57.25". Each assembly contains up to a maximum of 355 g ^{235}U (maximum 95 wt % enriched U). The weight of an assembly is about 13 pounds.

6.3 Model Specification

The model used and results from the criticality evaluation are presented in Appendix A.

6.4 Criticality Calculation

6.4.1 Subcriticality of a Single Package

The subcriticality of a single package containing two fuel assemblies can be seen from Figure 6.1[2]. The package contains a maximum of 710 g ^{235}U. From Figure 6.1, the optimumly moderated and reflected critical mass is 820 g ^{235}U which is 110 g more than the package contents. Therefore, the single package will remain subcritical.

6.4.2 Fissile Class III

6.4.2.1 Normal Conditions

It must be shown that two identical shipments in contact and fully reflected on all sides by water are subcritical. Two shipments (two packages) would contain four HFBR fuel assemblies (two assemblies per package). J.T. Thomas has shown (see Appendix A) that nine HFBR fuel assemblies (each containing 326 g ^{235}U (93.2 wt %)) in a package would have a $k_{eff} = 0.670 \pm 0.008$ (water in fuel region, package closely reflected by water) and an infinite array (water in fuel region) of packages would have a $k_{eff} = 0.812 \pm 0.007$. The HFBR fuel package will contain a maximum of 710 g ^{235}U vs 2.934 kg ^{235}U which was used in the Thomas calculations with the same fuel cell size per assembly in each case. The calculated k_{eff} is well below the 0.95 limit with over four times the contents and, therefore, a package containing only two fuel assemblies will remain subcritical.

6.4.2.2 Accident Conditions

Under accident conditions, even if the contents of the package (one shipment) were released assuming conditions of an optimumly moderated homogenous sphere and water reflected, the package will be subcritical (see § 6.4.1 above).

6.4.3 Enrichment

The fuel assemblies are limited to 355 g ^{235}U with a maximum enrichment of 95 wt %. For the shipment of two fuel assemblies, increasing the enrichment from 93.2 to 95 wt % will increase the calculated k_{eff} slightly, but will still be below the acceptable 0.95 limit.

6.5 Critical Bench Mark Experiments

The Justification for validity of the criticality calculations are in Appendix A.

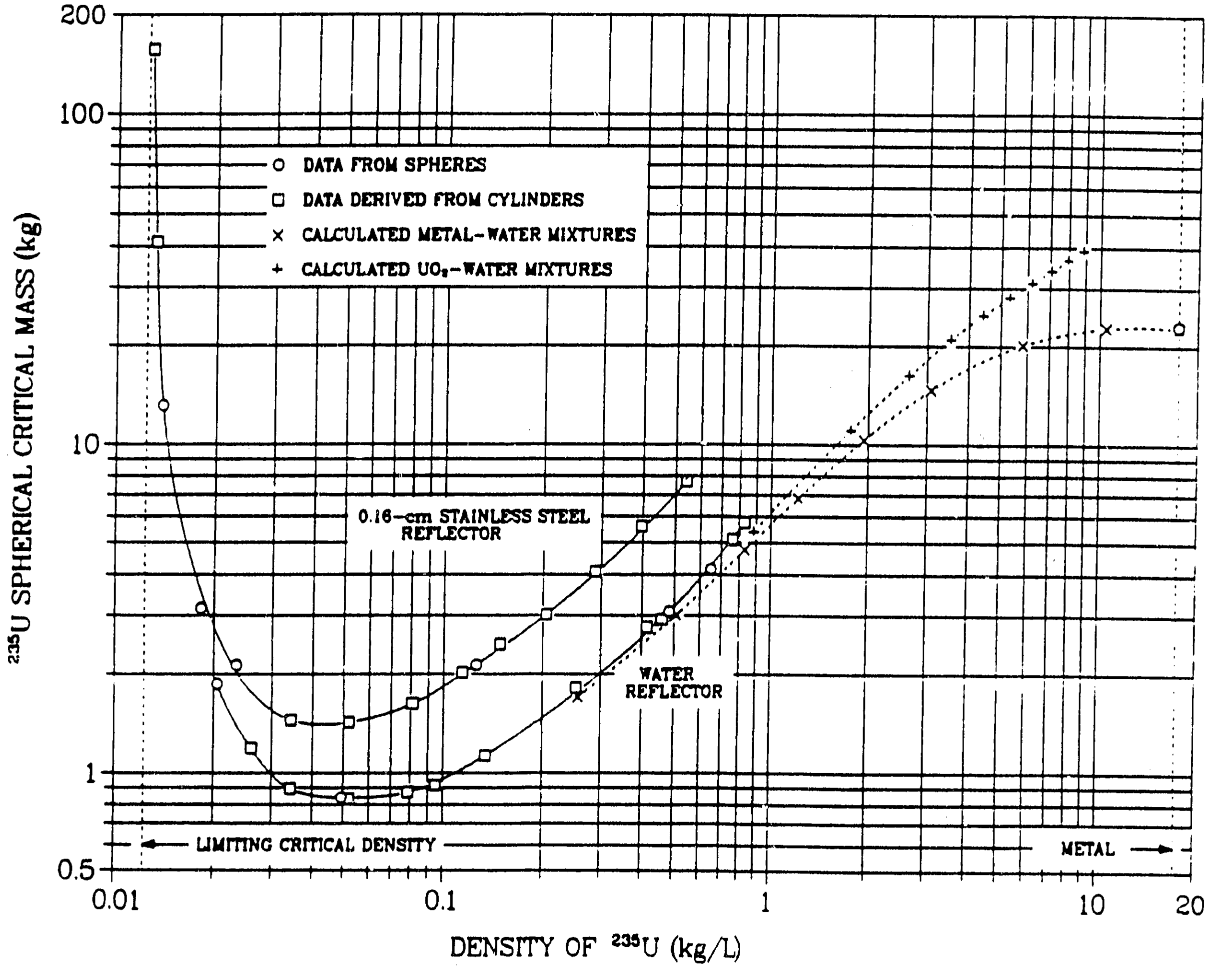


Figure 6.1 Critical masses of homogeneous water-moderated U(93.2) spheres "Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U," LA-10860-MS

6.6 References

1. Code of Federal Regulations, Title 10 - Energy Chapter I - Nuclear Regulatory Commission, Part 71 (10 CFR Part 71), Packaging and Transportation of Radioactive Material.

2. Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U, LA-10860-MS, 1986 Revision.

6.7 Appendix

A Nuclear Criticality Safety Assessment of ORR, NBS, and HFBR Fuel Element Shipping Package

Appendix A

Nuclear Criticality Safety Assesssment of ORR, NBS, HFBR Fuel Element Shipping Package

J. T. Thomas

Union Carbide Corporation, Nuclear Division

ORNL/CSD/TM-77

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List of Effective Pages

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Nuclear Criticality Safety Assessment of ORR, NBS, and HFBR Fuel Element Shipping Package

J. T. Thomas

(Sponsor: John H. Evans, Originator: J. T. Thomas)

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NOTICE This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

UNION CARBIDE CORPORATION, NUCLEAR DIVISION
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DEPARTMENT OF ENERGY

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J. T. Thomas

ABSTRACT

A fuel element shipping package employing a borated-phenolic foam as a thermal insulating material is designed to transport as many as seven fuel elements for use in the Oak Ridge Research Reactor, the Brookhaven Fast Beam Reactor, or the National Bureau of Standards Reactor. This report presents the criticality safety evaluation and demonstrates that the requirements for a Fissile Class I package are satisfied by the design.

I. INTRODUCTION

The nuclear criticality safety of a shipping package designed to transport as many as seven plate-type fuel elements is examined by calculational techniques. Three distinct packages are proposed, one for each of three sites having a light-water reactor. These are the Oak Ridge Research Reactor, the Brookhaven Fast Beam Reactor, and the reactor at the National Bureau of Standards. The three packages have similar neutronic characteristics, the same materials of construction, but differ slightly in their dimensions. The gross characteristics of a typical package are shown in Fig. 1.

The analysis is performed assuming there are nine fuel elements present in the package rather than the seven proposed. This modification is made because it facilitates the geometric description of the package in the calculation, and results in an overestimate of the neutron coupling between packages and of the k_{eff} of the arrays of packages.

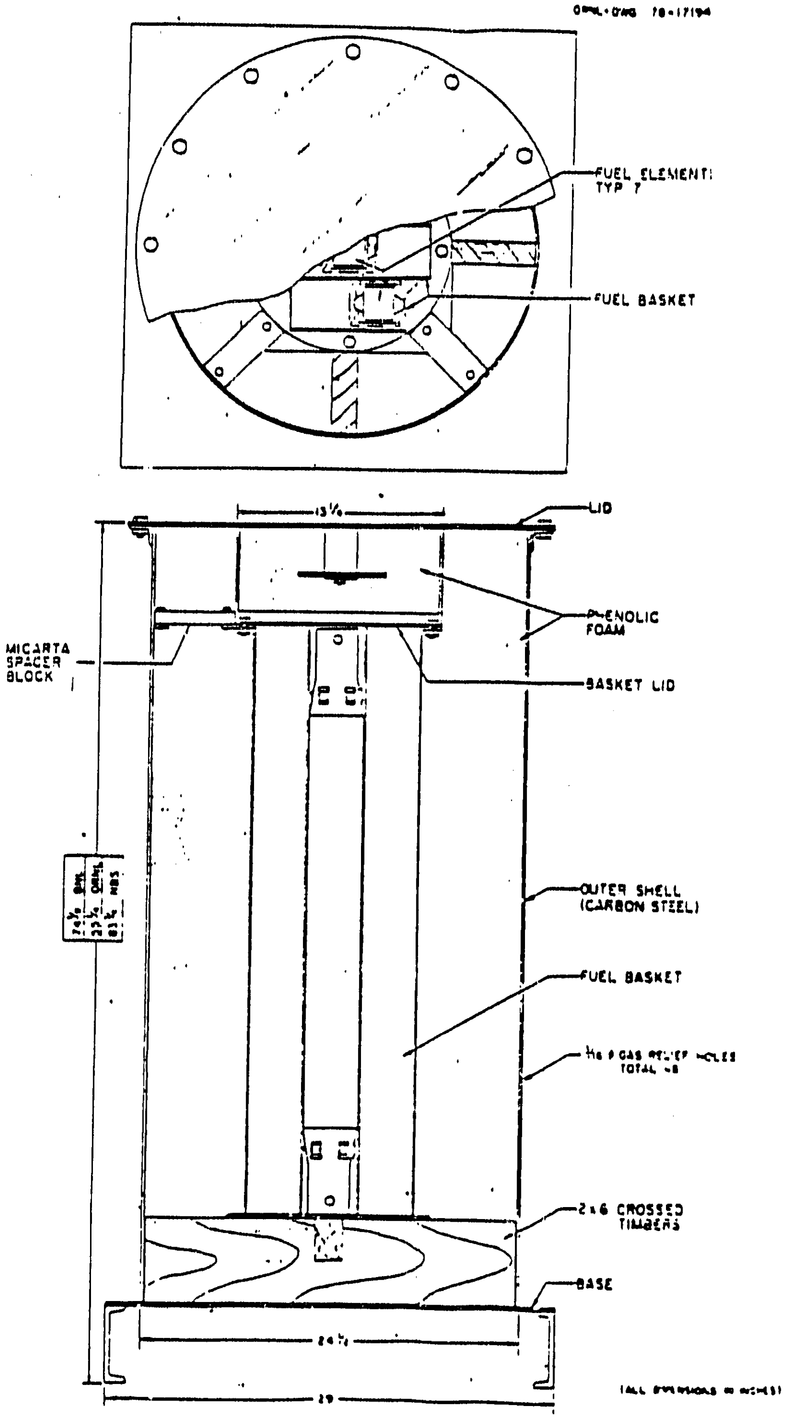

Fig. 1. Proposed Package Design

II. METHOD OF ANALYSIS

The neutron multiplication factors of the shipping package and of arrays of packages were calculated by the KENO IV code[1] and the Hansen-Roach neutron cross-section sets.[2] This combination of code and cross-section sets has been validated by calculation of critical experiments[3,4] with fuel elements of the same fissile materials and configurations. The results of the validation with fuel elements are reported in Refs. 5 and 6. The results of calculations of critical experiments with the borated-phenolic foam are reported in Ref. 7. The conclusion of the comparison of calculations and experiments is that systems calculated to have a k_{eff} of 0.98 should be regarded as having a potential for criticality. The analysis is performed with HFBR fuel elements containing 350 g U(93.2) per element.

III. DESCRIPTION OF CODE INPUT

Each plate in a fuel element is described in the code by a box type and these are arranged to form a fuel element within a region of the steel grid. One-half the thickness of the steel forming the 3 × 3 matrix is associated with each element. When the matrix of fuel elements is described in the code, the correct steel thickness is specified between fuel elements; however, only one-half the steel thickness is represented for the outer surface of the matrix. This description is conservative in that it will result in larger calculated k_{eff}'s than would be measured.

The geometry description is given in Table 1. A fuel element and its associated section of the matrix is formed by stacking box types in the order 9, 7, 5, 3, twelve 1's, 2, 4, 6, and 8. The different box

Table 1. Geometric Representation of Package.

BOX TYPE 1

REGION		Mixture	+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	1	+X = 2.8485E 00	-X =-2.8485E 00	+Y = 2.8950E-02	-Y =-2.8950E-02	+Z = 2.9027E 01	-Z =-2.9027E 01
2	CUBOID	2	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 6.4000E-02	-Y =-6.4000E-02	+Z = 3.0162E 01	-Z =-3.0162E 01
3	CUBOID	5	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 1.8540E-01	-Y =-1.8540E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
4	CUBOID	2	+X = 3.5814E 00	-X =-3.6814E 00	+Y = 1.8540E-01	-Y =-1.8540E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
5	CUBOID	6	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 1.8540E-01	-Y =-1.8540E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
6	CUBOID	5	+X = 3.7700E 00	-X =-3.7700E 00	+Y = 1.8540E-01	-Y =-1.8540E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
7	CUBOID	10	+X = 3.8460E 00	-X =-3.8460E 00	+Y = 1.8540E-01	-Y =-1.8540E-01	+Z = 8.8344E 01	-Z =-8.8344E 01

BOX TYPE 2

REGION		Mixture	+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	1	+X = 2.8485E 00	-X =-2.8485E 00	+Y = 2.8950E-02	-Y =-2.8950E-02	+Z = 2.9027E 01	-Z =-2.9027E 01
2	CUBOID	2	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 6.4000E-02	-Y =-6.4000E-02	+Z = 3.0162E 01	-Z =-3.0162E 01
3	CUBOID	5	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 1.8540E-01	-Y =-2.0060E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
4	CUBOID	2	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 1.8540E-01	-Y =-2.0060E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
5	CUBOID	6	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 1.8540E-01	-Y =-2.0060E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
6	CUBOID	5	+X = 3.7700E 00	-X =-3.7700E 00	+Y = 1.8540E-01	-Y =-2.0060E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
7	CUBOID	10	+X = 3.8460E 00	-X =-3.8460E 00	+Y = 1.8540E-01	-Y =-2.0060E-01	+Z = 8.8344E 01	-Z =-8.8344E 01

BOX TYPE 3

REGION		Mixture	+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	1	+X = 2.8485E 00	-X =-2.8485E 00	+Y = 2.8950E-02	-Y =-2.8950E-02	+Z = 2.9027E 01	-Z =-2.9027E 01
2	CUBOID	2	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 6.4000E-02	-Y =-6.4000E-02	+Z = 3.0162E 01	-Z =-3.0162E 01
3	CUBOID	5	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 2.0060E-01	-Y =-1.8540E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
4	CUBOID	2	+X = 3.5914E 00	-X =-3.5814E 00	+Y = 2.0060E-01	-Y =-1.8540E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
5	CUBOID	6	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 2.0060E-01	-Y =-1.8540E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
6	CUBOID	5	+X = 3.7700E 00	-X =-3.7700E 00	+Y = 2.0060E-01	-Y =-1.8540E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
7	CUBOID	10	+X = 3.8460E 00	-X =-3.8460E 00	+Y = 2.0060E-01	-Y =-1.8540E-01	+Z = 8.8344E 01	-Z =-8.8344E 01

Table 1. (Continued)

BOX TYPE 4

REGION		Mixture	+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	1	+X = 2.8485E 00	-X =-2.8485E 00	+Y = 2.8950E-02	-Y =-2.8950E-02	+Z = 2.9027E 01	-Z =-2.9027E 01
2	CUBOID	2	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 6.4000E-02	-Y =-6.4000E-02	+Z = 3.0162E 01	-Z =-3.0162E 01
3	CUBOID	5	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 2.0060E-01	-Y =-2.1340E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
4	CUBOID	2	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 2.0060E-01	-Y =-2.1340E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
5	CUBOID	6	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 2.0060E-01	-Y =-2.1340E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
6	CUBOID	5	+X = 3.7700E 00	-X =-3.7700E 00	+Y = 2.0060E-01	-Y =-2.1340E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
7	CUBOID	10	+X = 3.8460E 00	-X =-3.8460E 00	+Y = 2.0060E-01	-Y =-2.1340E-01	+Z = 8.8344E 01	-Z =-8.8344E 01

BOX TYPE 5

REGION			+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	1	+X = 2.8485E 00	-X =-2.8485E 00	+Y = 2.8950E-02	-Y =-2.8950E-02	+Z = 2.9027E 01	-Z =-2.9027E 01
2	CUBOID	2	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 6.4000E-02	-Y =-6.4000E-02	+Z = 3.0162E 01	-Z =-3.0162E 01
3	CUBOID	5	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 2.1340E-01	-Y =-2.0060E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
4	CUBOID	2	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 2.1340E-01	-Y =-2.0060E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
5	CUBOID	6	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 2.1340E-01	-Y =-2.0060E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
6	CUBOID	5	+X = 3.7700E 00	-X =-3.7700E 00	+Y = 2.1340E-01	-Y =-2.0060E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
7	CUBOID	10	+X = 3.8460E 00	-X =-3.8460E 00	+Y = 2.1340E-01	-Y =-2.0060E-01	+Z = 8.8344E 01	-Z =-8.8344E 01

BOX TYPE 6

REGION			+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	1	+X = 2.8485E 00	-X =-2.8485E 00	+Y = 2.8950E-02	-Y =-2.8950E-02	+Z = 2.9027E 01	-Z =-2.9027E 01
2	CUBOID	2	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 6.4000E-02	-Y =-6.4000E-02	+Z = 3.0162E 01	-Z =-3.0162E 01
3	CUBOID	5	+X = 3.1064E 00	-X =-3.1064E 00	+Y = 2.1340E-01	-Y =-1.9050E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
4	CUBOID	2	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 2.1340E-01	-Y =-1.9050E-01	+Z = 3.0162E 01	-Z =-3.0162E 01
5	CUBOID	6	+X = 3.5814E 00	-X =-3.5814E 00	+Y = 2.1340E-01	-Y =-1.9050E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
6	CUBOID	5	+X = 3.7700E 00	-X =-3.7700E 00	+Y = 2.1340E-01	-Y =-1.9050E-01	+Z = 8.8027E 01	-Z =-8.8027E 01
7	CUBOID	10	+X = 3.8460E 00	-X =-3.8460E 00	+Y = 2.1340E-01	-Y =-1.9050E-01	+Z = 8.8344E 01	-Z =-8.8344E 01

Table 1. (Continued)

BOX TYPE 7

REGION		Mixture	+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	1	2.8485E 00	-2.8485E 00	2.8950E-02	-2.8950E-02	2.9027E 01	-2.9027E 01
2	CUBOID	2	3.1064E 00	-3.1064E 00	6.4000E-02	-6.4000E-02	3.0162E 01	-3.0162E 01
3	CUBOID	5	3.1064E 00	-3.1064E 00	1.9050E-01	-2.1340E-01	3.0162E 01	-3.0162E 01
4	CUBOID	2	3.5814E 00	-3.5814E 00	1.9050E-01	-2.1340E-01	3.0162E 01	-3.0162E 01
5	CUBOID	6	3.5814E 00	-3.5814E 00	1.9050E-01	-2.1340E-01	8.8027E 01	-8.8027E 01
6	CUBOID	5	3.7700E 00	-3.7700E 00	1.9050E-01	-2.1340E-01	8.8027E 01	-8.8027E 01
7	CUBOID	10	3.8460E 00	-3.8460E 00	1.9050E-01	-2.1340E-01	8.8344E 01	-8.8344E 01

BOX TYPE 8

REGION		Mixture	+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	2	3.1064E 00	-3.1064E 00	6.4000E-02	-6.4000E-02	3.0162E 01	-3.0162E 01
2	CUBOID	5	3.1064E 00	-3.1064E 00	2.5400E-01	-2.5400E-01	3.0162E 01	-3.0162E 01
3	CUBOID	2	3.5814E 00	-3.5814E 00	2.5400E-01	-2.5400E-01	3.0162E 01	-3.0162E 01
4	CUBOID	6	3.5814E 00	-3.5814E 00	2.5400E-01	-2.5400E-01	8.8027E 01	-8.8027E 01
5	CUBOID	5	3.7700E 00	-3.7700E 00	2.5400E-01	-3.0540E-01	8.8027E 01	-8.8027E 01
6	CUBOID	10	3.8460E 00	-3.8460E 00	2.5400E-01	-3.8140E-01	8.8344E 01	-8.8344E 01

BOX TYPE 9

REGION		Mixture	+X	-X	+Y	-Y	+Z	-Z
1	CUBOID	2	3.1064E 00	-3.1064E 00	6.4000E-02	-6.4000E-02	3.0162E 01	-3.0162E 01
2	CUBOID	5	3.1064E 00	-3.1064E 00	2.5400E-01	-2.5400E-01	3.0162E 01	-3.0162E 01
3	CUBOID	2	3.5814E 00	-3.5814E 00	2.5400E-01	-2.5400E-01	3.0162E 01	-3.0162E 01
4	CUBOID	6	3.5814E 00	-3.5814E 00	2.5400E-01	-2.5400E-01	8.8027E 01	-8.8027E 01
5	CUBOID	5	3.7700E 00	-3.7700E 00	3.0540E-01	-2.5400E-01	8.8027E 01	-8.8027E 01
6	CUBOID	10	3.8460E 00	-3.8460E 00	3.8140E-01	-2.5400E-01	8.8344E 01	-8.8344E 01

REFLECTOR

REGION								
1	CORE BDY	0	+X = 1.1538E 01	-X =-1.1538E 01	+Y = 1.2192E 01	-Y =-1.2192E 01	+Z = 8.8344E 01	-Z =-8.8344E 01
2	CYLINDER	8	RADIUS = 2.3380E 01	+Z = 8.8344E 01	-Z =-8.8344E 01			
3	CYLINDER	9	RADIUS = 2.3380E 01	+Z = 9.5400E 01	-Z =-9.5400E 01			
4	CYLINDER	12	RADIUS = 3.1000E 01	+Z = 1.0311E 02	-Z =-1.0294E 02			
5	CYLINDER	11	RADIUS = 3.1320E 01	+Z = 1.0343E 02	-Z =-1.0358E 02			
6	CUBOID	0	+X = 3.1380E 01	-X =-3.1380E 01	+Y = 1.0360E 02	-Y =-1.0360E 02	+Z = 1.1380E 02	-Z =-1.1380E 02

types are required to preserve the different water-channel thicknesses and the nonfuel-bearing end plates of the HFBR element. The materials occupying the geometric regions specified in this case are representative of a calculation in the damaged package evaluations. The materials and their number densities are identified and reproduced in Table 2. The end boxes of the fuel elements are represented as a smeared density which preserves the mass of aluminum. This is material 6 in region 4 of boxes 1 through 9 in Table 1. The reflector region description of Table 1 specifies the geometry in the region between the 3 × 3 steel matrix to the outer container of carbon steel. The material mixture in region 4 normally would be 8, the undamaged borated-phenolic foam insulation, but in the case depicted region 4 represents the result of damage to the insulation by exposure to fire.

The principal damage to the package will be a charring of the borated-phenolic foam insulation. Actual tests[8,9] show that an average char depth from the outer surface will not exceed 6.4 cm. An over-estimate of neutron coupling between damaged package would be observed if a larger char depth is assumed; therefore, a value of 7.6 cm was used in the evaluation of the damaged package.

IV. RESULTS OF CALCULATIONS

The computed multiplication factors for the undamaged package are presented in Table 3. It is evident that the absence of water from the fuel region of the package results in very low values for k_{eff}. This is consistent with previous results[5,6] with these fuel elements. There is a large increase in k_{eff} when water occupies the fuel region; however, k_∞ remains well below a value of unity.

Table 2. Description of Materials for Code Input.

MIXTURE	NUCLIDE	DENSITY	
1	-92502	1.30703E-03	Uranium Oxide and Aluminum
1	92503	1.30703E-03	
1	92833	4.70802E-05	
1	92834	1.41241E-04	
1	8100	7.47300E-03	
1	13100	5.23867E-02	
2	13100	6.02726E-02	Aluminum
3	6100	1.73765E-02	Not used in study
3	1101	2.60647E-02	
3	17100	8.68925E-03	
4	502	5.00000E-02	
5	502	1.00000E 00	Water
6	13100	1.81190E-04	Aluminum
7	13100	1.81190E-04	Aluminum and Water
7	1101	6.32394E-02	
7	8100	3.16197E-02	
8	6100	4.41300E-03	Borated phenolic foam
8	1101	5.53800E-03	
8	8100	3.09800E-03	
8	5100	3.53600E-04	
8	14100	1.50400E-04	
8	11100	1.63600E-05	
8	17100	2.32800E-05	
8	13100	8.99500E-06	
8	12100	9.88300E-06	
8	20100	6.05600E-05	
9	6100	6.03980E-03	Borated phenolic foam and Wood
9	1101	7.20910E-03	
9	8100	3.89470E-03	
9	5100	3.11900E-04	
9	14100	1.32700E-04	
9	11100	1.44300E-05	
9	17100	2.05300E-05	
9	13100	7.93400E-06	
9	12100	8.71700E-06	
9	20100	5.34100E-05	
10	200	1.00000E 00	Stainless Steel
11	100	1.00000E 00	Carbon Steel
12	6100	6.03980E-03	Charred borated phenolic foam
12	1101	0.0	
12	8100	0.0	
12	5100	3.11900E-04	
12	14100	1.32700E-04	
12	11100	1.44300E-05	
12	17100	0.0	
12	13100	7.93400E-06	
12	12100	8.71700E-06	
12	20100	5.34100E-05	

Table 3. Computed Neutron Multiplication Factors for the Undamaged Package

Number of Packages	Conditions	k_{eff}	$\pm \sigma$
Single	Water in fuel region	0.669	0.008
Single	Water in fuel region, package closely reflected by water	0.670	0.008
Infinite array	Water in fuel region	0.812	0.007
Infinite array	Water in fuel region, water filling void between packages	0.812	0.007

Table 4 summarizes calculations of the damaged package condition. Again, one finds k_{∞} well below unity.

Table 4. Computed Neutron Multiplication Factors for the Damaged Package

Number of Packages	Conditions	k_{eff}	$\pm \sigma$
Single	No water present	0.033	0.002
Single	Water in full region	0.666	0.006
Single	Water in full region, package closely reflected by water	0.688	0.009
Infinite array	No water present	0.092	0.003
Infinite array	Water in fuel region	0.739	0.008
Infinite array	Water in fuel region, water filling void between packages	0.682	0.007

V. CONCLUSIONS

The evidence of this study shows that the package loaded with seven HFBR fuel elements meets the nuclear criticality safety requirements of a Fissile Class I package. In view of the comparative calculations of various similar fuel elements with different fissile material loadings reported,[5,6] it may be concluded that the package may also be used as a Fissile Class I package for the ORR and the NBS fuel elements with fissile material loadings at least as large as 350 g ^{235}U/element.

Fuel elements of similar construction used at the Oak Ridge National Laboratory, such as the PCA reactor (140 g ^{235}U/element) and the BSR reactor (200 g ^{235}U/element), may also be shipped in the container.

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7.0 OPERATING PROCEDURES

The HFBR Unirradiated Fuel Shipping Container is loaded, unloaded, and prepared for transport in accordance with approved operating procedures that ensure compliance with the requirements of Subpart G to 10 CFR Part 71 and 49 CFR Parts 170 through 189, and ensure that occupational radiation exposures are maintained as low as is reasonably achievable as required by 10 CFR § 20.1. The following sections list the generic steps in loading and unloading the package.

Fuel plate integrity is discussed in Chapter 4.0, Containment. The procedure to assure fuel plate integrity is the manufacturing and related inspection activity that guarantees continuous metal. Audits of manufacturing records by QA, followed by verification of QA release in Package Loading Procedure Step 8, provides the required assurance.

7.1 Procedures for Loading Package

The package is loaded in accordance with written operating procedures which include the following generic steps. Cotton gloves will be worn when handling an exposed surface of a fuel assembly.

1. Inspect the empty packaging for external damage using the requirements of Section 8.2.1.1 and contamination not exceeding 10^{-5} $\mu Ci/cm^2$ (10 CFR § 71.87 (i)). If the packaging is acceptable for shipping, continue with this procedure. Otherwise, initiate the repair and maintenance requirements of Section 8.2.1.1.

2. Verify that the Certificate of Compliance is current for the required shipping period and that the contents of the package will be in accordance with the approved contents of the package.

3. Move the packaging to the loading area.

4. Remove the bolts that secure the outer container lid and place the lid and bolts to the side. The lid must be handled by two people.

5. Remove the bolts that secure the inner basket lid and place the lid and bolts to the side.

6. Inspect the packaging to ensure that all spacers and gaskets are in place and in good condition, all bolts and nuts for the basket and packaging lids have lock washers and engage freely, and the interior of the packaging is clean and free of foreign material using the requirements of Section 8.2.1.2. If the components are acceptable, continue with this procedure. Otherwise, initiate the repair and maintenance requirements of Section 8.2.1.2.

7. Verify the presence of a blocking device to prevent the loading of more than two fuel assemblies into the packaging. If the blocking device is not present, the packaging should be immediately tagged to prevent the packaging from being used.

8. Load fuel assemblies one at a time. Verify each has been released by Quality Assurance. Inspect fuel assemblies to ensure polyethylene tubes are complete and undamaged. Patch if necessary with plasic tape. The assembly ends may be taped to provide dunnage. Record fuel assembly identification number. Repeat this process for a maximum of two fuel assemblies for the package.

9. Install the inner basket lid and torque the bolts to 8.3 ±1.6 ft-lb.

10. Install the outer container lid and torque the bolts to 25 ±1.6 ft-lb.

11. Remove the empty packaging labels and apply the radiation shipping label per 49 CFR § 172.403 to the outer container lid and cylindrical housing.

12. Install the two tamper proof (accountability) seals and record their numbers on the shipment documentation.

13. Conduct a radiation survey to verify compliance with the following radiation and contamination limits. Radiation level limits are specified in 71 CFR § 71.47 and 49 CFR § 173.441 for exclusive use shipments as 200 millirem per hour at any point on the external surface of the vehicle or vertical planes projected from the outer edges of the conveyance and 10 millirem per hour at 2 meter from the external surface of the vehicle or vertical planes projected from the outer edges of the conveyance. The maximum level of removable radioactive contamination on the package surface is specified in 10 CFR § 71.87(i) and 49 CFR § 173.443 as 10^{-5} μCi/cm^2.

14. Transfer the loaded package to the storage area or shipping vehicle. Each package must be isolated in accordance with other nuclear criticality safety procedures approved by the facility or shipped, one package per exclusive use vehicle.

15. Complete the appropriate shipping documentation.

7.2 Procedures for Unloading Package

The package is unloaded in accordance with written operating procedures which include the following generic steps. Cotton gloves will be worn when handling an exposed surface of a fuel assembly.

1. Conduct a radiation survey to verify that the contamination level on the external surfaces of the package is less than 10^{-5} μCi/cm^2. If the contamination is less than 10^{-5} μCi/cm^2, continue with this procedure. Otherwise, clean the external surfaces of the package until the contamination level is less than 10^{-5} μCi/cm^2.

2. Move the package to the unloading area, isolated from other fissile material in accordance with nuclear criticality safety procedures approved by the facility.

3. Verify that the two security seals are intact. If the seals are intact, remove the seals. Otherwise, notify shipping/security personnel and await their instructions.
4. Remove the bolts that secure the outer container lid and place the lid and bolts to the

side. The lid must be handled by two people.

5. Remove the bolts that secure the inner basket lid and place the lid and bolts to the side.

6. Unload fuel assemblies one at a time. Record fuel assembly identification number. Repeat this process until all the fuel assemblies are unloaded.

7. Clean the inside of the packaging to less than 10^{-3} $\mu Ci/cm^2$ per 49 CFR § 173.427.

8. Install the inner basket lid and torque the bolts to 8.3 ±1.6 ft-lb.

9. Install the outer container lid and torque the bolts to 25 ±1.6 ft-lb.

10. Clean the outside of the packaging to less than 10^{-5} $\mu Ci/cm^2$ per 49 CFR § 173.443.

11. Tag the packaging as "Empty".

12. Transport the empty packaging to an approved storage area.

7.3 Preparation of Empty Package for Transport

When transported empty, the HFBR packaging must be shipped fully assembled per 49 CFR § 173.427.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This chapter discusses the acceptance test for the proposed modifications to the packaging and the maintenance program to be used on the packaging in compliance with Subpart G of 10 CFR Part 71. Acceptance tests are not required on the HFBR packaging since new packagings will not be built.

The containment boundary of the HFBR package is the aluminum cladding together with the aluminum-cermet fuel. Acceptance tests are performed on the containment boundary during fuel fabrication. These tests are discussed in Chapter 4 Appendix A and will not be discussed in this chapter. Maintenance of the HFBR fuel is not addressed in this section. After fabrication and testing, no maintenance is performed on the fuel.

8.1 Acceptance Tests

8.1.1 Visual Inspection

Blocking devices are used to prevent loading more than two assemblies in the fuel basket, to prevent the use of the lid of the outer container as a lifting device, and to prevent the use of the base of the package as tie-down device. The welds attaching the blocking devices are visually inspected for cracks and repaired as necessary.

8.1.2 Structural and Pressure Tests

Structural or pressure acceptance tests are not performed on the packaging. The blocking device modifications do not affect pressure boundaries. Therefore, pressure tests are not required. All welds on both blocking devices are inspected for cracks and repaired as necessary.

8.1.3 Leak Tests

Leak tests are not performed on the package since both the fuel basket and outer container were not designed to be leaktight. The blocking device modifications do not affect the leak tightness of either the fuel basket or the outer container.

8.1.4 Component Tests

No component tests were performed other than the visual tests cited in Sect. 8.1.1.

8.1.5 Tests for Shielding Integrity

The packaging is not required to be shielded to meet radiation limits. Therefore, shielding integrity tests are not required even with the blocking device modifications.

8.1.6 Thermal Acceptance Tests

Thermal acceptance tests were not performed since the package contains less than one watt internal heat source and no coolant system. The blocking device modifications have no effect on the thermal performance of the package.

8.1.7 Containment Boundary Acceptance Tests

The containment boundary of the HFBR package is the aluminum cladding together with the aluminum-cermet fuel. The acceptance tests for the fuel plate integrity are described in Chapter 4 Appendix A. The blocking devices have no effect on the integrity of the fuel.

8.2 Maintenance Program

The following visual inspections of the package are conducted as part of the preparation process prior to each shipment. Because of this, no periodic maintenance program is required.

8.2.1 Structural and Pressure Tests

8.2.1.1 External Packaging

The packaging is examined for cracks, punctures, dents, and general condition. Any cracks, punctures and dents will be repaired. In the last 10 years of package usage not a single package has sustained any such damage. The 3/16-inch diameter vent holes in the outer housing are resealed with epoxy or resin if the previous vent hole epoxy seals are broken or otherwise deteriorated. The lid bolts and nuts are examined for defects, cracks and any other signs of deterioration, and replaced with bolts and nuts which are free of defects and in accordance with the original bolt and nut specifications. The package is not pressure tight. Therefore, pressure tests are not conducted.

8.2.1.2 Internal Components

The internal components of the packaging are examined for cracks, gasket deterioration and general condition. The gaskets will be replaced if worn or brittle. Cracks in the basket welds will be repaired. The basket lid bolts and nuts are examined for defects, cracks and any other signs of deterioration, and replaced with bolts and nuts which are free of defects and in accordance with the original bolt and nut specification. Epoxy may be used to form a thin coating over exposed foam within the packaging. The containment boundary (fuel plates) is maintenance free. The integrity of the containment boundary is assured by the stringency of the manufacturing tests which are described in the Chapter 4 Appendix A.

8.2.2 Leak Tests

Leak tests are not required for the packaging since the fuel plates provide the containment of radioactive material and the package does not include coolant or other subsystems containing liquids or gases. The containment properties and initial acceptance tests for the fuel plates are described in Section 4.1.4.

8.2.3 Subsystem Maintenance

The fuel assembly serves as the only subsystem of the shipping package. The acceptance tests of the containment boundary, as described in Section 4.1.4, establishes the integrity of this system.

8.2.4 Valves, Rupture Discs, and Gaskets on Containment Vessel

There are no valves, rupture discs, or gaskets associated with the containment boundary of the unirradiated fuel assemblies. The inner fuel basket and outer container lid gaskets are part of the overall package design. These gaskets are not designed to be water or gas tight and are therefore not subject to test. The gaskets are replaced when visual inspection identifies cracks or brittleness in the gasket material. The epoxy/seals on the outer housing 3/16-inch diameter vent holes are resealed with epoxy or resin if found broken or otherwise deteriorated during the visual inspections.

8.2.5 Shielding

Shielding is not required for the unirradiated fuel shipping package. Radiation emitted by the unshielded unirradiated fuel assemblies is below the levels specified in 10 CFR Part 71 and 49 CFR Part 173 for offsite shipment of radioactive materials. The packages are inspected prior to use by the health physics organizations for radiation and contamination as part of the package loading procedure (see Sect. 7.1).

8.2.6 Thermal

There are no systems required for thermal protection of the fuel assemblies during Normal Conditions of Transport.

8.2.7 Miscellaneous

There are no tests performed periodically on components and subsystems except the visual examinations of the packages performed in the process of loading fuel and preparing for shipment (see Sect. 8.2.1).

9.0 QUALITY ASSURANCE

9.1 Introduction

Chapter 9.0 establishes Quality Assurance (QA) requirements for design modification, purchasing, testing, handling, shipping, storing, cleaning, inspection, operation, maintenance, and repair of the High-Flux Beam Reactor (HFBR) Unirradiated Fuel Shipping Container in accordance with the requirements specified in the regulations of the US Nuclear Regulatory Commission (NRC), the US Department of Energy (DOE), and the US Department of Transportation (DOT). In addition, QA requirements for quality-affecting activities are included in this chapter for production of the aluminum clad fuel assemblies. New packagings can not be fabricated under these requirements. These requirements also address the fuel fabrication process. For clarity, a distinction will be made in the following sections of those requirements specific to the packaging and those pertinent to the fuel assembly. The QA plan developed is based on NRC Regulatory Guide 7.10, "Establishing Quality Assurance Programs for Packaging Used in the Transport of Radioactive Material;" DOE Order 1540.2, Hazardous Material Packaging for Transportation - Administrative Procedures; 10 CFR 71, "Packaging and Transport of Radioactive Material;" and ASME-NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities."

QA comprises those planned and systematic actions necessary to provide adequate confidence that a system or component will perform satisfactorily in service. The QA plan in this chapter applies to those activities affecting the HFBR Unirradiated Fuel Shipping Container and components which are important to safety. The HFBR Unirradiated Fuel Shipping Container relies on the fuel plates to provide containment. Therefore, the fuel plates are analyzed as an integral part of the package. Consequently, quality assurance requirements pertinent to fuel plate fabrication are identified in this section of the SARP.

9.1.1 Policy

All activities related to safety must be performed in accordance with approved quality assurance standards. This QA plan details specific criteria that must be adhered to by package users, and fuel fabricators. Detailed procedures that implement the requirements summarized in this plan must be used by and available to individuals in the workplace when performing important-to-safety activities associated with the package.

9.1.2 Scope/Applicability

The QA requirements established in this chapter are applicable to all activities related to the HFBR Unirradiated Fuel Shipping Container which are important to safety. All personnel, including subcontractors and vendors, that perform quality-affecting activities relative to the HFBR shipping package are subject to the provisions of this plan according to their degree of participation in the packaging activities.

9.2 Definitions

Terminology used in this quality assurance plan is consistent with definitions defined in

Subpart H of 10 CFR Part 71 and in Supplement S-1 (Terms and Definitions) of ASME NQA-1. It should be understood that the project titles described below which are used to assign task responsibilities are considered to be examples identifying functional responsibilities relative to the HFBR Unirradiated Fuel Shipping Container. Because of the many variables involved, such as the number of personnel, the type of activity being performed, and the location where activities are performed, the organizational structure for executing the QA plan may take various forms provided that the persons and organizations assigned the quality assurance functions have the required authority and organizational freedom, including independence from cost and schedule considerations.

Project Engineer:

The assigned engineer who has overall responsibility for the success of any engineering project. Design modification, procurement, and use of the package would be under the direction of the Project Engineer. The general responsibilities and duties of a project engineer include but are not limited to the following:

1. Coordinate communications on design activities to include interfaces among the packaging designer, suppliers and users.

2. Prepare and approve documents, including design criteria, specifications, drawings, procurement specifications, and procedural documents.

3. Check and verify design inputs.

4. Approve supplier design documents, test procedures, and other appropriate technical and quality submittal.

5. Ensure appropriate design verification is performed, to include quality assurance inspections as required.

6. Plan and direct project design modification and testing activities.

7. Develop and maintain design documentation and QA records.

Task Leader:

The assigned individual who assists the project engineer in the successful accomplishment of an engineering project. The task leader has direct involvement with any design modification, procurement, and use of packages under the direction of the project engineer. As a minimum, the task leader duties and responsibilities include the following:

1. Assist the project engineer in the performance of duties as stated above.

2. Review the certified drawings and specifications.

3. Procure and obtain appropriate materials to maintain the packaging.

4. Resolve quality assurance inspection comments concerning the packages.

5. Ensures that items of non-compliance are reported according to established procedures.

Quality Assurance Manager:

The individual who has been assigned the responsibility for verifying that the quality plan for the HFBR package has been implemented. The QA manager has sufficient authority and organizational independence to identify quality problems and to initiate, recommend, or provide solutions.

The general responsibilities and duties of the quality assurance manager include but are not limited to the following:

1. Develop and administer the QA program which is responsive to the requirements of DOE and NRC.

2. Coordinate the development of QA procedures.

3. Implement special QA requirements.

4. Ensure that an effective nonconformance system is in place which provides for the documentation of nonconforming conditions and timely resolution of problems.

5. Ensure that an effective corrective action system is in place and implemented such that root causes are identified and appropriate actions are taken to prevent recurrence of problems.

6. Ensure that an effective audit/surveillance program is implemented that uses qualified personnel and results in formal audit reports with defined corrective actions.

Quality Assurance Specialist:

Quality Assurance Staff Specialists who are assigned to engineering projects to ensure development and implementation of QA plans and requirements. As a minimum, the duties and responsibilities of the QA Specialist would be as follows:

1. Assist the QA Manager in the performance of duties as defined above.

2. Perform quality inspections of the packages during use and maintenance. Ensure that all appropriate documentation is available to verify the quality of the package.

3. Ensure that appropriate procedures are followed during use of the package.

Transportation Coordinator:

The transportation coordinator has been assigned to monitor package related activities. Specific duties and responsibilities include ensuring that the requirements, as stated in the SARP, for the following activities: design modification operation, and maintenance of the package are adhered to without exception. Also, notifying appropriate representative of the Department of Energy if at any time the package is not in compliance with the requirements, as stated in the approved SARP and license.

Maintenance Coordinator:

The assigned individual who has overall responsibility for ensuring that appropriate maintenance is performed on the packaging once a need is identified through the quality assurance inspection process. Ensures that routine maintenance is performed through the controlled process of work packages and work orders.

9.3 Quality Assurance Criteria Per ASME NQA-1

9.3.1 Organization

The structure of each organization and the assignment of responsibility for each function the organization performs with respect to packaging and fuel fabrication should ensure the (1) specified quality requirements are achieved and maintained by those who have been assigned the responsibility for performing the work, and (2) conformance to established requirements is verified by individuals and groups not directly responsible for performing the work. The persons or organization responsible for verifying quality should report through a management hierarchy so that required authority and organizational freedom, include sufficient independence from influences of cost and schedule, are provided.

The fuel fabricator should establish a formal organization structure and prepare organization charts identifying each organizational element that functions under the QA program such as, engineering, procurement, inspection, testing and quality assurance.

Requirements should be established by all organizations involved with packaging or fuel fabrication to ensure that designated QA individuals have the responsibility and authority to stop unsatisfactory work and the processing, delivery, or installation of nonconforming material; this authority should be delineated in writing.

An example of an implementing procedure that demonstrates project responsibilities and authorities is contained in Oak Ridge National Laboratory (ORNL) QA Procedure QA-RRD-1-100. An example of an organizational structure that demonstrates independence of the QA function is contained in the Figures 9.1 and 9.2. Figure 9.2, titled "Sample laboratory transportation program organization-division level," specifies the organizational structure and communication interfaces for the administrative matrix, and QA functions. The Research Reactors Division (RRD) reports to the President of Martin Marietta Energy Systems, Inc. through the Reactor Operations Director and to the Laboratory Director through the Associate

Director of Nuclear and Engineering Technology, whereas the Quality Department reports to the Laboratory Director through the Laboratory Associate Director for Support and Services.

Any organization that may be involved with either packaging or fuel fabrication will be required to document a formal QA program and organization that complies with the stated requirements of this section.

9.3.2 Quality Assurance Program

Decisions relative to quality are made at appropriate organizational levels. Each Project Task Leader, with input from the Quality Assurance Specialist, maintains the authority to develop the necessary quality assurance plans for their areas of responsibility to meet the requirements of the overall quality program. The Quality Assurance Specialist has the authority to initiate actions to halt transportation related activities when quality requirements are not being met.

The extent of quality effort given to an activity or package component is controlled by the quality level assigned and the attendant QA requirements. Activities associated with design modification, purchasing, testing, use, repair, handling, shipping, storing, cleaning, inspection and maintenance of the packaging as well as the individual packaging components are based upon a graded approach identified in 10 CFR § 71.101 and are assigned quality levels based on the following definitions.

QA Level 1 (Critical)

QA Level 1 items and activities are ones whose failure or malfunction will result in an unacceptable condition of containment, shielding, or nuclear criticality based upon federal regulations. QA Level 1 items and activities include items and activities that could directly impact public radiological health and safety.

QA Level 2 (Major)

QA Level 2 items and activities are ones whose failure or malfunction could indirectly result in an unacceptable condition of containment, shielding, or nuclear criticality. An unsafe condition could result only if the failure of a QA Level 2 item occurred in conjunction with the failure of another QA Level 2 item. QA Level 2 items and activities include items and activities for which failure could indirectly impact public radiological health and safety.

QA Level 3 (Minor)

QA Level 3 items and activities are ones whose failure or malfunction would not reduce packaging effectiveness and would not result in an unacceptable condition of containment, shielding, or nuclear criticality. QA Level 3 includes items and activities for which failure is unlikely to result in a predictable adverse impact on public health and safety.

Tables 9.1, 9.2, 9.3, and 9.4 summarize the Q-list for quality affecting activities and components, based on the above definitions. For the purpose of certifying the package, the HFBR unirradiated fuel assemblies are considered to be a part of the package configuration. Because of the significance of the aluminum clad fuel in providing containment, the fuel is included in the tables.

Personnel Training

QA indoctrination and training are routinely given to project personnel by the training section, who use QA procedures to ensure that personnel can fulfill inspection, maintenance, and operation requirements. Records of attendance at each training session are maintained by the organization conducting the training session. Quality-affecting personnel are instructed in the proper implementation of procedures concerning operation, maintenance, inspection, and quality assurance requirements for the HFBR package.

9.3.3 Design Control

The HFBR Unirradiated Fuel Shipping Containers (basket shell and outer housing) were designed and fabricated by ORNL in 1978. The fabrication work on these packages was performed prior to the requirements for a formal quality assurance program. At the time of fabrication, the packages were inspected by ORNL shop inspectors for conformity with the as-built drawings and were found to be acceptable.

Any required modifications or additions to the existing HFBR Unirradiated Fuel Shipping Container and fuel assembly will be controlled through a design control process. Design modifications will also be controlled by applicable analyses, testing, and documentation procedures as described in the Quality Assurance Program document on instructions, procedures, and drawings. In addition, any changes or modifications to the packages that vary from the approved certified configuration or specifications are PROHIBITED. The Statement, "Licensing Restrictions Apply", has been placed on the ORNL packaging Drawing Nos.: M-11518-OH-001-E, Rev. 0; M-11518-OH-002-E, Rev. 0; and M-11518-OH-003-D, Rev. 0; and on the B&W fuel Drawing Nos.: 4-8002-D, Rev. F (as modified by BNL letter dated October 17, 1991 (C. Wennes to R. H. Odegaarden)) and 9-8025E, Rev. M, to prevent revisions from being made to the drawings without the proper approval. Revisions will not be made to the drawings without the approval of the Quality Assurance Office. The Quality Assurance Office and the Transportation Coordinator would insure appropriate reviews and approvals which include DOE have been received before proceeding with the revision process.

Technical and quality assurance requirements for the fuel assemblies are contained in "Description and General Specifications for HFBR Fuel Element Type KM," dated May 29, 1987 (see Chapter 4 Appendix A).

If a packaging or fuel assembly modification or addition is required, the following specific activities will be completed in order to be in compliance with the design control requirements and the SARP.

1. Identification of applicable design codes and standards pertinent to modifications or additions to be made. Review and approval provided for each selection made. Initial notification must be given to DOE that a change is required for a specific reason.

2. Documentation of the design process with modifications reflected in the SARP. Review and approval for certification must be requested and received for each revision that affects the approved certified configuration.

3. Performance of design reviews.

4. Establishment of a design control change system for package modification.

    a. Project engineer is selected to coordinate communications on design activities to include interfaces among designated in-house groups, users, suppliers, and DOE.

    b. Project engineer reviews the SARP to identify design criteria, specifications, drawings, procurement specifications, and procedural documents required for package modification.

    c. Project engineer ensures that the necessary documents are prepared for fabrication to include procurement documents, work orders, and quality assurance inspection requirements and requests.

    d. Project engineer ensures that appropriate modification verification is performed. Also, verifies that the package was modified according to the conditions of the certificate of compliance.

    e. Project engineer ensures that design documentation and QA records are developed and maintained.

    f. Project engineer ensures that adequate controls are placed on the modification process to attain the required quality and verification of quality.

5. Establishment of a configuration control system.

6. Identification and control of design interfaces.

No packaging or fuel assembly additions or modifications will be fabricated and installed until the previously described activities have been completed.

Quality assurance levels for design control of the HFBR packaging components (inner basket and outer housing) and the fuel (containment) are listed in Tables 9.1, 9.2, 9.3, and 9.4. Classification of components into quality levels assures that critical parameters of a given component are reviewed in a manner consistent with their importance. Critical dimensions with tolerances and standards are shown on the drawings for each component. These drawings are developed, stored, updated, and controlled.

An example of implementing procedures for design reviews; for drawings, instructions, and procedure preparation; and for configuration control is contained in ORNL Procedures QA-RRD-3-100, QA-RRD-5-100, and RRAP-3.3, respectively.

Design Control on the HFBR Fuel Specifications

It should be noted that the fuel fabrication process has not been altered significantly over the years of operation and it is not anticipated that the fabrication process will vary from what is presented in the Chapter 4 Appendix A. It must be emphasized that the BNL specification, "Description and General Specifications for HFBR Fuel Element Type KM," was issued in the late 1970s under a different document control program than is in place today. However, if revisions were deemed necessary, the revised document shall be under a more stringent document control policy and receive a number of reviews by various sections before approval of the revision was given. The Quality Assurance Office will verify that the Project Engineer responsible for coordinating the certification of the HFBR Unirradiated Fuel Shipping Container has reviewed each fuel specification change and has identified all items that may affect the contents of the approved SARP. The revised fuel specification document would become part of the revised SARP once written approval was obtained from DOE.

9.3.4 Procurement Document Control

Packaging Procurement

The packagings were originally fabricated at ORNL in 1978. Therefore, no supplier certificate of compliance documents are available. However, other documents such as signed inspection checklists and as-built drawings are available as documentation of verification activities conducted during fabrication, use and maintenance of the shipping packaging.

Fuel Assembly Procurement

Fuel assemblies are procured to the requirements in BNL Specification "Description and General Specification for HFBR Fuel Element Type KM." The QA requirements invoked in this QA plan for fuel fabrication are specified in procurement documents for implementation by the fuel fabricator.

No new packaging will be procured under the certificate renewal for this certificate with the designation of AF.

Replacement Parts Procurement

The procurement of replacement parts important to safety is reviewed by QA personnel to ensure that appropriate technical and QA requirements are included in purchase orders consistent with the parts associated quality level to the package and SARP requirements. To assure that purchased material, equipment, and services conform to procurement documents, purchase orders are placed with qualified vendors or the parts are certified for use by applicable receipt inspection and/or testing techniques. Replacement parts meet requirements at least as stringent as the original criteria.

In the case of QA Level 2 fastener procurement, purchases will only be made directly from qualified fastener manufacturers. These fastener manufacturers will be required to certify the chemical and mechanical properties of each batch of bolts. Alternatively, if the procurement of the fasteners can not be placed directly with the manufacturer, in addition to the certification of the chemical and mechanical properties for each batch of fasteners, and in addition to the use of a qualified fastener supplier, an independent chemical analysis and tensile tests shall be performed for each new batch of fasteners prior to being made available for their use.

An example of an implementing procedure for procurement control is ORNL QA Procedure QA-RRD-4-100.

9.3.5 Instructions, Procedures, and Drawings

Activities affecting quality shall be prescribed by documented instructions, procedures, or drawings of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, or drawings. Appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished must also be documented. QA oversight is included within these documents according to such factors as quality level imposed and the complexity, importance, and special nature of the activity affecting quality.

Chapter 4 Appendix A contains the fuel assembly specification that is titled "Description and General Specifications for the HFBR Fuel Element Type KM." The fuel assembly specification is under document control of the operating facility. In addition, the fuel fabricator must establish a formal QA plan that contains implementing instructions, procedures, and drawings that satisfy the HFBR fuel assembly specification. Original fuel plate and assembly drawings are marked that "Licensing Restrictions Apply."

9.3.6 Document Control

All documents used to accomplish and/or verify quality-related activities are controlled. The controlled documents used in transportation activities include, but are not limited to, the following: HFBR AF SARP; reactor administrative procedures, design documents; procurement documents; QA manual; operating, maintenance and modification procedures; inspection and test procedures; nonconformance reports and corrective action; and "Description and General Specifications for HFBR Fuel Element Type KM," found in the Chapter 4 Appendix A.

9.3.7 Control of Purchased Items and Services

The results of supplier evaluations are documented, filed, and retained by Purchasing as long as the supplier is a current or prospective procurement source.

Contractors are controlled after contract placement by means of visits by the requester or his/her designee (surveillance) and/or QA personnel (audit and inspection). The contractors involved with fuel fabrication are also under routine surveillance with emphasis on the QA level 1 and 2 activities identified in Table 9.4.

9.3.8 Identification and Control of Items

Identification and control of items require methods to control the identification, handling, and storage of raw and fabricated materials from the time of receipt until delivery of the complete item to ensure that only correct and accepted items are used or installed.

Identification shall be maintained on the items or in documents traceable to the items, or in a manner that ensures that identification is established and maintained. Verifying the proper identification of project materials, parts, and components classified as Quality Level 1, Critical, and Quality Level 2, Major, is the specific responsibility of the Project Quality Assurance Specialist or a qualified alternate.

9.3.9 Control of Processes

Should packaging require major repairs necessitating the use of special processes such as welding or heat treating, procedures will be established to ensure that the special processes are controlled in accordance with the following criteria:

1. Procedures, equipment, and personnel are qualified in accordance with applicable codes, standards, and specifications.

2. The operations are performed by qualified personnel and accomplished in accordance with written process sheets with recorded evidence of verification.

3. Qualification records of procedures, equipment, and personnel are established, filed, and kept current.

In general, all welds must be made only by qualified welders or welding operators with approved procedures in accordance with Section IX of the ASME Code.

Control of Processes Affecting the Fuel Assemblies

Welding performed on the fuel assemblies must be in accordance with the specifications identified in the controlled document, "Description and General Specifications for HFBR Fuel Element Type KM."

9.3.10 Inspection

Inspections will be performed to verify conformance of a package related item or activity to identified standards and requirements prior to shipment. Any modifications, repairs, or replacements of shipping package items shall require reinspection to verify acceptability to the SARP requirements.

Visual inspections are conducted as part of the preparation process for shipping unirradiated fuel. These inspections include the following: a visual inspection of the inside and outside of the packaging for cracks, punctures, and dents; contamination does not exceed $10^{-5}\mu$ Ci/cm^2 in accordance with 10 CFR § 71.87(i); verification that all lid bolts are present; inspection of gasket surface and replacement if gaskets are worn or brittle; inspection of the lid-lifting blocking device to ensure all parts are in place and in working condition; and 3/16-inch diameter vent holes in the outer housing are sealed with epoxy or resin.

Fuel plate acceptance is based upon tests and inspections by the fuel plate fabricator, as specified in Section 4.1.4 and Chapter 4 Appendix A, that include inspection of fuel plates, core outline verification, blister inspection, ultrasonic inspection, and delamination test.

Checklists ensure that inspection of the package prior to shipping verify compliance with the following items:

- Packages are properly assembled
- The fuel basket has been blocked to prevent the insertion of more than two fuel assemblies into the package
- All shipping papers are properly completed
- Packages are conspicuously and durably marked as required by DOT regulations
- Measures are established to ensure that an individual designated by the user of the packages signs the shipping tags or indicators before authorization for shipping
- Operational and maintenance procedures are properly completed.

Pre-Maintenance Inspection

Qualified inspectors inspect the packaging for external and internal physical damage to the packaging to include identification of dents and scratches on the outer container, water damage to the wood, and wear of the gasket. Dents that have perforated the container will render the packaging unacceptable for immediate use until further evaluations or modifications can be made. All water-damaged wood will be replaced. Gaskets will be replaced prior to use if worn or brittle.

Maintenance of the HFBR fuel is not addressed in this section. The fuel is enclosed in a fuel assembly. As such, after the initial fabrication and testing, no maintenance is performed.

An example of implementing procedures to demonstrate item conformance and acceptance for inspection of packagings is contained in ORNL QA Procedures RRAP-3.3.1 and QA-RRD-10-102.

9.3.11 Test Control

Test control measures are employed to assure that the necessary tests are planned, are performed properly to specified requirements, and are documented to indicate that items have demonstrated their ability to perform satisfactorily in service. A test plan was prepared for each test required on each package. Since new shipping packages will not be fabricated under the certification for this SARP, new test plans will not be required to be developed.

9.3.12 Control of Measuring and Test Equipment

Measuring and test equipment (M&TE) that is used in quality-affecting activities are calibrated, adjusted, and maintained at prescribed intervals or prior to use. The M&TE is labeled or tagged to indicate the next calibration date. Transfer or in-house reference standards used in calibrating M&TE are traceable to nationally recognized standards. Should no known recognized standard exist, the basis for calibration is documented.

An example of an implementing procedure that demonstrated an effective calibration program is contained in ORNL QA Procedure QA-L-12-100.

9.3.13 Handling, Storage, and Shipping

Normal handling, storage, and shipping are implemented to preclude damage, loss, or deterioration because of environmental conditions, including shelf life limitations. When special treatment is required, technical specifications will be prepared to define such requirements and provide for their accomplishment. Handling, storage, and shipping of the package and fuel assemblies is divided into the following categories:

1. Package without Fuel: Packaging must be handled, stored, and shipped in accordance with 49 CFR § 173.427 and in such a manner as to preclude damage to the packaging. All packagings are inspected prior to use to verify that appropriate measures have been taken to ensure package integrity.

2. Package with Fuel: Packages are handled in accordance with the requirements of the SARP and DOT regulations.

3. Fuel in Storage at the Supplier Location: Measures must be taken to ensure that the fuel specifications for packaging and shipping, as defined in the BNL, "Description and General Specifications for HFBR Fuel Element Type KM", which is included in Chapter 4 Appendix A, are followed.

An example of an implementing procedure for handling, storage, and shipping of the shipping package is contained in ORNL QA Procedure QA-RRD-13-100.

9.3.14 Inspection, Test, and Operating Status

Measures are employed to ensure that the status of inspections, tests, and operating conditions, including maintenance activities, is known by organizations responsible for assurance of quality of the HFBR package. Status of individual items or the shipping package is indicated with tags, markings, or stamps on the item itself or included in the documentation accompanying the item.

9.3.15 Control of Nonconforming Items

Nonconformances must be documented and tracked through the identification process to resolution and disposition of corrective action. Procedures are required of the fuel fabricator that address the identification and control of nonconformances and include the initiation and processing of nonconformance reports by personnel through follow-up and closure. Nonconforming items may include hardware and raw materials. Nonconforming activities may include contracted services and day-to-day operations by personnel. Nonconforming items and services may result from a subcontractor's activities or activities by a service organization.

All items affected by the nonconformance will be tagged, segregated, and removed from use until the nonconformance has been appropriately resolved and closed. Disposition of nonconformances is the result of the combined effort between the technical staff and QA personnel. Should an item or the shipping package itself require rework or repair, the acceptability of the nonconforming item is verified by re-inspecting the item against the original requirements after the designated rework or repair. Should the technical requirements contained in the SARP not be satisfied, such as the tolerance range for ^{235}U loading, a nonconformance will be processed for certification approval.

An example of implementing procedures for controlling and resolving nonconformances is contained in ORNL QA Procedures QA-RRD-15-100 and QA-RRD-15-101.

9.3.16 Corrective Action

In order to prevent the recurrence of a nonconformance, the causes of the nonconformance are promptly identified and reported to appropriate levels of management. The QA manager ensures that the corrective action has been implemented.

An example of an implementing procedure for a corrective action system is contained in ORNL QA Procedure QA-RRD-15-101.

9.3.17 Quality Assurance Records

QA records furnish documentary evidence of the tasks affecting quality. They include, but are not limited to reports, analyses, data, computer codes, specifications, instructions, change orders and modifications, nonconformance results, contract documents, procedures, inspection and test data, audit results, maintenance and shipping records. QA records can be identified as either lifetime or nonpermanent. Both types of documents will be managed by a document control system that identifies and collects the QA records. The retention period for the packaging records (excluding fuel material) will be three years after the last use of the packaging. The retention period for the shipment (including the fuel material) will be five years after the shipping date.

Reviews are conducted at the completion of each project to determine receipt of adequate records.

The following criteria applies for the shipping packaging and fuel records:

FUEL ASSEMBLIES: All documents related to the fabrication, inspection, and shipping of the fuel will be maintained by the reactor facility for the life of the fuel assemblies or at least five years after shipment using a document control process.

Packages (Fabricated Prior to 1978): Records related to design modifications, inspections, and maintenance were not maintained in a formal document control system prior to 1988. After 1988, all records associated with QA-related activities have been identified as QA lifetime records, which have been placed in the controlled records management system. These records include design change notices, drawing revisions, material certification, and quality assurance inspection reports.

Packages (To be Fabricated): No new packages will be constructed.

Table 9.5 itemizes these applicable QA records and designates the retention periods.

9.3.18 Audits

Audits related to the packaging and fuel are conducted by the QA organization of the user. The Quality Assurance Specialist identifies the audit team leader and audit team from designated, qualified personnel. Individuals are qualified based on training, examination, and experience. Audit personnel should understand the activities they are reviewing and should not have direct responsibility for the activities being audited. Audit teams are responsible for preparing audit checklists, conducting the audit in accordance with the audit plan and good audit practice, and documenting the results in a final audit report, which is approved by the Quality Assurance Specialist.

Internal audits of the active and applicable assemblies of the QA Program such as design modification, operations, maintenance, and shipment are conducted at least once annually. When the activity and applicable assemblies are programmatically "shared" and are applicable to other projects/areas of an organization, they may be audited concurrently with other internally conducted audits designated to assess programmatic implementation.

External audits of QA assemblies for quality assurance programs of major suppliers or major contractors will be audited on a triennial basis. The 3-year period will begin with performance of an audit when sufficient work is in progress to demonstrate implementation of a quality assurance program having the required scope for purchases placed during the 3-year period. Management audits will be conducted at least once every 12 months.

Surveillance activities are conducted and are comprised of monitoring and observing selected documents and work activities to provide an effective, real-time means of evaluating and assessing the adequacy and effectiveness of methods for achieving quality and for assessing the quality of final results. Surveillance activities are conducted by qualified personnel who are independent of the activity under review. Surveillances will be used, as deemed necessary by either the QA Specialist or Project Engineer, during the following activities: performance of maintenance and operation activities related to the existing packages, and fuel fabrication.

An example of implementing procedures that demonstrates the audit and surveillance functions are contained in ORNL QA Procedures QA-RRD-18-100 and QA-RRD-18-103, respectively.

Table 9.1 Q-List

Packaging Outer Housing (including lid)	
Shell, 11-ga stainless steel (ASTM A240 or A167, Type 304 or 347)	QA Level 2
Closure lid, 11-ga stainless steel (ASTM A240 or A167, Type 304 or 347)	QA Level 2
Bottom plate, 1/4" thick stainless steel (ASTM A240, Type 304, 304L or 347)	QA Level 2
Channels (2), (4" x 1-3/4" x 29") stainless steel (ASTM 276 or A479, Type 304L or 347)	QA Level 3
Spacer clips (4), stainless steel (ASTM 276 or A479, Type 304L or 347)	QA Level 3
Threaded studs (4), 3/8-16UNC stainless steel (ASTM 276 or A479, Type 304L or 347)	QA Level 2
Bolts (6), 5/8-11UNC stainless steel (A193, grade B8, Class 2)	QA Level 2
Nuts (6), 5/8-11UNC carbon steel (A516, Grade 60)	QA Level 2
Dowel pins (2), 3/8 dia. x 7/8 stainless steel (ASTM 276 or A479, Type 304L or 347)	QA Level 3

Table 9.2 Q-List

HFBR Fuel Assembly Basket
(including lid)

Basket shell, 16-gauge stainless steel (ASTM A167 or A240, Type 304 or 347)	QA Level 3
Bottom plate, (13 x 13) 11-gauge stainless steel (ASTM A167 or A240, Type 304 or 347)	QA Level 3
Top plate, (16 x 16) 11-gauge stainless steel (ASTM A240 or A167, Type 304 or 347)	QA Level 3
Bolts, 3/8-16UNC alloy steel (ASTM A449 or SAE J429 Grade 5, 105,000 min. tensile)	QA Level 3
Nuts, 3/8-16UNC stainless steel (ASTM A194, Type 303 Grade 8F	QA Level 3
Basket lid, 1/8" thick aluminum alloy (AA2024-T4 or 6061-T6 ASTM B209)	QA Level 3
Neoprene spacers, (4 x 4 x 1/2)	QA Level 3

Table 9.3 Q-List Activities

Design (Modifications, Additions)	QA Level 2
Fabrication	QA Level 2
Inspection	
In-process	QA Level 2
Final	QA Level 2
Inservice	QA Level 2
Procurement	QA Level 2

Fuel Plate (Containment)

The fuel plate is considered a critical part of this shipping package. Therefore, activities associated with the fabrication of the fuel plates are all designated as QA Level 1, as defined on page 9-5. Specifications for the fabrication of fuel plates are detailed in Chapter 1 Appendix A and Chapter 4 Appendix A. The activities discussed in this document are to be performed to the highest level of quality, with any exceptions or deviations fully documented and dispositioned according to the approved procedures. Activities associated with the fabrication of the fuel plates include those steps involved from the purchasing of the raw materials to the final inspection of the finished fuel plates. All of the steps should be considered as QA Level 1. A summary of the activities are shown in Table 9.4.

Table 9.4 Q-List Activities (Fuel)

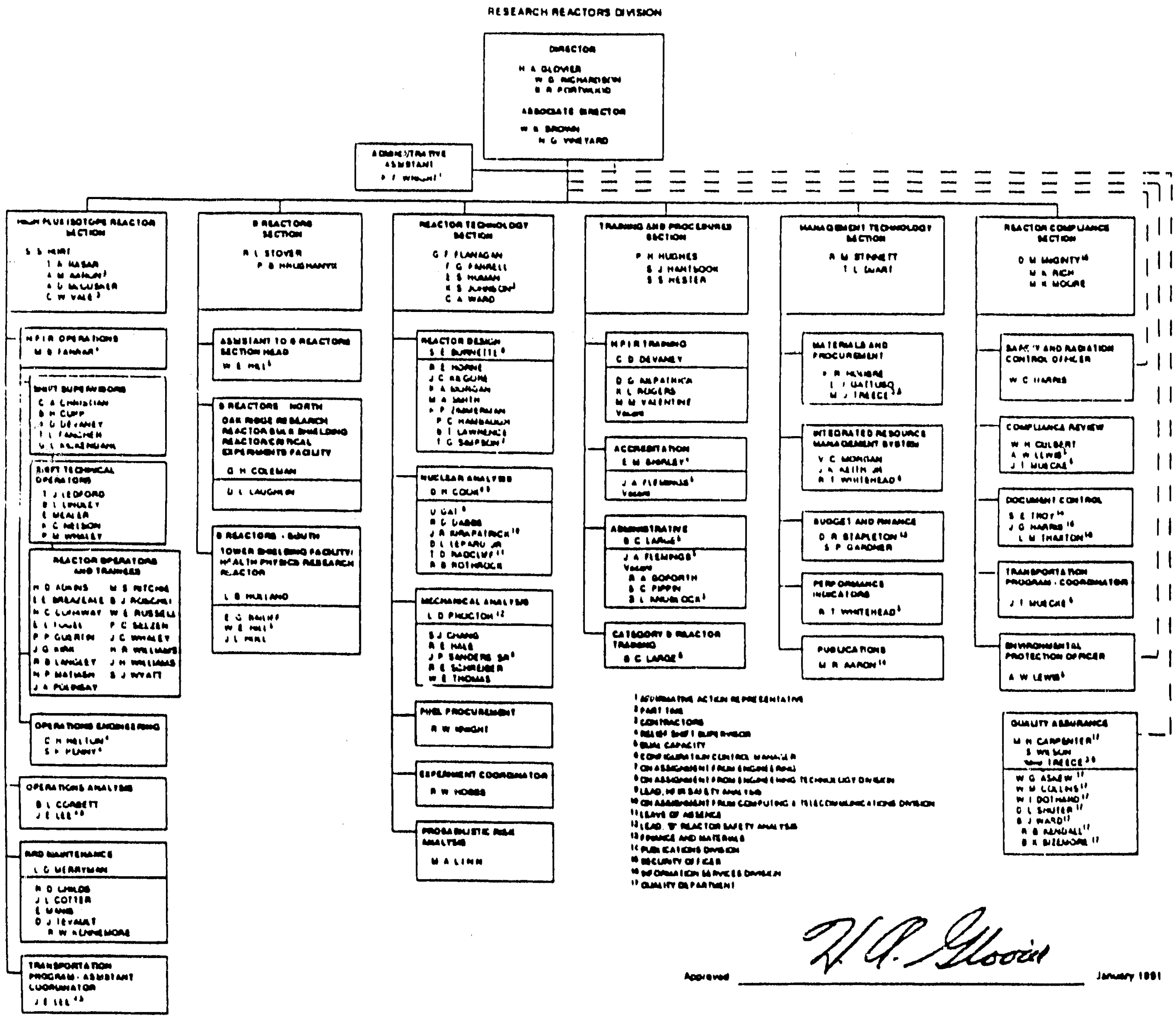
Fuel	
Fuel Plates (assembly)	QA Level 1
Procurement	
Certification of materials	QA Level 1
Chemical analyses of materials	QA Level 1
Fabrication	
Procedures qualification	QA Level 1
Fuel plate qualification	QA Level 1
Uranium loading	QA Level 1
Vacuum annealing	QA Level 1
Cleanliness	QA Level 1
Inspection	
Fuel plate dimensional inspection	QA Level 1
Core outline test	QA Level 1
Visual inspection of rolled plate for blister	QA Level 1
Ultrasonic inspection for non-bond	QA Level 1
Destructive examination to verify cladding thickness	QA Level 1
Delamination test	QA Level 1
Document Control	
Test results	QA Level 2
Material certification	QA Level 2
Uranium loading certification	QA Level 2
Storage	
Handling	QA Level 2
Packages	QA Level 2

Table 9.5 Retention Periods for Quality Assurance Records

Record	Retention Period
HFBR Unirradiated Fuel Shipping Container SARP (Includes QA plan for HFBR packaging)	L[1]
Computer code documentation	L
Audit reports	L
Nonconformance reports	L
Corrective action reports	L
Measuring and test equipment calibration records	L
Inspection reports	L
Purchase requisitions	L
Contract documentation	L
Contractor QA manual	L
Engineering drawings to include as-builts	L
Procurement correspondence	L
National standards and specifications (reference documents)	L
Design change notices	L
Drawing change notices	L
Contractor QA records data packages	L
Contractor training	L
Certifications for welders, inspectors	L
Maintenance records	L
Fuel assembly fabrication records	5 years after shipment[2]
Shipment records	5 years after shipment[3]

[1] Lifetime of the shipping packaging plus three years.
[2] Records of fuel fabrication will be maintained by the supplier and/or reactor facility and will be available on request to the reactor facility. The reactor facility maintains fuel assembly fabrication records for the lifetime of the fuel assembly in the reactor QA record program.
[3] Records of shipments will be maintained by shipper.

<u>Note</u>: Records such as audits, inspection reports, and nonconformances will be also be maintained as quality records by the reactor facility. A review will be conducted at the completion of each project to determine receipt of adequate records.



——— Indicates line function and responsibility for quality

- - - - - - - indicatessupportative/interface

Figure 9.1 Sample organizational structure for RRD

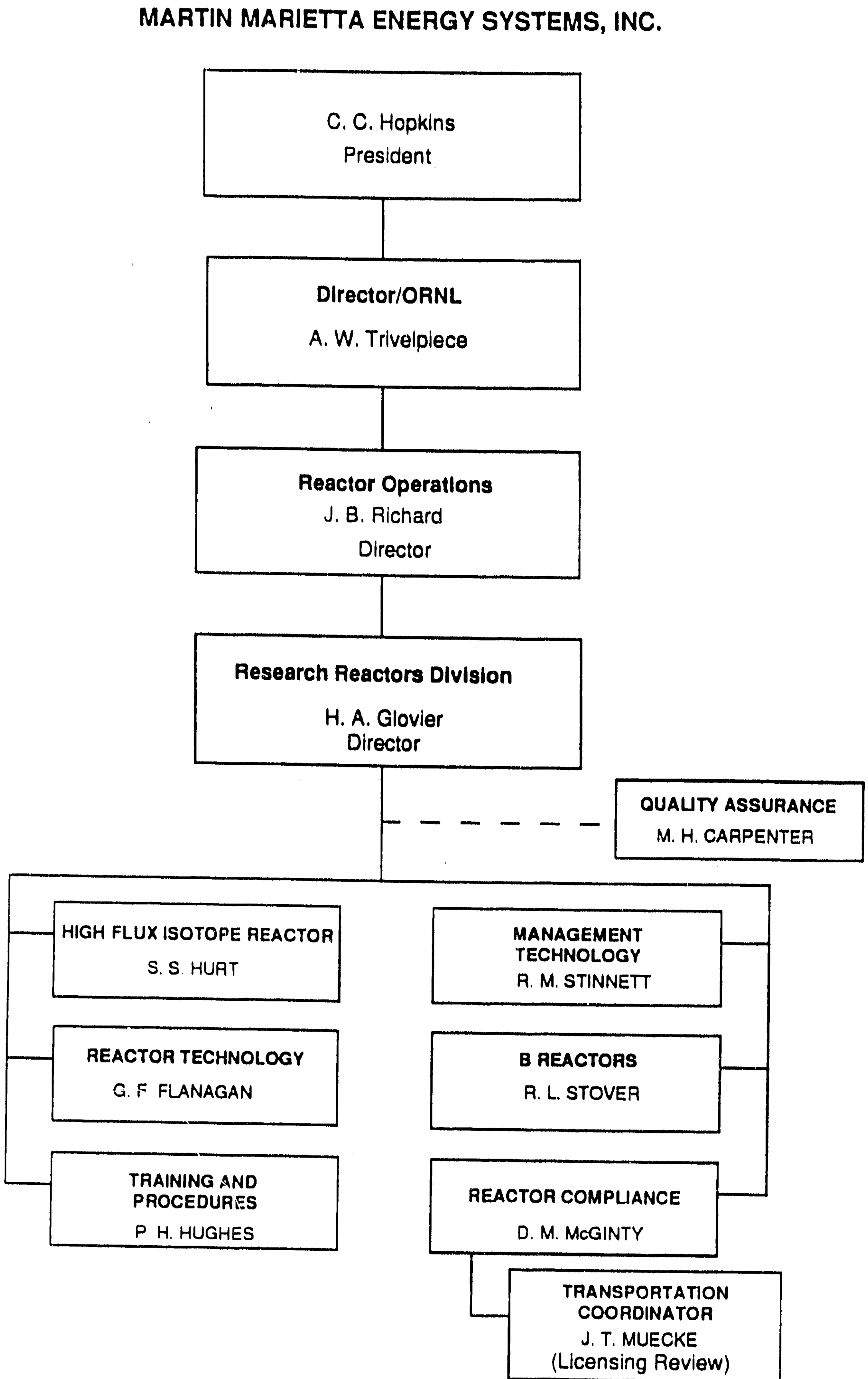


Figure 9.2 Sample laboratory transportation program organization-division level

END

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