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CESIUM CHLORIDE CAPSULE TESTING
FOR SPECIAL FORM QUALIFICATION

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J. E. Hammond

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CESIUM CHLORIDE CAPSULE TESTING FOR SPECIAL FORM QUALIFICATION

J. E. Hammond

Equipment and Instrument Development
Process Design and Development
Development Engineering Department
Research and Engineering Division

August 29, 1975

Operated for the Energy Research and Development Administration
by Atlantic Richfield Hanford Company under Contract E(45-1)-2130

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INTRODUCTION

The Atlantic Richfield Hanford Company (ARHCO) produces cesium chloride and strontium fluoride in encapsulated form at the 225-B Building Waste Encapsulation and Storage Facility (WESF) in the 200-East Area. The Energy Research and Development Administration (ERDA) has directed ARHCO to prepare capsule shipments to Holifield National Laboratory and Pacific Northwest Laboratory. ERDA and Department of Transportation standards for the packaging of radioactive material for transport allow for the shipment of encapsulated material, referred to as Special Form Material, in a packaging that has been licensed by ERDA for such shipments, provided that the capsules have been demonstrated to be capable of retaining their contents when subjected to specified tests.

Atlantic Richfield Hanford Company intends to ship the capsules in shipping cask NRBK-43, which has been licensed. The purpose of the test program described in this document was to qualify the cesium chloride capsules as Special Form Material, suitable for shipment in that cask with no need for additional protective packaging to retain the contents.

DESCRIPTION OF CAPSULES

The capsules are made by a double encapsulation process. The inner capsule, containing the cesium chloride and consisting of tubing closed at each end by welding on an end cap to form a cylinder nominally 2.250 inches outside diameter by 19.725 inches long, is placed in an outer capsule, also tubing with welded end caps. The cavity in the outer capsule is nominally 2.407 inches diameter by 19.975 inches long, larger than the inner capsule, which moves freely in the cavity. The nominal external dimensions of the outer capsule are 2.625 inches diameter by 20.775 inches long. All tubing and end caps are made of Type 316-L stainless steel. The capsule assembly and details are shown on attached drawings H-2-66760 and 66761; the design dimensions are listed in Table 1.

The tests described in this document were performed on one typical inner plus outer assembly and also on one inner capsule alone.

All capsule tubing is brought to the WESF with one end cap already welded on; this becomes the bottom cap. Assembling the capsules is done remotely in hot cells: the inner capsules are partially filled with molten cesium chloride; the inner top cap is welded on and the weld is tested; the completed inner capsule is placed in the outer; the outer top cap is welded on and the weld is tested. The finished capsules are then transferred to underwater storage.

Prior to starting up the WESF, the equipment and operating procedures were subjected to an extensive series of tests, one result of which was the production of a number of inner capsules filled with nonradioactive cesium chloride. Two of these inners, obtained for the special form qualification tests, had been made in the same manner and using the same equipment as the standard production capsules, and differed from standard capsules only in the nonradioactive nature of the contained salt. They had serial numbers XC-8 and XC-12.

One outer capsule, serial number XC-10, was also obtained. Inner XC-8 was placed into XC-10 and the outer top cap was welded on at the ARHCO Machine Shop, 272-W Building. The welding machine used is identical to the hot-cell welding machine at the WESF; it is used for welding on the bottom end caps and had previously been used to weld the bottom end cap onto XC-10.

The test items thus consisted of one double capsule, XC-8 in XC-10, and inner capsule XC-12.

TEST OBJECTIVE

The test objective was to show that both test items meet a description of Special Form Material given in ERDA Appendix 0529, Part 1, A.15.b.: "The material is securely contained in a capsule having no dimension less than 0.5 millimeter or at least one dimension greater than 5 millimeters which (1) will retain its contents is subjected to the tests prescribed in annex 4, (2) is constructed of materials which do not melt, sublime, or ignite in air at 1475°F, and (3) will not be dissolved or converted into a dispersible form in amounts greater than 0.005 percent by weight if immersed in water at 68°F or in air at 86°F." The properties of Type 316-L stainless steel are sufficiently well known that no tests are required to prove that this material meets requirements (2) and (3).

The tests prescribed in annex 4 of Appendix 0529 are as follows:

1. Free Drop - A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal surface, striking the surface in such a position as to suffer maximum damage.

2. Percussion - Impact of the flat circular end of a 1-inch diameter steel rod weighing 3 pounds, dropped through a distance of 40 inches. The capsule or material shall be placed on a sheet of lead, of hardness number 3.5 to 4.5 on the Vickers scale, and not more than 1-inch thick, supported by a smooth essentially unyielding surface.

3. Heating - Heating in air to a temperature of 1475°F and remaining at that temperature for a period of 10 minutes.

4. Immersion - Immersion for 24 hours in water at room temperature. The water shall be at pH6 - pH8, with a maximum conductivity of 10 micromhos per centimeter.

PROCEDURE

The capsule diameters and weights were determined before starting the tests.

The drop tests were performed in the ARHCO Boiler Shop, 277-W Building. The target was a piece of steel plate, 2-inches (50.8 mm) thick and approximately 3.5 feet (1.1 m) square on the concrete floor of an equipment fabrication pit and the capsules were dropped by hand from a platform adjacent to the pit. At that location, it was convenient to release the capsules from a distance of 32.8 feet (10 m) above the top surface of the plate and all drops were made at that height, resulting in an impact velocity of 46 ft/second (14 m/sec). The capsules were nearly vertical when released. Inner capsule XC-12 was dropped twice, once on each end striking with the long axis of the capsule about 30 - 45° from vertical. The double capsule was dropped twice on the bottom end and once on the top. In the first of the bottom end drops, the capsule appeared nearly horizontal on impact and it was decided to repeat that drop. The impact angles for the second bottom end drop and the top end drop were about 15 - 30° from vertical.

The percussion tests were performed in the ARHCO Machine Shop, 272-W Building. The capsules were laid horizontally on the concrete floor and a piece of pipe was used to guide the steel rod when released. In all cases, the impact point was about midway along the length of the capsule. A one inch diameter steel rod, weighing 1382 grams (3.05 lb) was dropped 40 inches onto each capsule with no visible damage resulting. The capsules were then rolled 90° and a second drop was made onto each capsule using another rod, the end of which had been machined to 0.978 inch (24.8mm). This rod weighed 1721 grams (3.8 lb) and was dropped 59 inches (1.5 m). The end of each rod had been machined flat with an edge radius of about 0.020 inch (0.5 mm).

The heating tests were also performed at the Machine Shop, using a heat treating furnace. The furnace was preheated to 1500°F (815°C) and the capsules were placed in it with the tip of the furnace temperature thermocouple touching an end cap on XC-12. Since this arrangement was considered too crude to assure that both capsules were heated to the required 1475°F, the furnace temperature was increased to 1600°F (871°C) and held for about 90 minutes, after which the furnace was turned off. Sixteen hours later, when the furnace had cooled to 600°F, the door was opened and during the next hour the furnace cooled to 200°F. The capsules were then removed and air-cooled to room temperature.

At this time the capsule diameters and weights were redetermined.

The immersion test was performed at the 271-T Building and consisted of immersing both capsules in a pan of room temperature tap water for 24 hours. A sample of water was tested at the Essential Materials Laboratory, 222-S Building, and had a pH of 7.2 and a conductivity of 140 micromhos per centimeter.

The capsules were then weighted for the third time.

DISCUSSION

There are no capsule failures or loss of capsule contents during any of the tests.

Following the tests, XC-10 and XC-12 were photographed to illustrate the damage resulting from the drop tests (attached Figures 1-4). In all cases the capsule impacted the steel plate at a corner of the end cap, flattening the edge and bending the end cap into the capsule. This compressed the end cap weld zone and displaced it lengthwise; the adjacent tubing was bulged outwards. In the photographs, the end cap damage and a profile of the tubing bulge are on the right.

A dye penetrant examination of the end cap welds of XC-10 and XC-12 was then made, using Uresco, Inc. penetrant P-149 and developer D-495A, inspected under ultraviolet light. There were no defects.

The capsule diameters were measured in inches to the nearest 0.001 inch. The D_1 diameters listed in Tables 3, 4, and 5 were measured in a plane parallel to the capsule serial number which had been electro-etched on the bottom cap; the D_2 diameters were perpendicular to D_1. Pre-test measurements were made one inch from each end and at the center. Post-test measurements were made of the maximum bulge at each end, occurring 0.6 to 0.8 inch from the end and not in line with D_1 or D_2, with additional measurements along the length. The 3.8 pound percussion tests impacted in the D_1 plane and the 3.05 pound tests in the D_2 plane.

Diameter measurements along the length of XC-10 (Table 3) indicate that some distortion of the tube took place during the heating test, during which the D_1 plane was horizontal. Table 3 also lists the approximate bulge heights from the drop tests and the indentations from the percussion tests. The indentation from the 3.05 pound rod was not observed until the diameters were measured; the indentation from the 3.8 pound rod was more pronounced and an arc was impressed in the tube surface by the edge of the rod. Neither indentation was sufficient to press the tube wall down against XC-8 inside.

The data of Table 4, which lists similar measurements for XC-12, indicate increases in capsule diameter ranging from about 0.010 inch at the top to 0.038 inch at the bottom. This swelling occurred during the heating test and the cause is not known. The indentations from the percussion tests may have been reduced during the swelling; as with XC-10, an arc was impressed in the tube surface by the edge of the 3.8 pound rod.

As shown in Table 5, XC-8 was not swollen similarly to XC-12. No comparison is being made of the tube bulging observed on XC-8 and XC-12, since the XC-12 bulges may have been affected by the swelling. XC-8 was not weighted or photographed and there was no dye penetrant examination of the welds.

The outer surfaces of XC-10 and XC-12 were dark gray-black after the heating test. XC-8 and in the inner surface of XC-10 were darkened only slightly. Table 2 shows a 0.5 gram weight increase for XC-12 and 0.7 gram for the XC-8, XC-10 assembly, due to oxide formation. The 0.1 gram changes after the immersion test are not considered significant. The water used for the immersion test contained considerable impurities, as indicated by the 140 micromhos per centimeter conductivity reading. However, even less effect on the Type 316-L stainless steel capsule material would be expected if the water had been of the specified purity.

Each end of the capsules was cut off about two inches (50 mm) from the outer face of the end cap, so as to cut off all of the bulged part of the tubing. The ends were then split lengthwise through the zone of maximum end cap damage, and one half of each end was acid etched for inspection of the end cap weld. All welds had penetrated 100 percent of the tube wall thickness except for the top weld on XC-12, where the penetration was 75 percent. In no case was there any evidence of tearing or cracking in the weld bead.

In summary, the inner capsule for cesium chloride proved capable of withstanding tests more severe than those specified in Annex 4 of ERDA Appendix 0529 with no loss of contents. When provided with the additional protection of the outer capsule, the assembly far exceeds the requirements to qualify as Special Form Material.

REFERENCES

1. Energy Research and Development Administration Manual Chapter 0529, June 14, 1973, "Safety Standards for the Packaging of Fissile and Other Radioactive Materials."

2. HWS-8835 REV 5 (unclassified), July 16, 1975, "Specification for Seamless 316L Authentic-Stainless Steel Tubing for Cesium Chloride Encapsulation."

Table 1

DESIGN DIMENSIONS

	Inches	Approximate Equivalent in mm
A. Inner Capsule		
1. Nominal length	19.725	501.0
2. Nominal diameter	2.250	57.2
3. Tubing		
a. Outside diameter (OD)*	2.250 ±0.005	57.2
b. OD at welds	2.246	57.0
c. Wall thickness (WT)*	0.103 ±0.009	2.6
d. WT at top weld	0.080	2.0
e. WT at bottom weld	0.090	2.3
4. End caps		
a. Thickness	0.400	10.2
b. Thickness at weld	0.300	7.6
c. Outside diameter	2.246	57.0
B. Outer Capsule		
1. Nominal length	20.775	527.7
2. Nominal diameter	2.625	66.7
3. Tubing		
a. Inside diameter*	2.407 ±0.008	61.1
b. OD at welds	2.619	66.5
c. Wall thickness*	0.119 ±0.011	3.0
d. WT at welds	0.100	2.5
4. End caps		
a. Thickness	0.400	10.2
b. Thickness at weld	0.300	7.6
c. Outside diameter	2.519	66.5
5. Nominal length of cavity	19.975	507.4

*Reference 2

TABLE 2

CAPSULE WEIGHTS, GRAMS

		XC-12	XC-8 and XC-10 Assembly
A.	Prior to Tests	4850.6	7336.8
B.	Following Drop, Percussion and Heating Tests	4851.1	7337.5
C.	Following Immersion Test	4851.0	7337.6

Note: The weights of the capsules and of the steel rods used in the percussion tests were determined using a Mettler P11 scale, accurate to ± 0.1 gram.

TABLE 3

OUTER CAPSULE XC-10
(diameters in inches)

	D_1	D_2
A. Pre-Test		
1 inch from bottom	2.618	2.617
Center	2.620	2.619
1 inch from top	2.617	2.618
B. Post-Test		
Bulge at bottom	2.653	
2 inches from bottom	2.638	2.609
4 inches from bottom	2.626	2.612
6 inches from bottom	2.624	2.617
8 inches from bottom	2.625	2.613
10 inches from bottom	2.627	2.611
		2.606*
12 inches from bottom	2.627	2.611
	2.595*	
14 inches from bottom	2.623	2.613
16 inches from bottom	2.621	2.616
18 inches from bottom	2.616	2.620
Bulge at top	2.670	

* Minimum diameter at percussion test impact zone.

TABLE 4

INNER CAPSULE XC-12
(diameters in inches)

	D_1	D_2
A. Pre-Test		
1 inch from bottom	2.252	2.250
Center	2.251	2.251
1 inch from top	2.250	2.251
B. Post-Test		
Bulge at bottom	2.295	
2 inches from bottom	2.288	2.288
4 inches from bottom	2.281	2.280
6 inches from bottom	2.276	2.275
8 inches from bottom	2.271	2.271
10 inches from bottom	2.270	2.266**
12 inches from bottom	2.268	2.267
	2.257*	
14 inches from bottom	2.266	2.267
16 inches from bottom	2.262	2.267
18 inches from bottom	2.261	2.263
Bulge at top	2.297	

* Minimum diameter at percussion test impact zone.

** Probable location of percussion test impact zone.

TABLE 5

INNER CAPSULE XC-8
(diameters in inches)

	D_1	D_2
A. Pre-Test		
1 inch from bottom	2.249	2.252
Center	2.250	2.250
1 inch from top	2.249	2.250
B. Post-Test		
Bulge at bottom	2.257	
2 inches from bottom	2.247	2.252
4 inches from bottom	2.250	2.250
6 inches from bottom	2.251	2.252
8 inches from bottom	2.249	2.249
10 inches from bottom	2.249	2.252
12 inches from bottom	2.247	2.252
14 inches from bottom	2.245	2.252
16 inches from bottom	2.248	2.252
18 inches from bottom	2.254	2.245
Bulge at top	2.272	

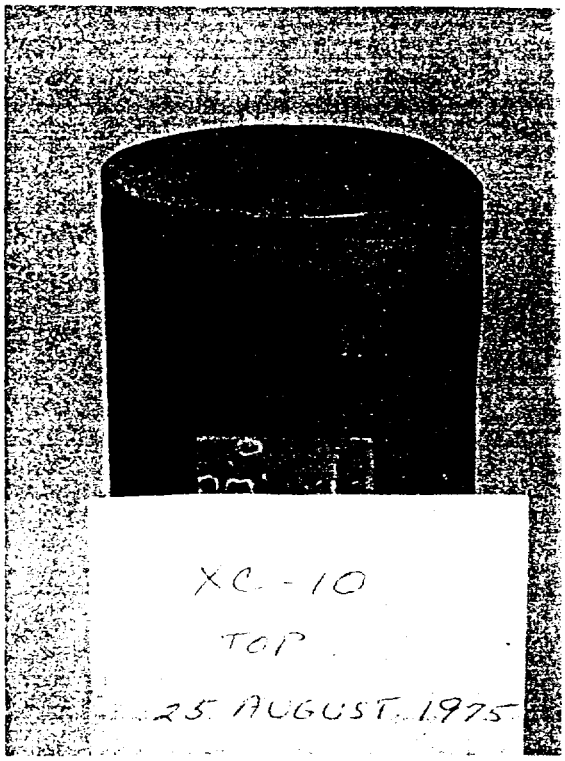


FIGURE 1

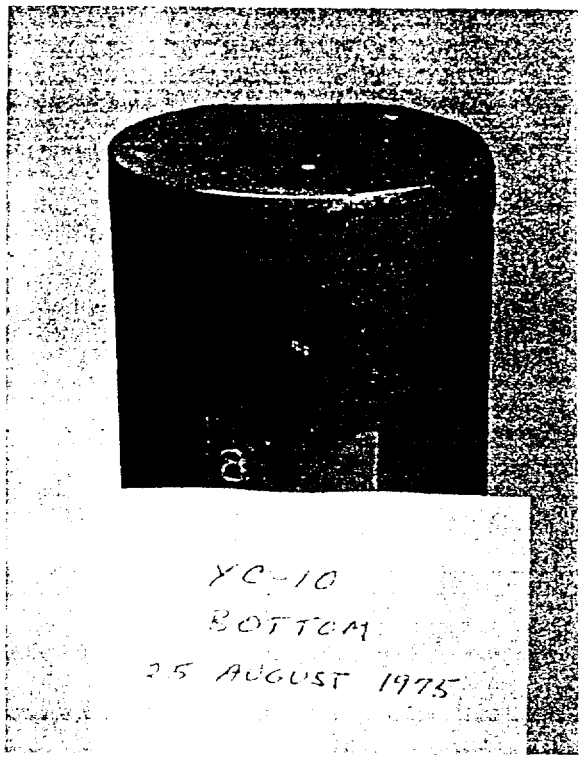


FIGURE 2

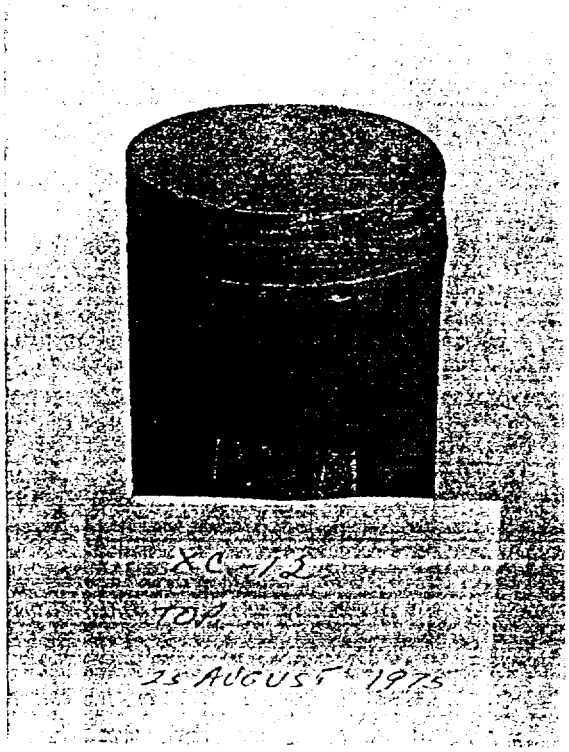
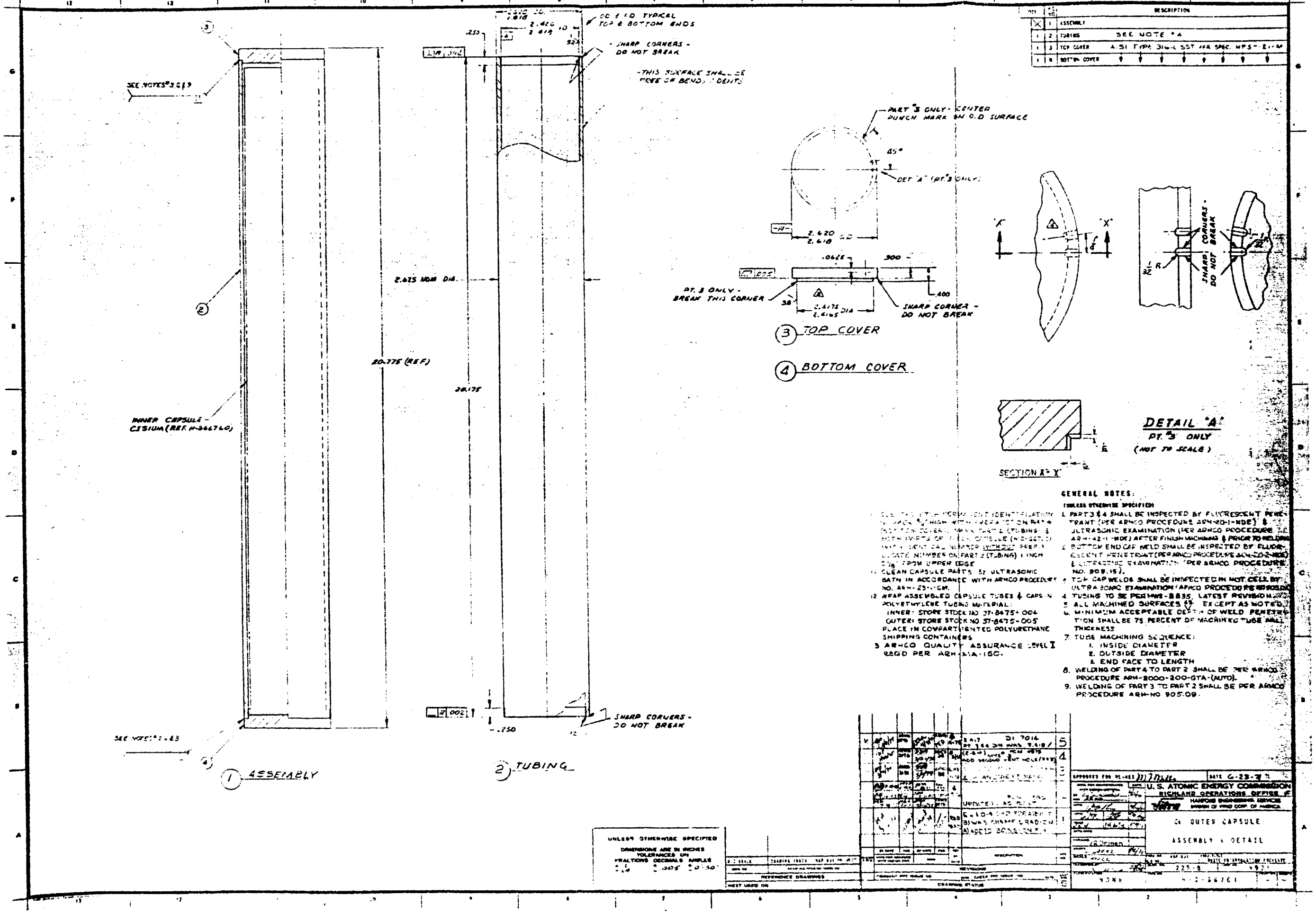


FIGURE 3

FIGURE 4

QTY	ITEM NO.	DESCRIPTION	
X	1	ASSEMBLY	
1	2	TUBING	SEE NOTE #4
1	3	TOP COVER	A.S.I. TYPE 316-L SST PER SPEC. WPS-21-M
1	4	BOTTOM COVER	" " " " " " " "



GENERAL NOTES:
(UNLESS OTHERWISE SPECIFIED)

1. PART 3 & 4 SHALL BE INSPECTED BY FLUORESCENT PENETRANT (PER ARMCO PROCEDURE ARM-20-1-NDE) & ULTRASONIC EXAMINATION (PER ARMCO PROCEDURE ARM-42-1-NDE) AFTER FINISH MACHINING & PRIOR TO WELDING.
2. BOTTOM END CAP WELD SHALL BE INSPECTED BY FLUORESCENT PENETRANT (PER ARMCO PROCEDURE ARM-20-2-NDE) & ULTRASONIC EXAMINATION (PER ARMCO PROCEDURE NO. 905.15).
3. TOP CAP WELDS SHALL BE INSPECTED IN HOT CELL BY ULTRASONIC EXAMINATION (ARMCO PROCEDURE 905.15).
4. TUBING TO BE PER WPS-8885, LATEST REVISION.
5. ALL MACHINED SURFACES 63 EXCEPT AS NOTED.
6. MINIMUM ACCEPTABLE DEPTH OF WELD PENETRATION SHALL BE 75 PERCENT OF MACHINED TUBE WALL THICKNESS.
7. TUBE MACHINING SEQUENCE:
   1. INSIDE DIAMETER
   2. OUTSIDE DIAMETER
   3. END FACE TO LENGTH
8. WELDING OF PART 4 TO PART 2 SHALL BE PER ARMCO PROCEDURE ARM-2000-200-GTA-(AUTO).
9. WELDING OF PART 3 TO PART 2 SHALL BE PER ARMCO PROCEDURE ARM-NO 905.09.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS DECIMALS ANGLES
± 1/64 ± .005 ± 0°30'

REV	DATE	DESCRIPTION
5		DI 7014
4		
3		
2		UPDATED AS BUILT
1	6-10-9	C) ADD TOP & BOTT. B) WAS CHANGE GRADE-CN A) ADD DOSSIER NO.

REFERENCE DRAWINGS
NEXT USED ON
REVISIONS
DRAWING STATUS

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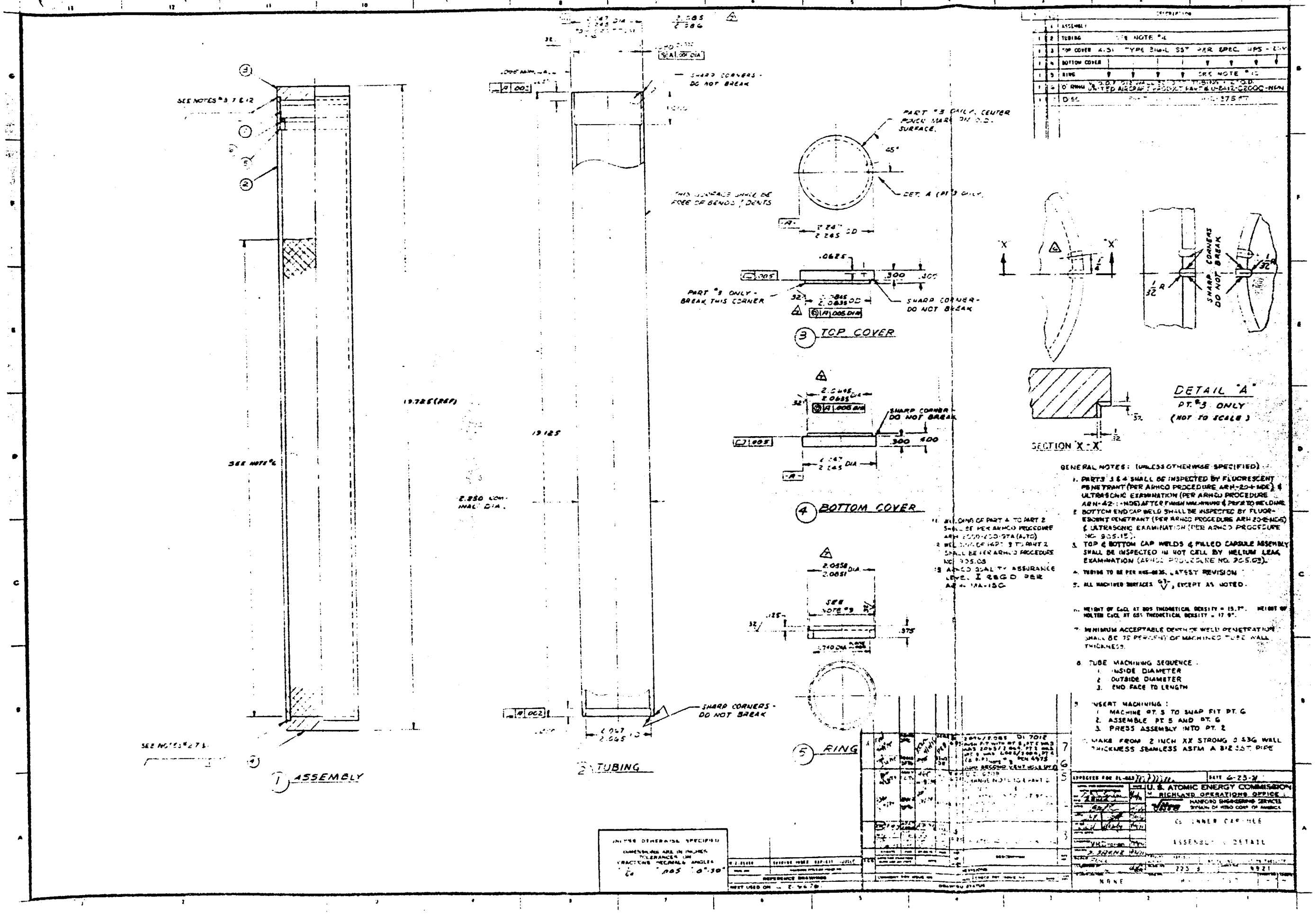

		DESCRIPTION
1	1	ASSEMBLY
1	2	TUBING SEE NOTE #4
1	3	TOP COVER A-51 TYPE 316-L SST PER SPEC. HPS - 2-4
1	4	BOTTOM COVER
1	5	RING SEE NOTE #10
1	6	O RING 1/8 O.D. 7 .012 WALL 2.2 O.D. TUBING + 2 O.D. UNITED AIRCRAFT PRODUCT PART # U-8412-C2000-NPN
1	7	DISC PART # U-8-375

GENERAL NOTES: (UNLESS OTHERWISE SPECIFIED)

1. PARTS 3 & 4 SHALL BE INSPECTED BY FLUORESCENT PENETRANT (PER ARHCO PROCEDURE ARH-20-1-NDE) & ULTRASONIC EXAMINATION (PER ARHCO PROCEDURE ARH-42-1-NDE) AFTER FINISH MACHINING & PRIOR TO WELDING.
2. BOTTOM END CAP WELD SHALL BE INSPECTED BY FLUORESCENT PENETRANT (PER ARHCO PROCEDURE ARH 20-2-NDE) & ULTRASONIC EXAMINATION (PER ARHCO PROCEDURE NO. 905.15).
3. TOP & BOTTOM CAP WELDS & FILLED CAPSULE ASSEMBLY SHALL BE INSPECTED IN HOT CELL BY HELIUM LEAK EXAMINATION (ARHCO PROCEDURE NO. 905.03).
4. TUBING TO BE PER HNS-0835, LATEST REVISION.
5. ALL MACHINED SURFACES 63 √, EXCEPT AS NOTED.
6. HEIGHT OF CaCl AT 80% THEORETICAL DENSITY = 15.7". HEIGHT OF MOLTEN CaCl AT 65% THEORETICAL DENSITY = 17.9".
7. MINIMUM ACCEPTABLE DEPTH OF WELD PENETRATION SHALL BE 75 PERCENT OF MACHINED TUBE WALL THICKNESS.
8. TUBE MACHINING SEQUENCE:
   1. INSIDE DIAMETER
   2. OUTSIDE DIAMETER
   3. END FACE TO LENGTH
9. INSERT MACHINING:
   1. MACHINE PT. 5 TO SNAP FIT PT. 6
   2. ASSEMBLE PT. 5 AND PT. 6
   3. PRESS ASSEMBLY INTO PT. 2
10. MAKE FROM 2 INCH XX STRONG 0.436 WALL THICKNESS SEAMLESS ASTM A 312 SST PIPE

11. WELDING OF PART 4 TO PART 2 SHALL BE PER ARHCO PROCEDURE ARH 2000-200-97A (AUTO)
12. WELDING OF PART 3 TO PART 2 SHALL BE PER ARHCO PROCEDURE NO. 905.08
13. ARHCO QUALITY ASSURANCE LEVEL I REQ'D PER ARH-MA-150

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS DECIMALS ANGLES
1/64 .005 0°-30'

REFERENCE DRAWINGS
NEXT USED ON 2-9678

APPROVED FOR RL-683 DATE 6-23-71

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