Atlantic Richfield Hanford Company
Richland, Washington 99352

ARH-3113

SAFETY ANALYSIS REPORT FOR PACKAGING TYPE LLD-1 SHIPPING CONTAINER

J. A. Herbolsheimer

Process Design and Development
Development Engineering Department
Research and Engineering Division

June 11, 1974

PREPARED FOR THE U.S. ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1) 2130

PRELIMINARY REPORT

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INTRODUCTION

The LLD-1 shipping container was developed from the Oak Ridge National Laboratory Type M-102 carrying case. Department of Transportation (DOT) Special Permit No. 4960 presently authorizes the shipment of large quantities of fissile radioactive materials in the LLD-1. Such materials shipped by Atlantic Richfield Hanford Company (ARHCO) in the LLD-1 are plutonium metal, plutonium oxide, or americium oxide. These contents are sealed in metal cans, two of which may be placed in the DOT Specification 2R vessel. This vessel consists of a 12-inch length of five-inch, schedule 120 steel pipe with a welded closure at one end. At the other end is a screwed plug closure having an O-ring seal. The 2R vessel is surrounded by felt insulation and located within a secondary enclosure of quarter-inch thick steel having a breech-lock lid sealed with a stainless steel O-ring. This assembly is supported in the center of a tubular birdcage structure measuring 16 inches by 16 inches by 25 inches high, overall. To prevent entry of objects into the confines of the birdcage, a sheet metal box of open construction envelops the cage.

The basic safety analysis of the LLD-1 is to be provided by Savannah River Plant, E. I. du Pont de Nemours and Company (SRP). Except as described in reference 1, the SRP Safety Analysis Report for Packaging will apply to ARHCO-controlled LLD-1 containers. Briefly, the ARHCO items requiring supplementary study are listed in reference 1 as:

1. The integrity of the O-ring materials, if different from the SRP counterparts.
2. The similarity of design, or equivalence of safety between ARHCO and SRP containers.
3. The safety of the contents packaged by ARHCO.

This document is directed toward examining such differences as exist between ARHCO and SRP controlled LLD-1 shipping containers.

EVALUATION

O-RING SEAL

Although ARHCO has been installing a stainless steel O-ring to seal the 2R container opening, use of the metal seal will be discontinued in favor of the Viton O-ring specified by SRP. That this change is permissible and will result in an effective closure has been established by the following analysis:

1. Drawings

   The ARHCO dimensions relating to the effectiveness of the seal have been compared with the corresponding SRP features. Excepting minor tolerance variations, these were in good agreement. Within the ARHCO drawing, the dimensions of the lid and body of the 2R vessel were checked to determine that the O-ring would clear the internal threads and would seat properly without jamming or convoluting on the shoulder machined in the body.

2. Theoretical

   The requirements for an effective O-ring seal as set forth in reference 2 were applied to the ARHCO design. It was found that the surface finishes, initial stretch, diameter loss, and radial squeeze were acceptable for the face-type seal employed in the 2R vessel.

3. Experimental

   The 2R vessels from six LLD-1 shipping containers were fitted with SRP specified Viton O-rings. The lids screwed down into the bodies without binding or dragging, and bottomed on the seal smoothly and soundly. Disassembly also was normal. The experiment was repeated with a second set of Viton O-rings, yielding the same results. Afterwards, the 12 O-rings were examined for evidence of injury. Nine showed only a dulling of the surface finish on areas of heavy contact with the metal parts. Three had, in addition to surface dulling, fine scratches varying in length from one-half to one and one-half inches, located near the flash on the outside of the ring. All of these scratches, being located 90 degrees around the O-ring cross-section from the sealing areas, were judged not to endanger the integrity of the seal. From their location and helical orientation, it is concluded that the scratches were caused by very small burrs located somewhere on the threads of two of the 2R bodies.

   A 2R vessel was fitted with a Viton O-ring and modified with an air inlet and pressure gauge. The lid was installed, and the vessel pressurized to 25 psig. After 24 hours the pressure was still at 25 psig, when corrected for a change in ambient temperature.

3. Practical

Inspection of the metal surfaces contacting the O-ring is an already existing requirement. A new Viton O-ring will be installed each time an LLD-1 is used for shipment.

OVERALL DESIGN SIMILARITY

The ARHCO and SRP drawings of the LLD-1 were compared as to materials, dimensions, weld callouts, heat treatments, surface finishes, and inspection requirements. Special attention was given to those items which, because of their importance, were listed in reference 3. It is concluded that the ARHCO containers are equivalent in safety, and identical in most features to the design evaluated by SRP.

Differences in certain dimensions were revealed in the comparison. These resulted from a loosening of some tolerances on the ARHCO drawings, and a reduction of a few surface finish requirements. These relaxations do not reduce the effectiveness of the packaging; however, they will result in cost savings in fabrication.

When evaluating the effect of wider tolerances on the seal of the 2R vessel, it is important to keep in mind that this closure was designed as a face seal, and not as a piston seal. The O-ring seals on its sides, compressed between the shoulders of the lid and body. It is not intended to seal on its inside and outside diameters, although it may do so, thus effecting a redundancy.

The only other noteworthy difference between ARHCO and SRP LLD-1 containers is in the outer box (called "basket" by SRP). Atlantic Richfield Hanford Company's box is made of 24-gauge galvanized sheet steel, seamed at the edges, whereas the SRP version is 0.102-inch thick 5052-H32 aluminum, welded at the edges and perforated with 13/16-inch square holes on one-inch centers. The comparative performance of these devices under the normal and accident conditions of reference 4 are evaluated below. Where the conditions have no significant interplay with the box or basket, the comment, "No effect," is made. Where the performances of the two enclosures are considered to be essentially equal, "No difference in performance," is entered.

Normal Conditions of Transport

1. Heat - In the attachment to reference 1, SRP performed its thermal analysis without regard to the basket, reasoning conservatively that the restriction of convective cooling by the basket would be more than offset by the beneficial effect of shading from the sun's rays. That the input from the sun was found to make up 70 percent of the total heat load is further justification for omitting the basket from a conservative analysis. The ARHCO box is open only at the bottom corners and at

the top surface. This will further restrict convection but will give increased shading as overcompensation. It is concluded that any difference in temperature that may exist due to dissimilarity of the outer enclosures will not be of significant magnitude to endanger the lading of the LLD-1, or to reduce the safety of the package.

2. Cold - Cold, down to -40 °F, is not a condition detrimental to the package or its contents.

3. Pressure - No effect.

4. Vibration - No difference in performance (based on shipping experience).

5. Water Spray - No effect.

6. Free Drop - No difference in performance.

7. Corner Drop - No difference in performance.

8. Penetration - The sole purpose of the box, or basket, is to prevent the entrance of a four-inch cube into the confines of the birdcage.

   An LLD-1 shipping container with an ARHCO box enclosure was subjected to nine applications of the penetration test of reference 4, Annex 1 as follows:

   A. Lid Impacts
      a. On center of lid
      b. At mid-point of long edge
      c. At corner (hasp end)
      d. Halfway between center and corner

   B. Side Impacts
      a. At mid-point of free edge (near nominal top of LLD-1)
      b. Repeat on same point
      c. In center of panel

   C. Bottom Impacts
      a. In center
      b. Near corner of panel

   Entry of a 2 5/8-inch or larger cube at any point was not possible at any time during the test sequence, nor after completion of the test.

9. Compression - No difference in performance.

Hypothetical Accident Conditions

1. Free Drop - No difference in performance.

2. Puncture - No difference in performance (puncture of the box would not violate the standards for accident conditions).

3. Thermal - The box, due to its higher melting point and reduced open area, will out-perform the basket.

4. Water Immersion - No effect.

SAFETY OF LOADINGS

In the LLD-1, ARHCO ships plutonium metal, plutonium oxide, and americium oxide.

1. Plutonium Metal - The adequacy of the container for shipments of plutonium metal will be established by SRP.

2. Plutonium Oxide - The addendum describes the mathematical study which determined the nuclear safety of the currently allowable loading (4.5 kilograms) of plutonium oxide.

   Considering thermal aspects, the attachment to reference 1 studied the the effects of a 21 watt total heat load internal to the LLD-1, under "Normal Conditions of Transport" and under "Hypothetical Accident Conditions" per reference 4. The thermal environment of the accident series was determined to be the most restrictive criterion. For the study, the contents of the package were taken to be plutonium buttons, but the results apply to plutonium oxide as well. The analysis shows that the contents, during and following a fire, will not exceed a temperature maximum of 586 °F, and that the 2R vessel temperature will peak no higher than 565 °F. The latter figure is 35 degrees below the 48-hour temperature limit of Viton, thus 21 watts is a safe maximum decay heat for shipments, including plutonium oxide.

3. Americium Oxide - Shipments of this material are limited to Type B quantities of ^{241}Am, or 20 curies for a Transport Group I element. Taking the specific activity to be 3.24 curies per gram, the maximum amount of ^{241}Am that may be shipped in the LLD-1 is 20/3.24 = 6.2 grams. This is so much less than the critical mass (71.4 kilograms for a reflected sphere of americium metal) that no criticality study was considered necessary.

   With a decay heat of 0.118 watts per gram, ^{241}Am will generate thermal energy in the LLD-1 at the rate of 0.118 x 6.2 = .73 watts. This will not compromise the safety of the shipment.

CONCLUSION

In the three categories specified by reference 1, ARHCO-controlled LLD-1 shipping containers will provide a degree of safety equivalent to that of SRP LLD-1's.

REFERENCES

1. Letter, March 28, 1974, H. D. Smith to G. T. Stocking, "AEC-AL-USA-4960-BLF—'LLD-1 Shipping Container.'"

2. Parker Seal Company, "Parker O-Ring Handbook," 1970.

3. Check list, January 15, 1974, G. W. Upington, "Inspection Check List for LLD-1 Shipping Containers."

4. Atomic Energy Commission Manual Chapter 0529, June 14, 1973, "Safety Standards for the Packaging of Fissile and Other Radioactive Materials."

ADDENDUM

CRITICALITY ANALYSIS

The following letter describes the mathematical procedures used to examine the nuclear safety of the LLD-1 shipping container.

Date: May 29, 1974

To: J. A. Herbolsheimer

From: R. D. Carter

Subject: LLD-1 SHIPPING CONTAINER CRITICALITY ANALYSIS FOR PLUTONIUM OXIDE

You requested that we check the LLD-1 shipping container for compliance with AEC Manual Chapter 0529 as a Class II shipping container and for only the plutonium oxide. We have completed our analysis and the results show that the LLD-1 is safe for currently allowable arrays. No attempt was made to determine maximum allowable arrays.

For the criticality calculations, we assumed that the container was loaded with 4.5 kilograms of $^{239}PuO_2$ at the maximum theoretical density of 11.46 grams per cubic centimeter. The current Transport Index is 1.3, which allows 38 units in a shipping array as a Class II container. The array calculations were done with the KENO Monte Carlo code (1) using Hansen-Roach 16-group cross section sets (2). About 8,000 to 10,000 neutron histories were used for the calculations.

Single Container

The single unit analysis was done using parameters available in ARH-600 (3). AEC Manual Chapter 0529, Part II, Section G requires that the single unit be safe for inleakage of water. The free volume of the inner case is 2.74 liters. If water leaked into the container (which we assumed to be the inner case), the container is safe because the mass required to go critical for 2.74 liters or less in spherical shape is at least 8 kilograms, fully reflected.

Since the material contained is not in solution, it is not necessary to consider leakage into the outer package. The single unit is therefore safe.

J. A. Herbolsheimer
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Undamaged Array

AEC Manual Chapter 0529, Part II, I.1 limits the number of packages such that five times that number of undamaged packages would be subcritical if closely reflected by water. The KENO calculation assumed 210 units in a 6 x 7 x 5 unit array. The calculated k-effective was 0.743 ± 0.010. The allowed array would then be at least 42 units with a Transport Index at least as low as 1.2. The current value of 1.3 is therefore safe.

Damaged Array

AEC Manual Chapter 0529, Part II, I.1.b. requires that twice the allowable number of packages shall be safe in any arrangement if each package were subject to the hypothetical accident conditions. The array shall include close water reflection and optimum interspersed moderation. Each package is in the most reactive credible configuration based on the damaged condition.

Drop tests of 250 feet for the LLD-1 (4) showed a reduction in volume of 30 percent. For the required 30 foot drop tests we assumed that this volume reduction was 10 percent and resulted entirely from a decrease in one horizontal dimension. For this damaged container array we assumed 90 units in a 6 x 5 x 3 array. The calculated k-effective was 0.694 ± 0.007. No interspersed moderation was investigated since the thickness of the surrounding steel is great enough that no increase in k-effective would result. No leakage of water into the container was assumed since the drop tests showed none. The allowed array would be at least 45 units at a Transport Index of 1.1. The current Transport Index of 1.3 is therefore safe.

RDC:ah

cc: RE Isaacson
WE Matheison

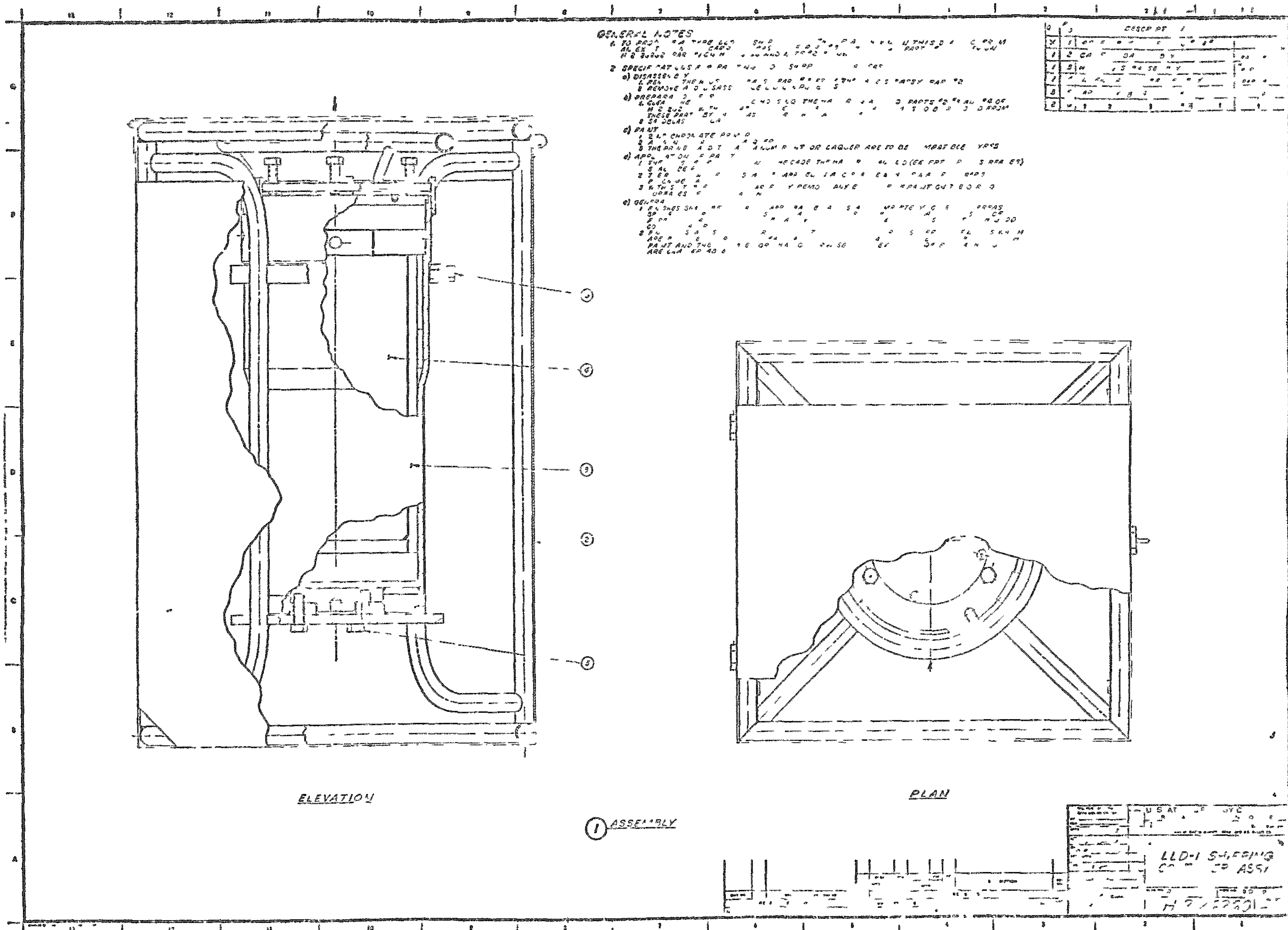
REFERENCES

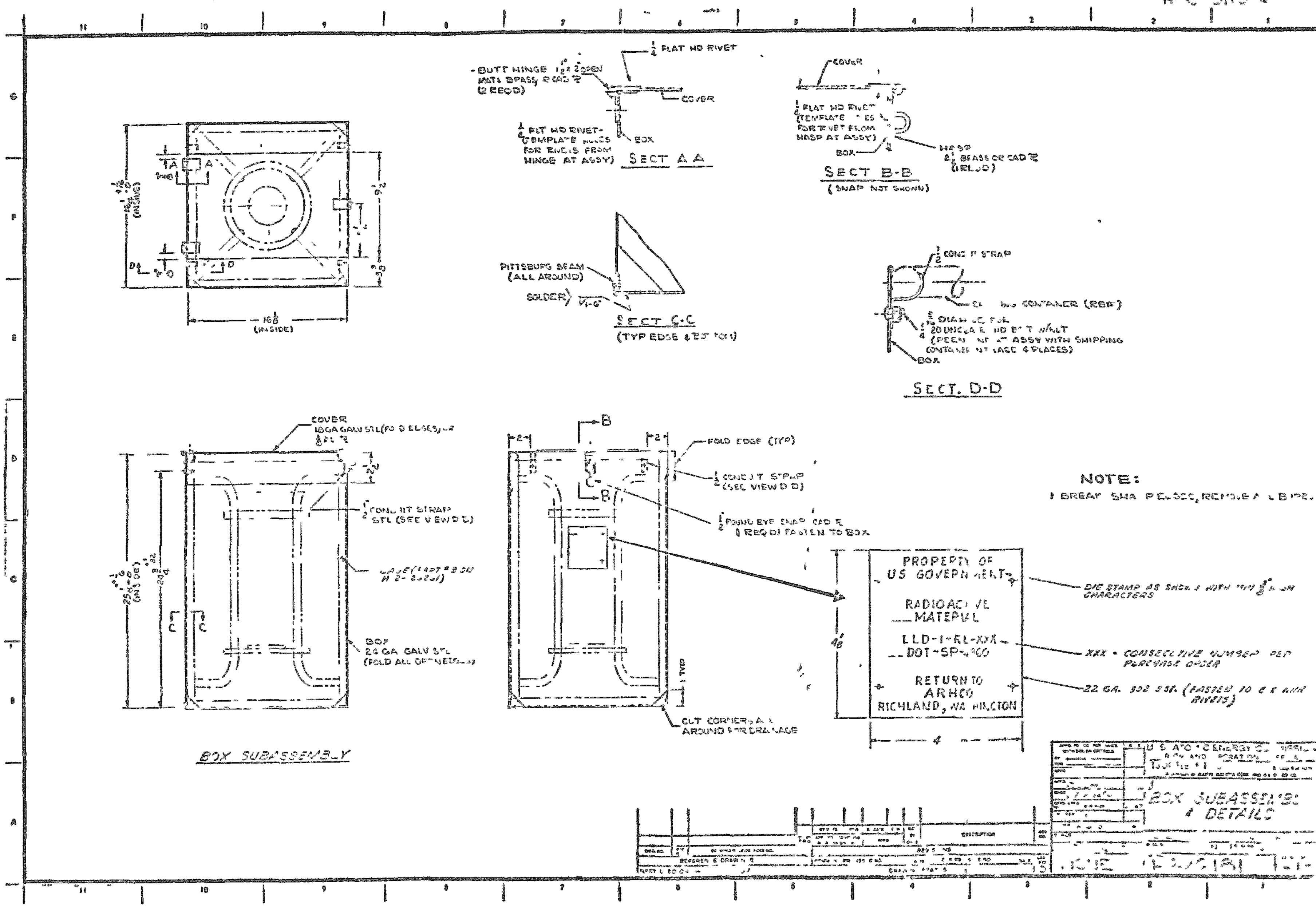
1. G. E. Whitesides and N. F. Cross, "KENO--A Multigroup Monte Carlo Criticality Program," CTC-5, January 1970.

2. G. E. Hansen and W. H. Roach, "Six and Sixteen Group Cross Sections for Fast and Intermediate Critical Assemblies," LAMS-2543, December 6, 1961.

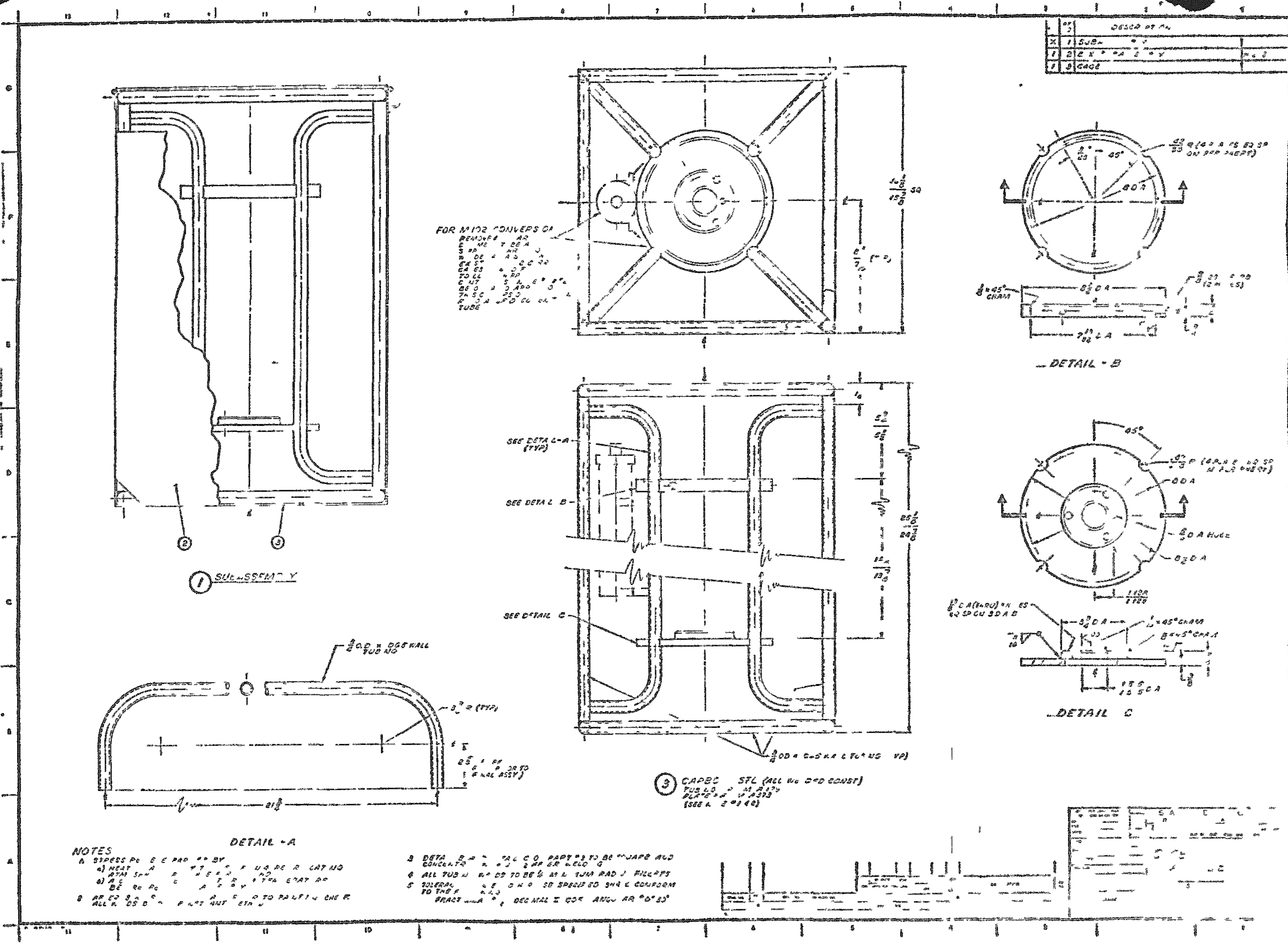
3. R. D. Carter, et. al., "Criticality Handbook," ARH-600, June 28, 1968.

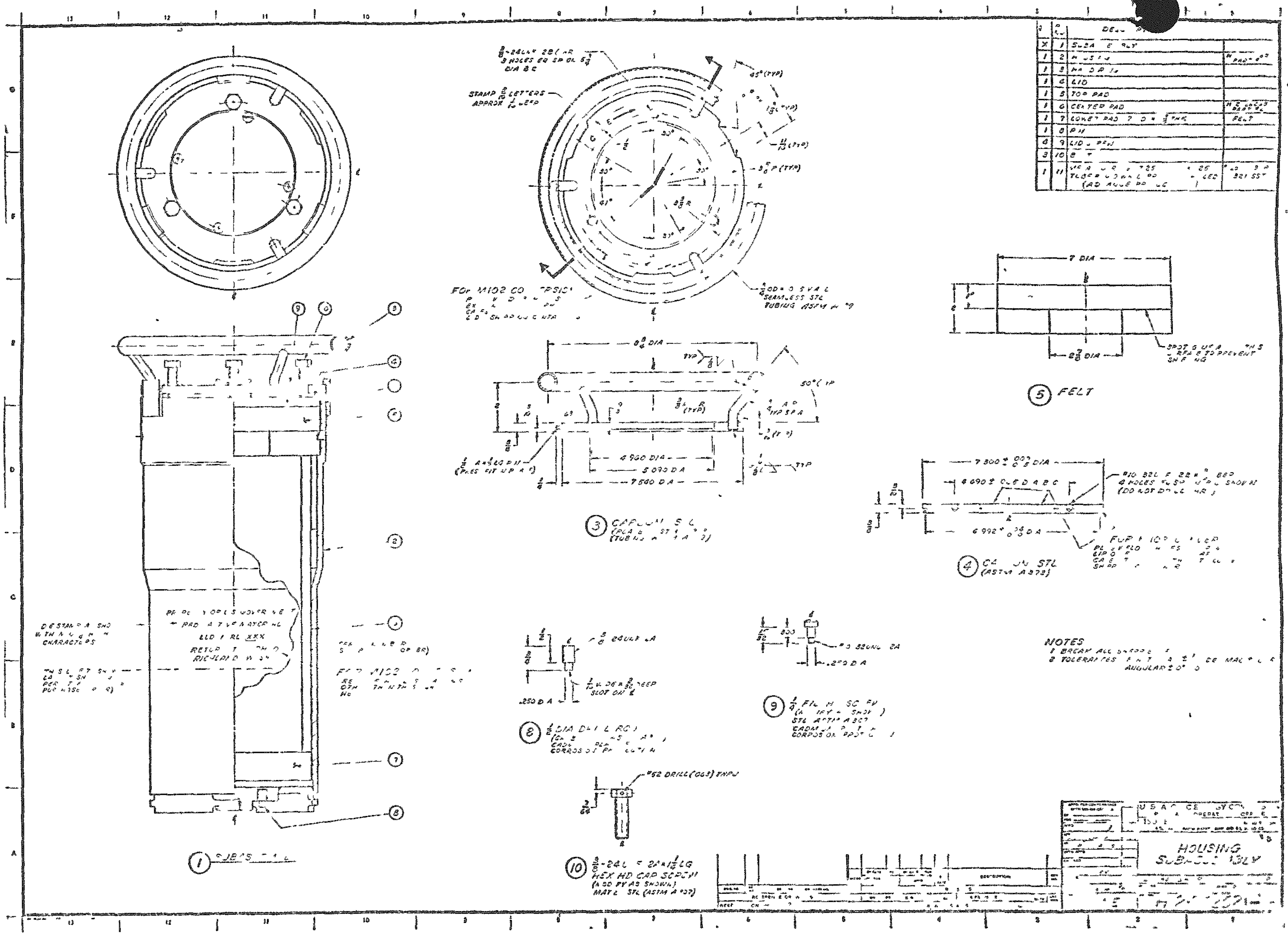
4. "Description of a Plutonium and Enriched Uranium Shipping Container and Integrity Tests on This Container," RFP-290, November 12, 1962.

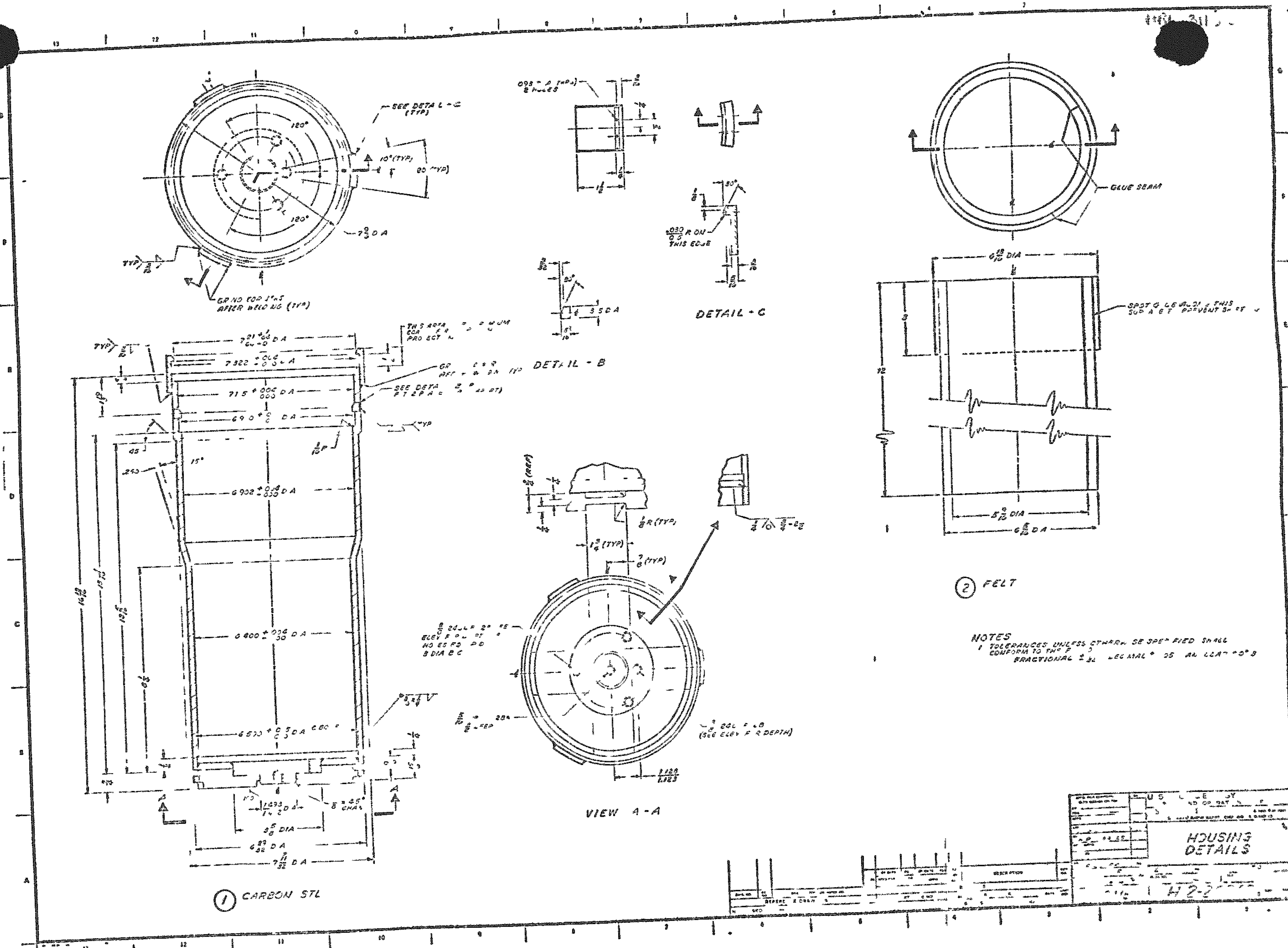

GENERAL NOTES
3
4
3
2
5
ELEVATION
PLAN
1 ASSEMBLY

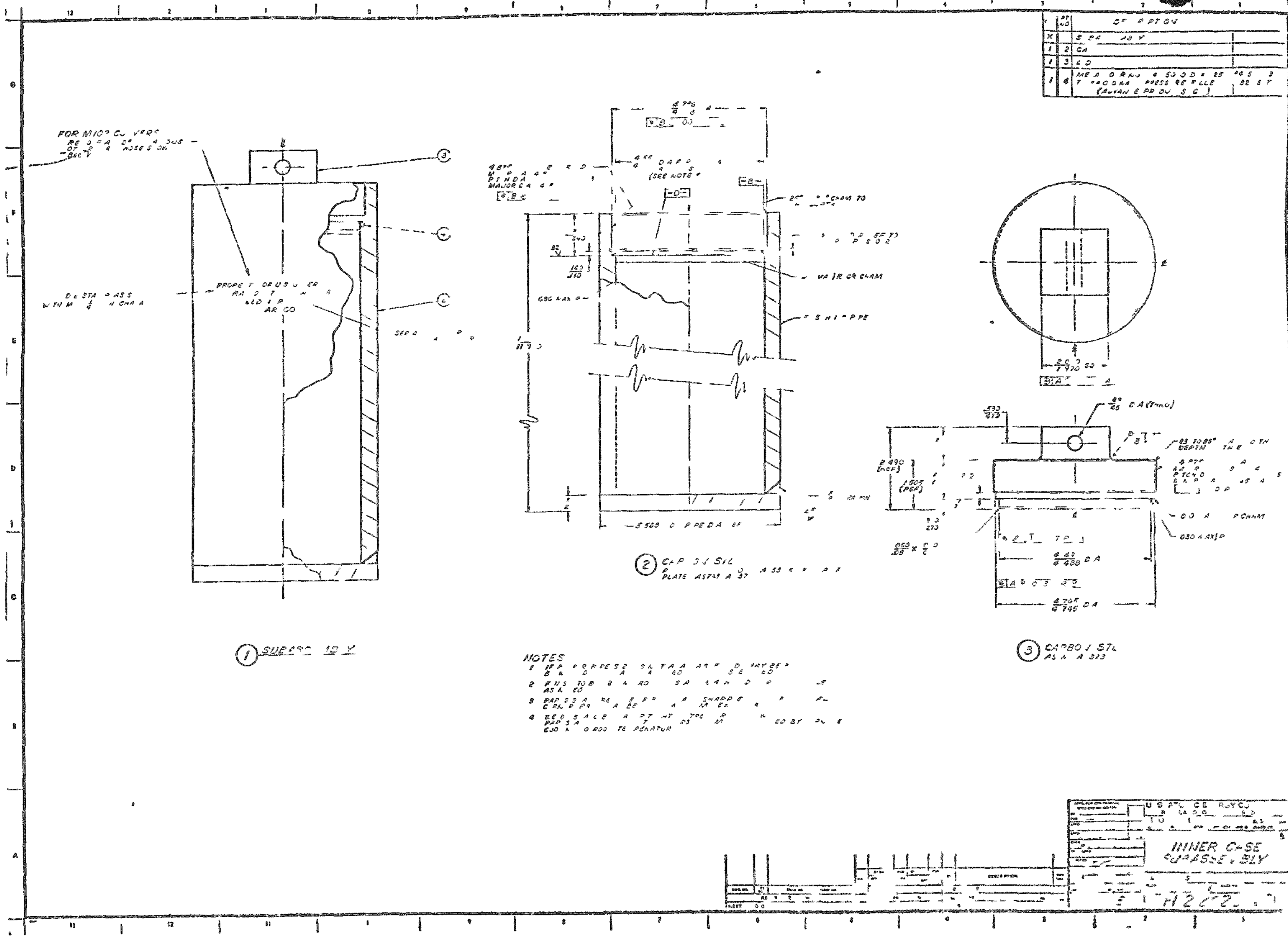


ARC-3113-C
BUTT HINGE 1½ x 2 OPEN
¼ FLAT HD RIVET
COVER
BOX
SECT A-A
SECT B-B
(SNAP NOT SHOWN)
PITTSBURG SEAM (ALL AROUND)
SOLDER
SECT C-C
(TYP EDGE & CORNER)
SECT. D-D
BOX
16⅛ (INSIDE)
COVER
BOX
24 GA GALV STL
FOLD EDGE (TYP)
CUT CORNERS ALL AROUND FOR DRAINAGE
BOX SUBASSEMBLY
NOTE:
PROPERTY OF
US GOVERNMENT
RADIOACTIVE
MATERIAL
LLD-1-RL-XXX
DOT-SP-4900
RETURN TO
ARHCO
RICHLAND, WASHINGTON
DIE STAMP AS SHOWN WITH CHARACTERS
XXX = CONSECUTIVE NUMBER PER PURCHASE ORDER
BOX SUBASSEMBLY & DETAILS


DETAIL - A
DETAIL - B
DETAIL C
SEE DETAIL C
NOTES


HOUSING
SUBASSEMBLY
5 FELT
7 DIA
4 CARBON STL (ASTM A 373)
NOTES
1 BREAK ALL SHARP EDGES
2 TOLERANCES
ANGULAR ± 0° 0
3 CARBON STL
4.960 DIA
5.070 DIA
7.500 DIA
8 3/4 DIA
1 SUBASSEMBLY
8 1/4 DIA DRILL ROD
.250 DIA
9 1/4 FIL HD SCREW
#52 DRILL (.063) THRU
10 3/8-24 UNF × 2 × 1 1/2 LG HEX HD CAP SCREW (ADD PV AS SHOWN) MATL STL (ASTM A 307)
LID
TOP PAD
CENTER PAD
STAMP 3/8 LETTERS APPROX 1/16 DEEP


SEE DETAIL - C (TYP)
10° (TYP)
GRIND TOP 3 TABS AFTER WELDING (TYP)
DETAIL - B
DETAIL - C
THIS EDGE
GLUE SEAM
VIEW A-A
1 CARBON STL
2 FELT
NOTES
1 TOLERANCES UNLESS OTHERWISE SPECIFIED SHALL CONFORM TO THE FOLLOWING: FRACTIONAL ± 1/64
HOUSING DETAILS
H 2-2


INNER CASE
NOTES
(SEE NOTE
4.745
4.488