CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

49

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U. S. ATOMIC ENERGY COMMISSION

UNION CARBIDE

ORNL-TM-1372

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0322091 2

HFIR PRESSURE VESSEL AND STRUCTURAL COMPONENTS MATERIAL SURVEILLANCE PROGRAM

J. R. McWherter
R. E. Schappel
J. R. McGuffey

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this document, send in name with document and the library will arrange a loan.

NOTICE This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES

3 4456 0322091 2

ORNL-TM-1372

Contract No. W-7405-eng-26

Reactor Division

HFIR PRESSURE VESSEL AND STRUCTURAL COMPONENTS MATERIAL SURVEILLANCE PROGRAM

J. R. McWherter, R. E. Schappel and J. R. McGuffey

JANUARY 1966

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U. S. ATOMIC ENERGY COMMISSION

HFIR PRESSURE VESSEL AND STRUCTURAL COMPONENTS MATERIAL SURVEILLANCE PROGRAM

J. R. McWherter, R. E. Schappel and J. R. McGuffey

Abstract

A review is made of the design considerations and fabrication precautions observed regarding prevention of radiation damage induced brittle fracture for the HFIR Pressure Vessel. The arrangement of specimens, dosimeters, containers and mounts is described and the reasoning behind specimen location in the vessel is given. The surveillance program is outlined and guidelines are established for operation of the vessel. Specifically it is recommended that a review of vessel operation be made if the NDT of any part occurs at a temperature higher than 60°F below the existing minimum operating temperature.

The effects of radiation on beryllium and aluminum components in the high flux near the fuel elements have been considered and the details of the surveillance program described.

An in-pile corrosion program has also been established to aid in determining the rate of corrosion of materials in the HFIR primary system. The basis for selection of the samples, their size and location, and a recommended schedule for periodic inspection is included.

Introduction

Radiation Damage

Pressure Vessel. In the design of the HFIR Pressure Vessel, precautions were taken to properly size all parts and to select materials of construction which would provide an optimum economic and technical balance and assure reasonable protection from brittle failure due to radiation damage. Because the reactor operates at relatively low temperatures, particular effort was made to maintain materials and design parameters within known limits wherever possible. The vessel was sized and nozzles were shaped so that all parts of the vessel, except those near horizontal

beam tubes, would experience an expected fast neutron dose of less than 10^{18} nvt. Design of the nozzle penetrations for the horizontal beam tubes was based on a conservative combination of experimental and analytical data used to determine the maximum fast neutron dose rate in the nozzle steel. Experimental data consisting of measurements in a simulated beam tube in the pool critical facility provided the basis for estimating the dose rate. The actual position of the beam tube in the vessel nozzle including machining and installation tolerances were considered in establishing dose rate values. These values were then corrected for differences in neutron spectrum between the HFIR and the experimental data.[1] The shift in nozzle NDT temperature with time was estimated from experimental radiation damage data.[2] To allow for the FTE concept of brittle fracture prevention, the initial minimum pressurized operating temperature of the vessel was set at 70°F which is at least 60°F higher than the maximum NDT temperature of any of the vessel materials. For those parts which will experience a shift in NDT temperature due to radiation embrittlement, materials were chosen with original NDT temperatures low enough so that the 60°F FTE margin will exist even after 20 years of 100 Mw reactor operation.

In the procurement of the vessel, the vendor was required to subject samples of the actual heat-treated materials used in fabrication of the carbon steel parts to Charpy V-notch impact tests. The results are shown in Table 1. Welding procedure qualification tests included impact tests of the welds and heat-affected zones of the base metal. In no case were impact values indicative of a NDT temperature greater than 10°F.

For vessel parts in proximity to the reactor core Charpy V-notch NDT curves were determined by ORNL personnel[3] from actual heat-treated vessel materials. These curves are shown on Figs. 1, 2, 3, and 4.

The original NDT and the predicted NDT temperatures after 20 years of 100 Mw operation are shown on Table 2.

Structural Components. The beryllium reflector assembly and all aluminum components have been designed to permit removal and replacement when required due to radiation damage.

Corrosion. Numerous out-of-pile static and dynamic corrosion tests[4] were performed to evaluate the corrosion resistance of materials of con-

Table 1. Charpy V-notch Tests--Vendor Data

Component	Material (ASTM Designation)	Test Temp. °F	Avg. Charpy Impact Value (ft-lbs)	Charpy Impact Value Corresponding to NDT (ft-lbs)
Shell Cylinder	A 212 GrB	+10	17	15
Hemispherical Head	A 212 GrB	+10	17	15
Top Head	A 105 GrII	+10	23	15
Top Flange	A 105 GrII	+10	94	15
Nozzle Forgings				
RH	A 105 GrII	+10	28	15
EF	A 105 GrII	+10	40	15
IC	A 105 GrII	+10	42	15
Cooling Water				
Inlet	A 105 GrII	+10	48	15
Vessel Lower				
Extension Transition	A 105 GrII	+10	39	15
HB #1	A 105 GrII	-20	51	15
HB #2	A 350 Gr LF3	-80	49	30
HB #3	A 350 Gr LF3	-65	38	30
HB #4	A 105 GrII	-20	51	15

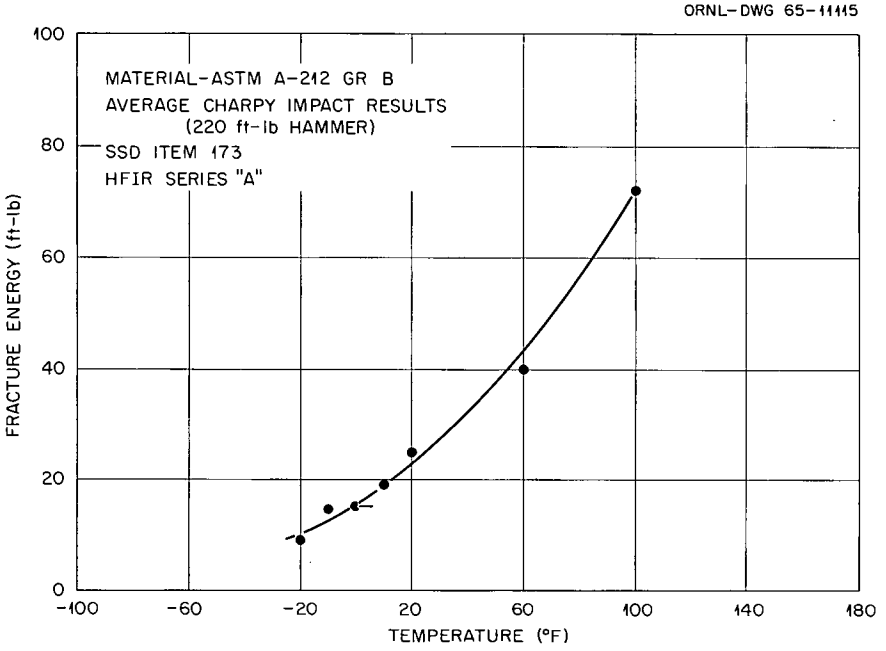


Fig. 1. Charpy V-Notch NDT Curve — Shell Material.

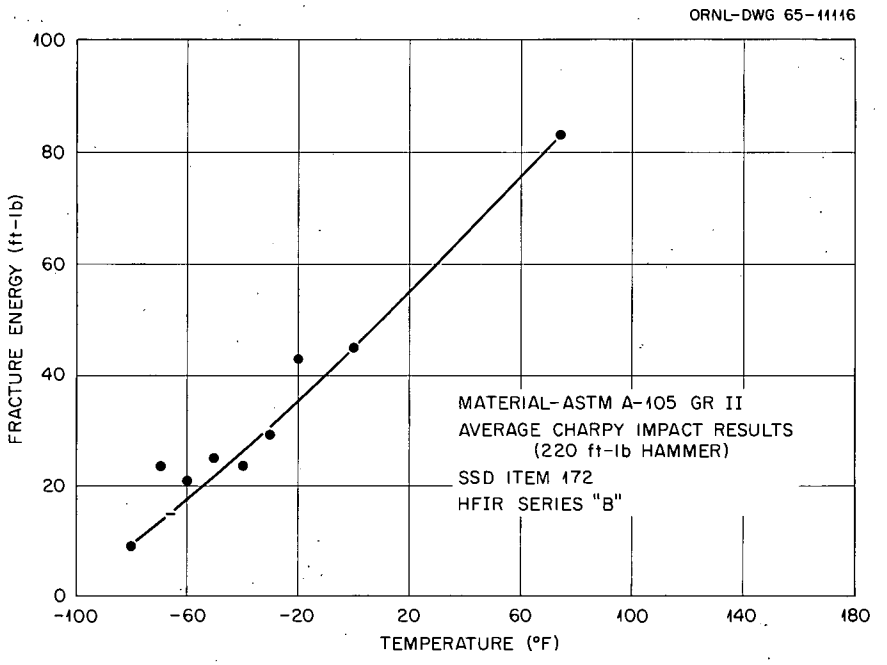


Fig. 2. Charpy V-Notch NDT Curve — HB 1 and HB 4 Material.

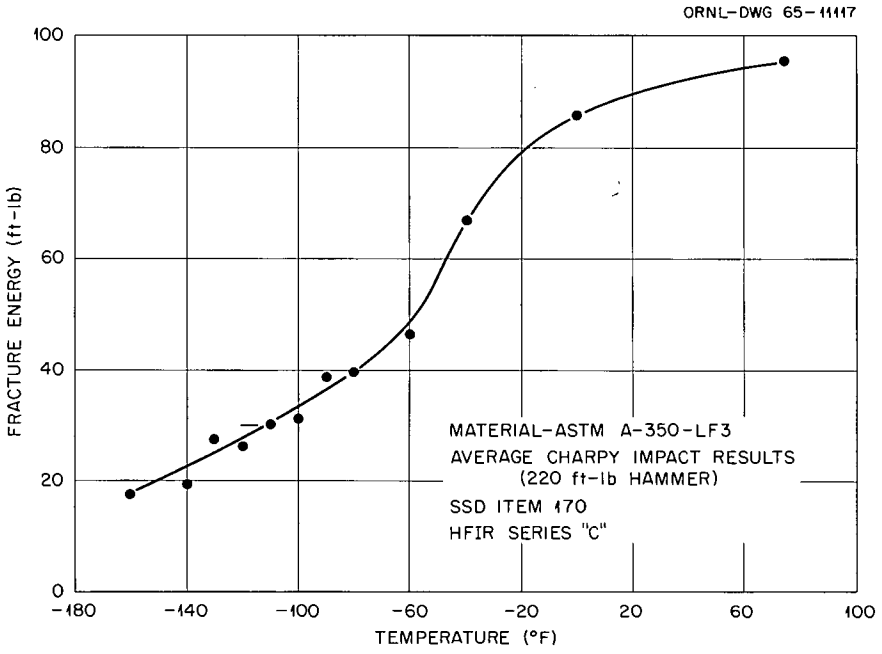


Fig. 3. Charpy V-Notch NDT Curve — HB 2 Material.

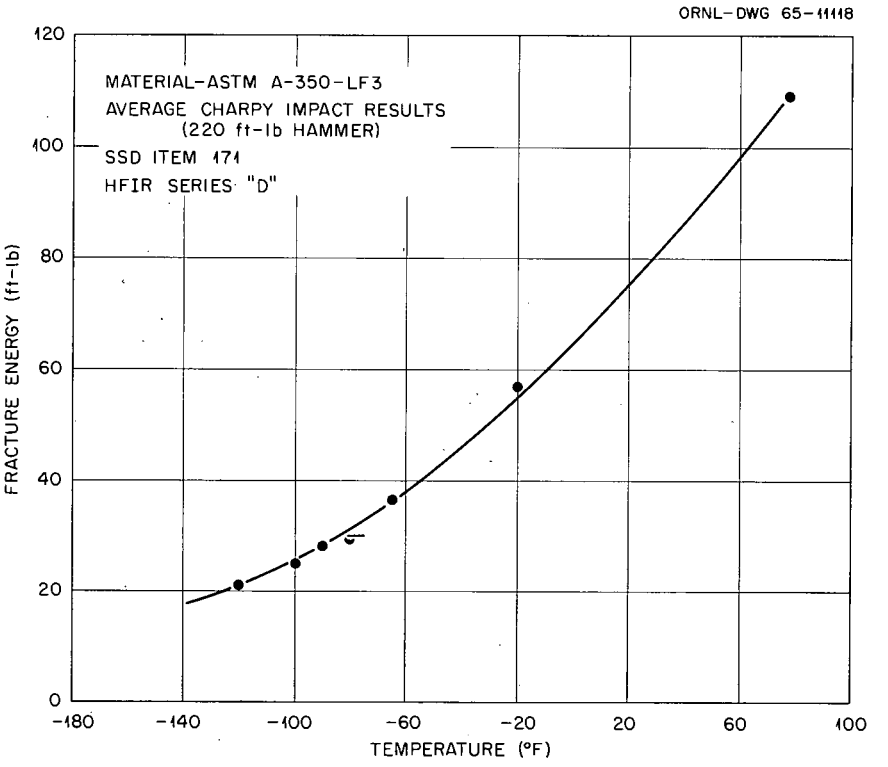


Fig. 4. Charpy V-Notch NDT Curve — HB 3 Material.

Table 2. NDT Data for Vessel Materials Based on ORNL Curves

Component	Original NDT (°F)	Calculated Fast Flux (nvt) 20 years		Expected 20 year Shift (°F)	Predicted NDT After 20 years of 100 Mw Operation (°F)
HB 1 and 4	-65	1.1×10^{18}	Corrected for spectrum shift and other factors	37	-28
HB 2	-115	2.9×10^{18}		80	-35
HB 3	-85	2.3×10^{18}		67	-18
Shell	0	$<10^{18}$	Not corrected for spectrum shift	0	0
All other parts	$\leq +10$	$<10^{18}$		0	≤ 0

struction used in the HFIR primary system, the structural components and control rod drives. The austenitic stainless steels and Inconel-X should be highly corrosion resistant; however, the aluminum alloys and the beryllium can be expected to undergo general corrosion and pitting particularly when dissimilar metal couples are involved. These data indicate that reasonable corrosion rates should be expected during operation of the reactor provided radiation effects or localized erosion does not materially alter the mechanism of attack.

Surveillance Program

Radiation Damage

Pressure Vessel. To supplement the analytical and experimental procedures followed in the design of the vessel, a surveillance program has been established as a guide for safe operation of the vessel. Charpy V-notch impact specimens made from actual heat-treated vessel materials are installed at selected locations as listed in Table 3 and shown in Fig. 5.

Table 3. Listing of Surveillance Specimen Locations

Material ASTM Designation	Representing Component	Location in Vessel	No. of Specimens	Key Number
A 105 GrII	HB #1	Mounted on beam tube in front of nozzle	30	1
A 350 GrLF3	HB #2	Mounted on beam tube in front of nozzle	30	2
A 350 GrLF3	HB #3	Mounted on beam tube in front of nozzle	30	3
A 105 GrII	HB #4	Mounted on beam tube in front of nozzle	30	4
A 212 GrB	Shell	Against wall of vessel behind IC #3 shield	21	5
A 212 GrB	Shell	Against wall of vessel at horizontal core mid-plane east of HB #1	24	6
A 212 GrB	Shell	Against wall of vessel at horizontal core mid-plane east of HB #4	24	7

Specimens have been cut from vessel materials as follows:

Specimen	Origin of Material	Specimen Location Map
Shell	Cutout for HB 2 nozzle	Fig. 6
HB 1 and 4	Spare Nozzle Forging (same heat)	Fig. 7
HB 2	Nozzle Prolongation	Fig. 8
HB 3	Nozzle Prolongation	Fig. 9

Orientation of the specimen length and notch is in accordance with the applicable ASTM specifications.

The locations selected for surveillance are the inner nozzle corner radius for all four HB nozzles, the shell girth at the reactor horizontal midplane and the shell in back of IC #3. Surveillance of the HB nozzles is deemed necessary since data on NDT shift in irradiated ASTM A350 GrLF3 nickel steel is limited. Shell girth specimens are located to measure the effect of any increase in radiation damage to the shell due to the

ORNL-DWG 63-394A

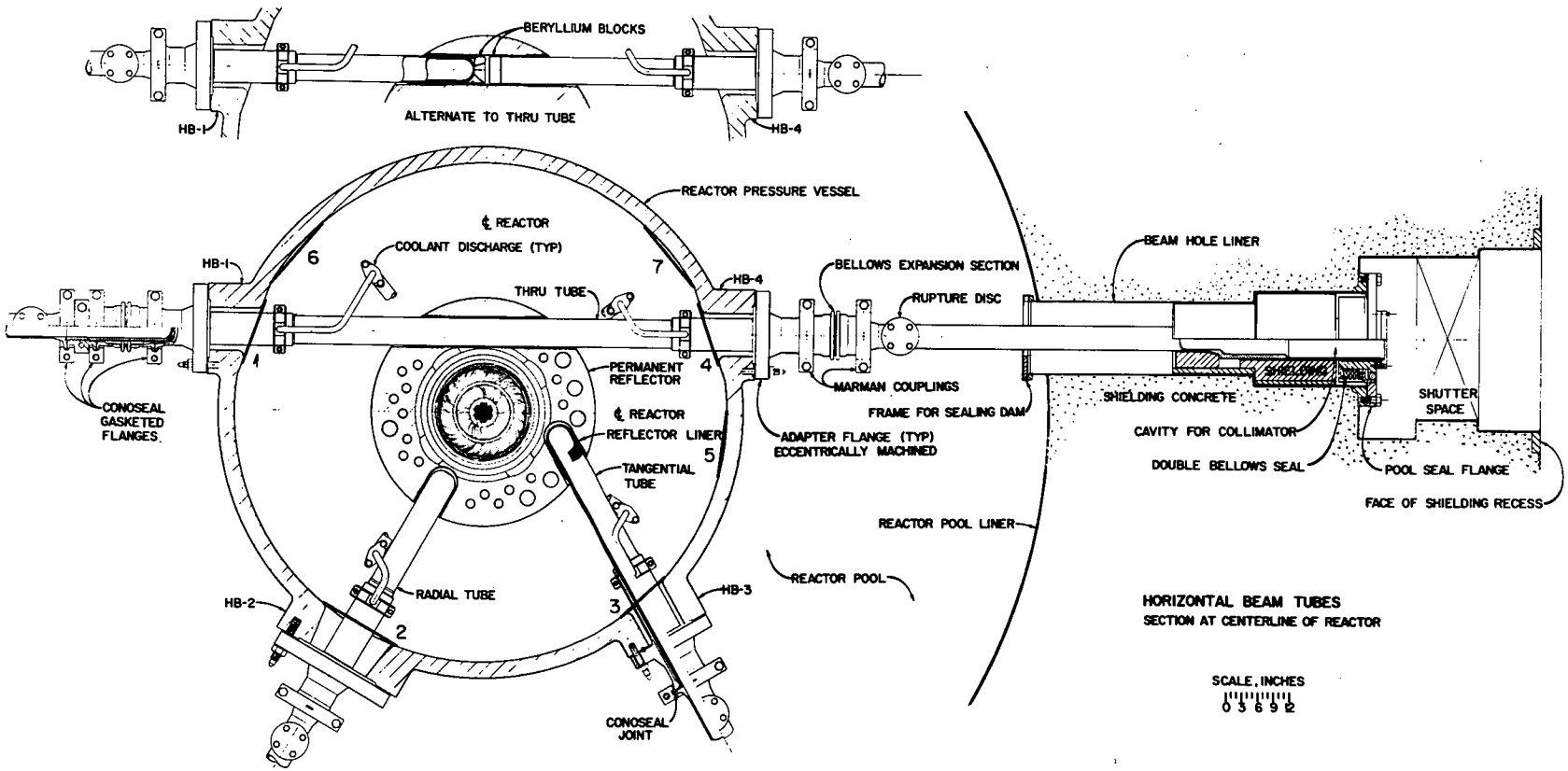


Fig. 5. Location of Surveillance Specimen Mounts.

E-M-56015

NOTE:
THIS DWG. IS IN KEEPING WITH NOTE 11 ON DWG. Nº E-49947

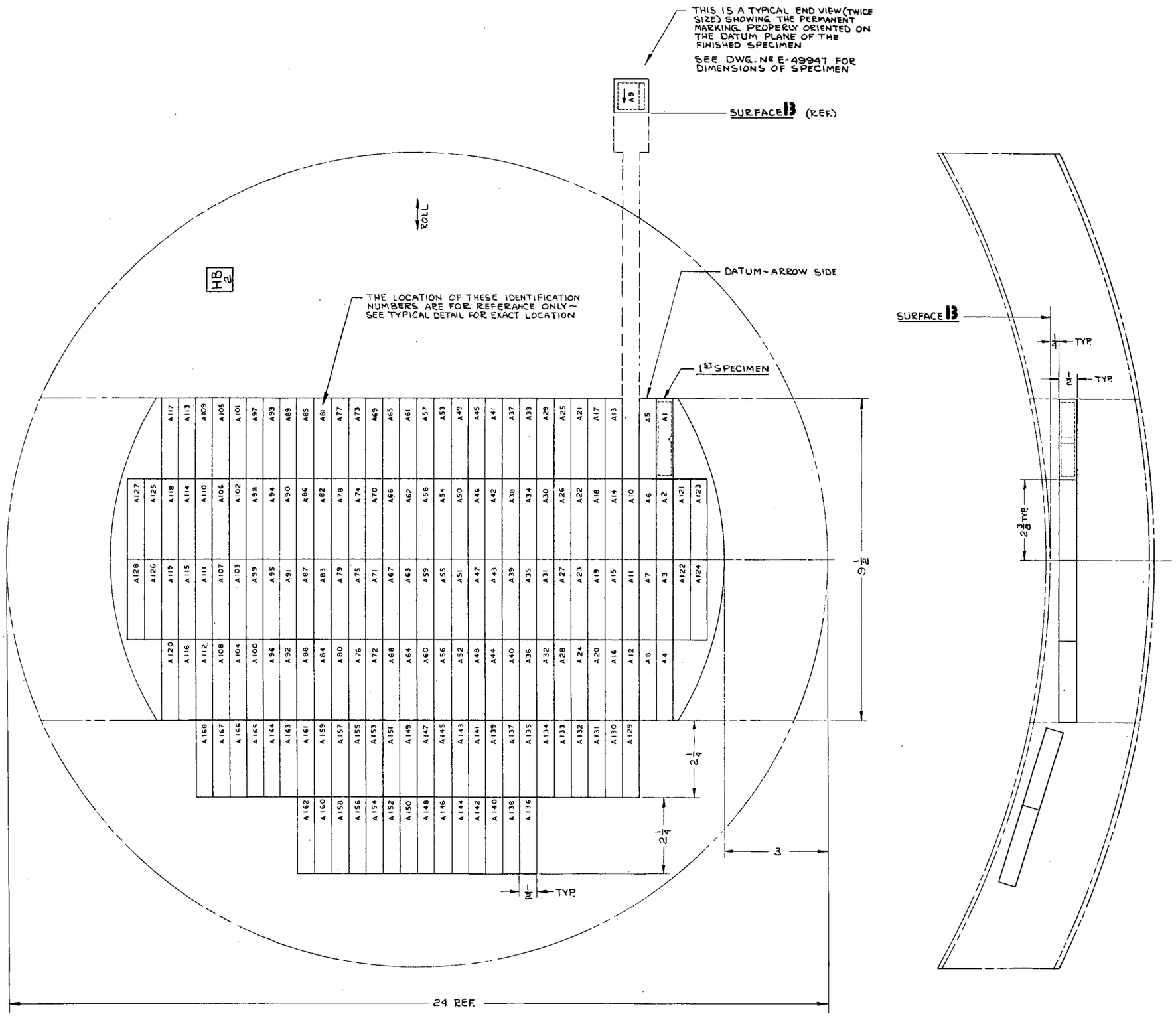


Fig. 6. Pressure Vessel Sample Shell Plate Specimen Detail.

E-M-56013

NOTE:
THIS DWG. IS IN KEEPING WITH NOTE 7 ON DWG. Nº E-49949

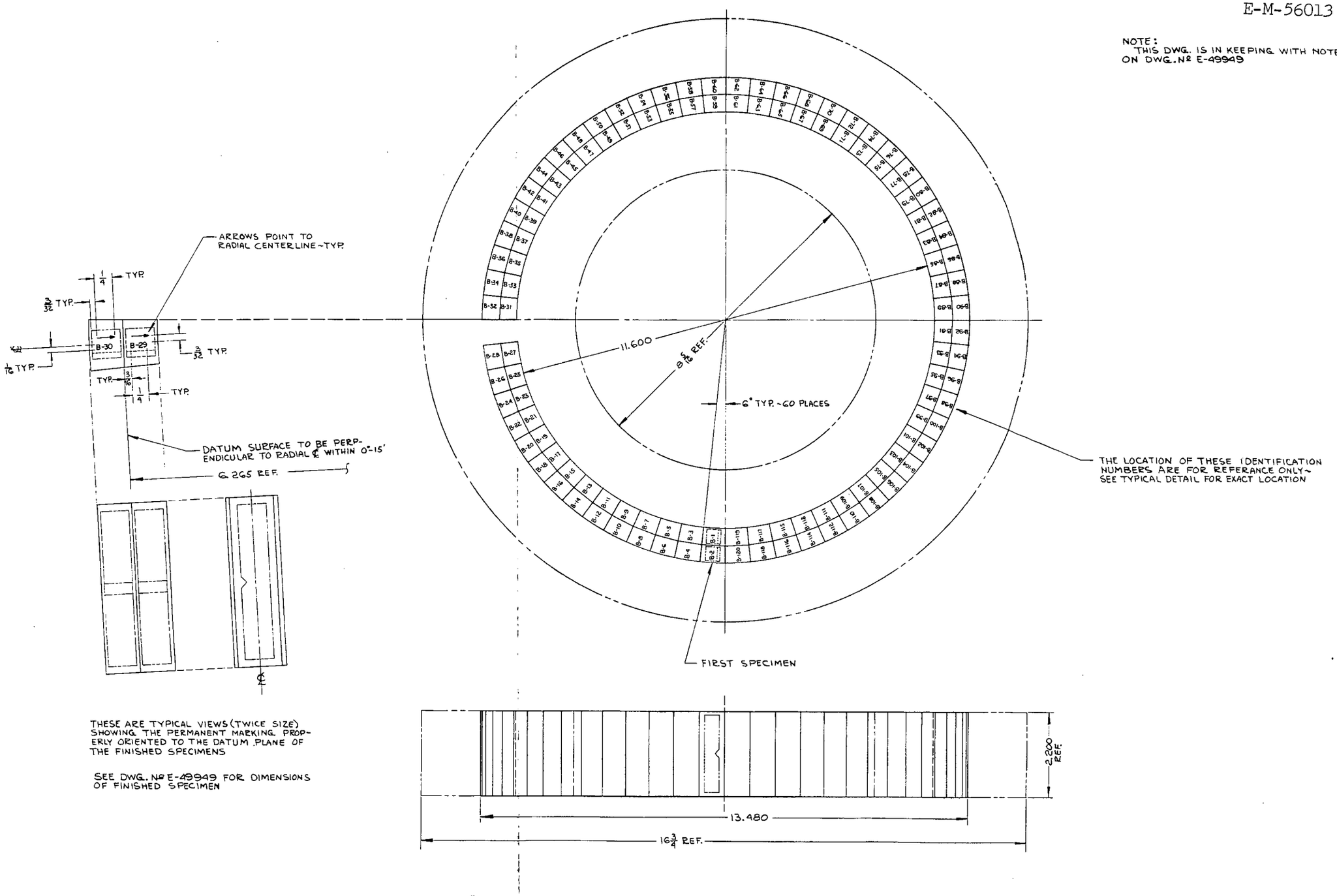


Fig. 7. Pressure Vessel Samples HB-1, HB-4, and EF Forging Specimen Detail.

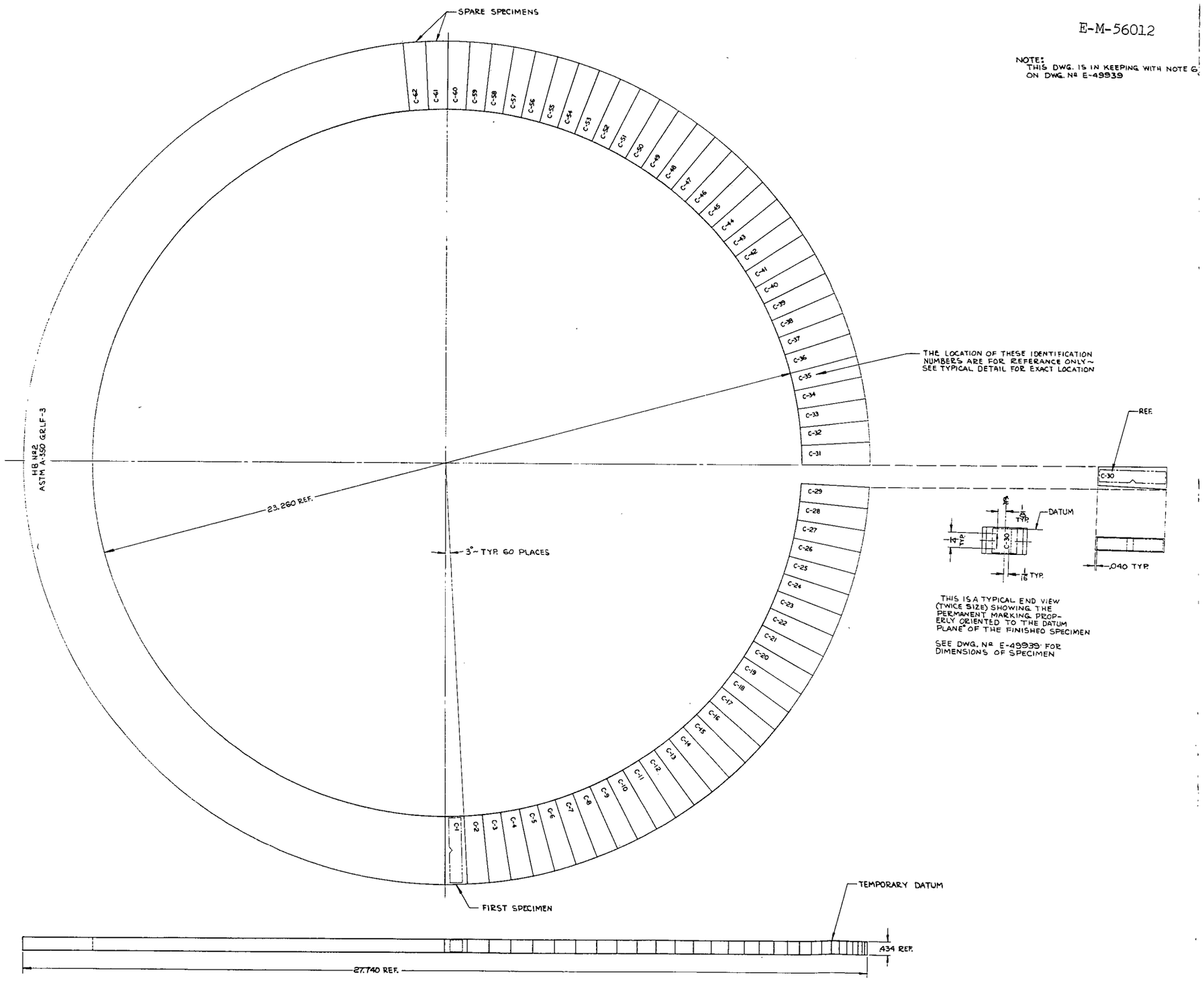


Fig. 8. Pressure Vessel Sample HB-2 Forging Specimen Detail.

E-M-56014

NOTE:
THIS DWG. IS IN KEEPING WITH NOTE 10 ON DWG. Nº E-49951

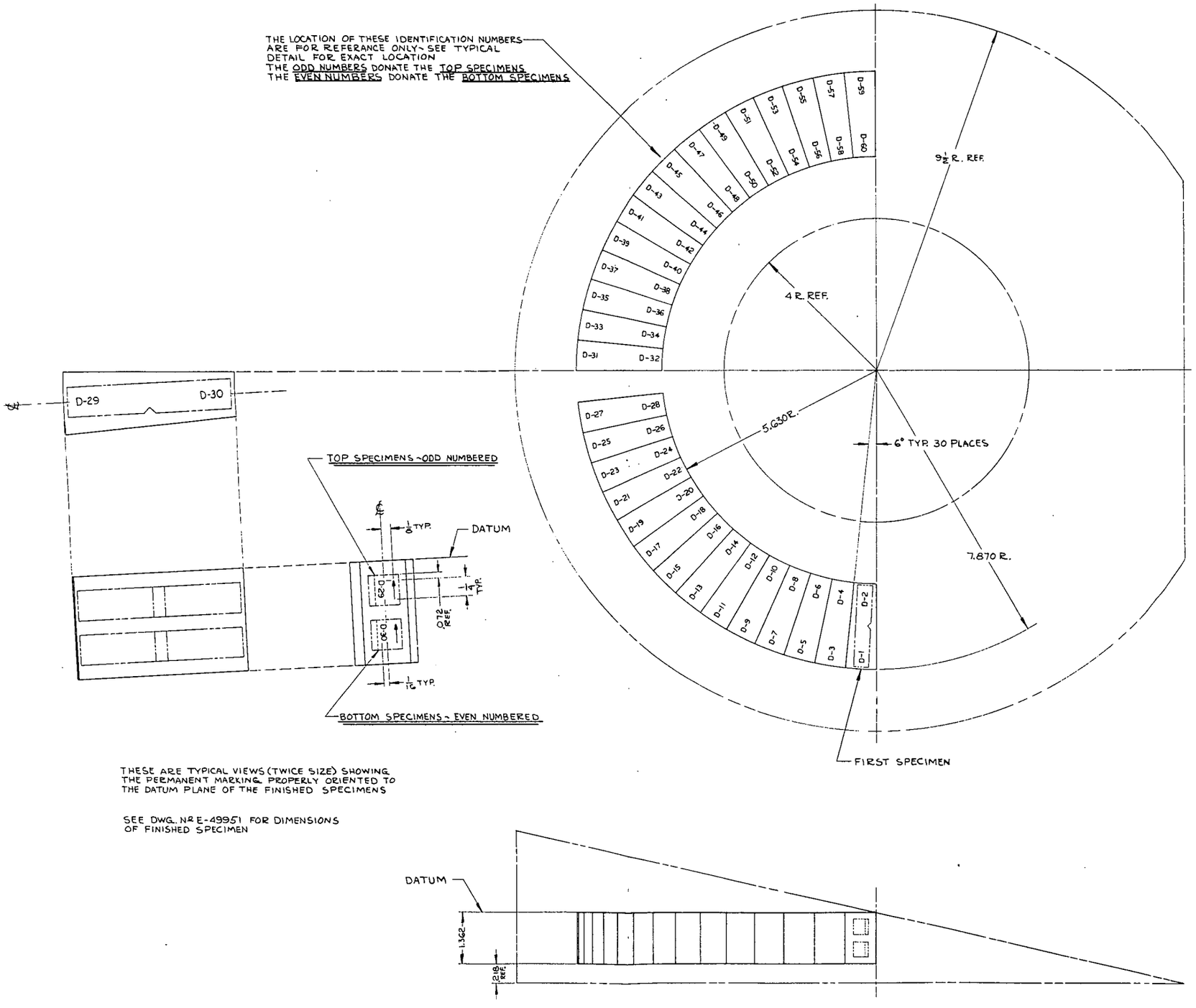


Fig. 9. Pressure Vessel Sample HB-3 Forging Specimen Detail.

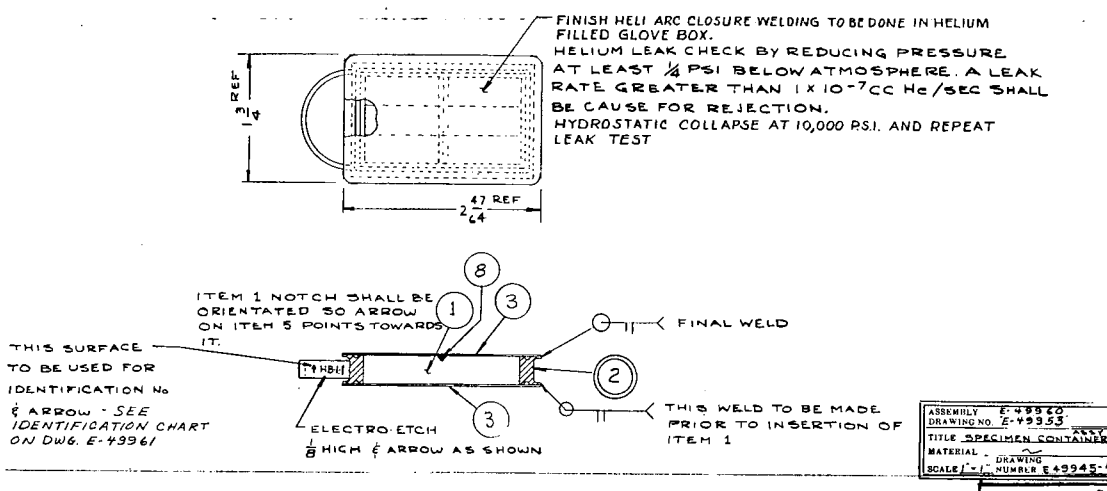
positioning of the through beam tube (HB 1 and 4). The specimens located behind IC #3 are intended to determine if the vessel steel in this location experiences greater neutron damage than the vessel steel proper due to the effect of replacing water shielding with the lead gamma shielding surrounding the ion chambers. Monitoring of other parts of the vessel has not been deemed necessary since the locations selected represent the areas of greatest expected neutron doses.

Standard size Charpy V-notch impact specimens are mounted three to a container as shown in Fig. 10. The container is designed with a looped handle to facilitate remote removal from the container mounts. The container mounts are shown in Figs. 11, 12, 13, 14 and 15. The specimen containers are removable from the shell girth mounts directly, while the mount for the HB specimens must be rotated into position for removal of a specimen container, and the mount for the IC #3 specimens slides on a track from behind the IC shielding. Design and fabrication of the specimen container was such that the gap between the specimen and any wall of the container was less than 1 1/2 mils assembled, in order to transfer gamma induced heating from the specimens to the vessel water at a rate which limits specimen temperature to less than 350°F.[5] Since no self annealing of the specimen material can take place below 450°F,[6] the specimens will provide impact properties which correlate with those of the vessel wall material.

To provide a means of determining approximate dose rate from activation analysis of nickel and iron, Type 302 stainless steel strips are inserted in the specimen "V" notch. A map of the source of these strips is shown on Fig. 16.

The schedule for removal and testing of the specimens is shown on Table 4. Sufficient samples are provided so that accumulation of radiation damage may be plotted and estimated past the 20-year point. Table 5 is an index relating specimen number and dosimeter number to container number. With the exception of the initial test of IC #3, two adjacent containers are to be removed for each test. To prevent the HB tube rotating holders from becoming unbalanced, whenever possible successive removal of samples (two adjacent containers) may be made from positions 180° apart followed by 90° from the previous two removals. It is planned that three specimens be broken at the suspected NDT temperature of material, after three

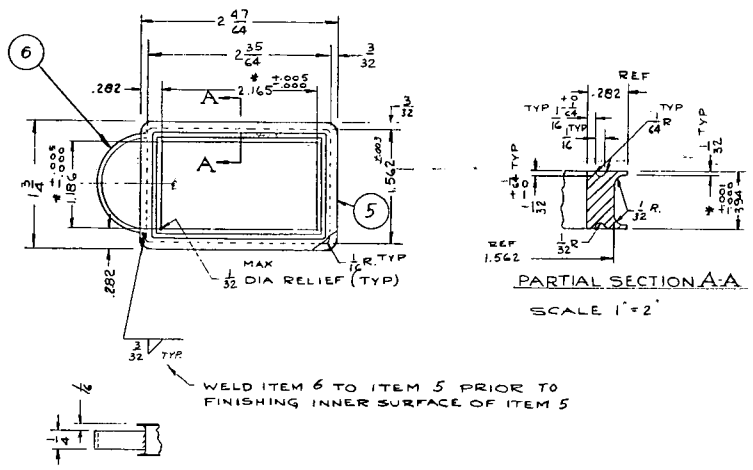
PARTS LIST			
ITEM NO.	DWG. NO.	QTY.	NAME
1		3	SIMPLE BEAM IMPACT SPECIMEN
2	E49945-7	1	FRAME SUB-ASSY
3	E49945-3	2	PLATES
8	E-49945-8	1	NOTCH PLUG



NOTE:
S.S.T. MATERIAL, WELDING AND FABRICATION TO CONFORM TO HFIR PROCUREMENT NOTES S.S.T. 2, D-42014

ASSEMBLY DRAWING NO.	E-49960 E-49953
TITLE	SPECIMEN CONTAINER ASSY
MATERIAL	~
SCALE 1"=1"	DRAWING NUMBER E49945-4

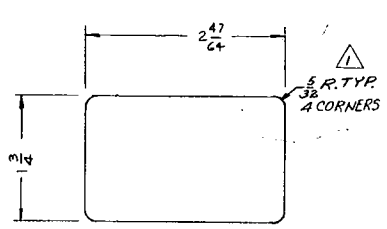
PARTS LIST			
ITEM NO.	DWG. NO.	QTY.	NAME
5	E-49945-1	1	FRAME
6	E-49945-2	1	BALE



NOTE:
SURFACES MARKED WITH ASTERISK(*) TO BE SQUARE WITHIN .002 T.I.R.

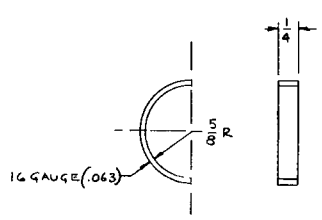
*TYPE 304L OR 347

ASSEMBLY DRAWING NO.	E 49945-4
TITLE	FRAME SUB ASSY
MATERIAL	SST* ASTM A240-61T
SCALE 1"=1"	DRAWING NUMBER E49945-1

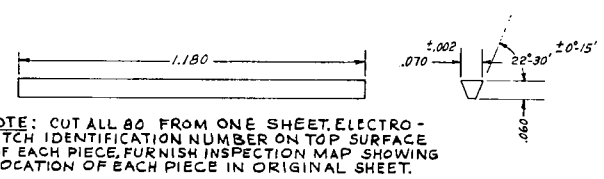


*MATL THK. .031 ±.002
*TYPE 304L OR 347 SST.

ASSEMBLY DRAWING NO.	E 49945-4
TITLE	PLATE
MATERIAL	SST* ASTM A240-61T
SCALE 1"=1"	DRAWING NUMBER E49945-3



ASSEMBLY DRAWING NO.	E 49945-7
TITLE	BALE
MATERIAL	304L* ASTM A240-61T
SCALE 1"=1"	DRAWING NUMBER E-49945-2



NOTE: CUT ALL 80 FROM ONE SHEET. ELECTRO-ETCH IDENTIFICATION NUMBER ON TOP SURFACE OF EACH PIECE, FURNISH INSPECTION MAP SHOWING LOCATION OF EACH PIECE IN ORIGINAL SHEET.

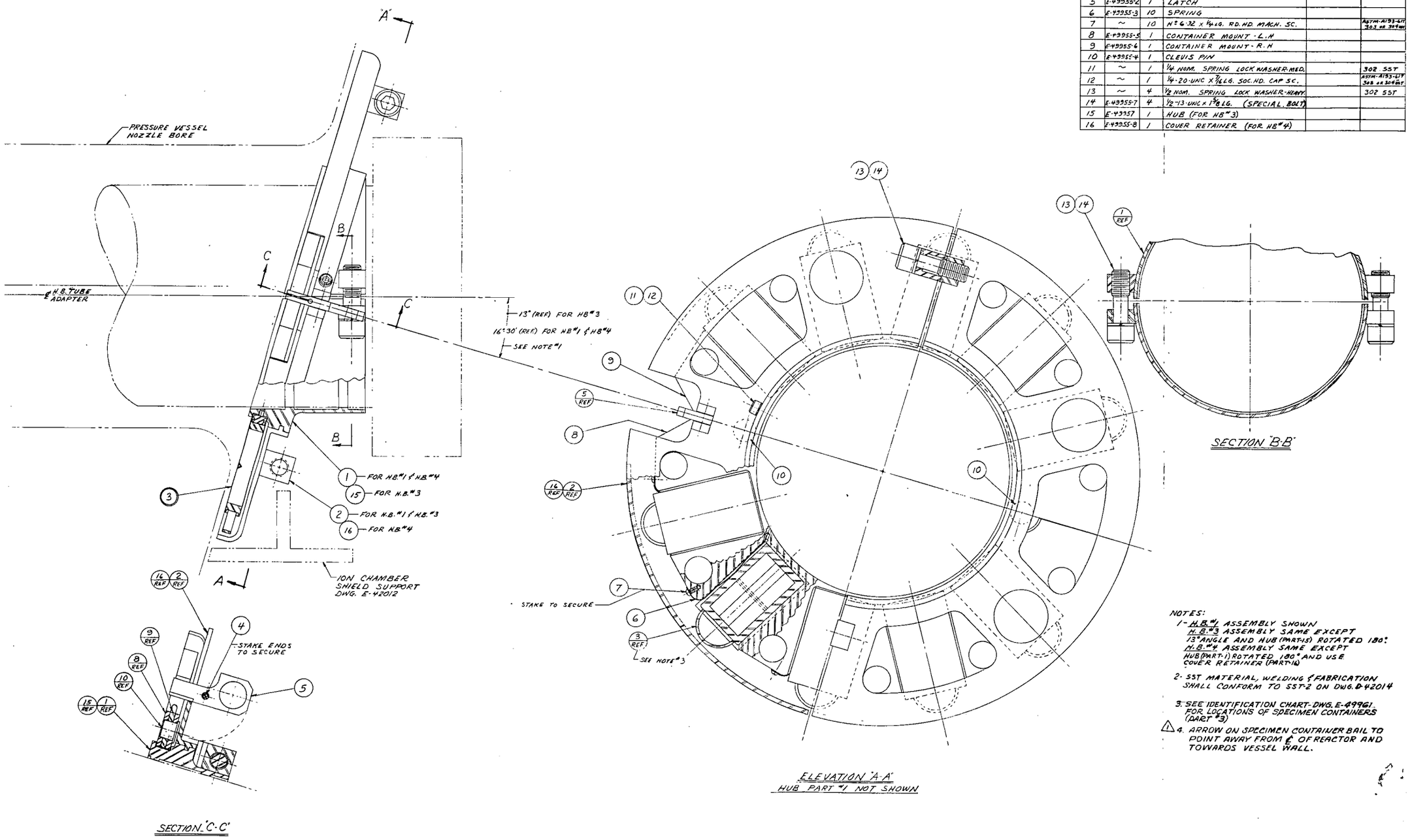
*TYPE 302

ASSEMBLY DRAWING NO.	E-49945-4
TITLE	NOTCH PLUG
MATERIAL	SST* ASTM A240-61T
SCALE 4x	DRAWING NUMBER E-49945-8

Fig. 10. Specimen Container.

E-49953

PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1	E-49954	1	HUB (FOR HB #1 & HB #4)		
2	E-49955-1	1	COVER RETAINER (FOR HB #1 & HB #3)		
3	E-49945-4	1	SPECIMEN CONTAINER ASS'Y.		
4	~	1	PIN. .188 DIA. x 3/4 LG.		ASTM-A276-UNS 304 SST
5	E-49955-2	1	LATCH		
6	E-49955-3	10	SPRING		
7	~	10	#2-6-32 x 1/4 LG. RD. HD. MACH. SC.		ASTM-A193-GR 303 or 304 SST
8	E-49955-5	1	CONTAINER MOUNT - L.H.		
9	E-49955-6	1	CONTAINER MOUNT - R.H.		
10	E-49955-4	1	CLEVIS PIN		
11	~	1	1/4 NOM. SPRING LOCK WASHER-MED.		302 SST
12	~	1	1/4-20-UNC x 3/8 LG. SOC. HD. CAP SC.		ASTM-A193-GR 303 or 304 SST
13	~	4	1/2 NOM. SPRING LOCK WASHER-HEAVY		302 SST
14	E-49955-7	4	1/2-13-UNC x 1 3/8 LG. (SPECIAL BOLT)		
15	E-49957	1	HUB (FOR HB #3)		
16	E-49955-8	1	COVER RETAINER (FOR HB #4)		



NOTES:
1- H.B. #1 ASSEMBLY SHOWN
H.B. #3 ASSEMBLY SAME EXCEPT 13° ANGLE AND HUB (PART-15) ROTATED 180°.
H.B. #4 ASSEMBLY SAME EXCEPT HUB (PART-1) ROTATED 180° AND USE COVER RETAINER (PART-16)

2- SST MATERIAL, WELDING & FABRICATION SHALL CONFORM TO SST-2 ON DWG. D-42014

3. SEE IDENTIFICATION CHART-DWG. E-49961 FOR LOCATIONS OF SPECIMEN CONTAINERS (PART #3)

△ 4. ARROW ON SPECIMEN CONTAINER BAIL TO POINT AWAY FROM ℄ OF REACTOR AND TOWARDS VESSEL WALL.

Fig. 11. Specimen Mount — HB Nos. 1, 3, and 4.

E-49960

PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1	E49958-1	1	CONTAINER MOUNT L.H.		
2	E49958-2	1	CONTAINER MOUNT R.H.		
3	E49959-10	1	COVER RETAINER		
4	E49959-4	1	HUB.		
5	E-49955-3	16	SPRING		
6	E-49945-4	16	SPECIMEN CONTAINER		
7	E-49955-2	1	LATCH		
8	E-49955-7	4	BOLT. (SPECIAL) $\frac{1}{2}$-13 UNC-2A		
9	~	4	$\frac{1}{2}$ LOCK WASHER, MED		SST 30#
10	~	16	SCREW #6-32-UNC-2A $\frac{1}{4}$ LG		ASTM-A193-61T 303 OR 304 SST
11	~	1	PIN 188 X $\frac{3}{4}$ LG		ASTM-A193-61T SST 304
12	~	1	$\frac{1}{4}$-20 UNC-2A X $\frac{7}{16}$ SOC.HD CAP SCR.		ASTM-A193-61T 303 OR 304 SST
13	~	1	$\frac{1}{4}$ LOCK WASHER, MED		SST 30#

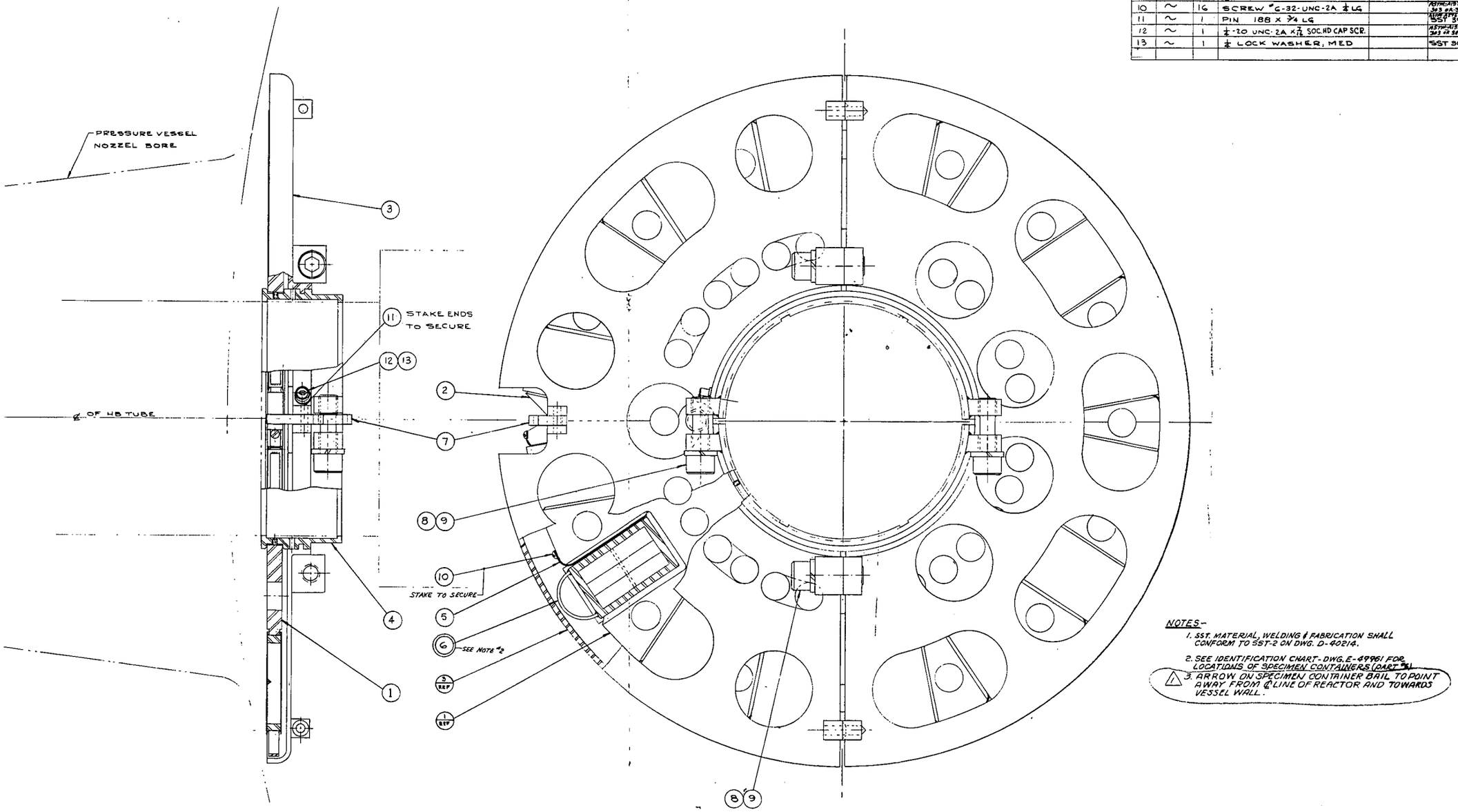
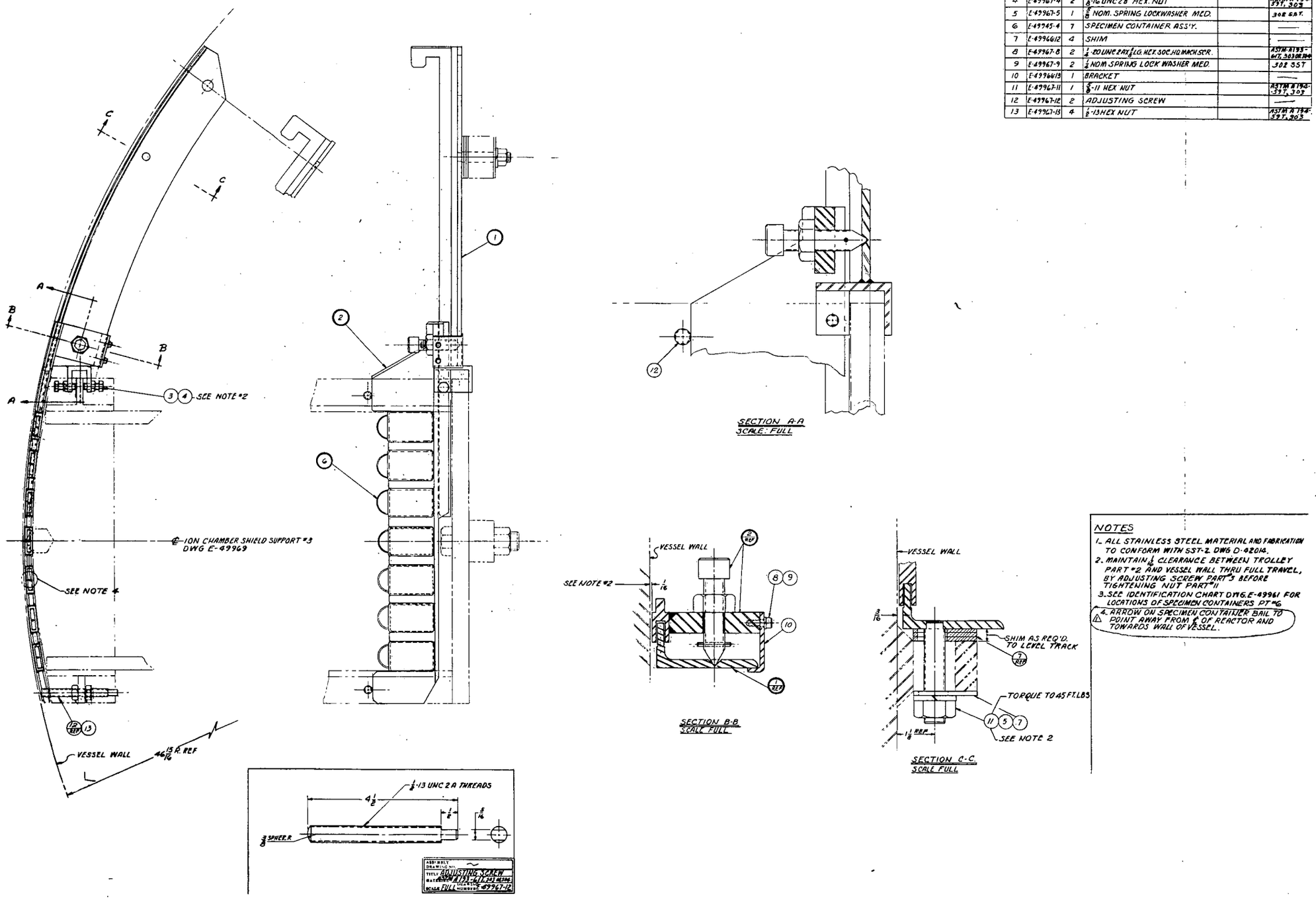


Fig. 12. Specimen Mount — HB No. 2.

E-49967

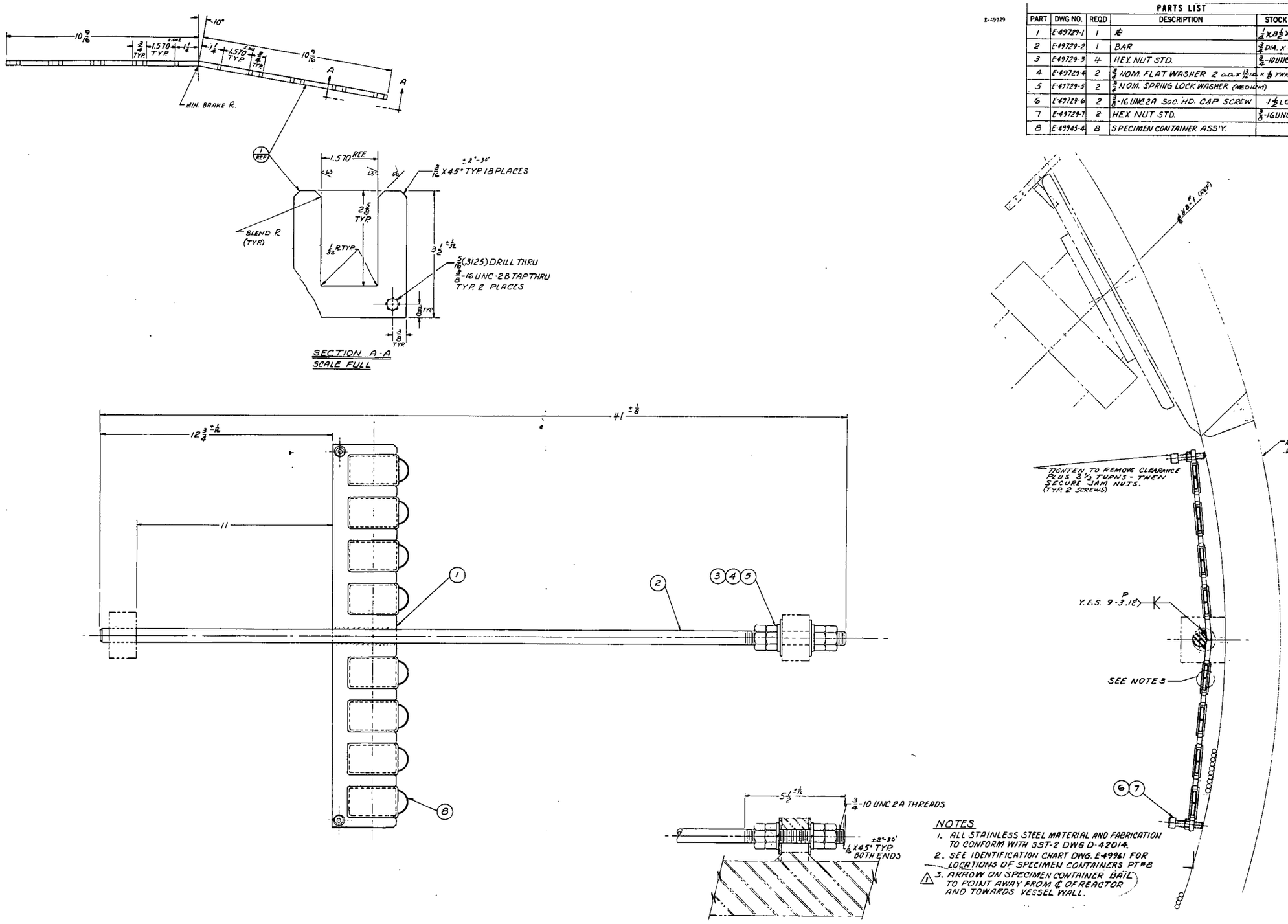
PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1	E-49966-4	1	TRACK		——
2	E-49966-11	1	TROLLEY		——
3	E-49967-3	2	3/8-16 UNC 2 A X 1 LG. HEX. HD BOLT		ASTM A-193-GR 7, 304
4	E-49967-4	2	3/8-16 UNC 2 B HEX. NUT		ASTM A 194-SST, 303
5	E-49967-5	1	3/8 NOM. SPRING LOCKWASHER MED.		302 S.S.T.
6	E-49945-4	7	SPECIMEN CONTAINER ASS'Y.		——
7	E-49966-12	4	SHIM		——
8	E-49967-8	2	1/4-20 UNC 2 A X 1/2 LG. HEX. SOC. HD. MACH. SCR.		ASTM-A193-GR7, 303 OR 304
9	E-49967-9	2	1/4 NOM. SPRING LOCK WASHER MED.		302 SST
10	E-49966-13	1	BRACKET		——
11	E-49967-11	1	5/8-11 HEX NUT		ASTM A 194-SST, 303
12	E-49967-12	2	ADJUSTING SCREW		——
13	E-49967-13	4	1/2-13 HEX NUT		ASTM A 194-SST, 303



NOTES

1. ALL STAINLESS STEEL MATERIAL AND FABRICATION TO CONFORM WITH SST-2 DWG D-42014.
2. MAINTAIN 1/16 CLEARANCE BETWEEN TROLLEY PART #2 AND VESSEL WALL THRU FULL TRAVEL, BY ADJUSTING SCREW PART #3 BEFORE TIGHTENING NUT PART #11
3. SEE IDENTIFICATION CHART DWG. E-49961 FOR LOCATIONS OF SPECIMEN CONTAINERS PT #6
4. ARROW ON SPECIMEN CONTAINER BAIL TO POINT AWAY FROM ℄ OF REACTOR AND TOWARDS WALL OF VESSEL.

Fig. 13. Specimen Mount — Shell Behind IC No. 3.

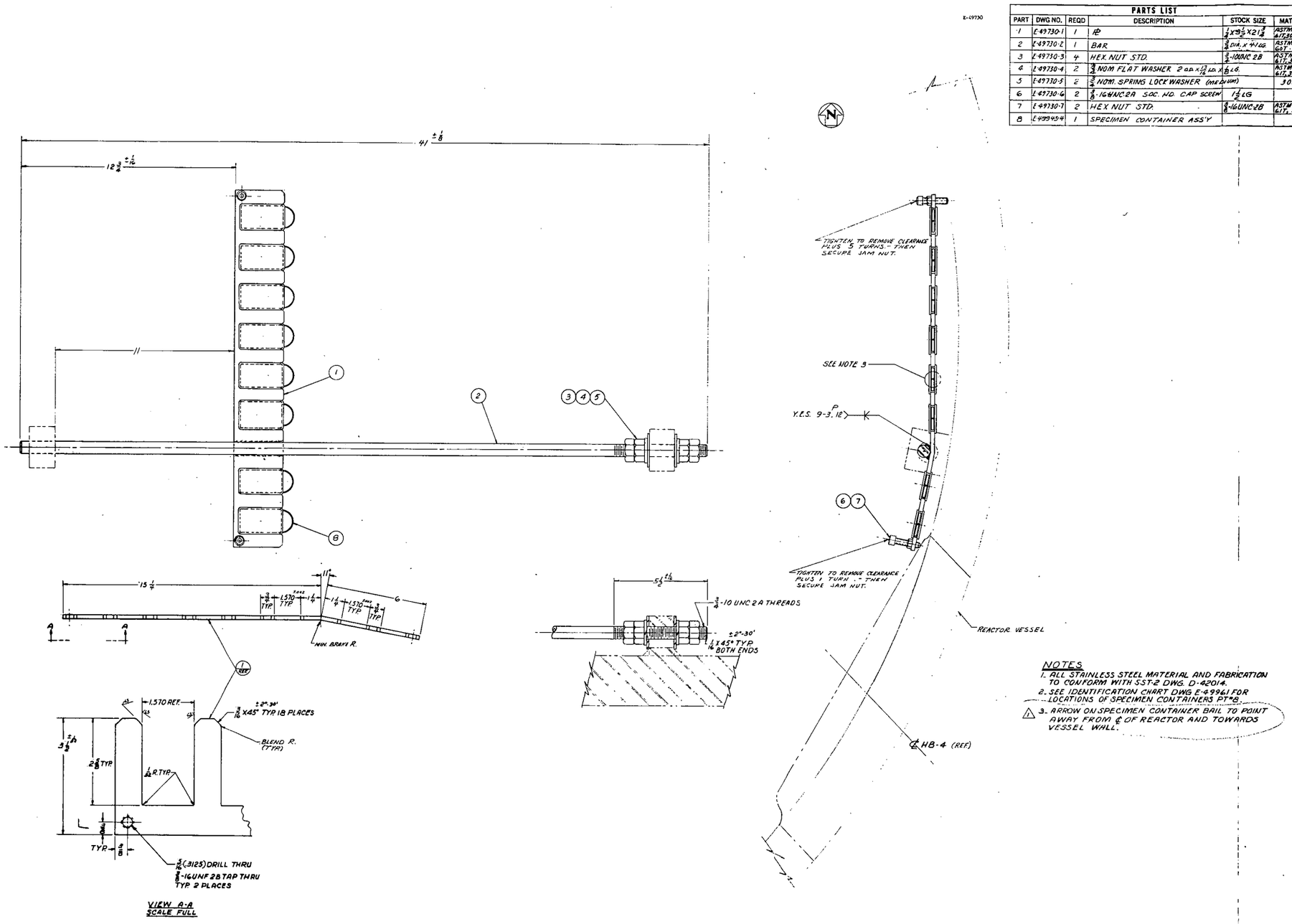


E-49729

PARTS LIST

PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1	E-49729-1	1	PL	$\frac{1}{4}$ X 8$\frac{1}{2}$ X 22	ASTM-A240-61T, 304L OR 347
2	E-49729-2	1	BAR	$\frac{3}{4}$ DIA. X 41 LG.	ASTM A269-60T, 304L
3	E-49729-3	4	HEX. NUT STD.	$\frac{3}{4}$-10 UNC 2B	ASTM A193-61T, 303
4	E-49729-4	2	$\frac{3}{4}$ NOM. FLAT WASHER 2 O.D. X $\frac{13}{16}$ I.D. X $\frac{1}{8}$ THK.		ASTM-A240-61T, 304 SST
5	E-49729-5	2	$\frac{3}{4}$ NOM. SPRING LOCK WASHER (MEDIUM)		302 SST.
6	E-49729-6	2	$\frac{3}{8}$-16 UNC 2A SOC. HD. CAP SCREW	1$\frac{1}{2}$ LG.	ASTM A193-61T, 304
7	E-49729-7	2	HEX NUT STD.	$\frac{3}{8}$-16 UNC 2B	ASTM A193-61T, 303
8	E-49945-4	8	SPECIMEN CONTAINER ASS'Y.		

Fig. 14. Specimen Mount — Shell Adjacent to HB No. 1.



PARTS LIST

PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1	E-49730-1	1	PL	1/4 X 9 1/2 X 21 3/4	ASTM-A240-61T, 304 (OR 347)
2	E-49730-2	1	BAR	3/4 DIA. X 41 LG.	ASTM-A269-60T, 304
3	E-49730-3	4	HEX. NUT STD.	3/4-10UNC 2B	ASTM-A193-61T, 303
4	E-49730-4	2	3/4 NOM. FLAT WASHER 2 OD X 13/16 ID X 1/8 LG.		ASTM-A240 61T, 304 SST.
5	E-49730-5	2	3/4 NOM. SPRING LOCK WASHER (MEDIUM)		302 SST.
6	E-49730-6	2	3/8-16UNC 2A SOC. HD. CAP SCREW	1 1/2 LG	
7	E-49730-7	2	HEX NUT STD.	3/8-16UNC-2B	ASTM A193-61T, 303
8	E-49945-4	1	SPECIMEN CONTAINER ASS'Y		

Fig. 15. Specimen Mount – Shell Adjacent to HB No. 4.

D-SK-RES-651103-1

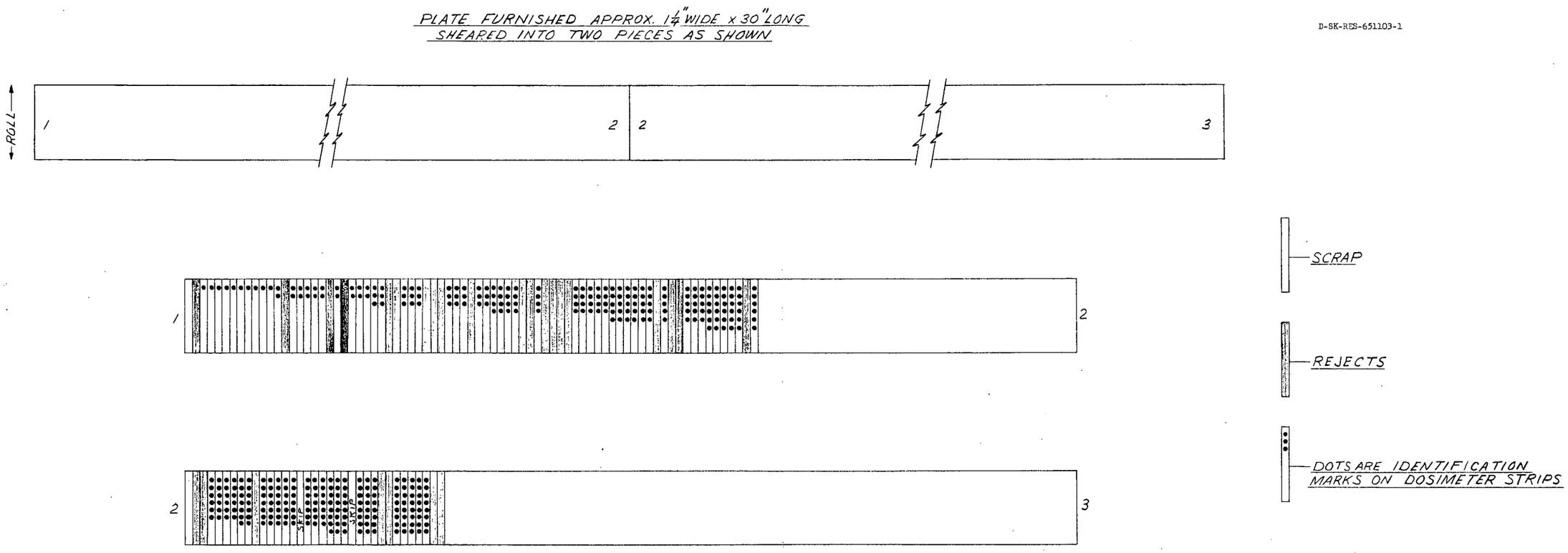


Fig. 16. Dosimeter Strips — Origin.

Tabel 4. Schedule for Surveillance Testing

Operating Time		Number of Specimens Removed						
						Shell		
Mw Days	Equivalent full power years	HB #1	HB #2	HB #3	HB #4	IC #3	HB #1	HB #4
73,000	2	6	6	6	6	none	none	none
182,500	5	6	6	6	6	3	6	6
365,000	10	6	6	6	6	6	6	6
547,500	15	6	6	6	6	6	6	6
730,000 or greater	20+	6	6	6	6	6	6	6

specimens have been broken at random temperatures to bracket the NDT temperature. When the average of the impact values for the final three specimens indicate a NDT temperature which is higher than 60°F below the minimum pressurized operating temperature, the operation of the vessel will be subjected to review. The NDT temperature of the material being tested is defined as the temperature at which the impact specimens fail as impact energies equal to the following:

Material Specification (ASTM Designation)	Vessel Component	Impact Energy (ft-lbs)
A 105 GrII	HB 1 and HB 4	15
A 212 GrB	Shell	15
A 350 Gr LF3	HB 2 and HB 3	30

To aid in preparation of hot cell tooling and testing equipment, two surveillance specimen containers, complete with specimens and dosimeter strip are available. The containers are labeled 6 and 7.

Spare impact specimens are available in the following numbers:

Shell	17
HB 1 and HB 4	24
HB 2	7
HB 3	11

Structural Parts. The location, geometry, and stress state of the beryllium parts will govern the extent of swelling and possible cracking

Table 5. Specimen, Dosimeter, and Container Numbering

Container No.	Lifting Bail Identification Marking	Specimen Numbers			Dosimeter Strip Number	Key Number*
8	HB-2-8	C-6	C-8	C-9	.	2
9	HB-2-9	C-10	C-16	C-17	.	2
10	HB-2-10	C-18	C-19	C-20	.	2
11	HB-2-11	C-21	C-26	C-27	.	2
12	HB-2-12	C-28	C-29	C-30	.	2
13	HB-2-13	C-31	C-32	C-37	.	2
14	HB-2-14	C-38	C-39	C-40	.	2
15	HB-2-15	C-41	C-48	C-49	.	2
17	HB-2-17	C-51	C-52	C-57	.	2
18	HB-2-18	C-58	C-60	C-62	.	2
19	HB-1-19	B-1	B-2	B-3	..	1
20	HB-1-20	B-4	B-5	B-6	..	1
21	HB-1-21	B-7	B-8	B-19	..	1
22	HB-1-22	B-21	B-22	B-23	..	1
23	HB-1-23	B-25	B-26	B-27	..	1
24	HB-1-24	B-31	B-32	B-33	..	1
25	HB-1-25	B-34	B-35	B-36	..	1
26	HB-1-26	B-37	B-38	B-42	..	1
27	HB-1-27	B-43	B-44	B-45	..	1
29	HB-1-29	B-46	B-47	B-48	...	1
30	HB-4-30	B-61	B-62	B-63	...	4
31	HB-4-31	B-64	B-65	B-66	...	4
32	HB-4-32	B-70	B-81	B-82	...	4
33	HB-4-33	B-83	B-84	B-85	...	4
35	HB-4-35	B-86	B-87	B-88	...	4
36	HB-4-36	B-101	B-102	B-103	...	4
37	HB-4-37	B-104	B-105	B-106	...	4
38	HB-4-38	B-107	B-108	B-111	....	4
39	HB-4-39	B-112	B-113	B-114	....	4
40	HB-4-40	B-116	B-117	B-118	....	4
41	HB-3-41	D-5	D-6	D-8	....	3
42	HB-3-42	D-15	D-16	D-17	....	3
43	HB-3-43	D-23	D-24	D-25	....	3
45	HB-3-45	D-26	D-27	D-28	....	3
46	HB-3-46	D-33	D-34	D-35	.....	3
48	HB-3-48	D-36	D-37	D-38	.....	3
49	HB-3-49	D-43	D-44	D-45	.....	3
50	HB-3-50	D-46	D-47	D-48	.....	3
51	IC-A-51	A-30	A-31	A-36	.....	5
52	HB-3-52	D-53	D-54	D-55	.....	3
53	HB-3-53	D-56	D-57	D-58	.....	3
54	IC-A-54	A-37	A-40	A-43	.....	5
55	IC-A-55	A-45	A-48	A-51	.....	5
56	IC-A-56	A-52	A-76	A-77	.....	5

Table 5. (continued)

Container No.	Lifting Bail Identification Marking	Specimen Numbers			Dosimeter Strip Number	Key Number*
57	IC-A-57	A-82	A-86	A-87	.....	5
58	IC-A-58	A-137	A-144	A-146	.....	5
60	IC-A-60	A-150	A-157	A-58	.....	5
61	HB-1-A-61	A-1	A-2	A-7	.....	6
62	HB-1-A-62	A-18	A-19	A-23	.....	6
64	HB-1-A-64	A-25	A-27	A-131	.....	6
65	HB-1-A-65	A-132	A-133	A-134	.....	6
68	HB-1-A-68	A-135	A-136	A-140	.....	6
69	HB-1-A-69	A-141	A-142	A-145	.....	6
70	HB-1-A-70	A-147	A-148	A-149	.....	6
71	HB-1-A-71	A-152	A-154	A-159	.....	6
72	HB-4-A-72	A-92	A-94	A-95	.....	7
73	HB-4-A-73	A-96	A-97	A-99	.....	7
74	HB-4-A-74	A-100	A-105	A-108	.....	7
75	HB-4-A-75	A-109	A-111	A-114	.....	7
76	HB-4-A-76	A-115	A-118	A-119	.....	7
77	HB-4-A-77	A-120	A-124	A-161	.....	7
79	HB-4-A-79	A-163	A-164	A-165	.....	7
80	HB-4-A-80	A-166	A-167	A-168	.....	7

*Refer to Table 3 and Fig. 5

from radiation effects. Small unstressed surveillance specimens are considered of limited value in predicting the life of the parts because the extent of dissimilarity is too great.
components before and after exposure to radiation. The removable beryllium will be checked in place under water with a measuring device designed for this purpose. The control rod access plugs are also to be dimensionally measured before and after radiation. It is planned to remove the inner portions of the beryllium for visual inspection at reasonable intervals with the first inspection being performed after 3 months of operation. The beryllium plugs, drawing E-42132-14 are to be measured for straightness prior to operation so that subsequent inspection may reveal the extent of damage as revealed by bowing.

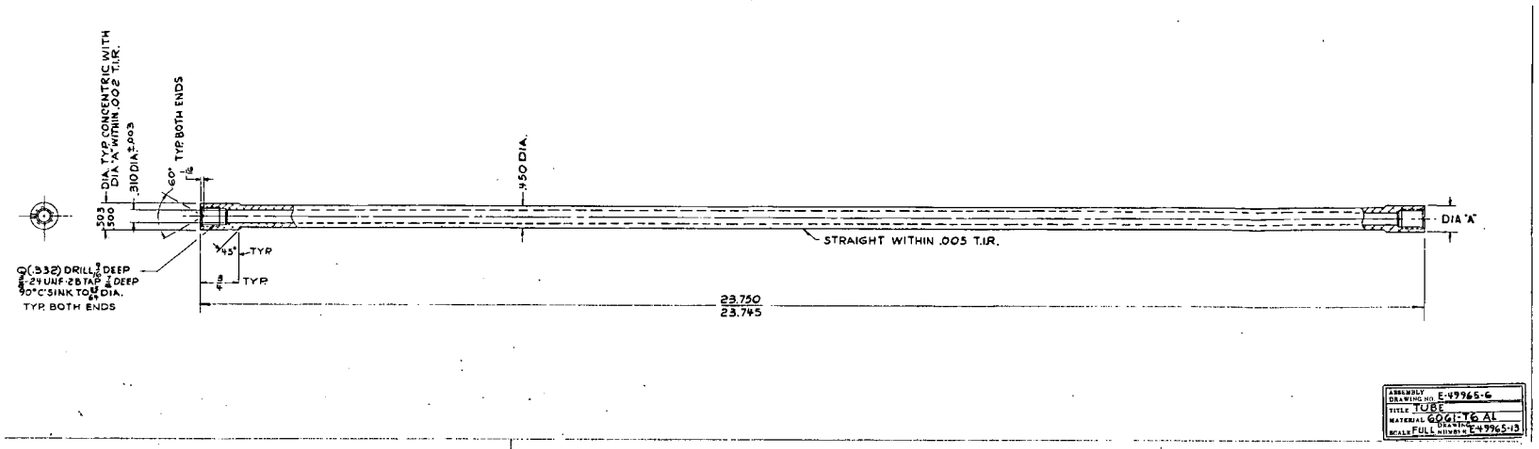
For certain aluminum components the expected accumulated radiation dose will exceed existing radiation damage data in a relatively short

period of time. Of particular concern are possible changes in the properties of the 6061T6 aluminum alloy beam tubes, the target plugs and tubes and tie bars in the reflector assembly. The surveillance program is as follows:

1. Ten aluminum tensile specimens will be installed in one of the holes in the removable beryllium as shown in Fig. 17. Two specimens are to be removed and tested after 1, 2, 3, 4, and 6 years of service. As each set is removed, new specimens are to be installed in their place. The results of these tests will be used to evaluate the serviceability of applicable components. Location of the samples is such that there is a direct relationship with the tie rods, while the radiation dosage of the beam tubes will be only one-third that of the samples.
2. Mechanical tests will be performed directly on pieces from the target plugs and target structural tubes as they become available during periodic removal.

Corrosion. The HFIR primary system is constructed mainly of stainless steel; however, there are numerous materials of construction inside the pressure vessel. For example, components of various grades of stainless steel, aluminum alloys, beryllium, and Inconel-X are used singularly and in combination to support and align the fuel elements.

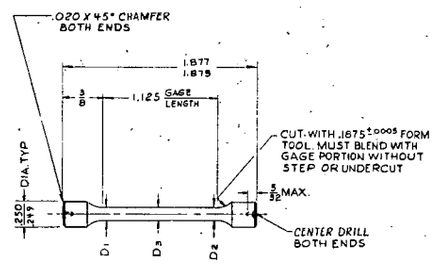
All of the base materials and dissimilar metal combinations were tested in out-of-pile corrosion tests to provide design data for estimating the rate of yearly attack. These tests were most beneficial, yet they need to be supported by spot checks in the actual system during operation. Accordingly, in-pile tests have been set up in two areas. Fig. 18 shows the disc assemblies of aluminum, beryllium, and stainless steel which have been installed in the outer shroud. These test assemblies provide: 1. a method of evaluating the effect of surface finish on the corrosion of aluminum and 2. galvanic cells between aluminum and beryllium, aluminum and stainless steel, and aluminum and Inconel-X. In this location the environment is inlet water at a low temperature and only moderate radiation effects.



PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1	E-49762-3	1	UPPER SUPPORT		
2	E-49965-7	2	SPACER		
3	E-49965-8	10	SPECIMEN & FLOW ADAPTOR SUB-ASSY.		
4	E-49965-13	1	TUBE		
5	D-49762-4	1	END GUIDE		

E-49965

ASSEMBLY DRAWING NO. E-49965-6
TITLE TUBE
MATERIAL 6061-T6 AL
SCALE FULL DRAWING NUMBER E-49965-13



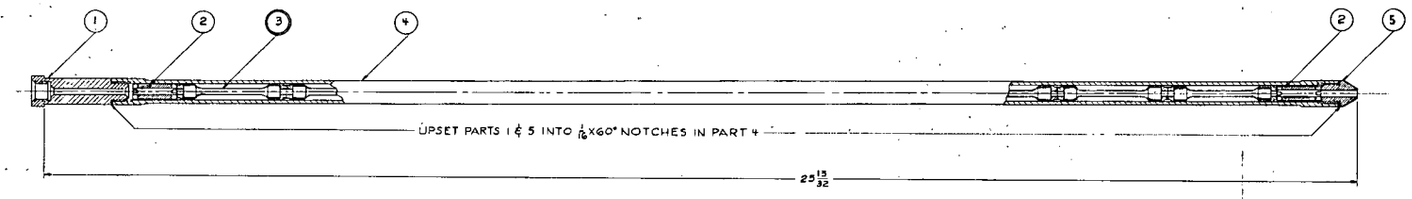
D1 & D2 DIM. = .125 +.000 −.005 (DIAMETERS MUST BE SAME WITHIN .0005 T.I.R.)

D3 MUST BE .0008 .0010 LESS THAN THE SMALLER OF D1 OR D2

NOTE
1. GAGE LENGTH MUST BE TURNED IN A MANNER THAT WILL PRODUCE A MINIMUM OF COLD WORKING OF THE MATERIAL IN THIS AREA.
2. GAGE LENGTH SURFACE MUST BE 16 MICRO-INCH FINISH OR BETTER.

MATERIAL FURNISHED FROM HFIR SURVEILLANCE STOCK

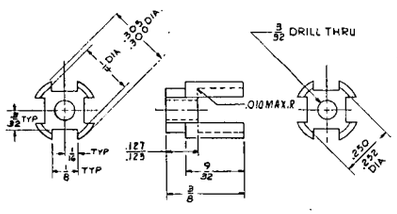
ASSEMBLY DRAWING NO. E-49965-8
TITLE TENSILE SPECIMEN
MATERIAL 6061-T6
SCALE 2X DRAWING NUMBER E-49965-10



ASSEMBLY DRAWING NO. E-42172
TITLE TENSILE SPECIMEN ASSY
MATERIAL
SCALE FULL DRAWING NUMBER E-49965-6

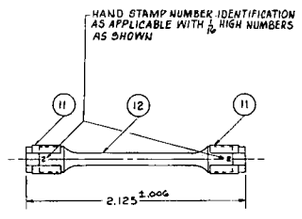
NOTE
ALL ALUMINUM MATERIAL AND FABRICATION TO CONFORM WITH AL-2 DWG D-42015

PARTS LIST			
PART	DWG. No.	REQD	DESCRIPTION
11	E-49965-9	2	FLOW ADAPTOR
12	E-49965-10	1	TENSILE SPECIMEN

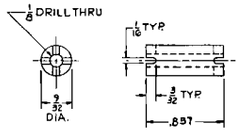


NOTE
BREAK ALL SHARP EDGES .005 MAX.

ASSEMBLY DRAWING NO. E-49965-8
TITLE FLOW ADAPTOR
MATERIAL ASTM B211-61 6061-T6
SCALE 4X DRAWING NUMBER E-49965-9



ASSEMBLY DRAWING NO. E-49965-6
TITLE SPECIMEN & FLOW ADAPTOR SUB-ASSY
SCALE 2X DRAWING NUMBER E-49965-8

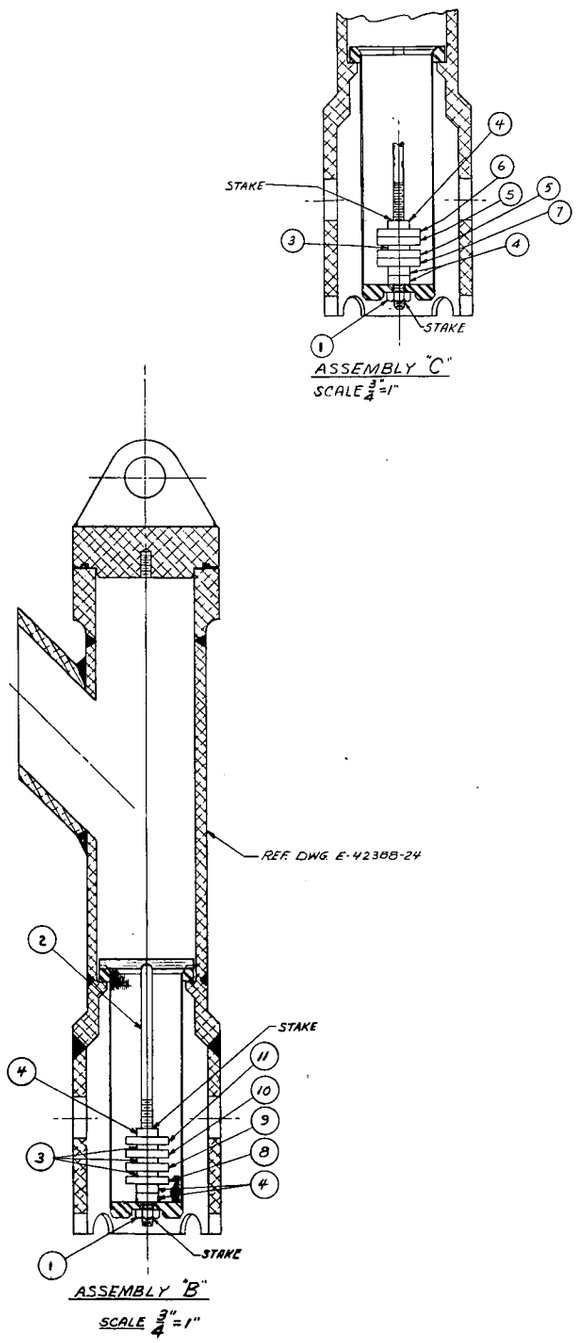


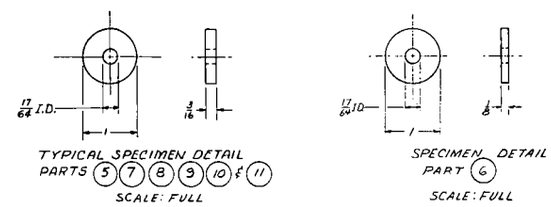
ASSEMBLY DRAWING NO. E-49965-6
TITLE SPACER
MATERIAL ASTM B211-61 6061-T6
SCALE 2X DRAWING NUMBER E-49965-7

Fig. 17. Aluminum Tensile Surveillance Specimens and Holder.

E-49942

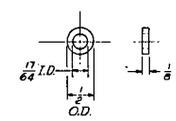
PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1		1	1/4-20 UNC-2B HEX. HD. NUT		304 SST.
2	E-49942-2	1	TEE BAR		6061 T-6 AL.
3	E-49942-3	5	WASHER		6061 T-6 AL.
4	E-49942-4	3	NUT		6061 T-6 AL.
5	E-49942-5	2	SPECIMEN A x 85-1, A x 8L-1		6061 T-6 AL.
6	E-49942-6	1	SPECIMEN A x 8L-2		304 L SST.
7	E-49942-7	1	SPECIMEN A x 85-2		BERYLLIUM
8	E-49942-8	1	SPECIMEN A x 84		6061 T-6 AL. ANODIZED
9	E-49942-9	1	SPECIMEN A x 83		6061 T-6 AL. PICKLED
10	E-49942-10	1	SPECIMEN A x 82		6061 T-6 AL. VAPOR BLASTED
11	E-49942-11	1	SPECIMEN A x 81		6061 T-6 AL. MACHINED



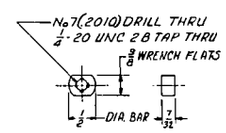


TYPICAL SPECIMEN DETAIL PARTS 5 7 8 9 10 & 11
SCALE: FULL

SPECIMEN DETAIL PART 6
SCALE: FULL

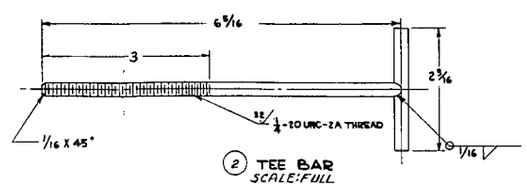


3 SPACER
SCALE: FULL



4 NUT
SCALE: FULL

NOTES
1. ALL ALUMINUM MATERIAL AND FABICATION TO CONFORM WITH DWG. D-42015
2. ALL STAINLESS STEEL MATERIAL AND FABRICATION TO CONFORM WITH DWG. D-42014



2 TEE BAR
SCALE: FULL

Fig. 18. Corrosion Assembly in Outer Shroud.

In the second location inside the vessel, the samples are placed in a holder and installed in a VEF hole in the beryllium. At this location the water temperature and the radiation level are higher than for the disc samples in the outer shroud. Fifty-six samples of stainless steel, beryllium, and aluminum all in contact with the aluminum holder are involved. As shown on Fig. 19 it is possible to remove a few samples at a time without affecting the remaining coupons.

All of the samples have been prepared to represent the heat treatment, surface finish, and area relationships which are involved in the major components so that the measured corrosion rates may indicate what is happening to the reactor parts.

It is recommended that the sample assemblies be removed at the end of the first six months of operation, inspected and returned, and then yearly examinations be made after this first inspection.

On the basis of out-of-pile corrosion studies and the concept of replaceable parts, only a modest in-pile corrosion-radiation program has been established. Should the preliminary findings refute this approach, additional samples can be installed in the VEF holes in the beryllium.

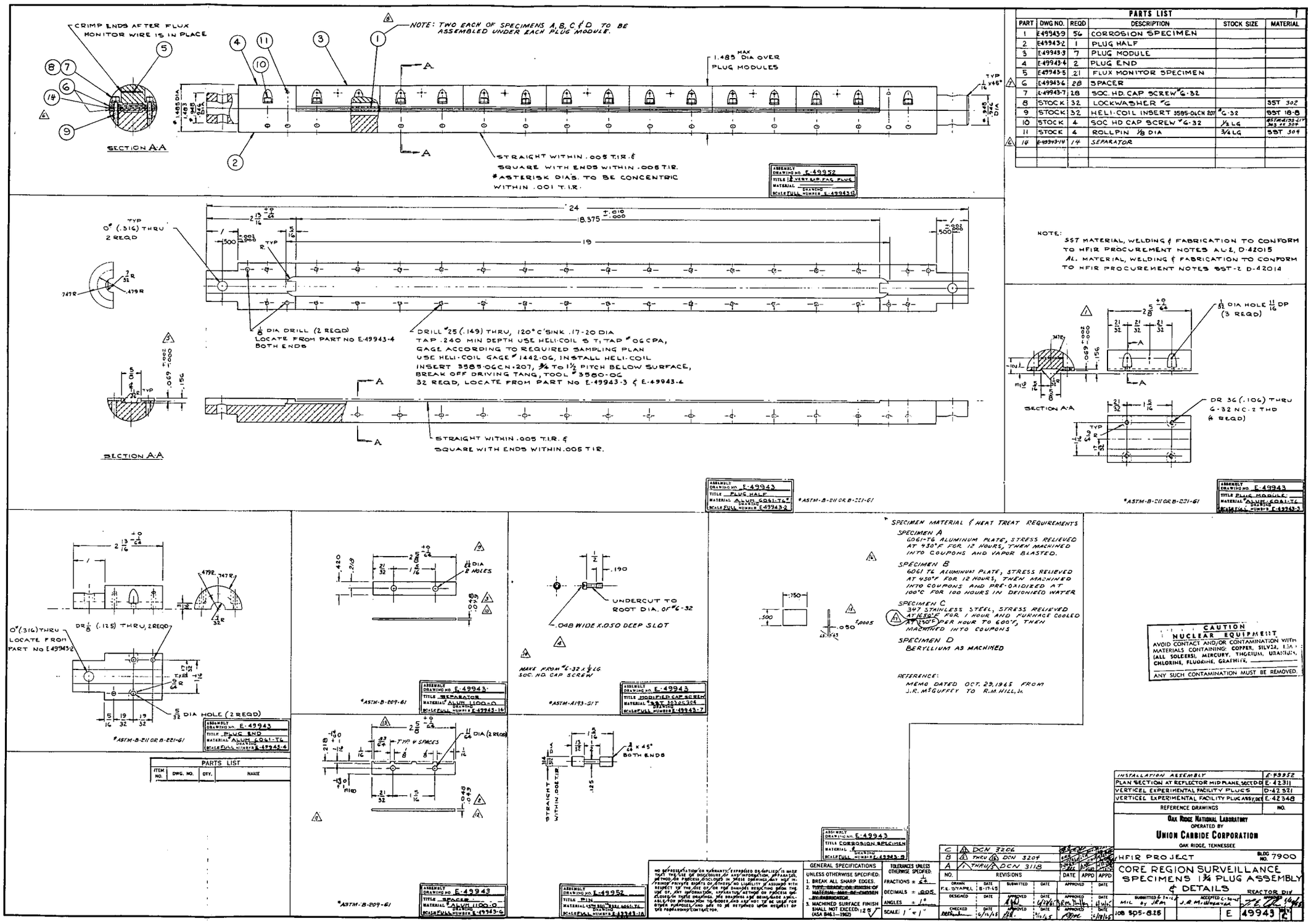


Fig. 19. Corrosion Sample in VEF Hole.

PARTS LIST

PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1	E-49943-9	56	CORROSION SPECIMEN		
2	E-49943-2	1	PLUG HALF		
3	E-49943-3	7	PLUG MODULE		
4	E-49943-4	2	PLUG END		
5	E-49943-5	21	FLUX MONITOR SPECIMEN		
6	E-49943-6	28	SPACER		
7	E-49943-7	28	SOC. HD. CAP SCREW #6-32		
8	STOCK	32	LOCKWASHER #6		SST 302
9	STOCK	32	HELI-COIL INSERT 3585-06CN 207	#6-32	SST 18-8
10	STOCK	4	SOC HD CAP SCREW #6-32	1/2 LG	ASTM/SIT 316 or 304
11	STOCK	4	ROLLPIN 1/8 DIA	3/4 LG	SST 304
14	E-49943-14	14	SEPARATOR		

References

1. H. C. Claiborne, "An Estimate of the Effect of Neutron-Energy Spectrum on Radiation Damage of Steel" USAEC Report, ORNL-TM-299, Oak Ridge National Laboratory, July 27, 1962.

2. R. G. Berggren, Personal communication.

3. R. G. Berggren, Personal communication.

4. J. L. English and J. C. Griess, Laboratory Corrosion Studies for the High Flux Isotope Reactor, ORNL-TM 1029 and ORNL-TM 1030.

5. H. A. McLain, Personal communication

6. J. R. Hawthorne, L. E. Steel, W. S. Pellini, Effects of Nuclear Radiation on the Properties of Reactor Structural Materials, ASME Paper Number 61-WA-332, pages 5 and 6.

Internal Distribution

1. G. M. Adamson
2. S. E. Beall
3. M. Bender
4. R. G. Berggren
5. F. T. Binford
6. A. L. Boch
7. R. B. Briggs
8. T. G. Chapman
9. R. D. Cheverton
10. H. C. Claiborne
11. W. G. Cobb
12. T. E. Cole
13. C. W. Collins
14. J. A. Cox
15. F. L. Culler
16. G. J. Dixon
17. J. L. English
18. W. K. Ergen
19. A. P. Fraas
20. W. R. Gall
21. J. C. Griess
22. P. N. Haubenreich
23. J. W. Hill
24. R. M. Hill
25. P. R. Kasten
26. W. H. Kelley
27. J. A. Lane
28. M. I. Lundin
29. R. N. Lyon
30. H. G. MacPherson
31. R. V. McCord
32. H. C. McCurdy
33. J. R. McGuffey
34. H. A. McLain
35. J. R. McWherter
36. A. J. Miller
37. E. C. Miller
38. P. Patriarca
39. A. M. Perry
40. H. W. Savage
41. A. W. Savolainen
42. R. E. Schappel
43. M. J. Skinner
44. I. Spiewak
45. D. B. Trauger
46. A. M. Weinberg
47. G. D. Whitman

48-49. Central Research Library (CRL)
50-51. Document Reference Section (DRS)
52-54. Laboratory Records Department (LRD)
55. Laboratory Records Department - Record Copy (LRD-RC)

External Distribution

60. Argonne National Laboratory (C. F. Matousek)
61-75. Division of Technical Information Extension (DTIE)
76. Research and Development Division, ORO
77-78. Reactor Division, ORO