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Safety Analysis Report for Packaging (SARP) of the Oak Ridge National Laboratory TRU Californium Shipping Container

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SAFETY ANALYSIS REPORT FOR PACKAGING (SARP) OF THE OAK RIDGE NATIONAL LABORATORY TRU CALIFORNIUM SHIPPING CONTAINER

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**UCC-ND Engineering.

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W. D. Box, L. B. Shappert, R. D. Seagren, B. B. Klima,*
M. C. Jurgensen, C. R. Hammond,**and C. D. Watson

ABSTRACT

An analytical evaluation of the Oak Ridge National Laboratory TRU Californium Shipping Container was made in order to demonstrate its compliance with the regulations governing off-site shipment of packages that contain radioactive material. The evaluation encompassed five primary categories: structural integrity, thermal resistance, radiation shielding, nuclear criticality safety, and quality assurance. The results of this evaluation demonstrate that the container complies with the applicable regulations.

1. INTRODUCTION

The ORNL TRU Californium Shipping Container was designed and fabricated at the Oak Ridge National Laboratory. The design was analyzed[1] in 1971 and reevaluated in 1974 to demonstrate compliance with the regulations. The results of the analyses are presented in Sects. 2 through 8 of this report. The package was inspected to ensure that it was in accordance with the drawings presented in Sect. 9.1.

The primary use of the container is to provide impact and thermal resistance, as well as shielding, for its contents during both normal transport and hypothetical accident conditions. The package is shipped by truck only on its own specially designed trailer. It can be transported by other modes if necessary. It complies with the Nuclear Regulatory Commission (NRC) regulations contained in the *Code of of Federal Regulations*, Title 10, Part 71;[2] *DOE Manual* Chapter 0529;[3] and all Immediate Action Directives (IAD) in effect as of this report date. The cask also complies with U.S. Department of Transportation regulations published in the *Code of Federal Regulations*, Title 49, Part 173.[4]

Calculations, engineering logic, and all related documents that demonstrate compliance with specifications are presented in subsequent sections of this report. Copies of the approval documents are reproduced in Sect. 9.2.

One shipping container was fabricated and originally assigned ORNL No. 10-S-21-211. Later, the Department of Transportation assigned Special Permit No. 5740 to the container.

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1.1 Description of the Package

The TRU Californium Shipping Container (see Fig. 1.1 and the engineering drawings in Sect 9.1) weighs 23,500 lb and consists of two 1 2-in.-thick, 66-in.-diam stainless steel hemispherical heads joined by a 6-in. cylindrical section. The cylindrical cavity is 3 in. in diameter by 6 in. long and is shielded by 30 in. of Blackburn limonite concrete having a density of ~175 lb ft.^{3} Reinforcing steel ties the concrete to the outer shell and the central cylindrical cavity. The wall of the cavity is 1-in.-thick stainless steel. Upper and lower ball valves located at the end of concrete-filled plugs define, isolate, and seal the cavity. The plugs utilize O-ring seals, are bolted in place, and are protected with a gasketed cover plate. Fusible plugs, which will melt in the thermal aspect of the hypothetical accident, will permit steam from the concrete and gases from the cover plate to escape (see Fig. 1.1). The typical ball valve, ball valve operator, and seal plug arrangement are shown in Fig. 1.2.

The top ball valve and plug may be replaced by other plugs, permitting multiple source shipments (see Fig. 1.3). Sources are contained in 2R or special-form containers (see Sect. 5).

The TRU Californium Shipping Container is shipped on its special trailer (see Fig. 1.4). A 1-in.-thick octagonal deck plate is welded to the trailer. Four chocks welded to this deck plate locate the container. The base of the container is attached to the deck plate by eight 2-in.-diam bolts. Four of the eight lifting ribs are used as tie-down points and are attached to the trailer by 7 8-in.-diam cables.

1.2 Contents of the Package

The cask is designed to transport isotopes of americium, curium, berkelium, californium, einsteinium, and fermium as a solid (either metal, oxide, oxysulfate, or dry salt) that will be carried inside the cask in a 2R or special-form capsule. The maximum quantity of any or all radionuclides shipped will be 3 g, which is defined as a large quantity.[5] The cask is designed for a maximum heat load of 5 watts (17 Btu hr). The quantities shipped will be limited by external dose rates[6] and or by internal heat loads.

2 STRUCTURAL EVALUATION

The package complies with the structural requirements of the regulations (see Sects. 2 through 4). The calculations, test results, and engineering logic presented in the following sections demonstrate compliance with these performance criteria. The effects of both normal transport and specified accident conditions on the structural integrity of the package are considered.

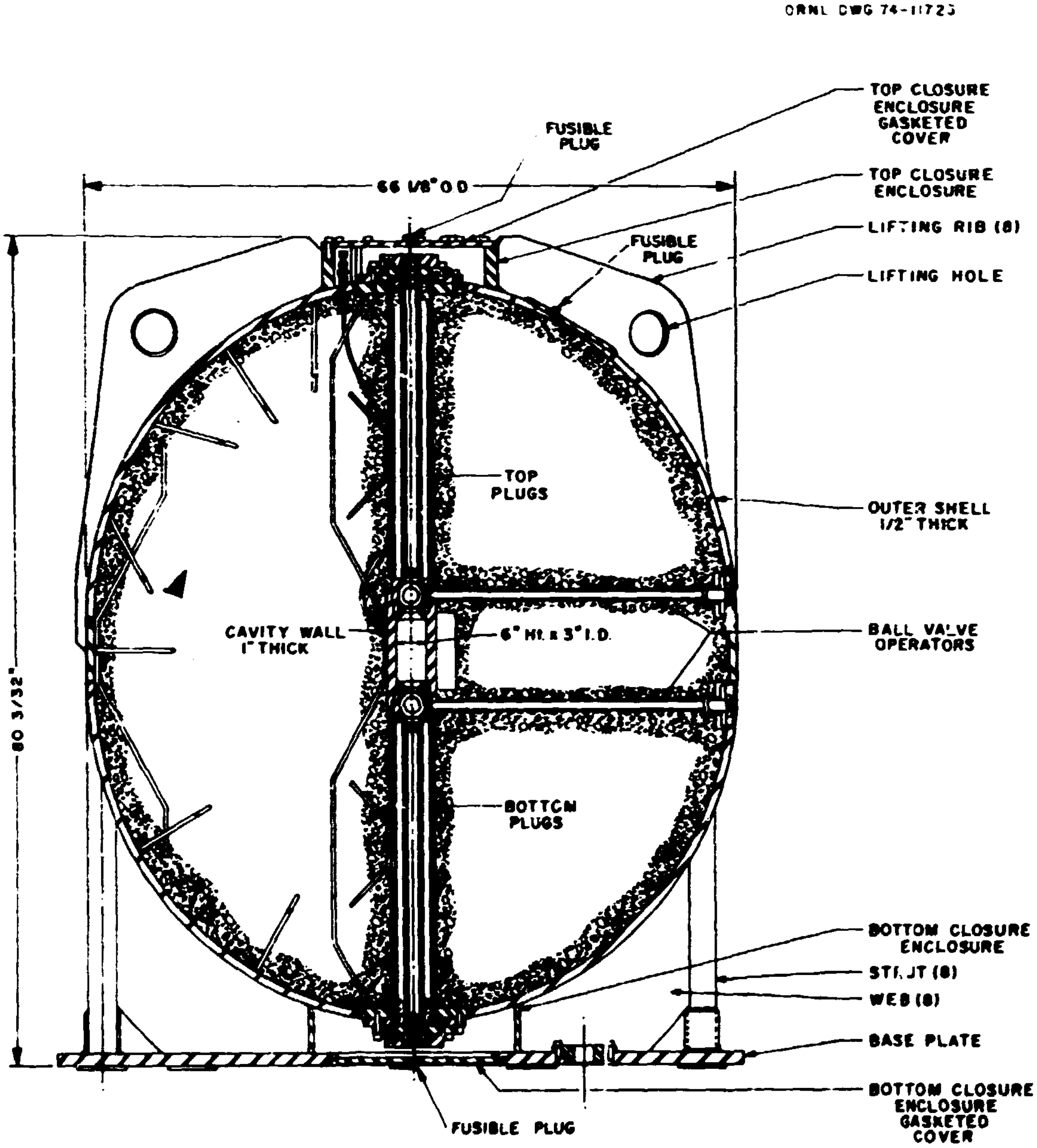
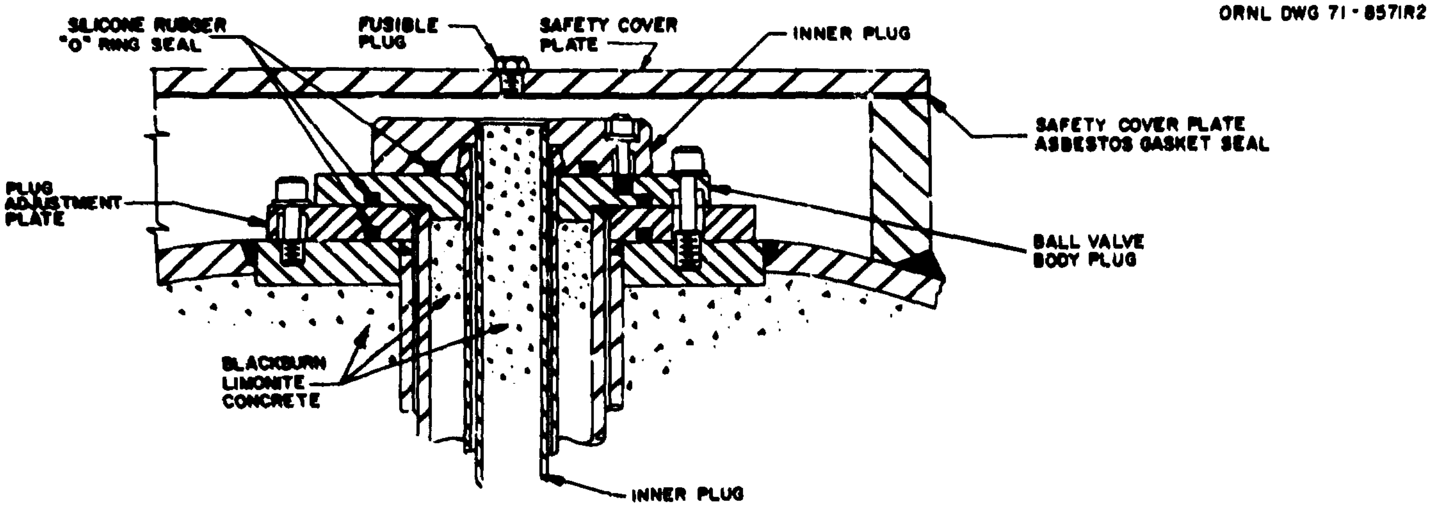
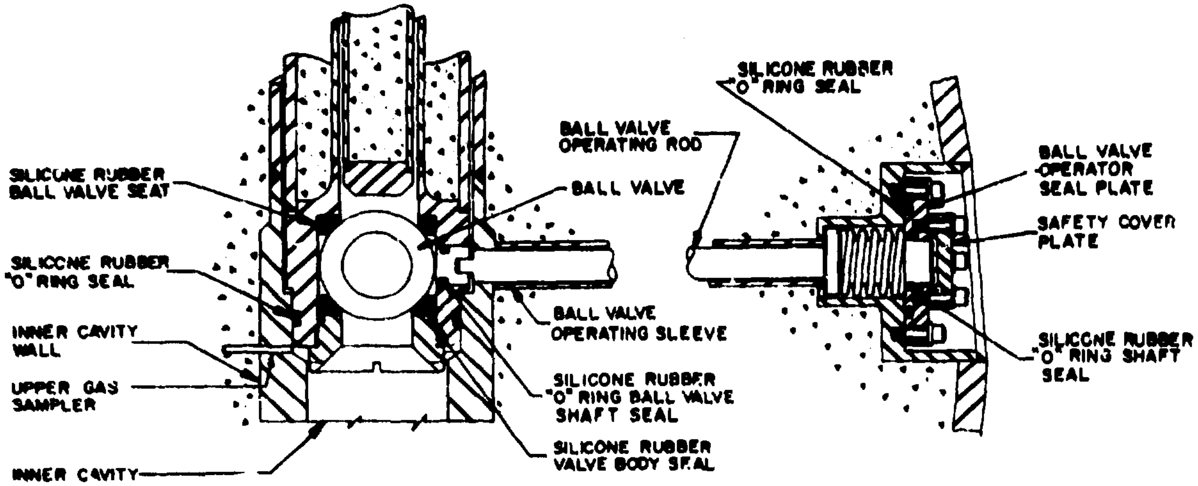


Fig. 1.1. TRU Californium Shipping Container.



TOP CLOSURE



BALL VALVE BALL VALVE OPERATOR

Fig. 1.2. Ball-valve upper closure for loading single-specimen shipment, showing plug and seal arrangement.

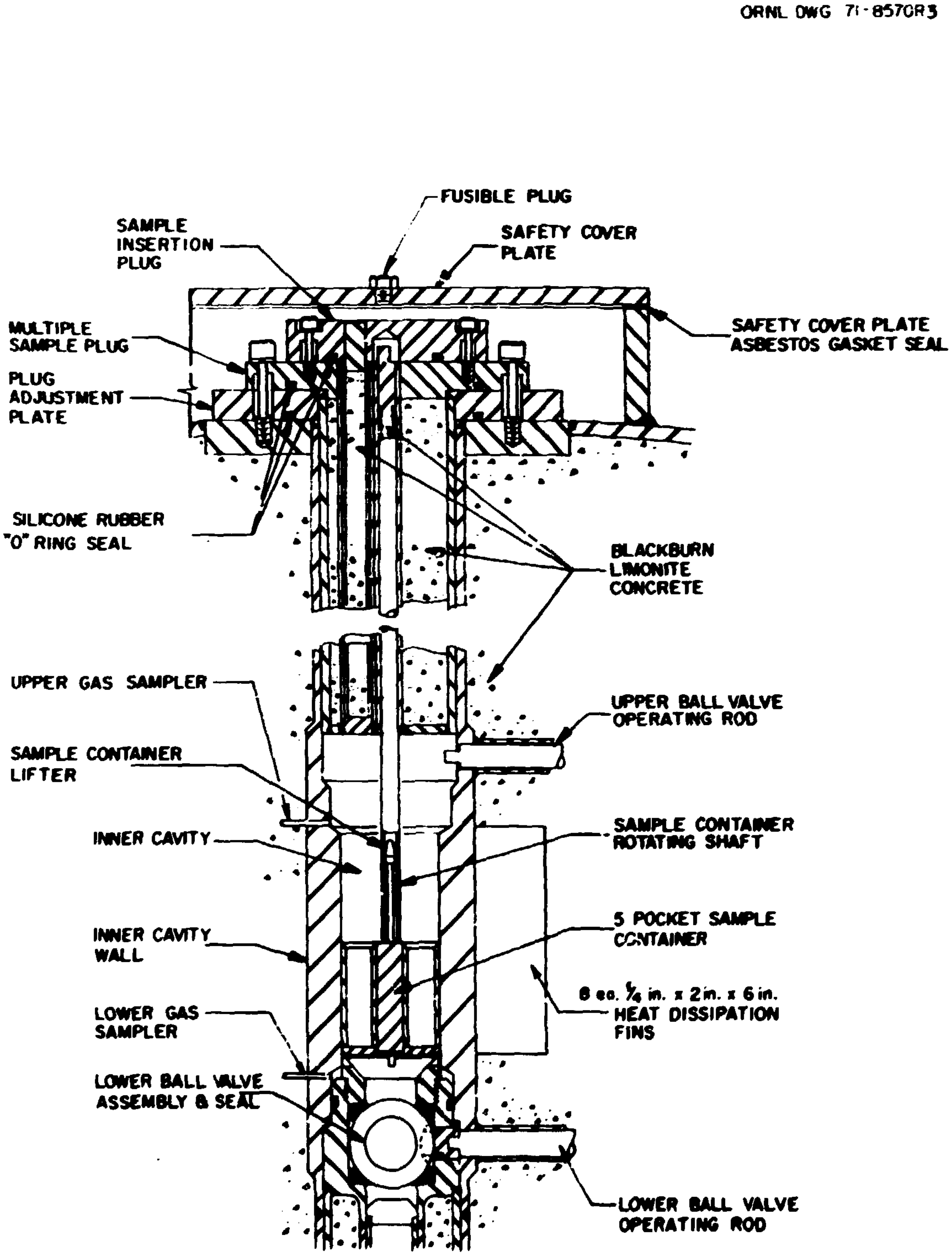


Fig. 1.3. Plug and sample container to permit multiple-specimen shipment (maximum, five specimens), showing plug and seal arrangement.

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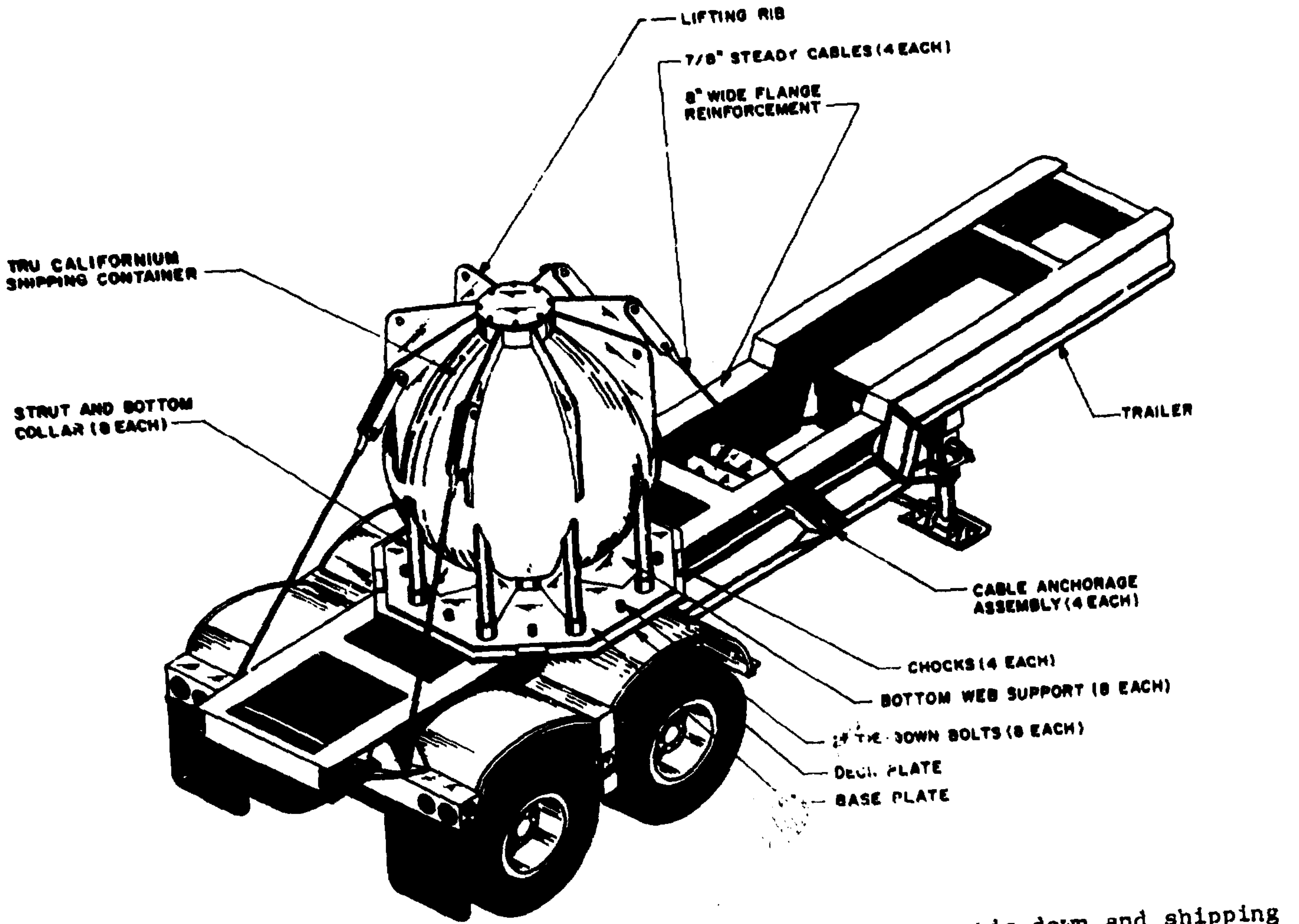

Fig. 1.4. TRU Californium Shipping Container tie-down and shipping assembly.

2.1 Mechanical Properties of Materials

The mechanical properties of 304L stainless steel and limonite concrete are summarized in Table 2.1.

2.2 General Standards for All Packages

The general standards for all packages include an evaluation of the following: (1) the chemical and galvanic reactions between the materials of construction and the intended package contents; (2) the method used for closure; (3) the cask-lifting devices, (4) the lid-lifting devices; and (5) the and tie-down devices used in securing the package to the trailer.

2.2.1 *Reactions between materials of construction and package contents*

The container is constructed, as shown in the as-built drawing (see Fig. 1.1 and Sect. 9.1), of type 304L stainless steel and limonite concrete. No evidence of any significant chemical, galvanic, or other reaction between these materials has been noted; additionally, past experience has not revealed any indication of reactions between these materials of construction and the intended package contents. Even if the contents were shipped in the chloride or oxysulfate form, they would be welded into a primary container capable of withstanding the action of these salts and thus would present no reaction problem to the cask materials.

2.2.2 *Closure*

The cask is equipped with a positive closure consisting of two cover plates, one on the top and one on the bottom, held in place with twelve 1 2-in.-diam bolts. The bolts on the top plate are seal wired in place to indicate tampering with or opening of the cask; the bottom plate is inaccessible in transit.

2.2.3 *Cask-lifting device*

The regulations require that if there is a system of tie-down devices which is a structural part of the package, this system must be capable of withstanding a static force applied to the center of gravity of the package with (1) a vertical component of two times the weight ($2\underline{W}$) of the package and its contents, (2) a horizontal component along the direction of travel of ten times the weight ($10\underline{W}$) of the package and its contents, and (3) a horizontal component in the transverse direction of five times the weight ($5\underline{W}$) of the package and its contents. This applied load shall not generate stresses in any material of the package in excess of the yield strength of that material. In addition, any tie-down device that is a structural part of the package must be designed so that failure of the device under excessive load will not impair the ability of the package to meet other requirements of the regulations.

Table 2.1. Mechanical properties of 304L stainless steel and limonite concrete

Properties	Symbol	Stainless steel 304L	Limonite concrete
	Static properties		
Tensile yield stress, psi	σ_y	30×10^{3}[a]	
Allowable shear stress, psi	τ_a	15×10^{3}[b]	
Ultimate shear strength, psi	τ_u	61,000[a]	
Young's modulus, psi	E	30×10^{6}[a]	
Poisson's ratio	ν	0.3[a]	
Weight density, lb/in.^{3}	γ	0.29[c]	0.101[d]
Thermal expansion coefficient, per °F	α	9.6×10^{-6}	
	Dynamic properties		
Specific energy, in.-lb/in.^{3}	S min	10×10^{4}	
	S max	26×10^{4}	
Yield stress, psi	σ_s	61.2×10^{3}[e]	

[a] International Nickel Company, Inc., *Mechanical and Physical Properties of Austenitic Chromium-Nickel Stainless Steel at Ambient Temperatures*, 1963.

[b] 50% of tensile yield stress.

[c] L. B. Shappert, Cask Designers Guide, ORNL NSIC-68, February 1970.

[d] B. B. Klima and L. B. Shappert, *The TRU Ten-Ton Californium Shipping Container*, ORNL-TM-3505 (Nov. 1971).

[e] Based on minimum ratio of yield/ultimate values for bolts as indicated in Table 5.1 and on minimum tensile strength of 95,000 psi (p. 55) given in D. D. Cannon's *Structural Analysis of Shipping Casks, Vol. 12, Energy Absorption Characteristics of Stainless Steel Bolts Under Impact Loading*, ORNL-1312, Vol. 12 (May 1972).

The Californium Shipping Container is designed to be lifted by holes in any two of eight lifting ribs that are symmetrically spaced around the cask. Both the ribs and the cask body are fabricated from 304L stainless steel. The lifting rib is analyzed in two ways: (1) to determine whether the stresses around the lifting hole are below the tensile yield stress (or the shear yield stress of 304L stainless steel), and (2) to determine the adequacy of the weld between the rib and cask body.

Stress around the lifting hole. Typically, the cask is lifted by two of the lifting ribs. However, it is feasible to lift the cask using one of the lifting ribs; thus it will be determined whether stresses above yield are produced for one rib supporting three times the cask weight. The rib is shown in Fig. 2.1. The rib at the lifting hole is assumed to be a curved beam with fixed ends spanning the diameter of the hole. Stresses in the curved beam can be found by calculating the stresses in a straight beam with identical fixity and loads and adjusting the stresses to account for the hyperbolic distribution of strain across a curved beam.

The maximum moment on the beam occurs when the load is centrally located. The load is assumed to act on a single line across the minimum thickness of the rib. The maximum moment produced by the load $3\underline{W}$ (three times the weight of the cask) is

$$M = \frac{3WL}{8} = \frac{3W 4\text{ in.})}{8} = 1.5\,W\text{ in.-lb.} \tag{1}$$

according to example 1d from Table 3 in Roark and Young.[7]

The maximum stress in the straight beam is $\sigma_{max} = Mc\ I$. The cross section of the beam under consideration is shown in Fig. 2.2.

For convenience, the cross section is represented by a rectangle with equal area.

The depth of the rectangle, d, is expressed as

$$d = 3 \quad 2[1/2(.25)^2] = 2.9375\text{ in.} \tag{2}$$

The moment of inertia, I, of this representative cross section is

$$I = bd\,3/12 \tag{3}$$

$$= 1/12(1)(2.9375)^3 = 2.11\text{ in.}^4.$$

Maximum stress on the convex side of the straight beam is expressed by

$$\sigma = \frac{1.5\,W(2.9375/2)}{2.11} = 1.04\,W, \tag{4}$$

and on the concave side the minimum stress is

$$\sigma = 1.04\,\underline{W}. \tag{5}$$

Stress amplification factors are taken from Example 1, Table 16 in Roark and Young.[8] By definition,

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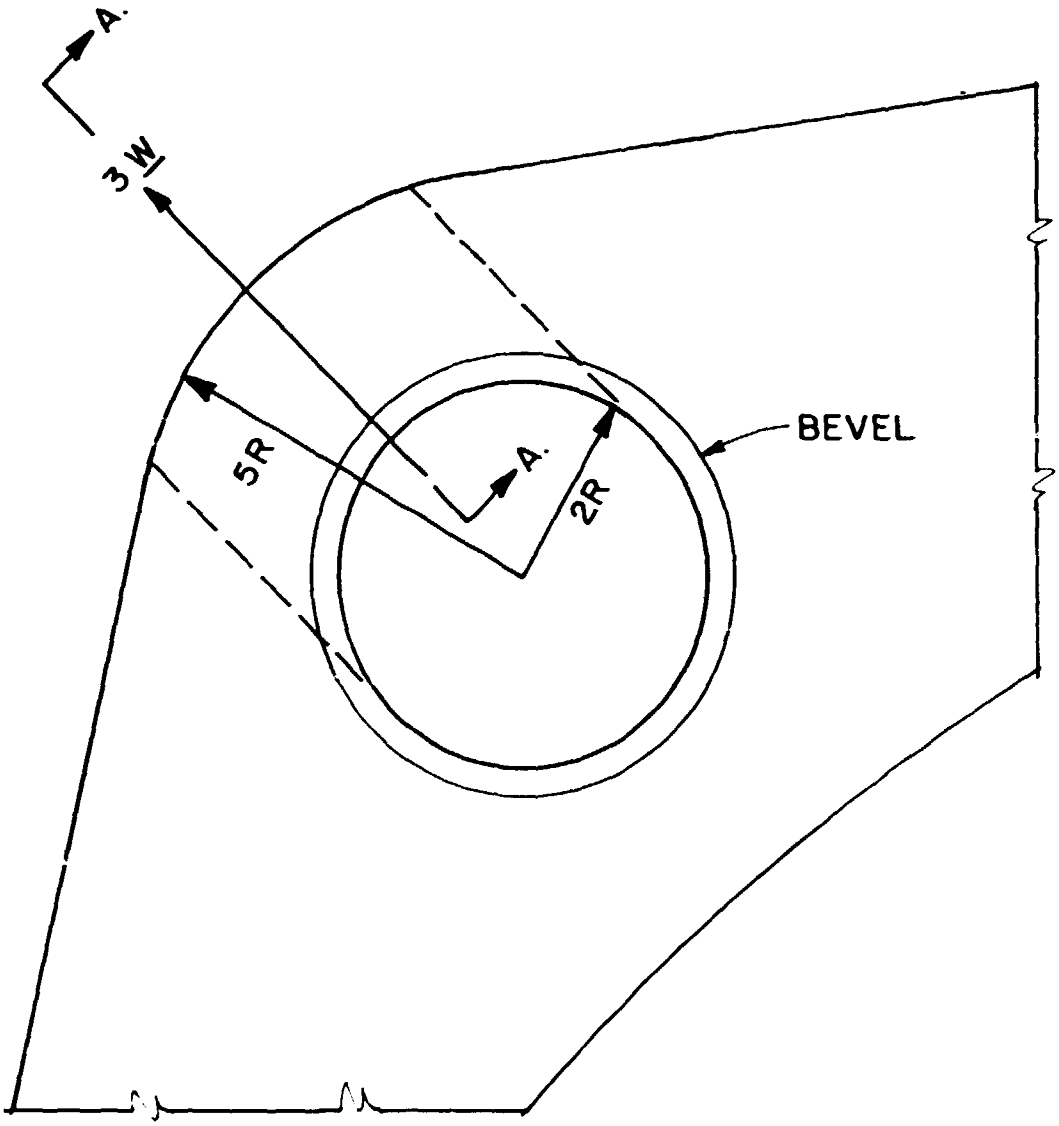

Fig. 2.1. Lifting lug eye.

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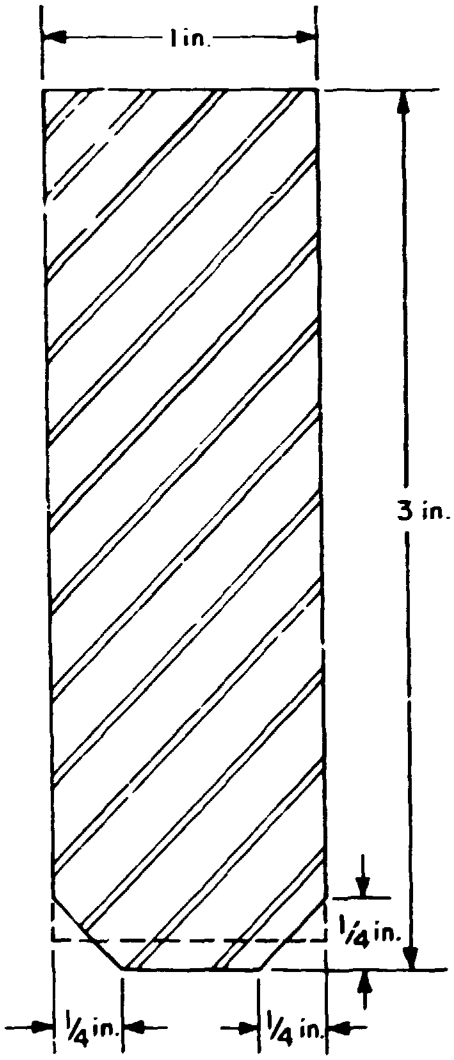

Fig. 2.2. Lifting lug cross section A.-A. of hole.

$\sigma_i = k_i\sigma$,

$\sigma_o = k_o\sigma$,

where

σ_i = actual stress on extreme fiber (concave side),

σ_o = actual stress on extreme fiber (convex side),

σ = ficticious stress on comparable fiber of straight beam;

also,

$$k_i = \frac{1}{3h/c}\,\frac{1 - h/c}{R/c - 1}\ , \tag{6}$$

$$k_o = \frac{1}{3h/c}\,\frac{1 + h/c}{R/c + 1}\ , \tag{7}$$

where

$$h/c = R/c - \frac{2}{\ln\left(\dfrac{R/c + 1}{R/c - 1}\right)}\ . \tag{8}$$

We have

$$R/c = \frac{2.0625 + \dfrac{2.9375}{2}}{2.9375/2} = 2.40\ , \tag{9}$$

$$h/c = (2.40) - \frac{2}{\ln\left(\dfrac{2.40 + 1}{2.40 - 1}\right)} = 0.15\ , \tag{10}$$

$$k_i = \frac{1}{3(0.15)}\,\frac{1 - 0.15}{2.40 - 1} = 1.39\ , \tag{11}$$

$$k_o = 1/3(0.15)\,\frac{1 + 0.15}{2.40 + 1} = 0.77\ . \tag{12}$$

Stresses at the extreme fibers of the curved beam are

$$\sigma_i = k_i \sigma . \tag{13}$$

where

$$\sigma_i = 1.39(-1.04\ \underline{W}) = 1.39(-1.04)(23,500) = -34,000 \text{ psi.}$$

$$\sigma_o = 0.77(1.04\ \underline{W}) = 0.77(1.04)(23,500) = 18,800 \text{ psi.}$$

The maximum shear in a curved beam is a function of the cross-sectional geometry and the initial curvature. Equation (5.13) from Oden[9] was used to determine shear stress in the lug eye. The equation was programmed for a Hewlett-Packard 97 calculator, and the shear stress was calculated at various points across the cross section. The location of the maximum shear stress was found to within ± 0.025 in. At that point, the shear stress had the value

$$\tau = 0.57\ V . \tag{14}$$

where

$$V = 3\underline{W}/2.$$

Substituting, we have

$$\tau_{max} = 0.57\ \frac{3W}{2} = 0.57(3/2)(23,500) = 20,100 \text{ psi.} \tag{15}$$

The results of this analysis indicate that if one lifting lug is used to support three times the weight of the the cask, localized yielding occurs. This loading case is a severe one for the lug since the load passes through the area of the web with least width. If the cask is lifted with two or more lugs with a standard sling or a sling with spreader bar (which is the normal method of lifting the cask), the stresses in each lug will be reduced to less than half of the stresses calculated for lifting by one lug. Yielding will not occur if two or more lugs are used to lift three times the weight of the cask.

Analysis of the weld between the lifting lug and cask. Stresses in the weld between the lifting lug and the outside shell of the cask are checked for the hypothetical case of lifting three times the weight of the cask with one lug. For convenience the weld is projected onto the chord of the cask as shown in Fig. 2.3. The coordinates of the end points of the chord and of the center of the lifting eye relative to the coordinate system shown are given on the figure.

Depending on the orientation of the lifting force, $3\underline{W}$, differing amounts of shear and normal force in the weld are produced. Assuming that the force is parallel to the chord shown

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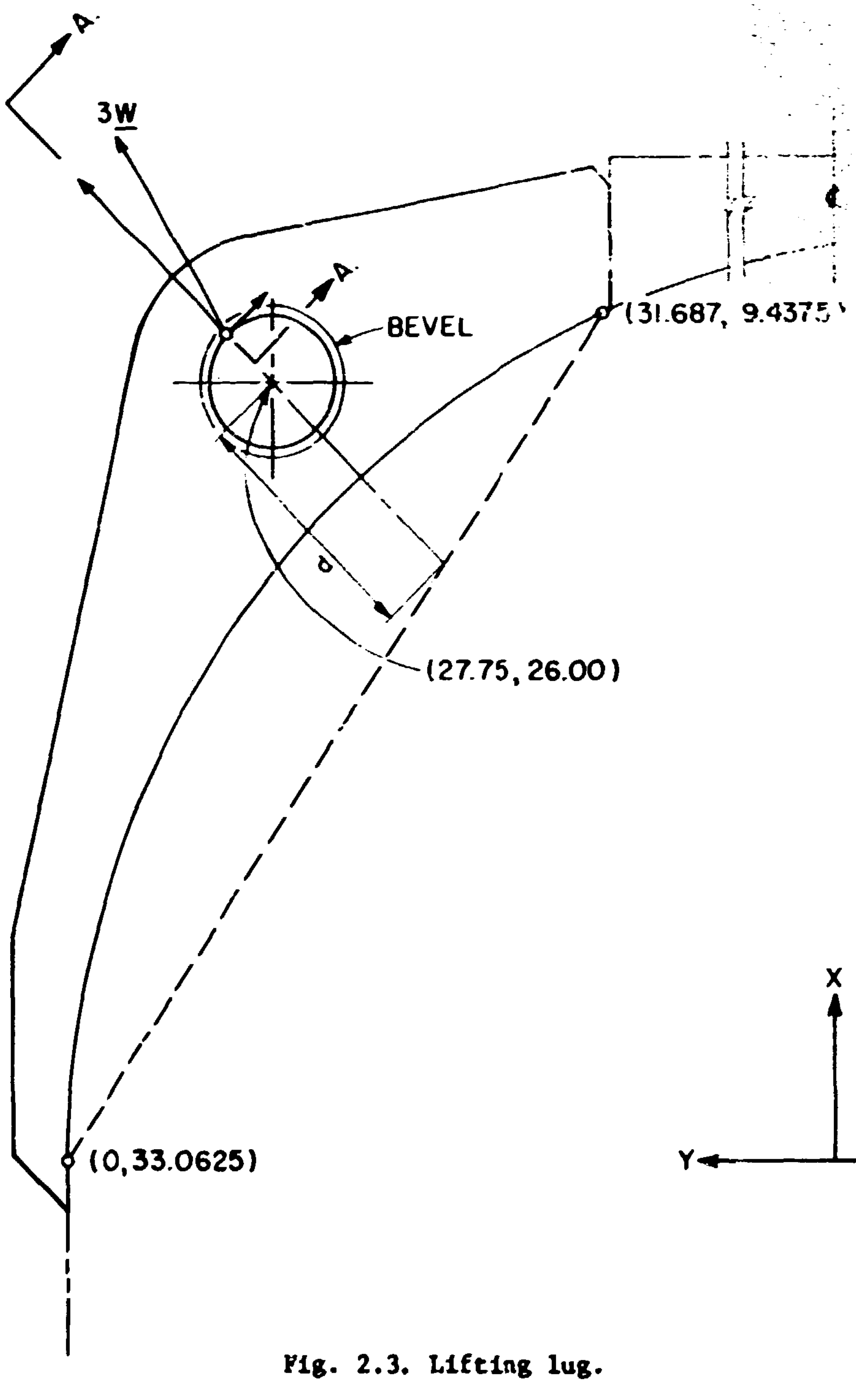

Fig. 2.3. Lifting lug.

in Fig. 2.3. mostly shear is produced. If the shear is assumed to be uniformly distributed over the projected area, the shear at any point is

$$\tau = \frac{3W}{A} = \frac{3(23{,}500)\text{ lb.}}{2(3/8)(\cos 45^\circ)\ [31.687 - 0)^2 + (9.4375 - 33.0625)^2]^{\frac{1}{2}}}\,. \tag{16}$$

$$= 3360 \text{ psi.}$$

where the nominal size of the fillet weld on each side of the lug is 3/8 in., and the throat of the weld lies on a plane inclined 45° to the lug. A moment is also produced with the magnitude of 3W times the distance (d) to the chord from essentially the center of the lifting hole.

Assuming that the weld acts as the fixed end of a cantilever beam, the stresses in the extreme fibers are

$$\sigma = \pm\frac{Mc}{I} = \frac{3W(10.92 \text{ in.})1/2}{2(1/12)(3/8)\cos 45^\circ[(31.687)^2 + (9.4375 - 33.0625)^2]}\,. \tag{17}$$

$$= \pm\, 0.24\ W = \pm\, 0.24\,(23{,}500) = \pm\, 5640 \text{ psi.}$$

where

d = 10.92.

If the load is oriented normal to the chord, shear is not produced directly, but a moment is still produced about the centroid of the weld area projected onto the chord. The moment arm is the distance from the midpoint of the chord to the line of action of the force. This distance is

$$M = [(27.75 - 0)^2 + (26.00 - 33.0625)^2 - (10.92)^2]^{1/2} \tag{18}$$

$$- 1/2\sqrt{(31{,}687 - 0)^2 + (0.4375 - 33.0625)^2}$$

$$= 6.71 \text{ in.}$$

Stress in the extreme fiber, with the cantilever beam analogy, now is

$$\sigma = \frac{3W}{A} + \frac{3W(6.71)c}{I} \tag{19}$$

or, in particular

$$\sigma = \frac{3W}{2(3/8)(\cos 45^\circ)\left[(31.687 - 0)^2 + (9.4375 - 33.0625)^2\right]^{1/2}} + \frac{3W(6.71\text{ in.})/2}{2(1/12)(3/8)\cos 45^\circ\left[(31.687 - 0)^2 + (9.4375 - 33.0625)^2\right]} \tag{20}$$

$$= 0.289\,W = 0.289(23{,}500) = 6790\text{ psi.}$$

To cover cases between the two extremes, the absolute values of the stresses are summed. The maximum shear stress in the weld is

$$\tau_{\max} = \left[\left(\frac{6790 + 5640}{2}\right)^2 + (3360)^2\right]^{1/2} \tag{21}$$

$$= 7070\text{ psi.}$$

Since this is well below the allowable shear stress of 14,000 psi, the weld is clearly adequate to support 3 times the weight of the cask.

2.2.4 *Tie-down device*

The primary tie-down for the ten-ton TRU shipping cask is a set of eight bolts evenly spaced on a 56-in.-diam circle. The bolts pass through the octahedral base plate of the cask and are threaded into a plate fastened to the bed of a trailer. Cables also connect the lifting flanges near the top of the cask to the trailer and serve to steady the cask while in transit.

The tie-down devices are required to be capable of withstanding a static force applied to the center of gravity of the package with (1) a vertical component of two times the weight of the package plus its contents, (2) a horizontal component along the direction of travel of ten times the weight of the package plus its contents, and (3) a horizontal component in the transverse direction of five times the weight of the package and its contents. The applied load is not allowed to generate stresses in any material of the package in excess of the yield strength of that material. Also, any tie-down device that is a structural part of the package must be designed so that failure of the device will not impair the ability of the package to meet other requirements of the regulation.

Analysis. The properties of the materials are listed in Table 2.1.

No credit is given to the tie-down cables to resist the hypothetical set of forces. Figure 2.4 shows the forces that will be considered in an analysis of the bolts. The vertical ($2\underline{W}$) force produces no moment in the bolt pattern, and it will be considered separately from the two horizontal forces, but the effects of all the forces will be combined later. The horizontal forces can be summed vectorally to produce a single resultant horizontal force, P. We have

$$P = (F_x^2 + F_y^2)^{1/2} = [(10\underline{W})^2 + (5\underline{W})^2]^{1/2} \; . \tag{22}$$

$$= 11.2\,\underline{W}.$$

The center of mass of the cask is ~42 in. (d) above the bottom of the base plate, and so the horizontal resultant produces a moment, M, about the base of the cask with

$$M = dP. \tag{23}$$

$$= (42 \text{ in.})\,(11.2\,\underline{W}) = 470\,\underline{W}.$$

The bolts are assumed to be just snug and with no tensile preload. The moment of the horizontal forces is resisted by the eight, 2-in. bolts in tension and by some part of the contact area of the base plate. The contact area is composed of eight circuclar pads, each 5 in. in diameter and spaced at the points of the octahedron on a 63-1/8-in.-diam circle.

Figure 2.5 shows the cross section of the base of the cask. It is assumed that the distribution of internal forces in the bolts and base plate generated by the applied moment is identical to that at a beam cross section. It follows that vertical strain at the base plate is a linear function of the distance from the neutral axis across the cross section. Figure 2.5 also shows the variation of tensile load in the bolts and the change in compressive stress in the base plate.

For the case of no applied vertical load, the vertical internal forces in the bolts must be in equilibrium with the resultant force of the stresses in the plate. The location of the neutral axis can be determined from an expression of this equilibrium. To ease computations, the circular contact pads on the bottom of the base plate are conceptually replaced by square pads of equal area. Preliminary iterative calculations using data from Table 2.2, progressively increasing the number of pads in contact per trial over the total area of the pads, indicated that two pads would be in contact, and one more would be partially in contact. The first two bolts are in the compressive strain area and so are not effective. The final quotation for the location of the neutral axis is

$$A_b \sum_{i=3}^{8} (b_i - a) = A_p \sum_{i=1}^{2} (a - y_i) + \left(\frac{A_p}{2}\right)^{1/2} \left[a - \left(15.49 - \left(\frac{A_p}{2}\right)^{1/2}\right)\right]^2 \; . \tag{24}$$

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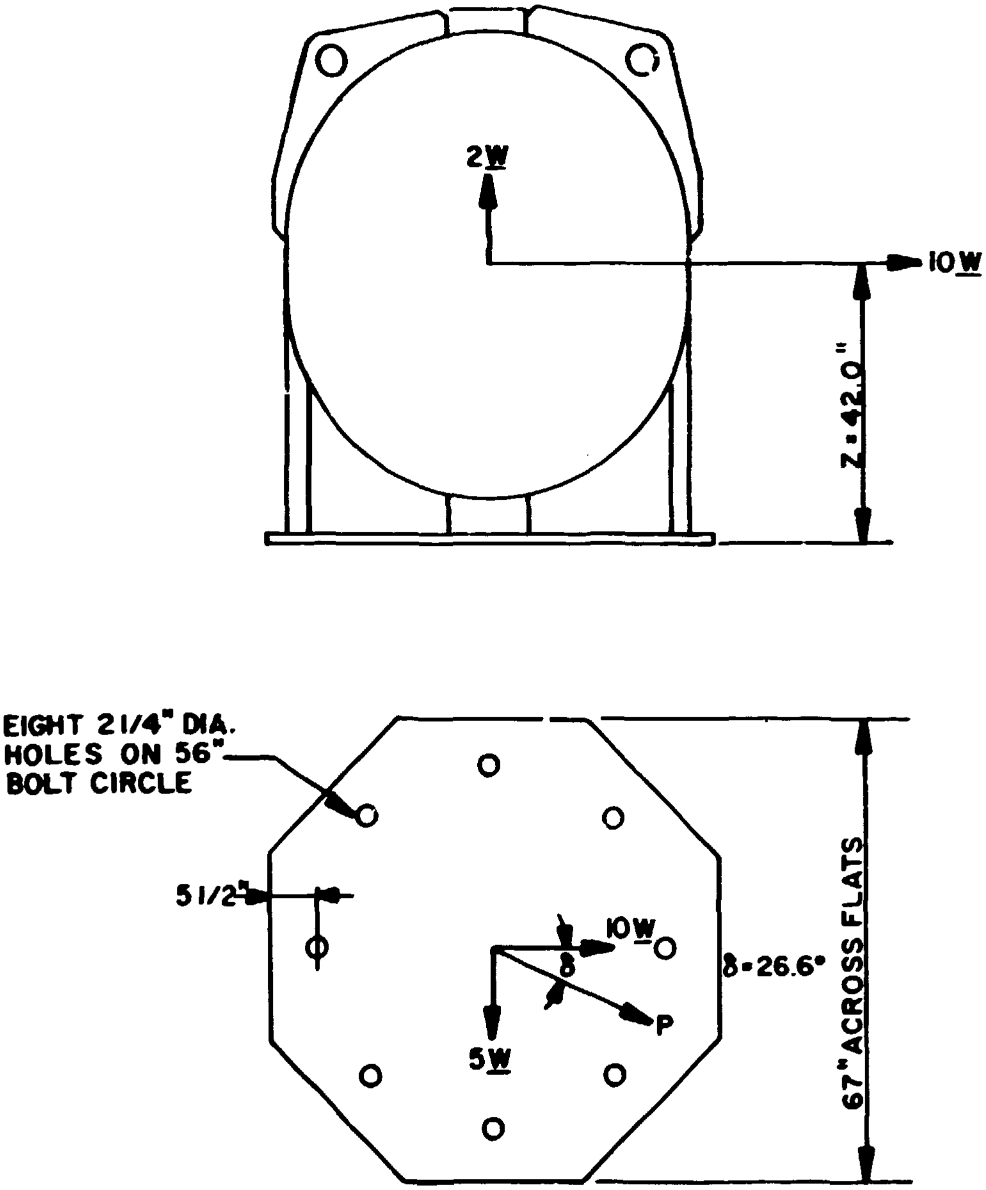

Fig. 2.4. Analysis of the forces imposed on the tie-down bolts.

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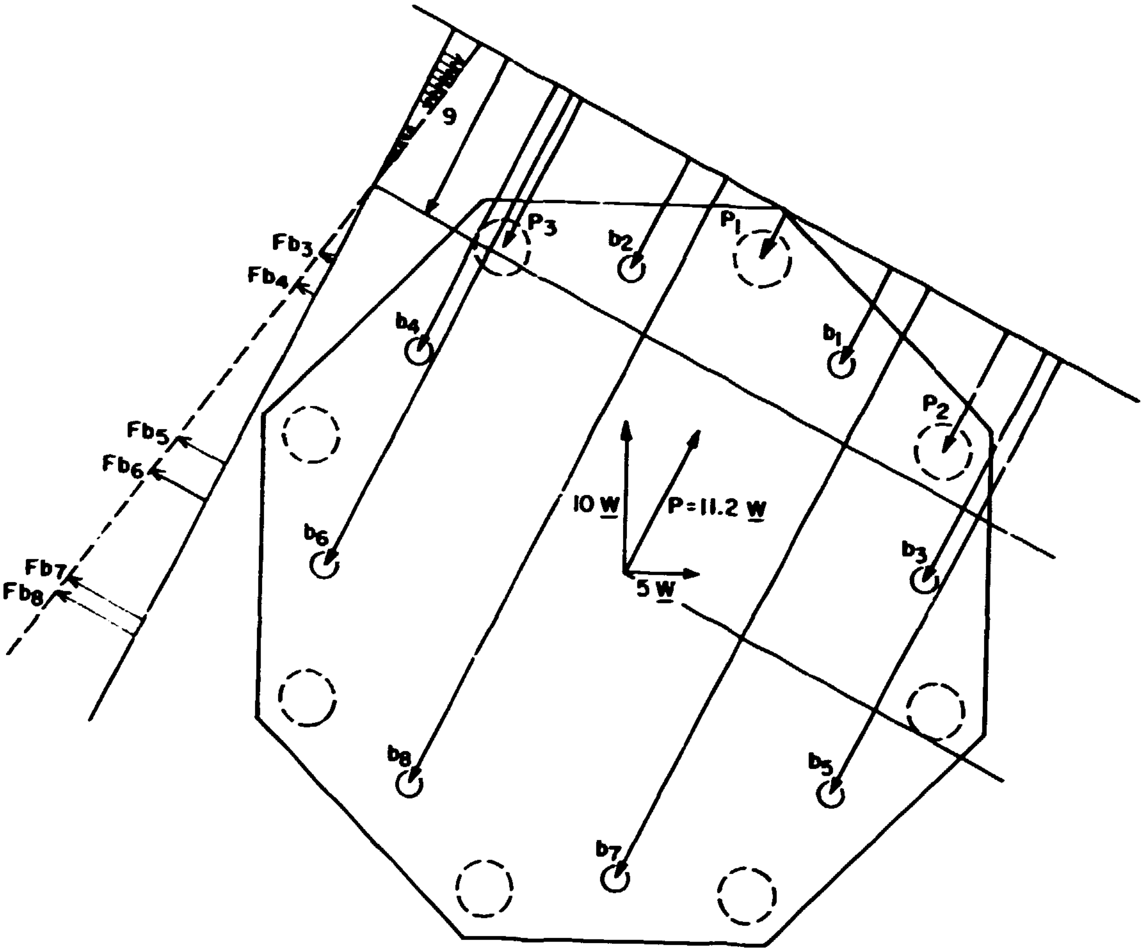

Fig. 2.5. Cask tie-down system.

Table 2.2. Distances of the bolts and three pads from the extreme part of the base measured parallel to the resultant force

---

$$b_1 = 36.17 - 28.00 \cos (45^\circ - 26.57^\circ) = 9.61 \text{ in.}$$

$$b_2 = 36.17 - 28.00 \cos (0^\circ + 26.57^\circ) = 11.12$$

$$b_3 = 36.17 - 28.00 \cos (90^\circ - 26.57^\circ) = 23.65$$

$$b_4 = 36.17 - 28.00 \cos (45^\circ + 26.57^\circ) = 27.31$$

$$b_5 = 36.17 - 28.00 \cos (135^\circ - 26.57^\circ) = 45.02$$

$$b_6 = 36.17 - 28.00 \cos (90^\circ + 26.57^\circ) = 48.69$$

$$b_7 = 36.17 - 28.00 \cos (180^\circ - 26.57^\circ) = 61.21$$

$$b_8 = 36.17 - 28.00 \cos (135^\circ + 26.57^\circ) = 62.73$$

$$P_1 = 36.17 - 31.56 \cos (26.57^\circ - 22.5^\circ) = 4.69 \pm 2.50$$

$$P_2 = 36.17 - 31.56 \cos (67.5^\circ - 26.57^\circ) = 12.33 \pm 2.50$$

$$P_3 = 36.17 - 31.56 \cos (26.57^\circ + 22.5^\circ) = 15.49 \pm 2.50$$

$$P_4 = 36.17 - 31.56 \cos (112.50^\circ - 26.57^\circ) = 33.93 \pm 2.50$$

---

where

A_b = the bolt area (2.30 in.^{2}),

a = the distance from the extreme point of the octagonal base to the neutral axis,

b_i = the distance of the i^{th} bolt from the extreme point,

p_i = the distance of the i^{th} pad from the extreme point, and

A_p = the area of each pad. (A_p = 19.63 in.^{2}).

From this, we get a = 17.24 in. From the analogy with a beam, and using data from Table 2, the moment of inertia about the neutral axis of the effective cross section can be calculated.

The moment of inertia, assuming uniform stress across each bolt, is

$$I = \sum_{i=3}^{8} A_b (b_i - a)^2 + 2\left[\frac{\pi}{4}(2.5)^4\right] + \sum_{i=1}^{2} A_p (a - p_i)^2 \tag{25}$$

$$+ \frac{(2.5)^4}{4}\left[\alpha - \sin\alpha\cos\alpha + 2\sin^3\alpha\cos\alpha - \frac{16\sin^6\alpha}{9(\alpha - \sin\alpha\cos\alpha)}\right] ,$$

$$= 17{,}200 \text{ in.}^4 ,$$

where

$\alpha = \pi/2 - \arcsin[(15.49 - a)/2.5]$

a = 17.24 in.

The vertical stress in the extreme bolt due to bending is

$$\sigma_B = \frac{Mc}{I} = \frac{M}{I}(b_8 - a) = \frac{470.4\,W\,(62.73\text{ in.} - 17.24\text{ in.})}{17{,}200} , \tag{26}$$

$$= 1.24\,W\text{in.}^2 ,$$

$$= (1.24)(23{,}500\text{ lb}) = 29{,}200\text{ psi.}$$

The two horizontal loads also produce a shear across the bolts. It is assumed that the shear taken by each bolt is equal and uniform across the cross section. Then, the shear stress in any bolt is

$$\tau = \frac{11.2\ \underline{W}}{8A_b} = \frac{11.2\ (23{,}500\ \text{lb})}{8\ (2.30\ \text{in.}^2)} = 14{,}300\ \text{psi}\,. \qquad (27)$$

The vertical force of 2$\underline{W}$ produces an axial stress in the bolts. If the incremental load of this force is shared equally by all of the bolts, then the additional vertical stress is

$$\sigma_A = \frac{2\underline{W}}{8A_b} = \frac{2(23{,}500\ \text{lb.})}{8(2.30\ \text{in.}^2)} = 2{,}600\ \text{psi}. \qquad (28)$$

The combined effect of the three stresses on the most stressed bolt is compared to the yield strength of the bolt using the maximum shear stress theory of failure. The maximum shear stress is found with a Mohr's circle analysis, noting that stresses normal to the vertical stress are all zero. The principal stresses are

$$0,\ \text{and}\ \frac{(29{,}000 + 2{,}600)}{2} \pm \left\{ \left(\frac{29{,}200 + 2{,}600}{2}\right)^2 + \left[14{,}300\right]^2 \right\}^{1/2} \qquad (29)$$

or

$\sigma_1 = 37{,}300$ psi,

$\sigma_2 = 0$ psi,

$\sigma_3 = -5{,}500$ psi.

The maximum shear stress in this case is

$$\tau_{MAX}\ \frac{\sigma_1 - \sigma_3}{2} = 21{,}400\ \text{psi}\,. \qquad (30)$$

The specification of bolting material on UCC-ND Drawing No. M11230-EN-014-D requires only steel. This is insufficient to prevent yielding. Therefore, Grade 5 bolts with a yield strength of at least 80 ksi will be used to fasten the cask to the trailer. The tie-down procedure will limit the torque on these bolts to 230 ft.-lbs.

Analysis of welds between struts and strut collars. Four inches above the base plate top, support struts of nominal 2 1/2-in. pipe are welded to the strut collar that is attached to the base plate. Since welds at this level circumscribe the 2 1/2-in. pipe, they provide less area than welds between the 3-in. strut collar and the base plate. Further, the 3-in. pipe has a wall thickness of 0.216 in., which reduces the effective weld thickness from the specified nominal 1/4-in.

The cross section of the cask supports 4 in. above the base plate passes through the web of the gusset plates and the inner collar, thus the full thicknesses of these components are effective. The moment of inertia of the section about a centroidal axis is the same in all directions and has the value

$$\begin{aligned} I &= 8(\pi/4)[1.438 + 0.216 \cos 45^\circ)^4 - (1.438)^4 - (1.438)^4] \\ &\quad + \pi[(1.438 + 0.216 \cos 45^\circ)^2 - (1.438)^2] \\ &\quad \times [2(31.563)^2 + 4(31.563 \cos 67.5^\circ)^2] \\ &\quad + \pi/4\,[(10.75)^4 - (10.25)^4] \\ &\quad + 8/2(1/2)(1/3)\,[(29.125)^3 - (10.75)^3] \\ &= 21{,}200 \text{ in.}^4 . \end{aligned} \tag{31}$$

The moment produced by the resultant force at this section is

$$M = (36 \text{ in.})\ 11.2\ \underline{W} \text{ lb} = 403.2\ \underline{W} \text{ in.-lb.} \tag{32}$$

Stress at the extreme fiber of the weld due to this moment is

$$\begin{aligned} \sigma_B &= \frac{Mc}{I} = \frac{403.2\ \underline{W} \text{ in.-lb}}{21{,}200 \text{ in.}^4}[(31.563 + 1.438 + 0.25 \cos 45^\circ) \cos (26.57^\circ - 22.5^\circ)] \ , \\ &= 0.63\ W = 0.63(23{,}500) = 14{,}800 \text{ psi.} \end{aligned} \tag{33}$$

The area of the cross section 4 in. above the base plate is

$$\begin{aligned} A &= 8\pi[(1.438 + 0.216 \cos 45^\circ)^2 - (1.438)^2] + \pi[(10.75)^2 - (10.25)^2] \\ &\quad + 8(1/2)(29.125 - 10.75) = 118.1 \text{ in.}^2 . \end{aligned} \tag{34}$$

The axial stress in the section due to the vertical force, averaged over the area of the section, is

$$\sigma_A = \frac{2\underline{W}}{A} = \frac{2(23{,}500)\ \text{lb.}}{118.1\ \text{in.}^2} = 400\ \text{psi.} \tag{35}$$

The total axial stress at the extreme fiber of the weld is

$$\sigma = 15{,}200\ \text{psi}, \tag{36}$$

which is well within the allowable value of 28,000 psi. Additionally, this cross section is not critical for shear since the shear area here is larger than at the base plate.

Analysis of welds between support struts, gussets, and collar and base plate. The welded connections between the cask and the base plate are analyzed under the same loads applied to the bolts. The resultant of the two horizontal forces is 11.2 $\underline{W}$, where $\underline{W}$ is the weight of the cask. This force acts about 40 in. above the top of the base plate and produces a moment at the top of the base plate of

$$M = 11.2\ \underline{W}\ (40\ \text{in.}) = 448.0\ \underline{W}\ \text{in.-lb.}$$

The welds resisting this moment are: (1) eight 1/4-in. fillet welds around the outer circumference of nominally 3-in. pipe, (2) eight pairs of 3/16-in. fillet welds along 1/2-in. thick gusset plate, and (3) a full-penetration double-bevel weld flanked by 3/16-in. fillets on each side around a 1/2-in. thick collar ring with a mean radius of 10.5 in. The pipe supports are located on a 63-1/8-in.-diam circle; the gusset plate welds run from the collar outward to 5 in. short of the pipe support. A view of the welds from above the base plate is shown in Fig. 2.1.

The vertical stresses due to the horizontal forces in these welds are assumed to be distributed like those at a cross section of a beam loaded by an end moment. The moment of inertia of the weld material about an axis through the centroid of the cross section is independent of the orientation of the centroidal axis since the welds are uniformly spaced in circular patterns. For convenience, an axis, y-y in Fig. 2.6, through two of the struts is chosen. Also, the moment of inertia of the gusset plate welds is calculated from the equation $I = J/2$ where I is a moment of inertia and J is the polar moment of inertia. The area used to represent an area of fillet welds is the area of the throat of the weld which in this case is cos 45° or 0.707 times the nominal thickness times length of the weld. The moment of inertia of the weld area at the top of the base plate is

$$\begin{aligned} I &= 8(\pi/4)[(1.75 + 0.25\cos 45^\circ)^4 - (1.75)^4] \\ &\quad + \pi[(1.75 + 0.25\cos 45^\circ)^2 - (1.75)^2] \\ &\quad \times [2(31.563)^2 + 4(31.563\cos 67.5^\circ)^2] \\ &\quad + \frac{\pi}{4}[(10.75)^4 - (10.25)^4] \\ &\quad + 16/2\,(3/16)\cos 45^\circ\,(1/3)\,[(25.125)^3 - (10.75)^3] \\ &= 12{,}300\ \text{in.}^4\ . \end{aligned} \tag{37}$$

The stress due to bending in the weld fiber at the most distant point from the neutral axis which is orthogonal to the resultant horizontal force is

$$\sigma_B = \frac{448.0\ \underline{W}\ \text{in.-lb.}}{12{,}300\ \text{in.}^4}\ [(31.563 + 1.75 + 0.25 \cos 45^\circ)] \qquad (38)$$

$$\times \cos(26.57^\circ - 22.5^\circ)$$

$$= 1.22\ \underline{W} = 1.22(23{,}500) = 28{,}600\ \text{psi.}$$

The vertical 2$\underline{W}$ force also produces a vertical stress in the welds at the base plate which is assumed to be uniformly distributed over the weld area. Total area of weld in that plane is

$$A = 8\pi[(1.75 + 0.25 \cos 45^\circ)^2 - (1.75)^2] \qquad (39)$$

$$+ \pi[(10.75)^2 - (10.25)^2]$$

$$+ 16(3/16)(\cos 45^\circ)(25.125 - 10.75) = 79.8\ \text{in.}^2.$$

Stress at any point in the weld, due to the vertical force, then is

$$\sigma_A = \frac{2W}{A} = \frac{2(23{,}500)}{79.8} = 590\ \text{psi.} \qquad (40)$$

The maximum vertical stress in the weld is the sum of the two vertical stresses and is

$$\sigma_{max} = 29{,}200\ \text{psi.} \qquad (41)$$

This stress is localized at the extreme fiber where shear stress is absent. The stress resulting from the hypothetical loading condition slightly exceeds the yield of 304L stainless steel (the 300 series stainless steel with the least yield strength).

The shear stress across the base plate welds due to the horizontal resultant is zero at the extreme fibers and so must be greater than average elsewhere. Shear stress is not a serious concern for steel without a thin web, but if is it assumed that the maximum shear is twice the average shear across the cross-sectional area, then

$$\tau_{max} = 2\left(\frac{V}{A}\right) 2\left(\frac{11.2\ \underline{W}}{79.8\ \text{in.}^2}\right) = 0.28\ \underline{W} \qquad (42)$$

$$= 0.28(23{,}500) = 6600\ \text{psi.}$$

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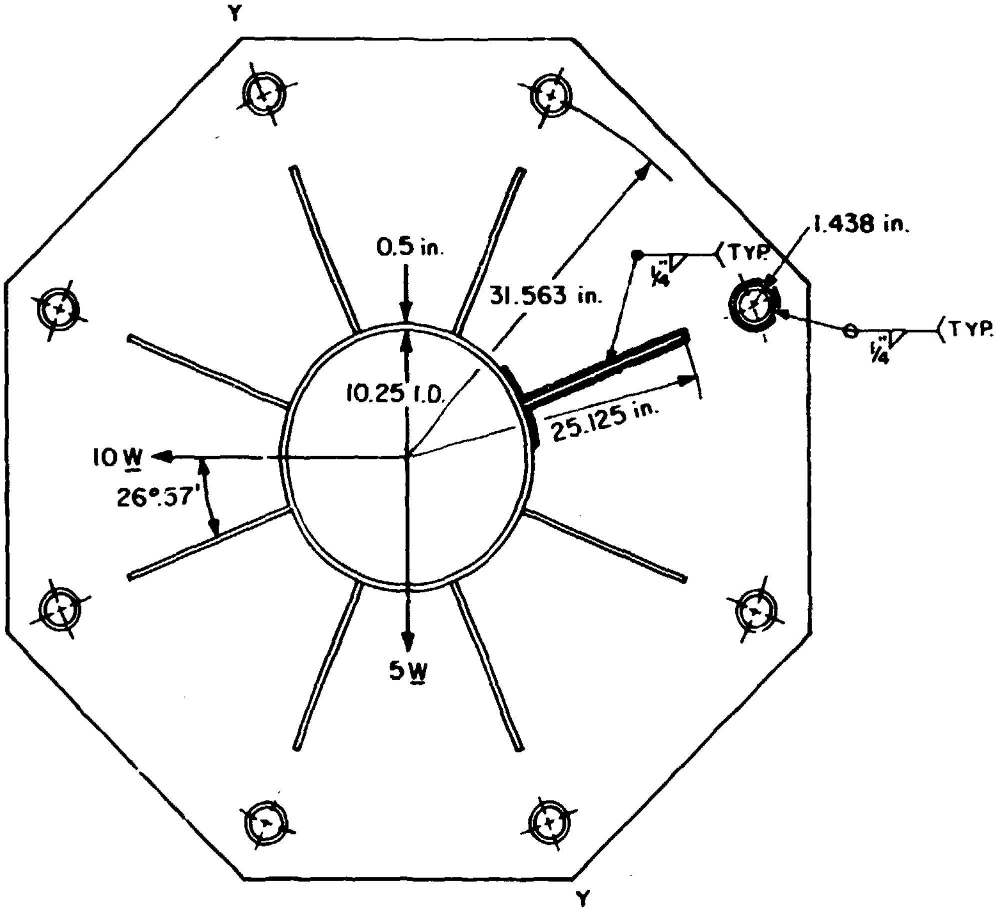

Fig. 2.6. Cross section of welds between support struts, gussets, and collar and base plate.

This value is well within the allowable value of 14,000 psi shown in Table 2.1, which indicates that the welds are adequate.

2.3 Standards for Type B and Large Quantity Packaging

The structural standards for large quantity packaging of the regulations cover load resistance of the packaging and the external pressure which the package must withstand. Compliance of the TRU Californium Shipping Container with these requirements is discussed in the following subsections.

2.3.1 *Load resistance*

When regarded as a simple beam supported at its ends along any major axis, the container must be capable of withstanding a static load, normal to and uniformly distributed along its length, that is equal to five times its fully loaded weight without generating stress in any material of the cask in excess of the yield strength of that material. The TRU Californium Shipping Container is almost spherical; therefore, this requirement is not applicable.

2.3.2 *External pressure*

The regulations require that the design of the shipping package be adequate to ensure that the containment vessel will suffer no loss of contents if subjected to an external pressure of 25 psig.

Spherical shell. The maximum external pressure that may be withstood by the 1/2-in.-thick stainless steel spherical shell, assuming no support from the reinforcing steel or from the concrete, may be calculated (Par. UG-28(d), ref. 11) as follows:

$$P_a = B/r_i/t_h = 10{,}000/32.5/0.5 = 154 \text{ psig}, \qquad (43)$$

where

P_a = allowable working pressure, psia,

B = factor, 10,000 (Fig. UNF-28.8, ref. 11),

r_i = inside radius of spherical shell, 32.5 in.,

t_h = thickness of spherical shell, 0.5 in.

The spherical shell of the cask is, therefore, sufficiently thick to withstand a 25-psi external pressure; however, in addition, the internal reinforced concrete shield completely eliminates the possibility that the shell will buckle under external pressure.

Top and bottom closure plates. The maximum external pressure (P) that may be withstood by the 1/2-in.-thick stainless steel flange closure above and below the access plugs may be calculated (Par. UG 34(c)(2), ref. 11) as follows:

$$P = St^2/cd^2 = 13.300\ (0.5)^2/0.25\ (16.75)^2 = 47 \text{ psig}, \qquad (44)$$

where

S = maximum allowable stress value, 13,300 psig, (Table UHA-23, ref. 11),

t = thickness of cover, 0.5 in.,

c = attachment factor, 0.25,

d = diameter of the bolt circle, 16.75 in.

The top and bottom closure flange is, therefore, sufficiently thick to withstand an external pressure of 25 psig.

All openings to the cask cavity are gasketed and are not expected to leak under an external pressure of 25 psig. Hence the regulations are met.

3. COMPLIANCE WITH STANDARDS FOR NORMAL CONDITIONS OF TRANSPORT

The regulations stipulate that a single package must be able to withstand the normal conditions of transport without substantially reducing the effectiveness of the package and without releasing radioactive material from the containment vessel. The contents of the container are limited such that the package will contain no gases or vapors that could reduce the effectiveness of the packaging. No circulating coolant other than atmospheric air is used, and no mechanical cooling device is required or provided. The TRU Californium Shipping Container and its inner containers are designed so that the contents will not be vented to the atmosphere under normal conditions of transport. These normal conditions include the effects of heat, cold, pressure, free drop, and penetration.

3.1 Heat

The cask must be so designed and constructed that if it were subjected to direct sunlight at an ambient temperature of 130°F in still air, its effectiveness would not be reduced. In addition, the temperature of the accessible external surfaces of the cask shall not exceed 122°F in the shade when fully loaded, assuming still air at ambient temperatures. If the cask is transported in a vehicle assigned for the sole use of the consignor, the maximum accessible external surface temperature shall be 180°F.

3.1.1 *Heat tests*

To evaluate the adequacy of the Californium cask under normal operating conditions, heat transfer tests were conducted both in the shade and in direct sunlight.

The cask was first placed in the crane bay of a building where the ambient temperature was controlled at 70°F. The temperature of the cask was measured with thermocouples and recorded over a four day period to ensure equilibrium conditions.

The results of these tests extrapolated to 100°F are presented in Table 3.1 It is apparent that should the ambient temperature reach 100°F in the shade, the maximum surface temperature should not be greater than about 10°F higher than this.

The cask was next placed outside on a bitumenous surface for a period of eight days in the middle of May. During the test, the weather was clear and mild with bright, sunny days. A thermocouple was attached to the top cupola and another was attached to the side of the cask 45 from the center line and midway between two of the external ribs.

In full sunlight with an ambient temperature of 130°F, the surface temperature should not exceed approximately 165°. The inclusion of a 5W heat source in the cavity of the cask would not be expected to raise these projected temperatures a measurable amount because of the large surface area over which this heat will be dispatched. Thus, the cask meets the conditions specified in Sect. 3.1.

Table 3.1. Cask temperatures

Location	Cask in shade °F	Cask in sun °F
Top of cask	107	162
Side of cask	110	160
Ambient	100	130

3.2 Cold

The shipping package must be able to withstand an ambient temperature of -40° F in still air and shade.

Taking T_1 = -40° F (420° R) and assuming no internal heat load, the final or maximum pressure (P_2) in any cavity sealed at a pressure of 14.7 psia and a temperature of 70° F (530° R) is

$$P_2 = (P_1T_2)/T_1 = 11.65 \text{ psia.} \tag{49}$$

The resulting pressure differential is less than the 25-psig differential pressure investigated in Sect. 2.3.2. A temperature of -40° F is within the operating temperature range of the seals and the stainless steel cladding, structural components, and fasteners. Brittle fracture of these components under the stipulated cold condition is unlikely because the temperatures of these components are above their ductile-to-brittle transition temperatures.

The above considerations indicate that the stipulated cold conditions will not reduce the effectiveness of the packaging, and that the container conforms to the requirements for the cold condition of normal transport.

3.3 Pressure

The regulations for normal conditions of transport specify that the package be able to withstand an atmospheric pressure of 0.5 times the standard atmospheric pressure, the resulting pressure being 7.35 psia.

When the model is under full heat load, trapped air in all sealed cavities will expand and exert internal pressures. Assuming assembly at 70° F and 14.7 psia, the resulting pressure of any trapped air is

$$P_2 = (P_1T_2)/T_1 = (14.7)(590)/530 = 16.4 \text{ psia,} \tag{50}$$

where

P_1 = assembly pressure, 14.7 psia,

T_1 = assembly temperature, 530° R,

T_2 = assumed cask surface temperature, 590° R.

The internal heat load (5W) is expected to contribute nothing to the cask surface temperature. The increase in pressure is therefore calculated by Eq. (50) and is 16.4 psia (1.7 psig). The maximum differential pressure expected across the cavity seals is therefore 23.7 psia (9.0 psig).

The cask and its silicone rubber seals (see Figs. 1.2 and 1.3) will be able to withstand these pressures without damage or reduction in the effectiveness of the packaging. Therefore, the container conforms to the requirement for the reduced pressure condition of normal transport.

3.4 Vibration

The container is of welded construction, and vibrations received in transit are not expected to affect the integrity of the weldment. All fasteners are equipped with lock washers and are not expected to loosen during such vibrations.

In addition, the cask, built several years ago, has operated in the transportation environment, suffering no ill effects as a result of vibrations encountered.

3.5 Water Spray

The containment capabilities of the TRU Californium Shipping Container are not compromised by water spray since all external surfaces are of stainless steel. The closure seal is impervious to water.

3.6 Free Drop

The regulations for normal conditions of transport require that a package weighing more than 20,000 lb be capable of withstanding a free drop through a distance of 2 ft onto a flat, essentially unyielding, horizontal surface, striking the surface in a position in which maximum damage is expected to result. A free drop of the TRU Californium Shipping Container through a distance of 2 ft is expected to produce a denting of the outside steel shell and possibly some slight fracturing of the concrete. Any concrete that might be fractured will be contained, and no reduction in effectiveness of the package or loss of contents is expected to occur due to the 2-ft free drop. Analysis of the hypothetical accident 30-ft free drop (Sect. 4.1) indicates that damage (if any) from a 2-ft drop will be insignificant.

3.7 Penetration

The regulations for normal conditions of transport stipulate that the package must be capable of withstanding the impact of the hemispherical end of a vertical steel cylinder which weighs 13 lb, has a 1-1/4-in. diam. and is dropped from a height of 40 in., typically onto the exposed surface of the package that is expected to be the most vulnerable to puncture.

The maximum energy imparted to the cask is 520 in.-lb. Approximately 50,000 in.-lb is required to deform 1 in.^{3} of stainless steel; therefore, the energy of impact would deform about 0.0104 in.^{3} of material. If the hemispherical head of the impactor struck the stainless steel shell, the depth of penetration would not exceed the depth of a spherical sector having a volume of 0.0104 in.^{3}. The volume of a spherical segment of one base is

$$V = (1/3)\pi h(3rh - h^2). \qquad (51)$$

where

h = height of segment (or depth of penetration), in., and

r = radius of sphere, 0.625 in.

The preceding equation becomes

$$h^3 - 1.875h^2 + 9.93 \times 10^{-3} = 0. \qquad (52)$$

This gives a maximum depth of penetration of 0.074 in. Damage of this magnitude would not reduce the effectiveness of the cask. This actual test was performed on the cask and no damage resulted to it.

3.8 Compression

Since the weight of the TRU Californium Shipping Container exceeds 10,000 lb, this section is not applicable.

4. COMPLIANCE WITH STANDARDS FOR HYPOTHETICAL ACCIDENT CONDITIONS

The standards for the hypothetical accident conditions stipulate that a container used for the shipment of fissile or large quantities of radioactive material shall be designed and constructed in such a manner and its contents limited so that, if it is subjected to the specified free-drop, puncture, thermal, and water-immersion conditions, the following requirements would be met:

1. The reduction in shielding would not be sufficient to increase the external radiation dose rate to more than 1000 mR/hr at a distance of 3 ft from the outside surface of the package.
2. No radioactive material would be released from the package except for gases containing total radioactivity not to exceed 0.1% of the total radioactivity of the contents of the package.
3. The contents would remain subcritcal.

4.1 Free Drop

The first in the sequence of hypothetical accident conditions to which the cask must be subjected is a free drop through a distance of 30 ft onto a flat, essentially unyielding, horizontal surface, striking the surface in a position in which the maximum damage is expected to occur. Since the cask is essentially a sphere, three orientations will be considered: (1) a random drop on the rounded stainless steel outer shell, (2) a drop on the top to test the bolts holding the top plugs, and (3) a drop on the bottom to test the bolts holding the bottom plugs.

4.1.1 *Drop on rounded stainless steel outer shell*

When the TRU Californium Shipping Container is dropped on the rounded outer stainless steel shell, the energy will be absorbed by bending the outer shell and crushing or cracking the concrete.

Very little information is available in the literature concerning the impact of heavy concrete pieces on essentially unyielding stationary objects. However, a series of tests were performed at the Brookhaven National Laboratory, with three unencased reinforced concrete waste shipping containers. These containers, which weighed ~10 tons, were dropped 30 ft onto a 10-in.-thick slab of armor plate.[13] These containers had wall thicknesses of 6 in., 12 in., and 17 in. Containers that had wall thicknesses of 12 in. or 17 in. passed the drop test, with the latter one showing only hairline cracks and essentially no loss of shielding.

The Californium Shipping Container is shielded with 30 in. of reinforced concrete completely encased in a 1/2-in.-thick stainless steel outer shell and weighs 11.75 tons. Thus this container weighs approximately the same as the concrete waste shipping containers that were tested, has almost twice the shielding thickness, and has a thick outer steel shell that will help spread the impact forces over a broad area of the cask surface. It is, therefore, concluded that the Californium Shipping Container will suffer only localized damage to the outer shell and concrete at the point of impact and that no significant cracks will occur in the shielding. Hence the cask dropped in this manner will meet the hypothetical accident requirements of a 30-ft drop.

Should the impact occur in the region of the actuator stems, the force is likely to be transmitted to the valve mechanism shown in Figs. 1.2 and 1.3 which could result in a loss of the seal. The ball valve will physically remain in place.

Even though the cask seal is lost, the primary line of containment will remain the welded container, described in Sect. 5. Thus no loss of radioactive material is expected from an impact on the side.

4.1.2 *Drop on top flange*

The possibility of failure of the bolts which hold the top concrete shielding plugs in the cask was investigated. It was assumed that the cask was dropped, upside down, on its top flange, from a height of 30 ft onto a solid, essentially unyielding surface. Under these conditions the wall of the cupola (to which the top flange is bolted) and the 1-in.-thick lifting ribs would deform, absorbing the kinetic energy of the cask. An analysis was made using the equations given in Sect. 9.3.

Results indicate that the cupola would crush approximately 1 in. before all kinetic energy would be absorbed. This is not possible, because after collapsing 0.5 in. the top flange would come in direct contact with the bolted plug flanges. At this time of contact, the number of *g*'s experienced by the cask would rapidly increase, the cask would come to rest in less than the remaining 0.5 in. predicted in the analysis, and the plug flanges would be driven back into the body of the cask. The predicted *g* loading of the cask, shown in Fig. 4.1 as a function of deformation, should be realistic up to the point at which the top flange encounters the plug flanges. Under these conditions the bolts holding the plugs in place will have to resist about 425 *g*'s before the plugs are driven back into the cask body. Therefore, the force to be resisted by the bolts becomes

$$F = ma, \tag{53}$$

where

m = mass of the plugs, 3.60 slugs,

a = maximum acceleration experienced by the plugs, ft/sec^2, 425 g.

Substituting, the applied load is

$$F = (3.60)(425)(32.2) = 49{,}200 \text{ lb}. \tag{54}$$

The area of metal in tension by this force is the stress area of the eight bolts. The area of the bolts under stress is

$$A = NA = (8)(0.122) = 0.976 \text{ in.}^2, \tag{55}$$

where

N = number of bolts, 8,

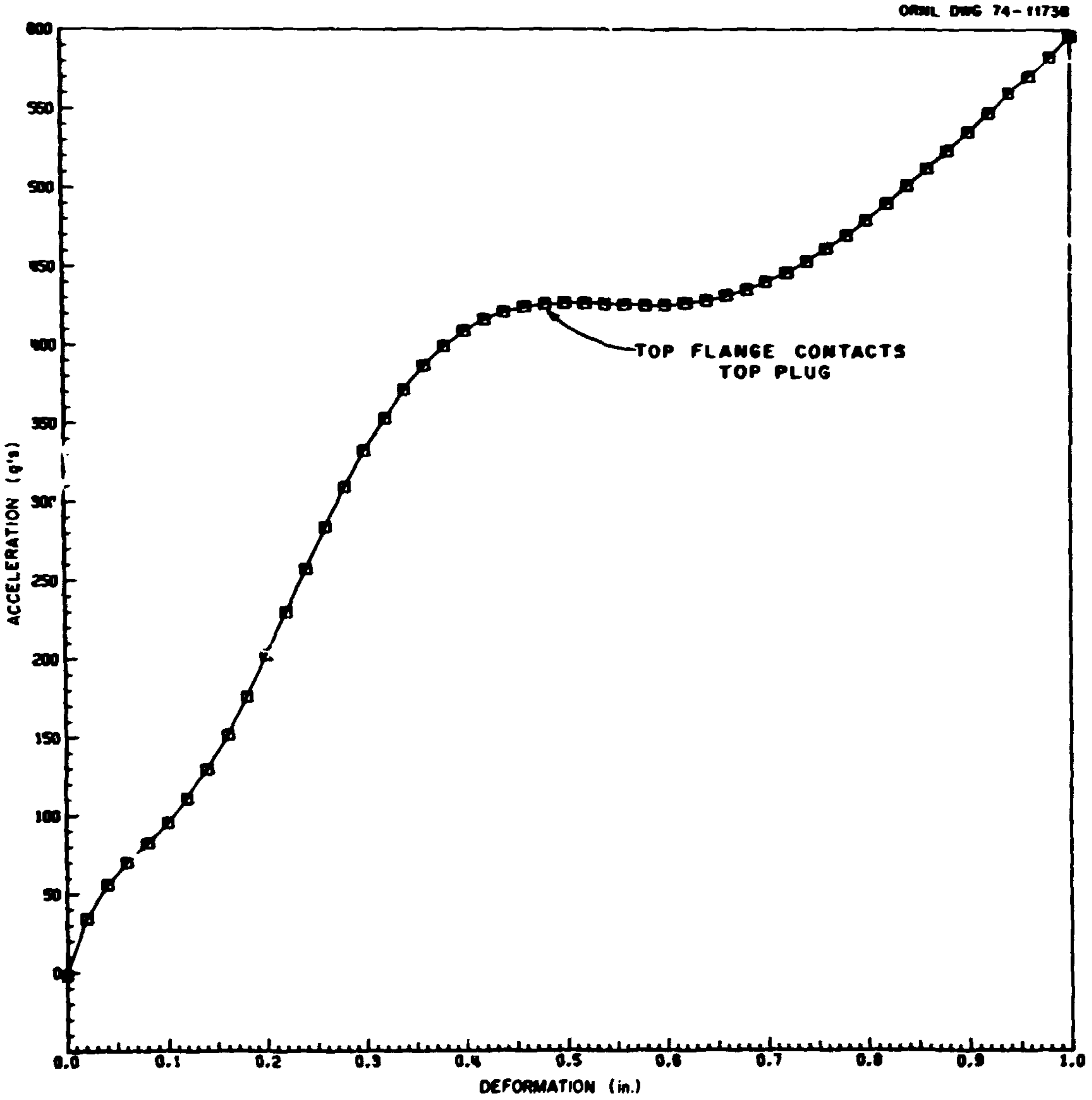

Fig. 4.1. Acceleration vs deformation as a result of computer analysis of 30-ft drop on top flange.

A = area of bolt, 0.122 sq in.^2.*

The total load-bearing capacity of the bolts is determined from

$$F_{max} = A\sigma_s, \tag{56}$$

where

σ_s = yield strength of stainless steel, 61,200 psi (see Table 2.1 footnote e)

$F_{max} = (0.976)(61{,}200) = 59{,}700$ lb.

Since F_{max} is greater than the applied load, the plugs will remain attached to the cask, and the contents will remain in the cavity.

4.1.3 *Drop on bottom flange*

The possibility of failure of the bolts which hold the bottom shielding plugs in the cask was investigated. It was assumed that the cask was dropped base down from a height of 30 ft onto a solid, essentially unyielding surface. Under these conditions, the walls of the cupola, the base plate (to which the bottom flange is bolted), the eight 1-in.-thick webs, and the eight struts–all would be deformed, absorbing the kinetic energy of the cask. An analysis was made using the equations given in Sect. 9.3.

Results indicate that the cupola would crush approximately 0.6 in. before all the kinetic energy would be absorbed. The relationship between acceleration and deformation for the drop onto the bottom flange is shown in Fig. 4.2. There is additional clearance at the bottom flanges due to the offset bottom cupola cover. Under these conditions, the bolts holding the plugs in place will have to resist about 1000 g's. Therefore, the force to be resisted by the bolts is

$$F = ma, \tag{57}$$

where

m = mass of the plugs, 3.60 slugs,

a = maximum acceleration experienced by the plugs, ft/sec^2, 1000 *g*.

Substituting,

$$F = (3.60)(1000)(32.2) = 115{,}900 \text{ lb.} \tag{58}$$

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*Body of bolt turned down to a 0.394-in. diam. or 0.122 in.^2.

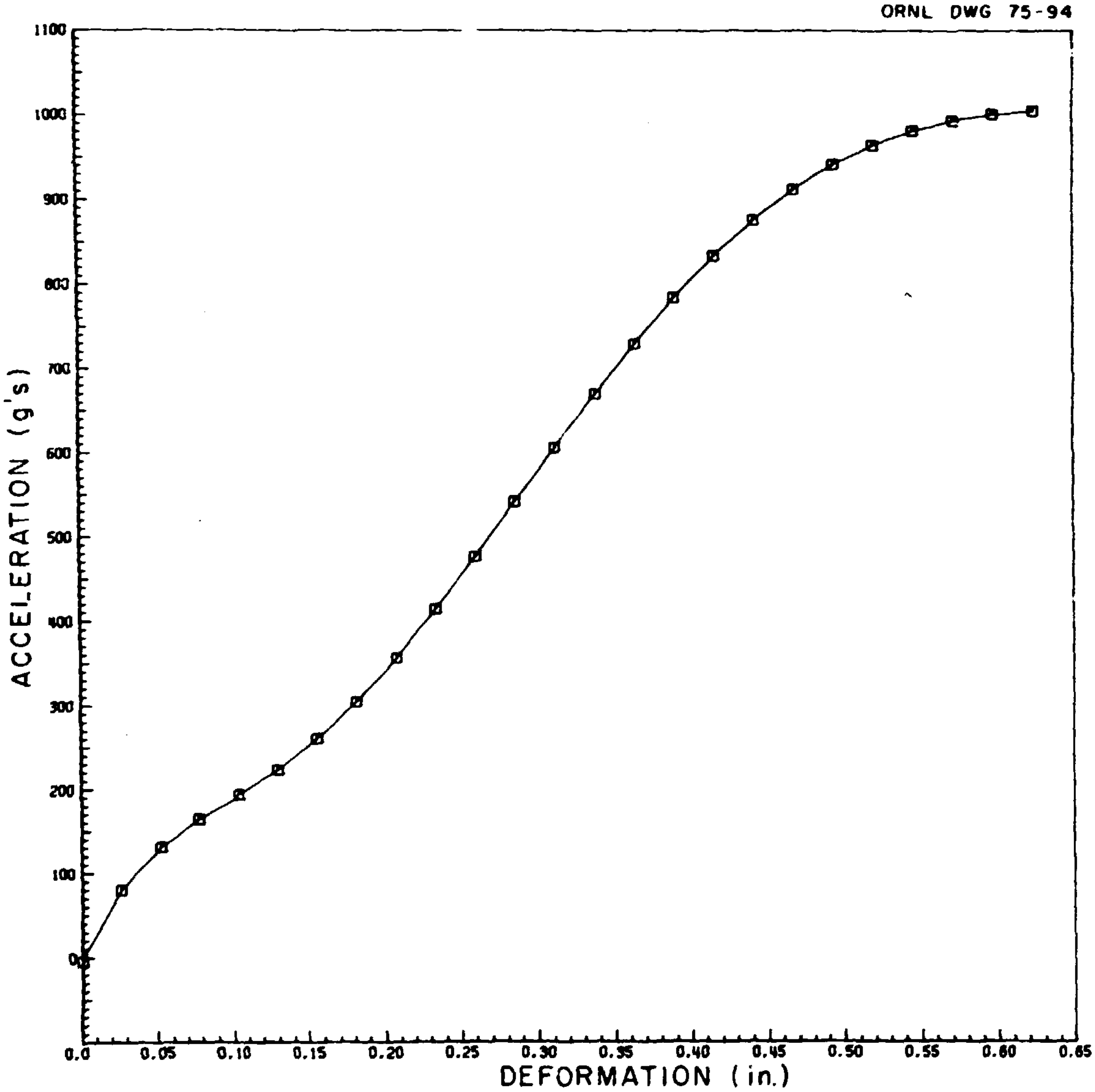


Fig. 4.2. Acceleration vs deformation as a result of computer analysis of 30-ft drop on bottom flange.

The area of metal in tension by this force is the stress area of eight turned down 1 2-in. bolts. The area of the bolts under stress is 0.976 in.^{2}, as indicated in Eq. (55).

The total load-bearing capacity (F_{max}) of the bolts was determined to be 59,700 lb. as indicated in Eq. (56). Since F_{max} is less than the applied load, the bolts will fail and the ends of the plugs will drop into the bottom closure cover (see Fig. 1.1).

The bottom cover plate is retained by twelve 1/2-in. cap screws which have the following load-bearing capacity:

$$F_{max} = NA\sigma_s = 12(0.142)(61{,}200) = 104{,}300 \text{ lb.} \qquad (59)$$

where

N = number of bolts, 12,

A = area of bolts, 0.142 in.^{2} (ref. 10),

σ_s = tensile strength of stainless steel, 61,200 psig (see Table 1).

The load bearing capacity of these bolts will hold the plugs from further travel. The bottom closure cover is a gasketed sealed cavity, and the inner container upon which containment depends is still retained in the cavity essentially without movement. No loss of containment or appreciable loss of shielding is anticipated.

4.2 Puncture

The second in the sequence of hypothetical accident conditions to which the cask must be subjected is a free drop through a distance of 40 in. to strike, in a position in which maximum damage is expected, the top end of a vertical mild-steel bar mounted on an essentially unyielding, horizontal surface. The mild-steel bar shall have a diameter of 6 in. with the top horizontal and its edge rounded to a radius of 1/4 in., and the bar shall be of such length that it will cause maximum damage to the cask but not less than 8 in. long. The long axis of this bar shall be normal to the surface of the cask upon impact.

To analyze the puncture accident, a rather conservative model can be used which considers all the energy absorbed by the cask is absorbed by the outer stainless steel shell with no *consideration given to the concrete shielding.*

The energy of impact will be absorbed by the 6-in.-diam mild-steel bar and the 1/2-in.-thick cask outer shell. Figure 4.3 illustrates the configuration for this computational model. The absorbed energy U = Wh = (23,500)(40) = 940,000 in.-lb, and

$$U = Wh = U_{SS} , U_{MS} = F_{SS}\Delta_{SS} , F_{MS}\Delta_{MS} = \sigma_{SS}A\epsilon_{S}L_{SS} , \sigma_{MS}A\epsilon_{MS}L_{MS}. \qquad (60)$$

where

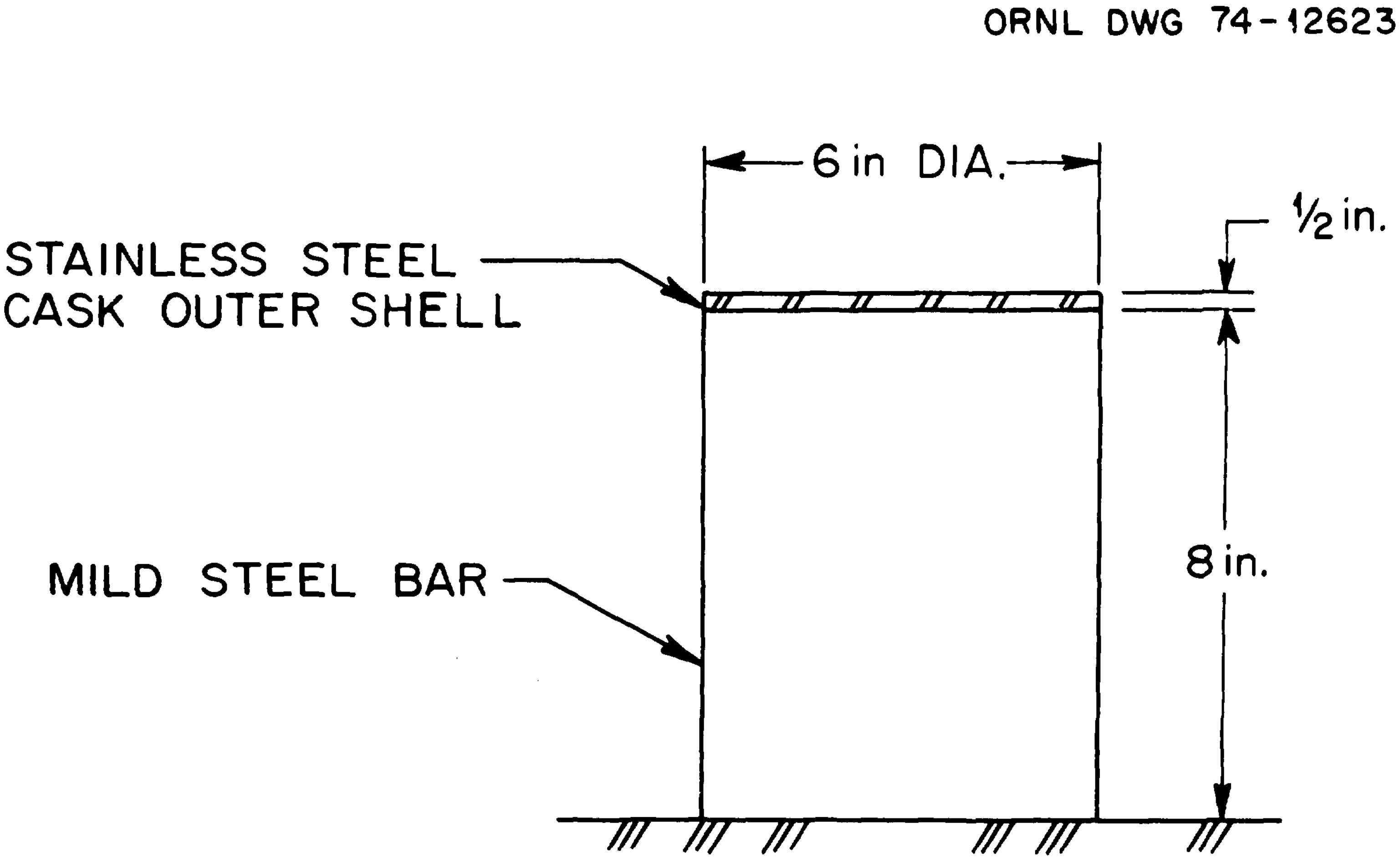


Fig. 4.3. Model used for puncture analysis.

U = energy, in.-lb,

$\underline{W}$ = weight of cask, 23,500 lb,

h = drop height, 40 in.,

F = force, lb,

Δ = deformation, in.,

σ = stress, psig,

A = undeformed cross-section area of member, in.^{2},

ϵ = strain, in./in.,

L = undeformed length of member, 0.5 in.,

SS = subscript for stainless steel,

MS = subscript for mild steel.

Since the force is the same in both members, we can write

$$\sigma_{SS}A = \sigma_{MS}A, \tag{61}$$

and since the areas are the same,

$$\sigma_{SS} = \sigma_{MS} = \sigma.$$

Then Eq. (60) becomes:

$$U = \sigma A(\epsilon_{SS}L_{SS} , \epsilon_{MS}L_{MS}). \tag{62}$$

For plastic deformation of stainless steel and mild steel, simple stress-strain relations can be written as[14]

$$\sigma_{SS} = (4.33 \text{ x } 10^5)\epsilon_{SS} , 60{,}000 \tag{63}$$

and

$$\sigma_{MS} = (2.56 \text{ x } 10^5)\epsilon_{MS} , 60{,}000. \tag{64}$$

Rearranging yields the following result:

$$\epsilon_{SS} = (\sigma_{SS} - 60{,}000)/(4.33 \text{ x } 10^5) \tag{65}$$

and

$$\epsilon_{MS} = (\sigma_{SS} - 60{,}000)/(2.56 \text{ x } 10^5). \tag{66}$$

Substitution of Eqs. (65) and (66) into Eq. (62) and eliminating the material subscripts yields a quadratic equation as follows:

$$\sigma^2 - (6.0 \text{ x } 10^4)\sigma - (1.694 \text{ x } 10^7) = 0, \tag{67}$$

which yields the result $\sigma = 60{,}281$ psig.

The strain on the stainless steel cask shell is

$$\epsilon_{SS} = (60{,}281 - 60{,}000)/(4.33 \text{ x } 10^5) = 0.00065 \text{ in./in.}, \tag{68}$$

and the deformation is

$$\Delta_{SS} = \epsilon L = (0.00065)(0.50) = 0.000325 \text{ in.} \tag{69}$$

From Newton's second law, the peak acceleration is

$$a_{max} = F/m = Fg/\underline{W} = \sigma Ag/\underline{W} = (60{,}281)(\pi)(6)^2(g)/(4)(23{,}500) = 72.5\ g. \tag{70}$$

This acceleration is less than that associated with the end impact resulting from the 30-ft free drop discussed in Sect. 4.1, and it is therefore concluded that the inner container will continue to provide containment under the puncture accident condition.

The stainless steel outer shell will deform plastically; however, because of the support from the concrete, it will not rupture. Impact-induced cracks that may occur in the concrete shielding material are intergranular in nature, thus offering a labyrinth path for radiation without reducing the shielding properties.

4.3 Thermal Evaluation

4.3.1 *Hypothetical thermal accident condition discussion*

The third in the sequence of hypothetical accident conditions specified by the regulations to which the cask must be subjected is a 30-min exposure to a source of radiant heat having a temperature of 1475°F and an emissivity coefficient of 0.9 or equivalent. For calculational purposes, it shall be assumed that the package has an absorption coefficient of 0.8. The package shall not be cooled artificially until after the 30-min test period and the temperature at the center of the package has begun to fall, or until 3 hr following the test period.

A computer program, HEATING-3, which has been modified to evaluate the phase change of materials and is applicable to the IBM 360 computer, was used to determine the temperature distribution when exposed to these thermal environments.

It was assumed that the container was loaded with a decay heat load of 50 W, a factor of 10 higher that will be used in this package (see Sect. 1.2), which will therefore provide an upper limit on the expected cask temperatures under the hypothetical thermal accident condition. The temperature distribution from 100° F ambient condition and a 50W source was input as starting temperatures for the accident (fire) calculation.

The damage from the free drop and puncture portions of the hypothetical accident would not adversely affect the performance of the container in the hypothetical thermal accident. Hence the undamaged configuration was assumed.

4.3.2 *Thermal properties of materials*

The thermal properties of materials used to compute the temperature distribution under steady-state and transient conditions are listed in Table 4.1

4.3.3 *Thermal accident analysis*

The computational model representing the TRU Carrier is illustrated in Fig. 4.1. The contents were modeled as a homogenous cylinder with the decay-heat generation rate of 50 W uniformly distributed throughout the volume.

As the HEATING-3[10] code cannot be used to model a sphere, the exterior surface was modeled using a group of concentric cylinders whose outside surfaces approximated the surface of a sphere. The radius and length of these cylinders were chosen so that the resulting surface had the same surface area as that of the actual cask. Natural convection heat transfer coefficients for a sphere were used for the exterior of the cask.

Convection, radiation, and conduction were assumed to transfer heat across large air gaps in heat transfer model, except in cases where, because of the combination of narrow gaps and small temperature differences, it can be shown that heat convection contributes essentially nothing to the heat transfer process.

4.3.4 *Container temperatures*

The results of the computer analysis are presented graphically in Fig. 4.4. Cask temperatures are followed for 3 hr after the conclusion of the fire since regulations specify that the cask cannot be artificially cooled prior to this time unless the temperature in the center of the cask has begun to fall.

Table 4.1. Thermal properties of materials used to compute temperature distribution

Material	Temperature (°F)	Thermal conductivity Btu $hr^{-1}ft^{-1}(°F)^{-1}$	Density lb $in.^{-3}$	Heat capacity Btu $lb^{-1}(°F)^{-1}$
Fuel		6.62	0.0978	0.214
Seal		0.143	0.0347	0.469
SST 304L	32.0	7.736	0.282	0.130
	212.0	9.428		
	932.0	12.571		
	1292.0	14.989		
	1472.0	15.000		
Air	32.0	0.017	4.11×10^{-5}	0.240
	212.0	0.018		
	392.0	0.022		
	572.0	0.026		
	752.0	0.029		
Concrete	—	0.600	0.090	0.21

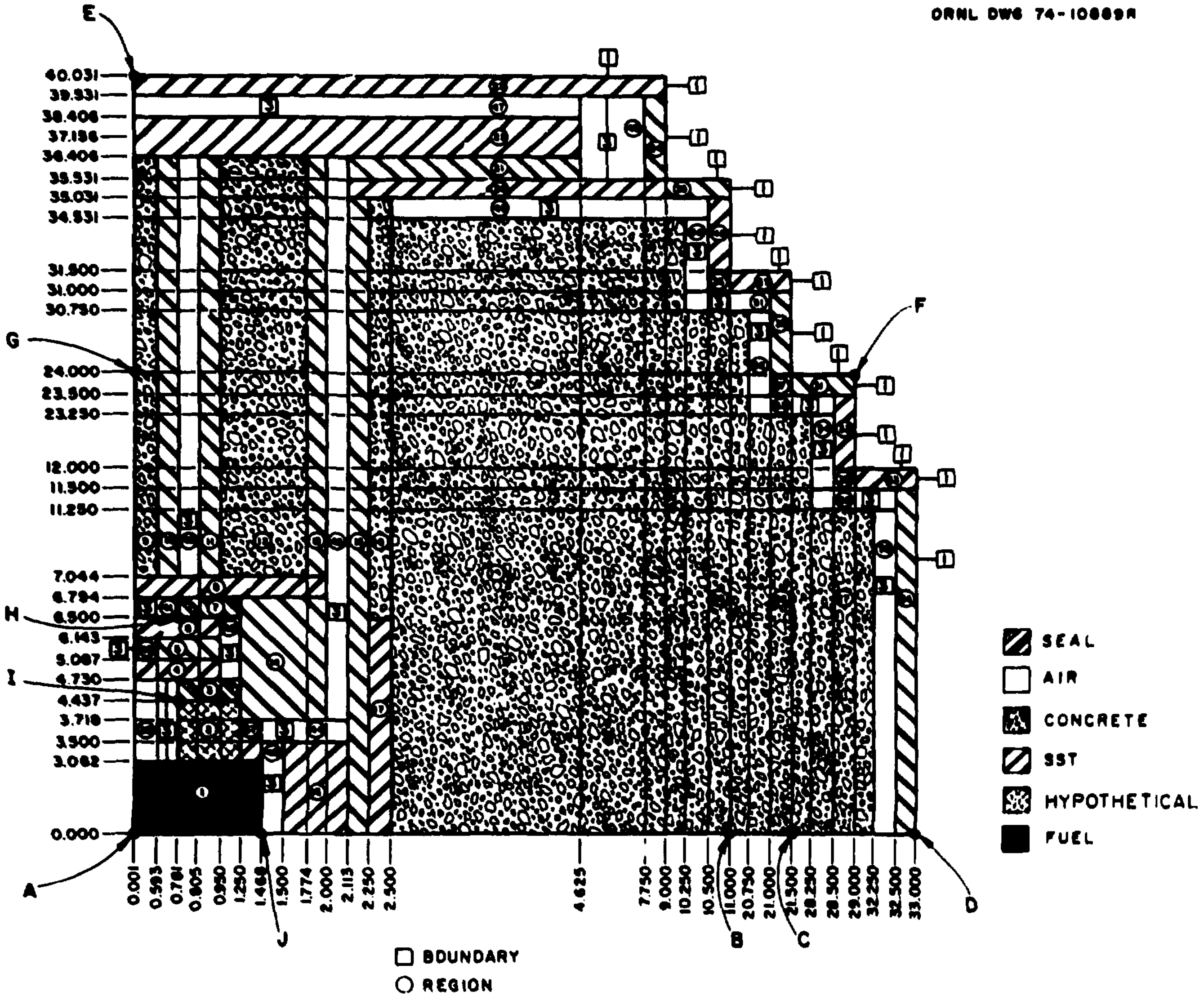


Fig. 4.4. TRU Californium Shipping Container computational model to determine temperature distributions under normal transport and hypothetical accident conditions.

Throughout the entire test period, the mid-point temperature of the cask remained almost constant. Following the fire, the outer parts of the cask cooled rapidly; after 3 hr, the maximum calculated temperature in the cask was 345°F, located approximately in the top inner plug plate. It is apparent that the inner container fuel contents will remain at its equilibrium temperature which, from Table 3.2, would be about 110°F. Such temperatures will cause no problems to the contents; nor will it have any significant (degrading) effect on the seals of the inner containers. Consequently, if the cask is subjected to the high-temperature thermal environment, it is capable of withstanding it with no loss of contents and, therefore, meets this part of the regulations.

5. CONTAINMENT

Sources and other shipments are confined inside the inner cavity of the TRU Californium Shipping Container in either a special-form or a 2R container. These containers–their uses and inspections–are described below.

5.1 Containment Boundaries

The containment boundaries for the shipping options available with the Californium cask are (a) the cask cavity sealed by its gaskets (Figs. 1.2 and 1.3) and (b) an inner container that meets either 2R specifications or special form requirements. Any material carried in a 2R container will be enclosed in a welded capsule. In all cases, there will be at least one welded seal between the source and the cask cavity.

5.2 Special-Form Shipments

The welded encapsulation provides primary containment for all special-form shipments (see Figs. 5.1 - 5.3) for examples of special-form encapsulations). If the material is doubly encapsulated, the outer welded capsule provides secondary containment. Visual inspection of these lines of containment are performed on a routine basis, and the welds are radiographed. The cask seals form an additional line of containment. The cask is equipped with gasketed closures which are leak-tight during normal transport. An accident might result in a rupture of the seals, but the contents in their primary containers would remain in the cavity.

5.2.1 *Special-form containers*

The ORNL Operations Division is authorized by Laboratory management to certify that a material conforms to the special-form requirements of Appendix D of 10 CFR Part 71.[15] The tests prescribed have been performed on a number of capsule designs. When a capsule is similar in design to a capsule previously tested (i.e., in relation to size, mass, wall thicknesses, materials, weld, etc.), the design is certified as passing the special-form requirements based on previous test results. If this similarity does not exist, it is required that a prototype be tested as prescribed.

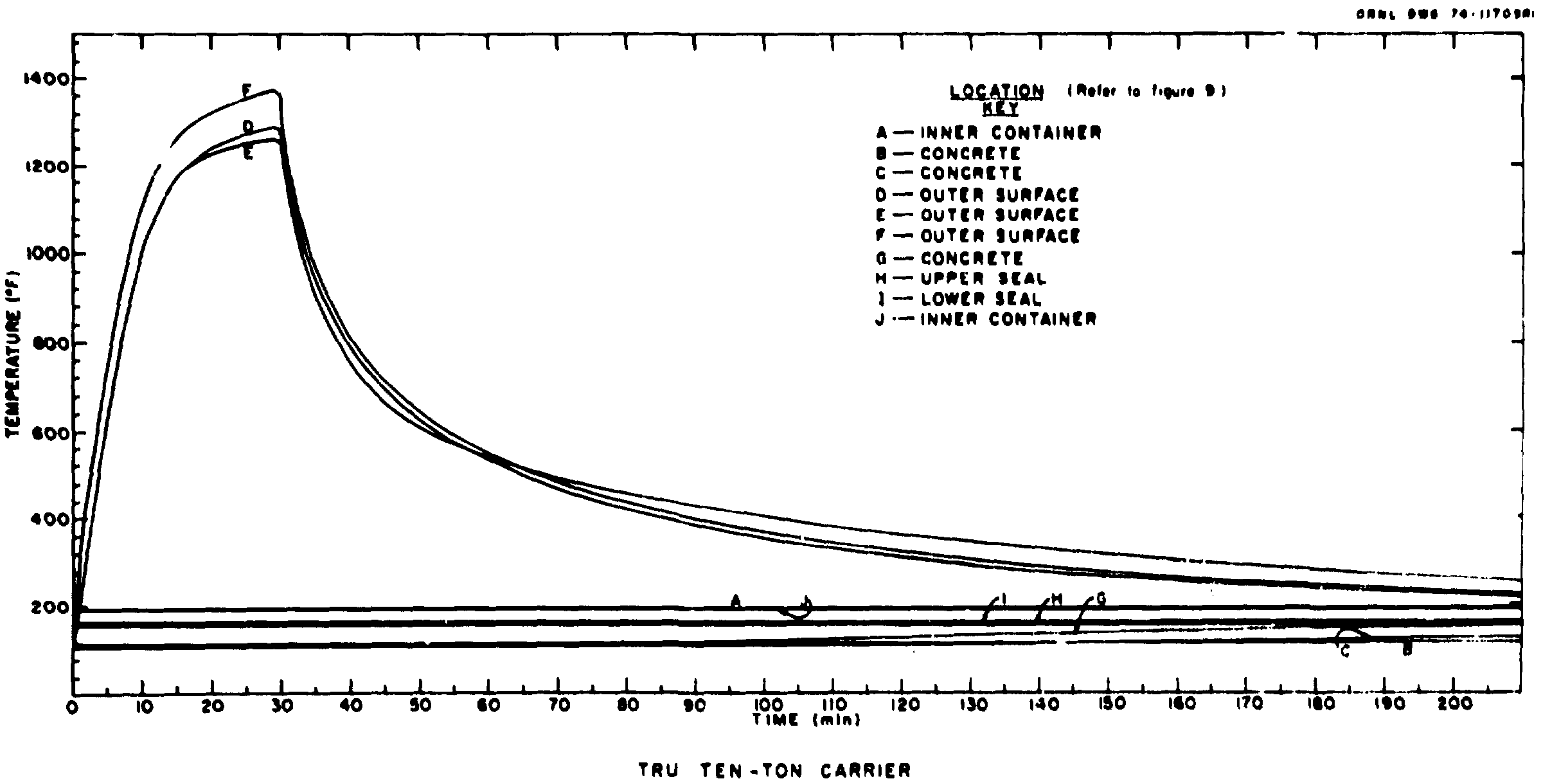


Fig. 4.5. Temperature distribution in the TRU Californium Shipping Container during and after the thermal portion of the hypothetical accident.

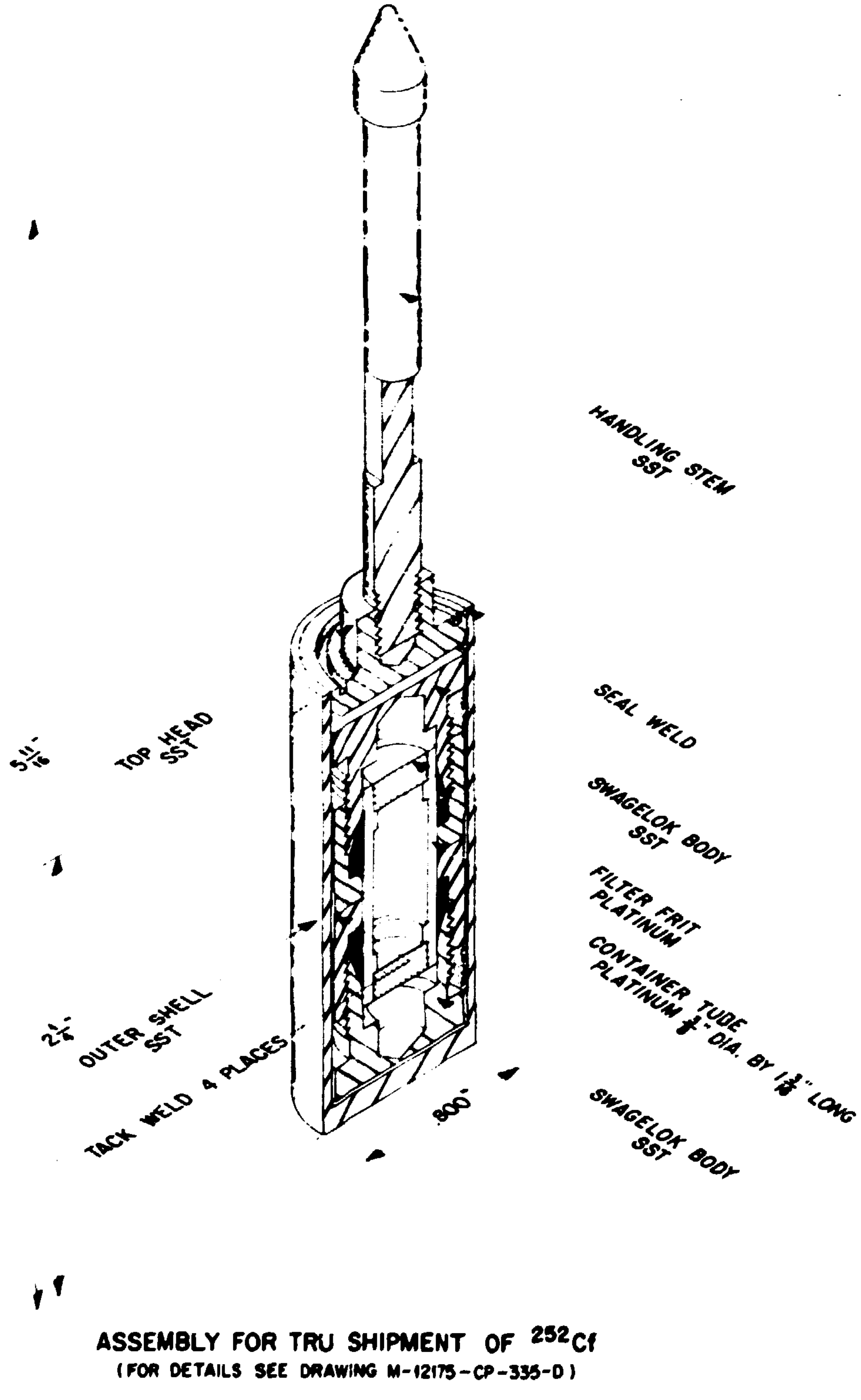
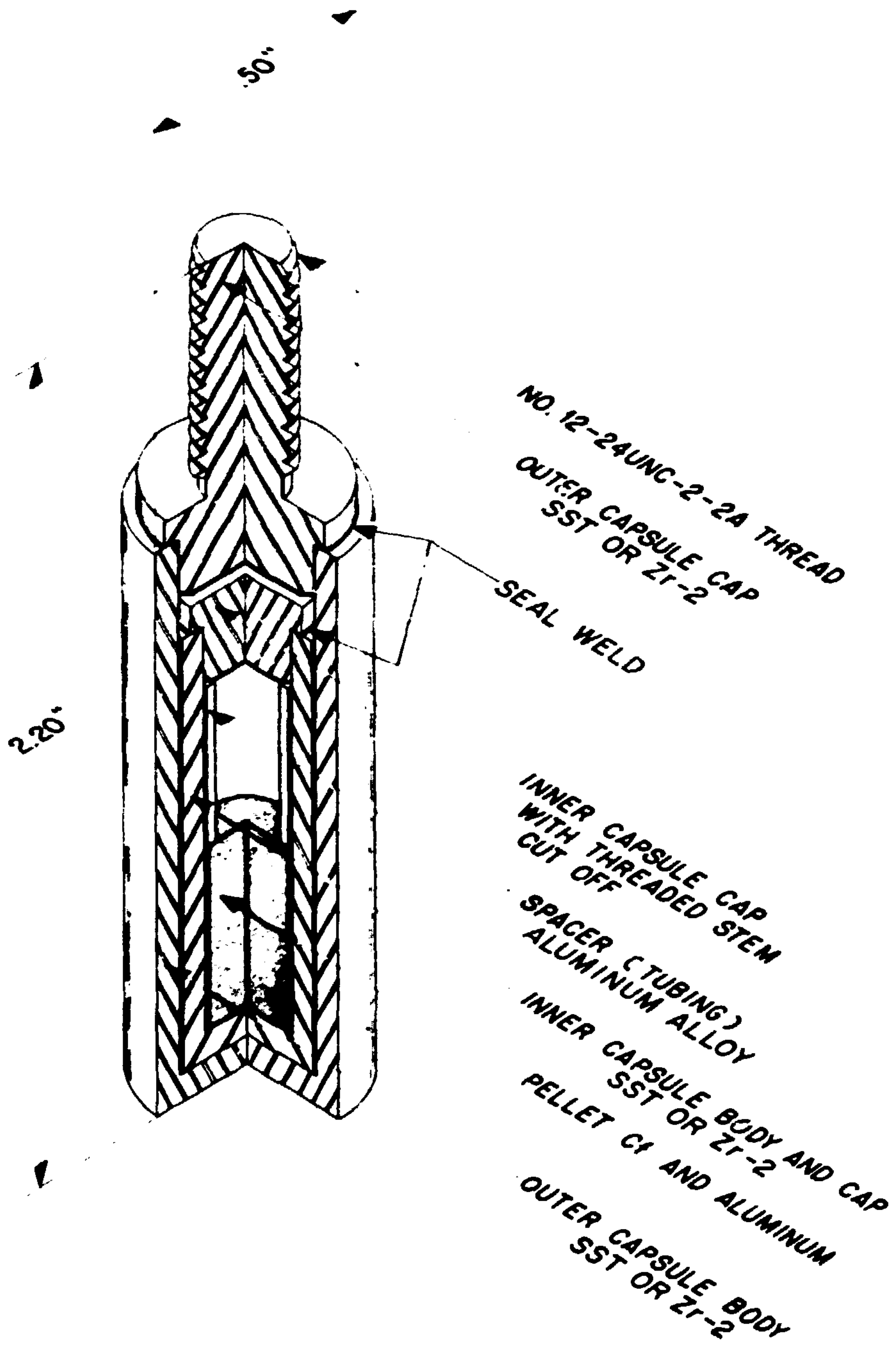


Fig. 5.1. Assembly for TRU shipment of ^{252}Cf (for details see Drawing M-12175-CP-335-D) — a typical special-form inner container.

ORNL DWG 74-11675R1



STANDARD NEUTRON SOURCE CONTAINER
(FOR DETAILS SEE DRAWING M-12175-
CP-636-D)

Fig. 5.2. Standard neutron source container (for details see Drawing M-12175-CP-636-D) — a typical special-form inner container.

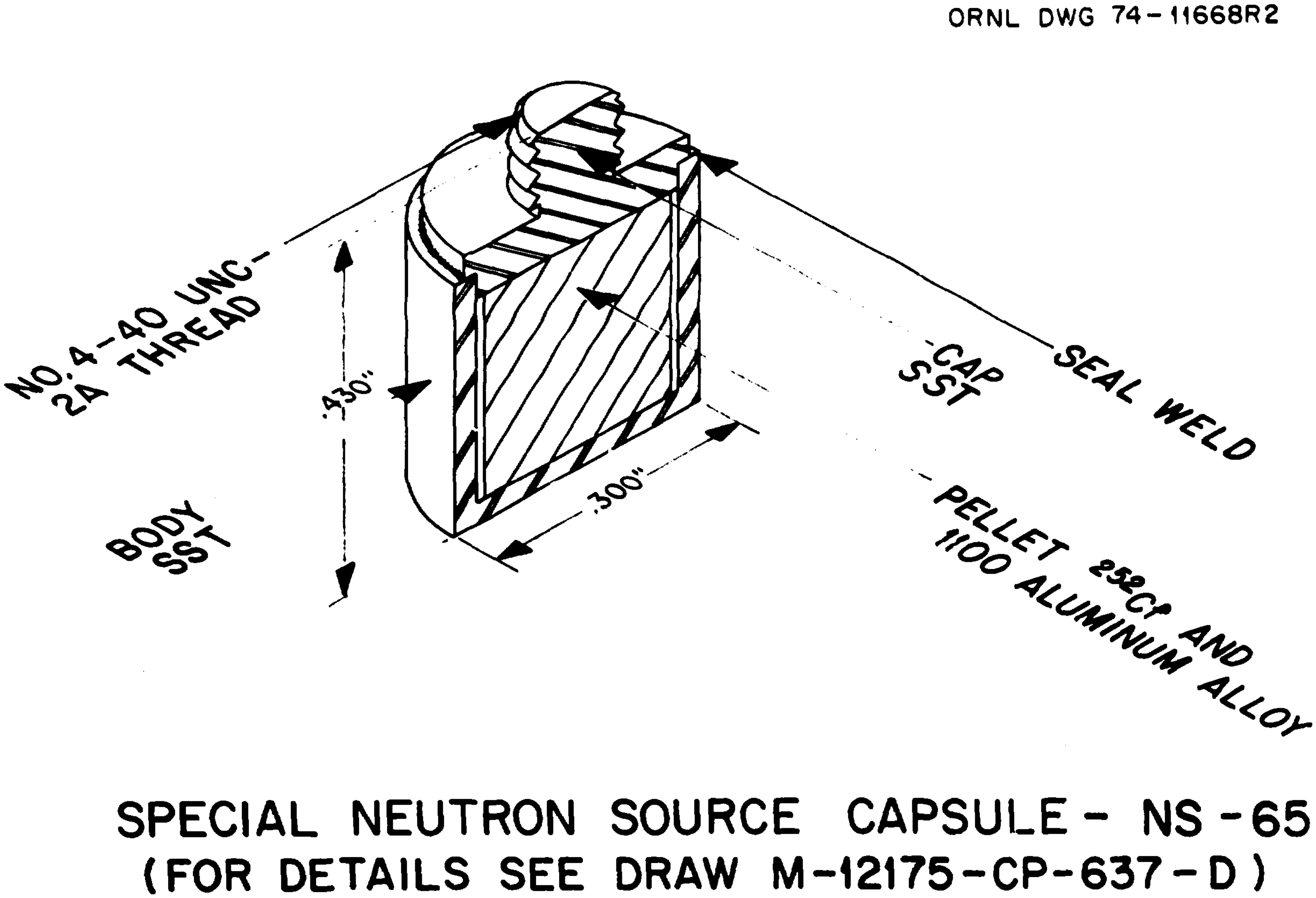


Fig. 5.3. Special neutron source capsule — NS-65 (for details see Drawing M-12175-CP-637-D) — a typical special-form inner container.

5.2.2 *Specification 2R containers*

Specification 2R[16] inner containers (shown in Fig. 5.4) may be used with the TRU Californium Shipping Container. These will be made from pipe and pipe fittings or tube and tube fittings. Wall thicknesses and closures will be made in accordance with Specification 2R.

Fabrication will be in accordance with ORNL Quality Assurance Procedures. Applicable approved ORNL procedures will be used for welding. All welds will be appropriately inspected in accordance with approved ORNL weld inspection procedures.

5.3 Containment Requirements for Normal Conditions of Transport

The test sequence for containers of special-form materials is more severe than for those with normal conditions of transport. The pressure increases that are encountered will be less than those experienced in the thermal test for special-form materials. No loss of primary coolant (air) is expected.

The 2R containers, housing a welded capsule, are designed for pressures and temperatures in excess of those encountered in normal transport. No release of radioactive material, loss of coolant (air), or contamination of coolant should occur.

5.4 Containment Requirements During the Hypothetical Accident

The test series for special-form containers demonstrates that special-form encapsulation will not fail or leak contents as the result of the free falls. The thermal test temperatures of special-form containers exceed those experienced by the inner cavity contents during the hypothetical accident (see Sect. 4.3.3); hence no release will occur during the thermal exposure. The water immersion test for special form is identical to that specified in the hypothetical accident conditions.

The 2R containers, housing a welded capsule, are designed for pressures and temperatures in excess of those encountered in the hypothetical accident.

6. CRITICALITY

The analysis for the single container given below is adequate for an infinite array of similar containers because the concrete shielding assures essentially no interaction.

6.1 Evaluation of a Single Package

A study[17] has been made of the criticality of californium and other transuranium elements under conditions of optimum moderation and water reflection. Californium-251 had the smallest critical mass (10 g). The quantity of isotopes to be carried by this cask is limited to 3 g. Approval of the use of this cask for that quantity of fissile material has been granted by Nuclear Safety Review 750 (see Sect. 9.2).

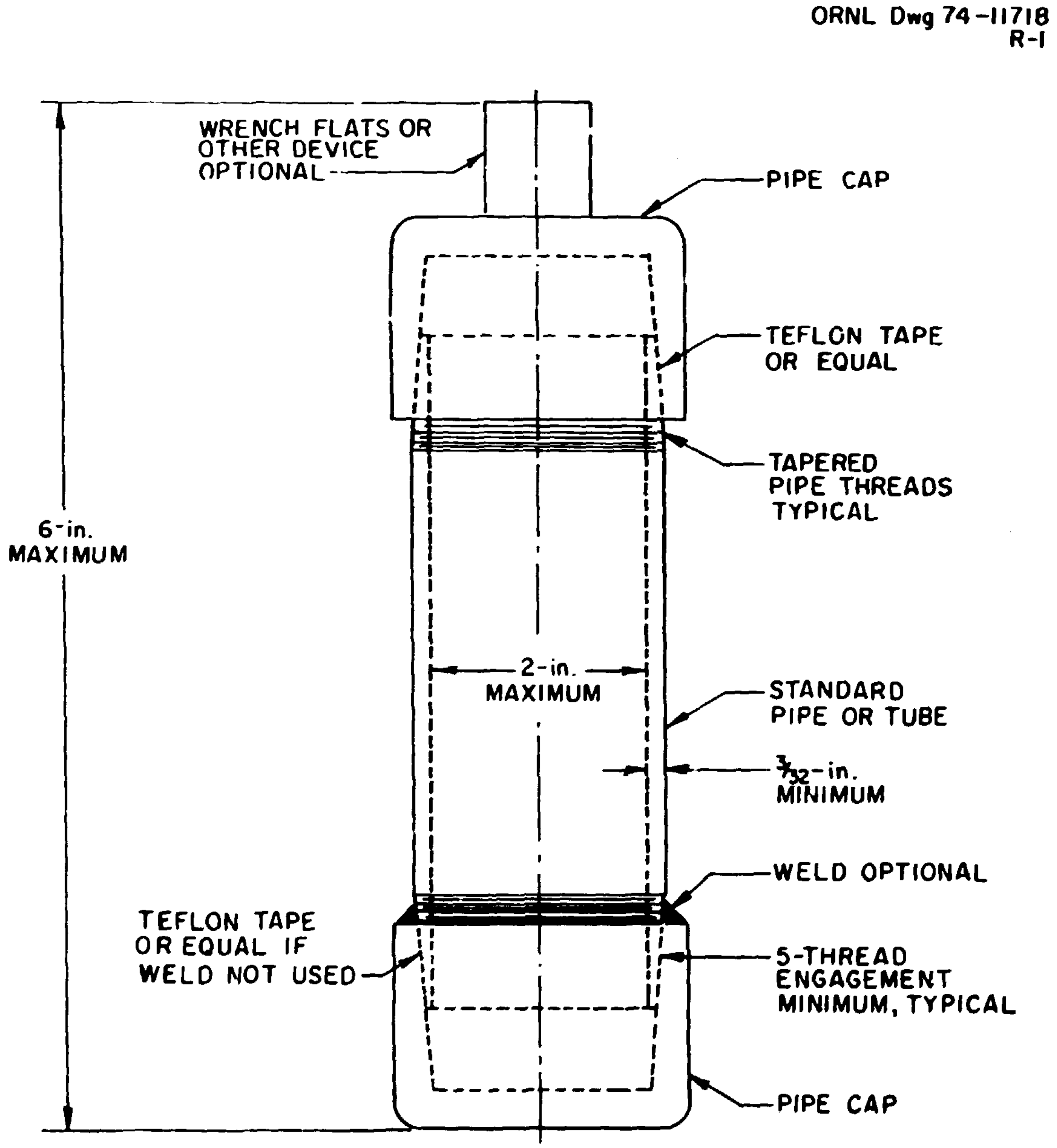


Fig. 5.4. Typical pipe-element Specification 2R inner container.

Since the quantites of fissionable isotopes carried is below all minimum critical masses for these isotopes under optimum moderation and reflection, and since the cask effectively isolates the contents from neutron interaction with packages of similar design, unlimited numbers could be stacked together without creating a criticality problem. Thus the package is adequate for Fissile Class I shipments.

7. SHIELDING EVALUATION

7.1 Discussion and Results

The TRU Californium Shipping Container is designed with its cavity surrounded by a 1-in. thickness of stainless steel and a 1/2-in.-thick outer spherical shell. The shielding cavity between the two is filled with limonite concrete to a nominal thickness of 30 in. The shielding effectiveness has been checked with transuranium sources and found to be adequate. A 44-mg (1.7-W) ^{252}Cf source produced a reading of 7 mrem/hr gamma at a distance of 6 ft from the cask surface. In this case, the drivers compartment registered less than 1 mrem/hr. The cask contents will be limited to the source that will not exceed the allowable radiation dose limits of the DOT regulations.[6] The shielding effectiveness will not be reduced by the hypothetical 30-ft drop accident, concrete fractures in an intergranular manner providing a labyrinthine pathway for radiation, allowing no possibility of radiation streaming.

8. QUALITY ASSURANCE

8.1 Fabrication, Inspection, and Acceptance Tests

The fabrication of this container was performed in the shops of the Oak Ridge National Laboratory in accordance with normal shop fabrication procedures and prior to the adaption of a formal quality assurance program by the DOE and ORNL. Material was specified on the original drawings as "304L SST." Material was withdrawn from Bill of Materials Stores stock. The casks were inspected by ORNL Shop Inspection Department personnel for conformance to the drawings, quality of workmanship, and compliance with welding requirements when fabricated. In the opinion of the inspecting personnel, the weldments were made in accordance with the drawings and specifications. This is further supported by the fact that the casks have operated for 6 years without failures or loss of effectiveness. The routine operating inspection procedures specify periodic weld inspections to verify weld integrity.

A formal quality assurance program has now been prepared[18] and future shipping containers will be constructed in accordance with provisions set forth in this program.

8.2 Operating Procedures and Routine Inspection

The Transuranium Processing Plant, Chemical Technology Division, has established operating and routine inspection procedures and standard checklists to ensure that all shipments are safe and that they comply with DOE regulations as well as all ORNL procedures and regulations. A copy of typical procedures and checklists are presented in Sect. 9.4.

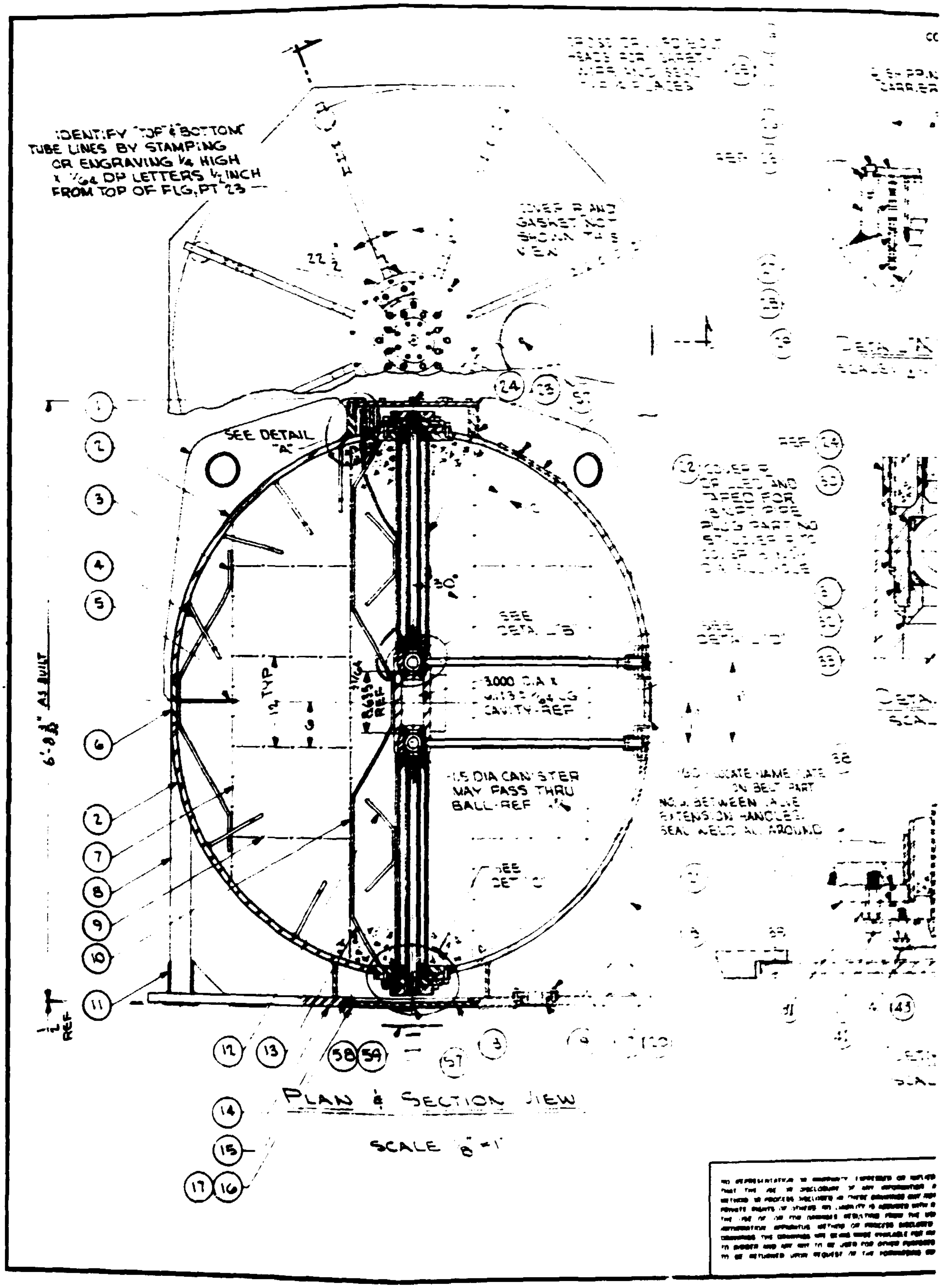
8.3 Periodic Maintenance and Inspection

Inspections are required prior to each shipment or biennially (see Sect. 9.4). Maintenance will be required only when routine inspections indicate damage.

9. APPENDIXES

9.1 Appendix A: Drawings Associated with the TRU Californium Shipping Container

Title	Drawing No.	Page
Shipping Carrier Assembly	M-11230-EN-001-D	58
Shipping Carrier Weldment	M-11230-EN-002-D	59
Shipping Carrier - Detail Sheet No. 1	M-11230-EN-003-D	60
Shipping Carrier - Detail Sheet No. 2	M-11230-EN-004-D	61
Shipping Carrier - Detail Sheet No. 3	M-11230-EN-005-D	62
Shipping Carrier - Detail Sheet No. 4	M-11230-EN-006-D	63
Shipping Carrier - Detail Sheet No. 5	M-11230-EN-007-D	64
Shipping Carrier - Detail Sheet No. 6	M-11230-EN-008-D	65
Shipping Carrier Trailer Modification Assembly	M-11230-EN-012-E	66
Shipping Carrier Trailer Modification Tie Down Details	M-11230-EN-014-E	67
Modified Plug to Handle Multiple Items	M-11230-EN-017-D	68
Shipping Carrier Trailer Modifications Radioactive Sign Mounting Bracket	M-11230-EN-018-E	69
TRU Ten-Ton Californium Shipping Container	M-12166-CD-019-D	70

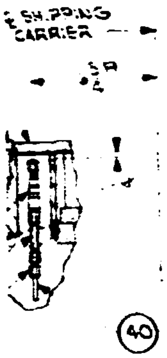


PLAN & SECTION VIEW

SCALE 1/8" = 1'

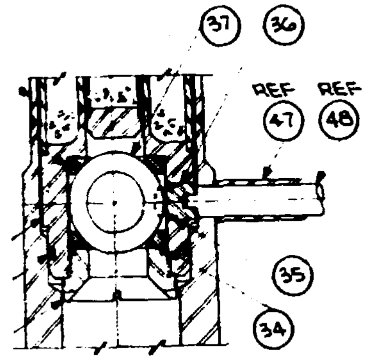
COMMENTS 1. HEMISPHERICAL HEAD - CODE CERTIFICATION NOT REQUIRED ASME HEMISPHERICAL, 66" O.D. X 1/2" WALL, 0" STRAIGHT FACE, 11" DIA HOLE ON CENTER LINE OF HEAD. SEGMENTED HEAD ACCEPTABLE (SEGMENTED HEAD MUST BE FULL PENETRATION WELDED WITH THE 11" DIA. HOLE NOT PENETRATING ANY WELDS.) 100% RADIOGRAPH A WELDS.

2. SHIELDING - BLACKBURN LIMONITE CONCRETE FILL.
3. QUICK-CONNECT - SWAGELOK, STEM ASSEMBLY NO. 400-1/4 QC-200-316, BODY ASSEMBLY NO. 1/4-QC-700-2-316 WITH SILICONE RUBBER O-RINGS, CRAWFORD FITTING CO., 29500 SOLON ROAD, SOLON, OHIO 44139
4. SEAT, BODY SEAL & BALL FOR DOUBLE-SEAL TYPE A-36 2" VALVE JAMESBURY CORP., 640 LINCOLN ST., WORCESTER, MASS. 01605
5. TURN BODY OF BOLT DOWN TO .010 UNDER ROOT DIA. FROM HEAD TO WITHIN 1 1/2 DIAMETERS OF END.
6. TURN BODY OF BOLT DOWN TO .010 UNDER ROOT DIA. FROM HEAD TO WITHIN 1 DIAMETER OF END.
7. CROSS DRILL HEAD OF BOLT .070 DIA. FOR SAFETY WIRE.
8. JOHNS MANVILLE, INC. 22 EAST 40TH ST. NEW YORK 16, N. Y.

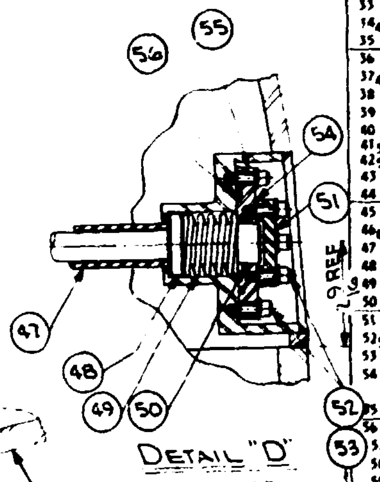


A ... A TYP 2 PLACES
...E: 1/2 = 1

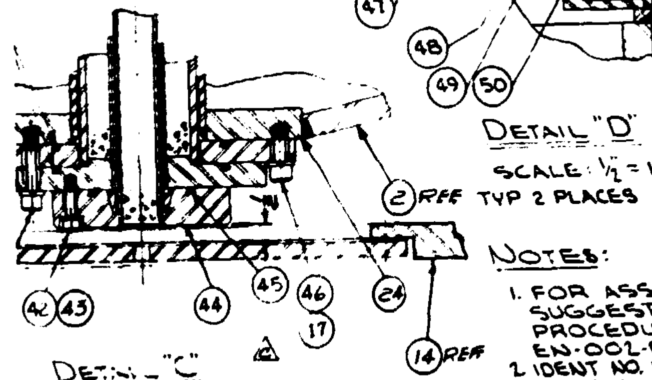
⚠1 NOTE
SKID ASSY FOR THIS CARRIER IS SHOWN ON DWG EN-009-D



DETAIL "B" TYP 2 PLACES
SCALE: 1/2" = 1"



DETAIL "D"
SCALE: 1/2 = 1"



DETAIL "C"
SCALE: 3/8" = 1"

CROSS DRILLED BOLT HEADS FOR SAFETY WIRE AND SEAL

NOTES:

1. FOR ASSEMBLY AND SUGGESTED WELDING PROCEDURES SEE DWG EN-002-D.
2. IDENT NO. HAS BEEN ASSIGNED 10-S-21-211 AND IDENT TAG WILL BE PROVIDED BY PROGRAM ENGINEER.

PARTS LIST

PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
1	EN-003-D	8	RIB		ANY 300 SST
2_1	THIS DWG	2	HEAD, HEMISPHERICAL, (MODIFIED)		ANY 300 SST
3	EN-003-D	16	REINF. BAR "A"		STEEL
4	EN-003-D	48	REINF. BAR "B"		STEEL
5	EN-003-D	16	REINF. BAR "C"		STEEL
6	THIS DWG	1	BELT, 66" O.D. X 65" I.D. X 1/2" THK X 6" WIDE		ANY 300 SST
7	THIS DWG	1	MESH, REINF. CONC. 4" X 4" X 10 GA. WIRE 50" DIA X 45" HIGH (45 X 157)		STEEL
8	EN-007-D	8	STRUT		ANY 300 SST
9	THIS DWG	4	MESH, REINF. CONC. 4" X 4" X 10 GA. WIRE 50" O.D. X 17" I.D		STEEL
10	THIS DWG	1	MESH, REINF. CONC. 4" X 4" X 10 GA. WIRE 17" DIA X 67" HIGH (67 X 54)		STEEL
11	THIS DWG	8	PIPE, 3" NPS SCH 40 X 4" LG		ANY 300 SST
12	EN-003-D	8	REINF BAR "D"		ANY 300 SST
13	EN-003-D	8	REINF BAR "E"		ANY 300 SST
14	EN-004-D	1	BASE PLATE		ANY 300 SST
15_8	EN-004-D	1	GASKET		JM 60
16	THIS DWG	12	SCREW, SOC HD CAP 1/2" -13 NC-2 X 1" LONG		ANY 300 SST
17	THIS DWG	64	WASHER, SPRING LOCK, FOR 1/2" DIA SCREW		ANY 300 SST
18	EN-004-D	2	COVER PLATE		ANY 300 SST
19	EN-004-D	2	BUSHING		ANY 300 SST
20	THIS DWG	8	BOLT, SOC HD CAP 1/2" - 13 NC - 2 X 1 1/2" LONG		ANY 300 SST
21_2	THIS DWG	AS REQD.	SHIELDING		CONCRETE
22	THIS DWG	1	COVER PLATE, 10" DIA X 1/2" THK		ANY 300 SST
23	EN-005-D	1	UPPER RING		ANY 300 SST
24	EN-005-D	1	ACCESS TUBE		ANY 300 SST
$25_{6,7}$	THIS DWG	12	SCREW, SOC HD CAP 1/2" - 13 NC - 2 X 1 1/2" LONG		ANY 300 SST
26_8	EN-004-D	1	GASKET		JM-60
27_3	THIS DWG	2	QUICK-CONNECT, SINGLE END SHUT-OFF 1/4" TUBE TO 1/8" FEMALE PIPE		316 SST
28	THIS DWG	2	NIPPLE, 1/8" NPS SCH 40 X 2" LONG		ANY 300 SST
29	THIS DWG	2	CONNECTOR, FEMALE, 1/4" TUBE TO 1/8" PIPE		ANY 300 SST
30_4	THIS DWG	4	SEAT		SILICONE RUBBER
31	EN-006-D	2	VALVE BODY		SEE DETAIL
32	THIS DWG	2	O-RING, 3 1/4" I.D. X 3 5/8" O.D. X 3/16"		SILICONE RUBBER
33	EN-006-D	2	PLUG		ANY 300 SST
34_4	THIS DWG	2	BODY SEAL		SILICONE RUBBER
35	THIS DWG	2	O-RING, 3/4" I.D X 7/8" O.D. X 1/16"		SILICONE RUBBER
36	EN-006-D	2	STEM		ANY 300 SST
37_4	THIS DWG	2	BALL		ANY 300 SST
38	THIS DWG	4	O-RING, 5 1/2" I.D. X 5 7/8" O.D. X 3/16"		SILICONE RUBBER
39	EN-007-D	2	ADJUSTMENT PLATE		ANY 300 SST
40	EN-007-D	1	TUBE, 1/4" O.D. X .069" WALL 144" LONG		ANY 300 SST
41_5	THIS DWG	16	BOLT, CAPTIVE, SOC HD CAP 1/2"-13 NC-2 X 2 1/4" LONG		ANY 300 SST
42_5	THIS DWG	16	BOLT, CAPTIVE, SOC HD CAP 3/8"-16 NC-2 X 1 3/8" LONG		ANY 300 SST
43	THIS DWG	16	WASHER, SPRING LOCK, FOR 3/8" DIA BOLT		ANY 300 SST
44	EN-007-D	2	INNER PLUG		SEE DETAIL
45	EN-007-D	2	O-RING 3 1/8" I.D. X 3 1/2" O.D. X 3/16"		SILICONE RUBBER
46_6	THIS DWG	16	BOLT, CAPTIVE, SOC HD. CAP 1/2"-13 NC-2 X 1 1/2" LG		ANY 300 SST
47	EN-008-D	2	HOUSING		ANY 300 SST
48	EN-008-D	2	EXTENSION BAR		ANY 300 SST
49	EN-003-D	2	SPRING		SPRING STL
50	THIS DWG	2	O-RING, 1" I.D. X 1 1/4" O.D X 1/8"		SILICONE RUBBER
51	EN-006-D	2	END PLATE		ANY 300 SST
$52_{5,7}$	THIS DWG	8	BOLT, CAPTIVE, SOC HD CAP 1/4"-20 NC-2 X 7/8" LONG		ANY 300 SST
53	THIS DWG	8	WASHER, SPRING, LOCK, FOR 1/4" DIA BOLT		ANY 300 SST
54	THIS DWG	2	GASKET, 2 1/8" O.D. X 1 1/8" I.D. X 1/16" THK WITH (4) 5/16" DIA HOLES EQ. SPACED ON 1 5/8" DIA BC		JM-60
55	EN-006-D	2	COVER PLATE		ANY 300 SST
56	EN-006-D	2	O-RING 2 1/8" I.D. X 2 1/2" O.D. X 3/16"		SILICONE RUBBER
57	EN-003-D	3	PIPE PLUG 1/8" NPT		ANY 300 SST
58	EN-008-D	1	ADAPTER		ANY 300 SST
59	THIS DWG	1	O-RING, 1 3/4" ID X 2 1/8" OD X 3/16"		SILICONE RUBBER
60	EN-008-D	1	NAME PLATE		ANY 300 SST

REFERENCE DRAWINGS	NUMBER
DETAIL SHEET NO. 6	EN-008-D
" " NO. 5	EN-007-D
" " NO. 4	EN-006-D
" " NO. 3	EN-005-D
" " NO. 2	EN-004-D
" " NO. 1	EN-003-D
WELDMENT	EN-002-D

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

TRU SHIPPING CARRIER — BLDG NO. 7920

SHIPPING CARRIER ASSEMBLY

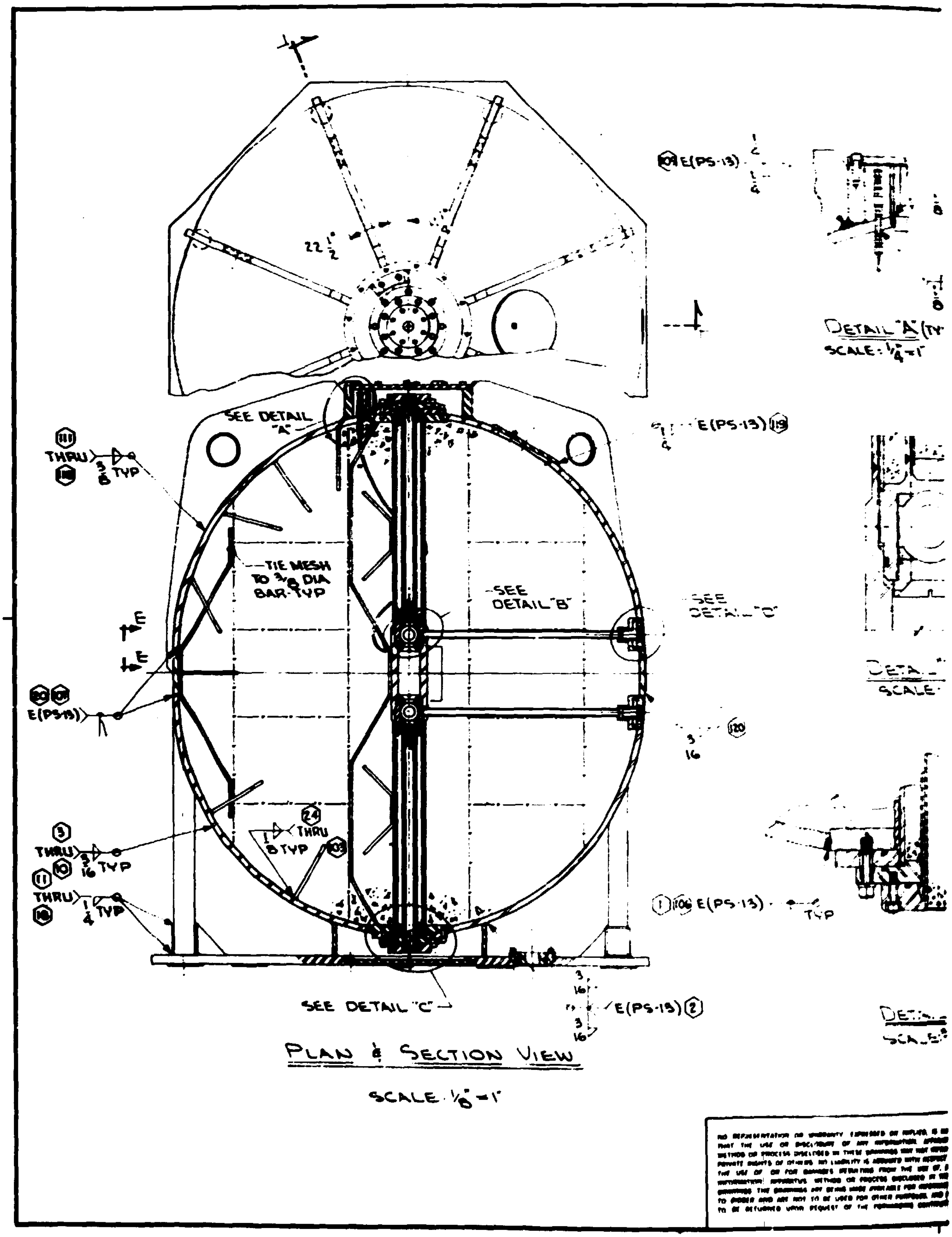
M 11230 EN 001 D 3

NO.	REVISIONS	DATE	APPD	APPD
3	⚠3 REVISED DETAIL "C", ADDED ⚠ LHM	[illegible]	[illegible]	[illegible]
2	⚠2 REVISED TO AS BUILT	6-1-[illegible]	[illegible]	[illegible]
1	⚠1 NOTE ADDED	[illegible]	[illegible]	[illegible]

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
A WILLIAMS	9-25-61				
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE
SQ Lewis	9-19-61				
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE
SQ Lewis	9-21-61				

GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: √ (ASA B46.1–1962)

TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ± 1/16
DECIMALS ± —
ANGLES ± 1°
SCALE: NOTED

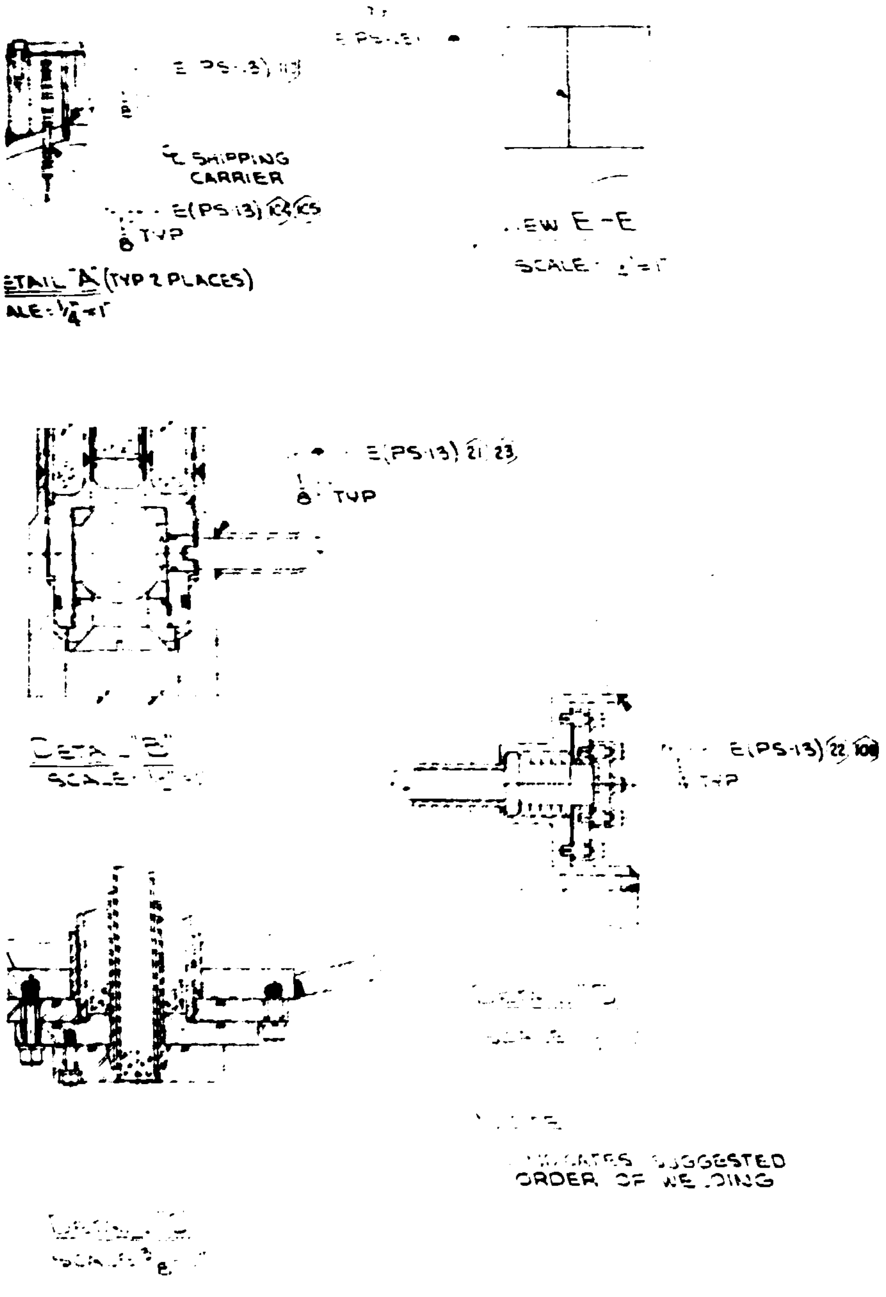


PLAN & SECTION VIEW

SCALE 1/8"=1'

PARTS LIST

PART	DWG NO	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



SHIPPING CARRIER ASSY	EN-001-D
REFERENCE DRAWINGS	NUMBER

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

TRU SHIPPING CARRIER BLDG NO 7920

SHIPPING CARRIER
WELDMENT

SUBMITTED	ACCEPTED	APPROVED
	H. D. Arnold	H. G. Duggan

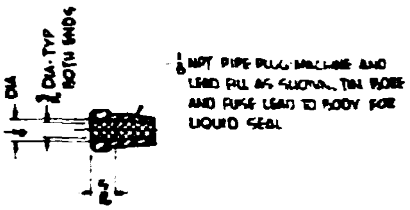
					REV.
M	11230	EN	002	D	

GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED
1 BREAK ALL SHARP EDGES
2 TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR
3 MACHINED SURFACE FINISH SHALL NOT EXCEED (ASA B46 1 - 1962) √

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ±
DECIMALS ±
ANGLES ±
SCALE

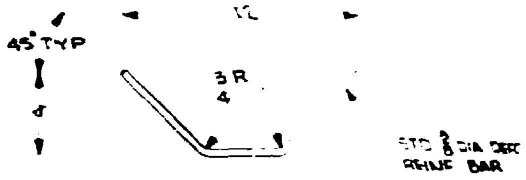
NO	REVISIONS	DATE	APPD	APPD

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
	3-20-67				
DESIGNED	DATE	APPROVED	DATE	APPROVED	DATE
	9-18-67				
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE
	10-2-67				



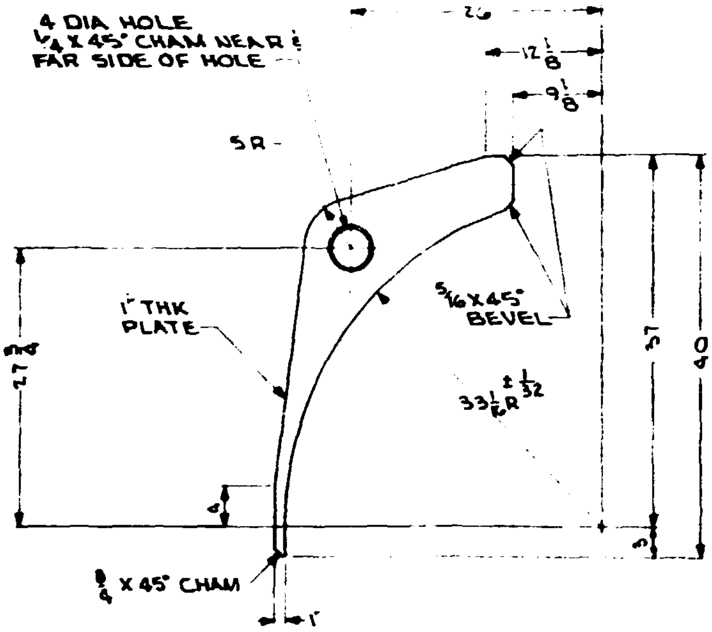
(57) 1/8 PIPE PLUG (MOD)

MAT'L: ANY 300 SST
8-REQ'D
SCALE: 1"=1"
TOLERANCE ±1/64



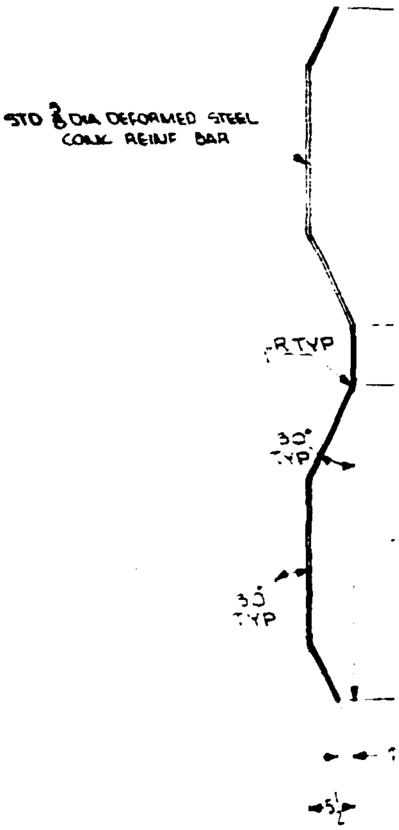
(12) REINF BAR "D"

8-REQD
SCALE: 1/4"=1"



(1) RIB

MAT'L: ANY 300 SST
(8) REQ'D
SCALE: 1/8"=1"



(13) REINF F

8-REQ'
SCALE:

SPRING DATA

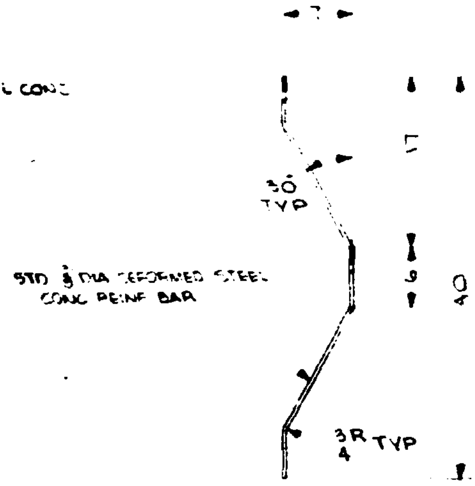
WIRE SIZE	.125
OUTSIDE DIA	1.562
PITCH	.175
ACTIVE COILS	5
TOTAL COILS	7
FREE LENGTH	1.625
RATE	24 LB/IN ±2.4 LB
ENDS	SQUARE & GROUND

(49) SPRING

MAT'L: SPRING STL
(2) REQ'D

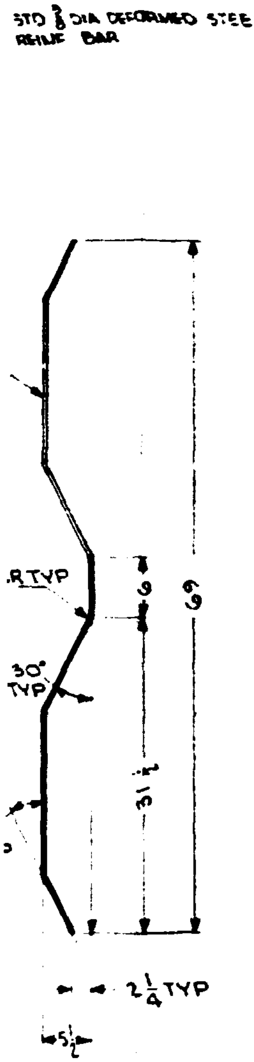
PARTS LIST

PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



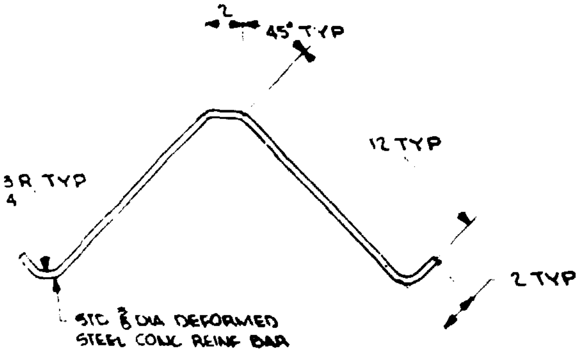
③ REINF BAR "A"

16-REQD
SCALE: 1/8" = 1"



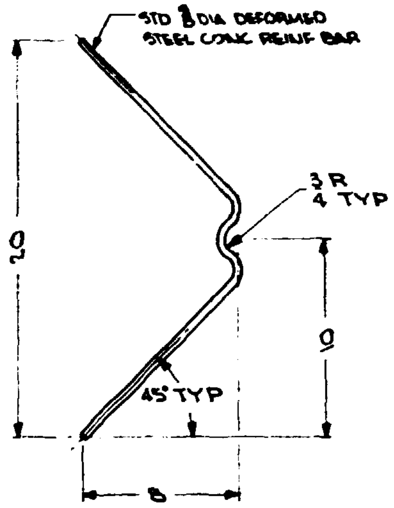
) REINF BAR "E"

8-REQD
SCALE: 1/8" = 1"



④ REINF BAR "B"

48-REQD
SCALE: 1/4" = 1"



⑤ REINF BAR "C"

16-REQD
SCALE: 1/4" = 1"

NOTE
TOLERANCE ON ALL REINF BARS TO BE ±1/8

SHIPPING CARRIER ASSY	EN-001-D
REFERENCE DRAWINGS	NUMBER

Oak Ridge National Laboratory
Operated by
Union Carbide Corporation
Oak Ridge, Tennessee

TRU SHIPPING CARRIER 7920

SHIPPING CARRIER
DETAIL SHEET No.1

[illegible]

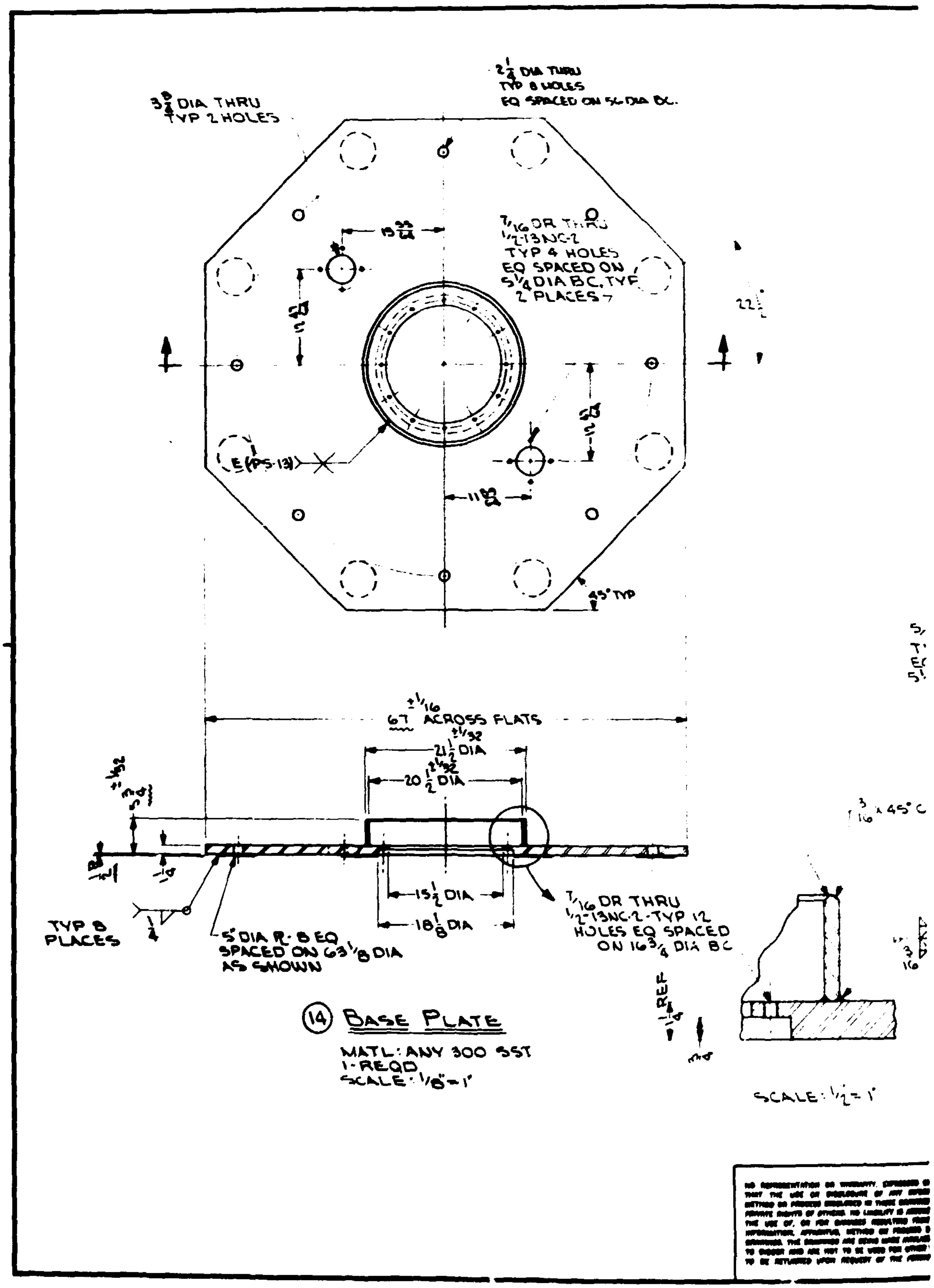
GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: 125√ (ASA B46.1-1962)

TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ± 1/16
DECIMALS ± .005
ANGLES ± 0°30'
SCALE: NOTED

NO.	REVISIONS	DATE	APPD	APPD

DRAWN A WILLIAMS	DATE 6-5-67	SUBMITTED	DATE	APPROVED	DATE		
CHECKED S.O. Lewis	DATE 6-1-67	APPROVED	DATE	APPROVED	DATE		
CHECKED S.O. Lewis	DATE 10-4-67	APPROVED	DATE	APPROVED	DATE		

APPROVED G. J. Gallaga		APPROVED		APPROVED H. J. Duggan		
	M	11230	EN	003	D	

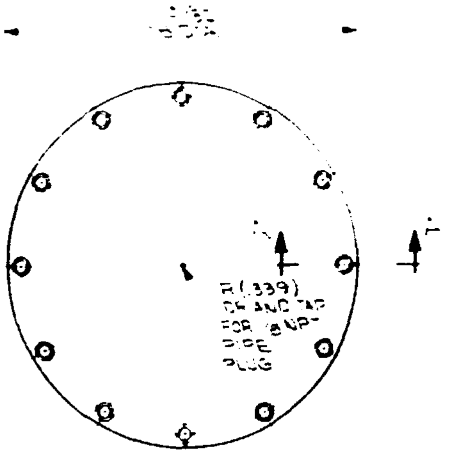


⑭ BASE PLATE

MATL: ANY 300 SST
1-REQD
SCALE: 1/8"=1"

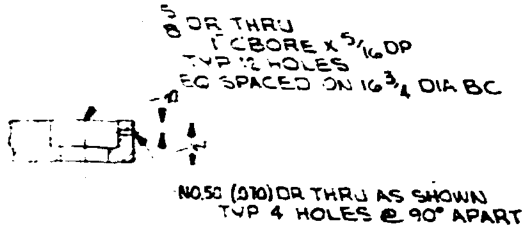
PARTS LIST

PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



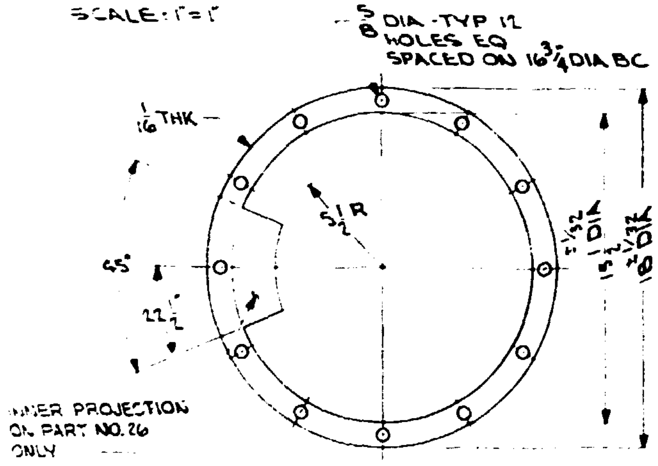
(18) COVER PLATE

MATL: ANY 300 SST
2-REQD
SCALE: 1/4 = 1"



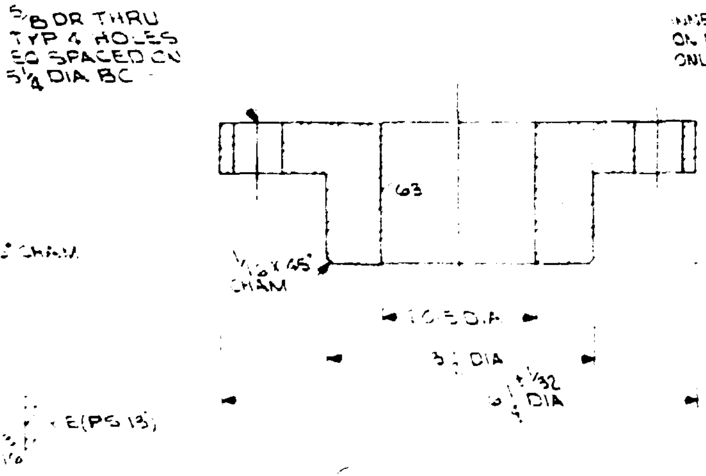
SECTION A-A

SCALE: 1"=1"



(15) (26) GASKET

MATL: JM-60 ASBESTOS
1-EACH REQD
SCALE: 1/4" = 1"



(19) BUSHING

MATL: ANY 300 SST
2 REQD
SCALE: 1"=1"

1/2 = 1"

SHIPPING CARRIER ASSY — EN-001 D

REFERENCE DRAWINGS — NUMBER

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

TRU SHIPPING CARRIER — BLDG. NO. 7920

SHIPPING CARRIER
DETAIL SHEET NO. 2

M 11230 EN 004 D

H. B. Burch
H. E. Duggan

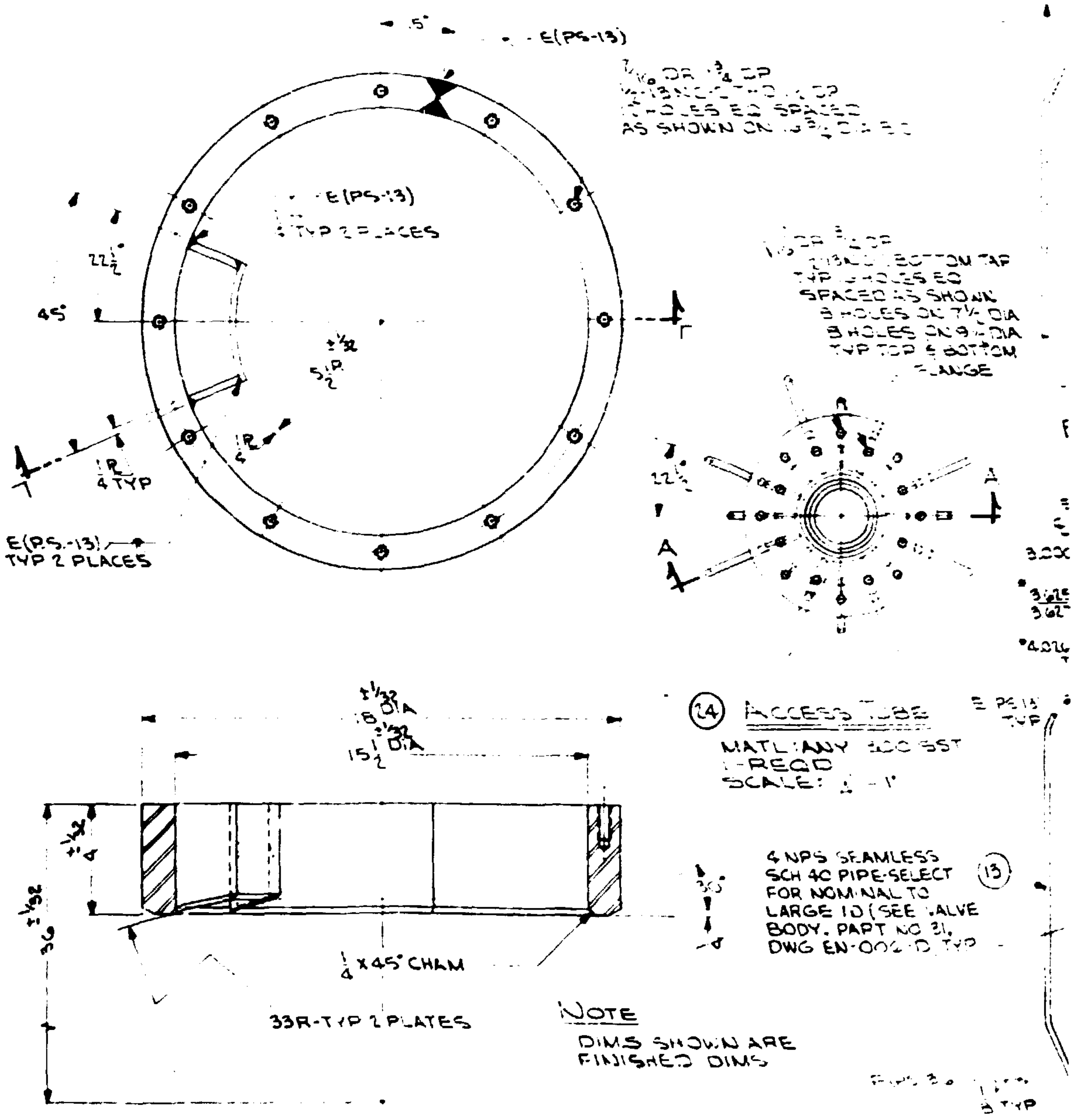
GENERAL SPECIFICATIONS

UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: 125 √ (ASA B46.1-1962)

TOLERANCES UNLESS OTHERWISE SPECIFIED.
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 0°30'
SCALE: NOTED

NO.	REVISIONS	DATE	APPD	APPD

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
A. WILLIAMS	6-7-67				
DESIGNED S.O. Lewis	DATE 6-1-67	APPROVED	DATE	APPROVED	DATE
CHECKED S.O. Lewis	DATE 10-5-67	APPROVED	DATE	APPROVED	DATE



(24) ACCESS TUBE

MATL: ANY 300 SST
1-REQD
SCALE: 1/4 = 1"

NOTE

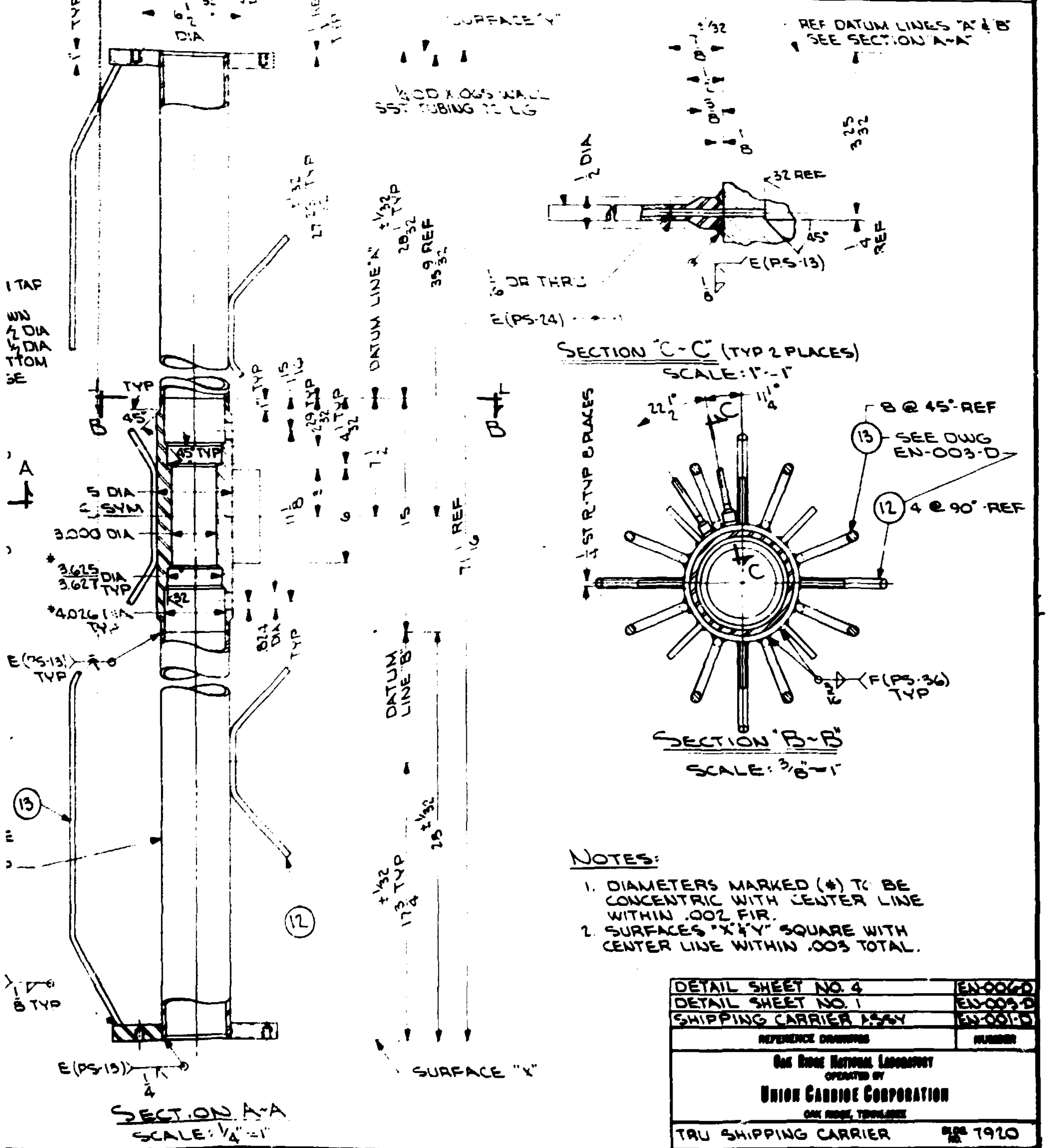
DIMS SHOWN ARE
FINISHED DIMS

(23) UPPER RING

MATL: ANY 300 SST
1-REQD
SCALE 3/16" = 1"

PARTS LIST

PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



NOTES:

1. DIAMETERS MARKED (*) TO BE CONCENTRIC WITH CENTER LINE WITHIN .002 FIR.
2. SURFACES "X" & "Y" SQUARE WITH CENTER LINE WITHIN .003 TOTAL.

REFERENCE DRAWINGS	NUMBER
DETAIL SHEET NO. 4	EN-006-D
DETAIL SHEET NO. 1	EN-003-D
SHIPPING CARRIER ASSY	EN-001-D

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

TRU SHIPPING CARRIER — BLDG NO. 7920

SHIPPING CARRIER
DETAIL SHEET NO. 3

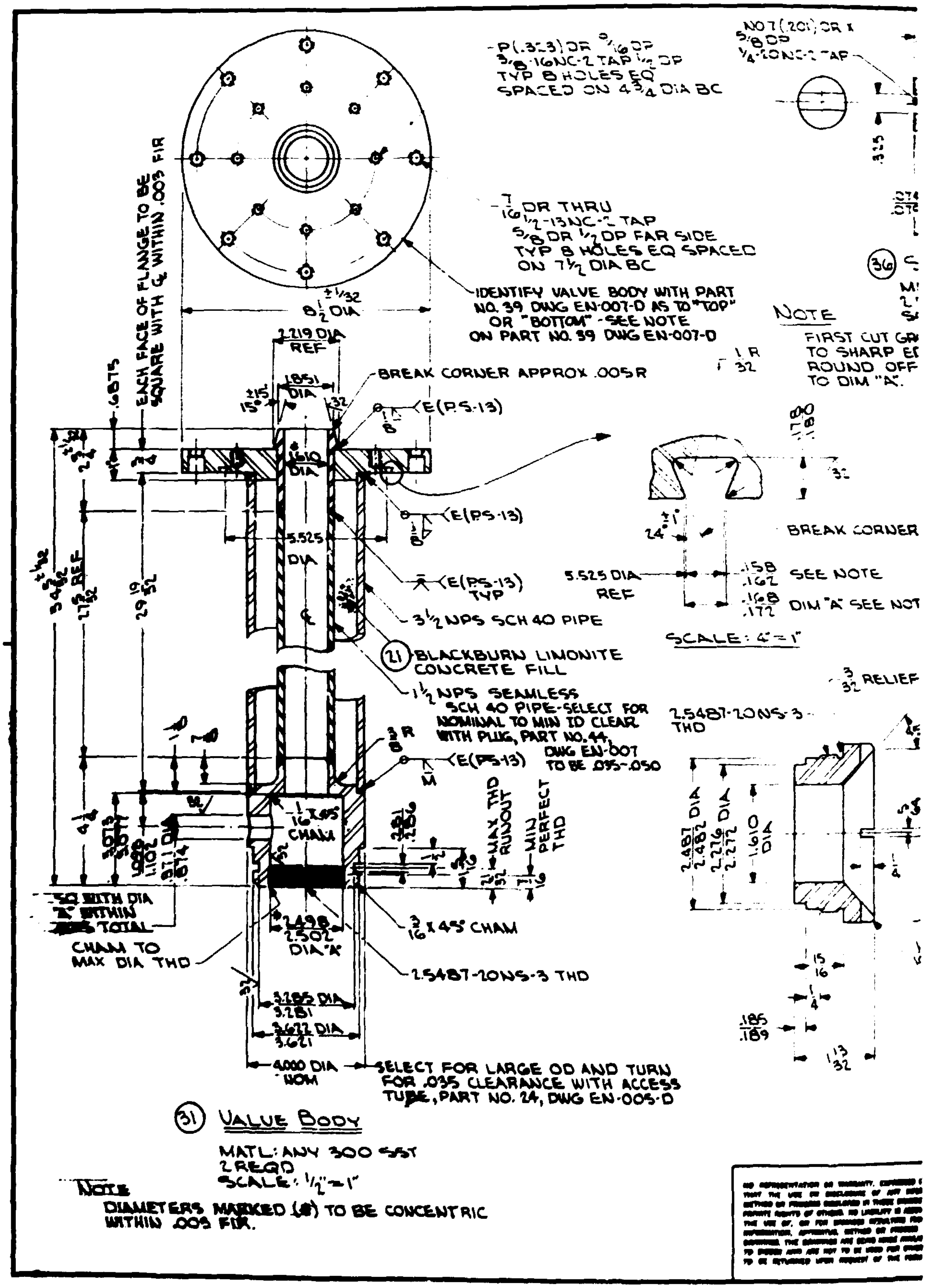
GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: 63 (ASA B46.1—1962)

TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 0°30'
SCALE: 3/8"=1" & NOTED

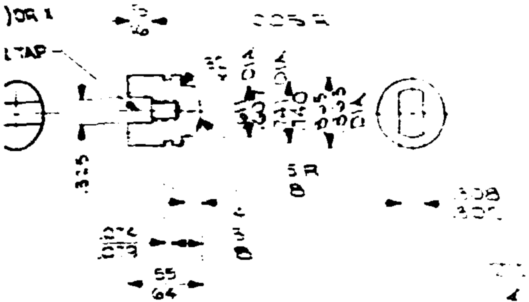
NO.	REVISIONS	DATE	APPD	APPD

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
A. WILLIAMS	6-9-67				
CHECKED S.O. Lewis	6-5-67	APPROVED			
TRACED S.O. Lewis	10-6-67	APPROVED			

M | 11230 | EN | 005 | D

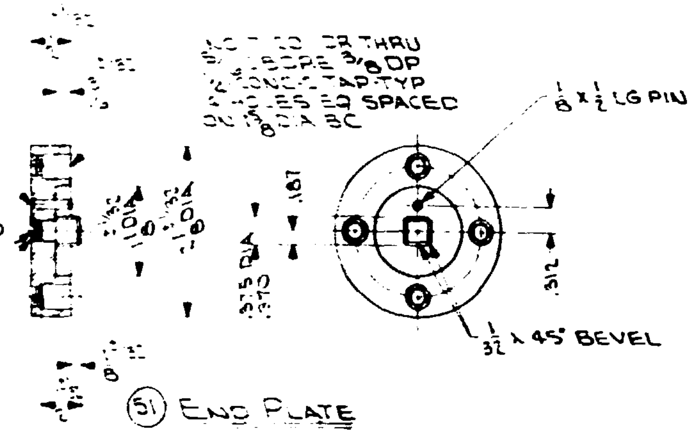

P(.323) DR 9/16 DP 3/8-16NC-2 TAP 1/2 DP TYP 8 HOLES EQ SPACED ON 4 3/4 DIA BC
NO 7 (.201) DR X 5/8 DP 1/4-20NC-2 TAP
.325
7/16 DR THRU 1/2-13NC-2 TAP 5/8 DR 1/2 DP FAR SIDE TYP 8 HOLES EQ SPACED ON 7 1/2 DIA BC
IDENTIFY VALVE BODY WITH PART NO. 39 DWG EN-007-D AS TO "TOP" OR "BOTTOM" - SEE NOTE ON PART NO. 39 DWG EN-007-D
36
NOTE
FIRST CUT GR
TO SHARP E
ROUND OFF
TO DIM "A".
8 1/2 DIA ±1/32
2.219 DIA REF
1.851 DIA
1.610 DIA
15° ±15'
BREAK CORNER APPROX .005R
EACH FACE OF FLANGE TO BE SQUARE WITH ℄ WITHIN .003 FIR
.6875
E(P.S-13)
1/32 R
BREAK CORNER
24° ±1°
5.525 DIA
5.525 DIA REF
.158 .162 SEE NOTE
.168 .172 DIM "A" SEE NOTE
SCALE: 4" = 1"
E(P.S-13) TYP
3 1/2 NPS SCH 40 PIPE
21 BLACKBURN LIMONITE CONCRETE FILL
1 1/2 NPS SEAMLESS SCH 40 PIPE - SELECT FOR NOMINAL TO MIN ID CLEAR WITH PLUG, PART NO. 44, DWG EN-007 TO BE .035-.050
3/32 RELIEF
2.5487-20NS-3 THD
2.487 2.482 DIA
2.276 2.272 DIA
1.610 DIA
15/16
1/4
.185 .189
1 13/32
3/8 R
E(P.S-13)
1/16 X 45 CHAM
MAX THD RUNOUT
MIN PERFECT THD
.50 WITH DIA "A" WITHIN .005 TOTAL
CHAM TO MAX DIA THD
2.498 2.502 DIA "A"
3/16 X 45° CHAM
2.5487-20NS-3 THD
3.285 3.281 DIA
3.622 3.621 DIA
4.000 DIA NOM
SELECT FOR LARGE OD AND TURN FOR .035 CLEARANCE WITH ACCESS TUBE, PART NO. 24, DWG EN-005-D
31 VALUE BODY
MATL: ANY 300 SST
2 REQD
SCALE: 1/2" = 1"
NOTE
DIAMETERS MARKED (●) TO BE CONCENTRIC WITHIN .003 FIR.

PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



㊱ STEM

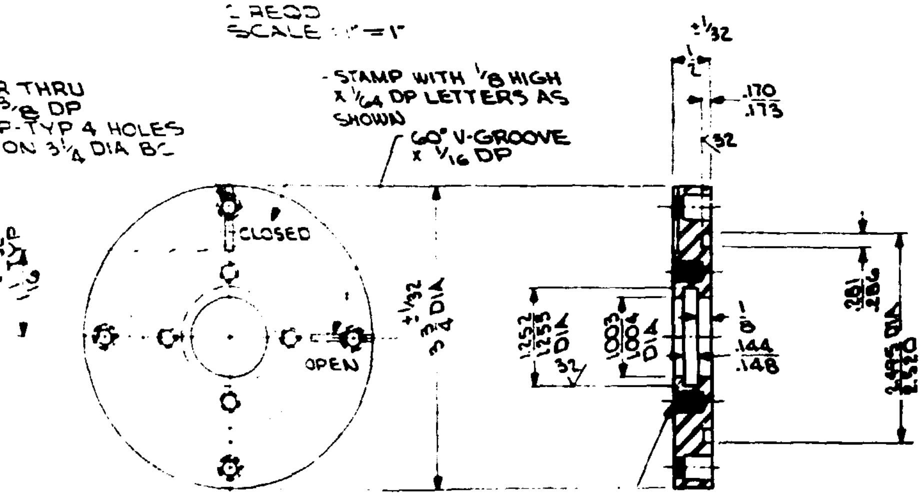
MATL: ANY 300 SST
2 REQD
SCALE: 1"=1"



(51) END PLATE

MATL: ANY 300 SST
2 REQD
SCALE: 1"=1"

TE
FIRST CUT GROOVE
TO SHARP EDGE, THEN
ROUND OFF EDGES
TO DIM "A".



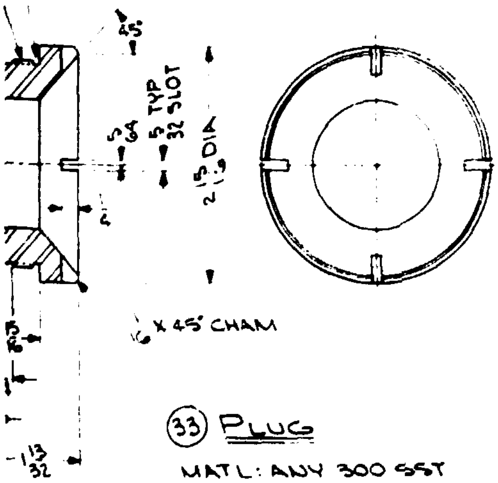
(55) COVER PLATE

MATL: ANY 300 SST
2 REQD
SCALE: 1"=1"

EAK CORNER-TYP

E NOTE

A "A" SEE NOTE



㉝ PLUG

MATL: ANY 300 SST
2 REQD
SCALE: 1"=1"

DETAIL SH NO. 5	EN-007-D
DETAIL SH NO. 3	EN-005-D
SHIPPING CARRIER ASSY	EN-001-D
REFERENCE DRAWINGS	NUMBER

Oak Ridge National Laboratory
operated by
Union Carbide Corporation
Oak Ridge, Tennessee

TRU SHIPPING CARRIER 7920

SHIPPING CARRIER
DETAIL SHEET No. 4

GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: 63 (ASA B46.1-1962)

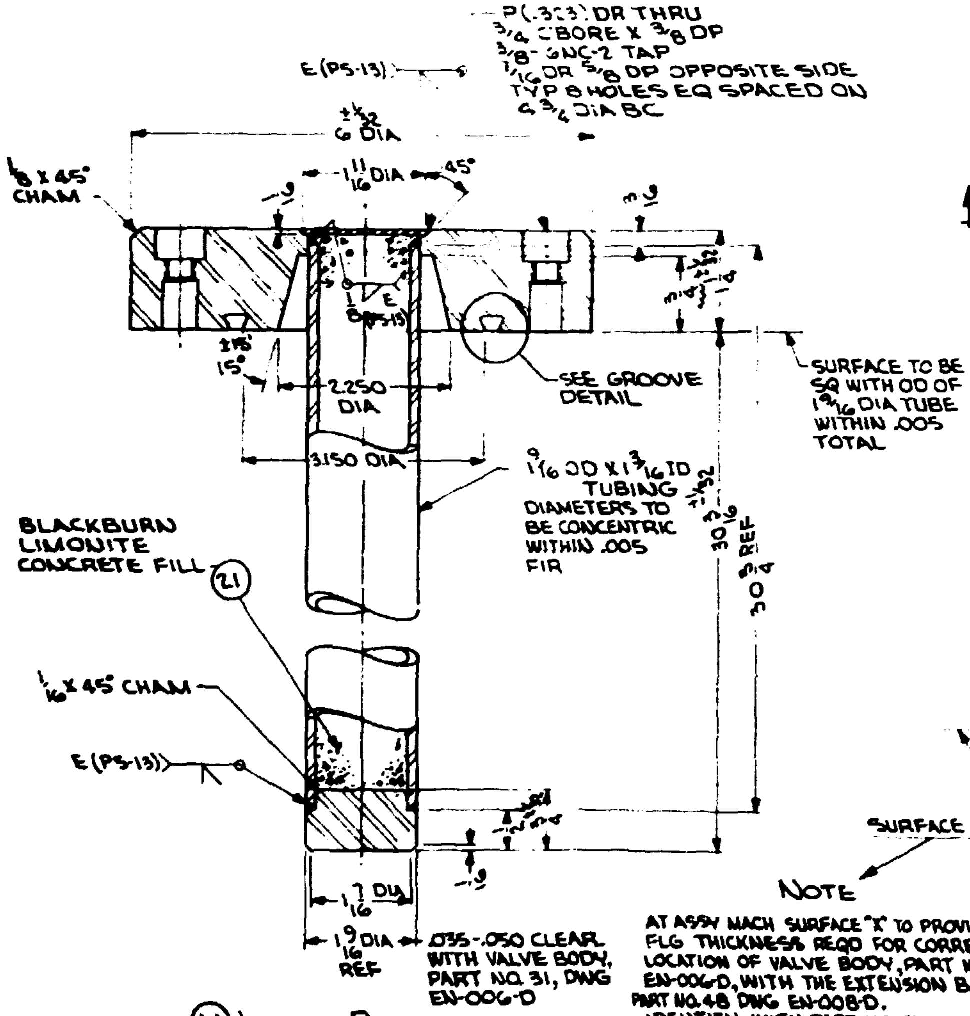
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64
DECIMALS ±.005
ANGLES ±0°30'
SCALE: 1"=1" NOTED

NO.	REVISIONS	DATE	APPD	APPD

DRAWN	A WILLIANS	DATE	6-29-67
CHECKED	SQ Lewis	DATE	6-1-67
CHECKED	SQ Lewis	DATE	10-3-67

Ted Zellgen W O Laugh H. E. Duggan

O M 11230 EN 006 D

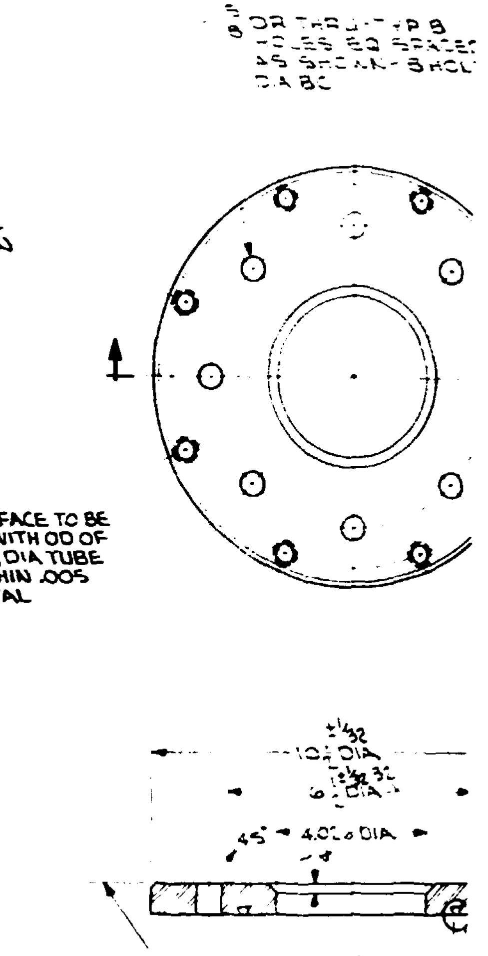


NOTE

AT ASSY MACH SURFACE "X" TO PROVIDE FLG THICKNESS REQD FOR CORRECT LOCATION OF VALVE BODY, PART NO. 31 DWG EN-006-D, WITH THE EXTENSION BAR, PART NO. 48 DWG EN-008-D.
IDENTIFY WITH PART NO. 31 AS TO "TOP" OR "BOTTOM" BY STAMPING EDGE OF FLG WITH 1/4 HIGH LETTERS.

㊹ INNER PLUG

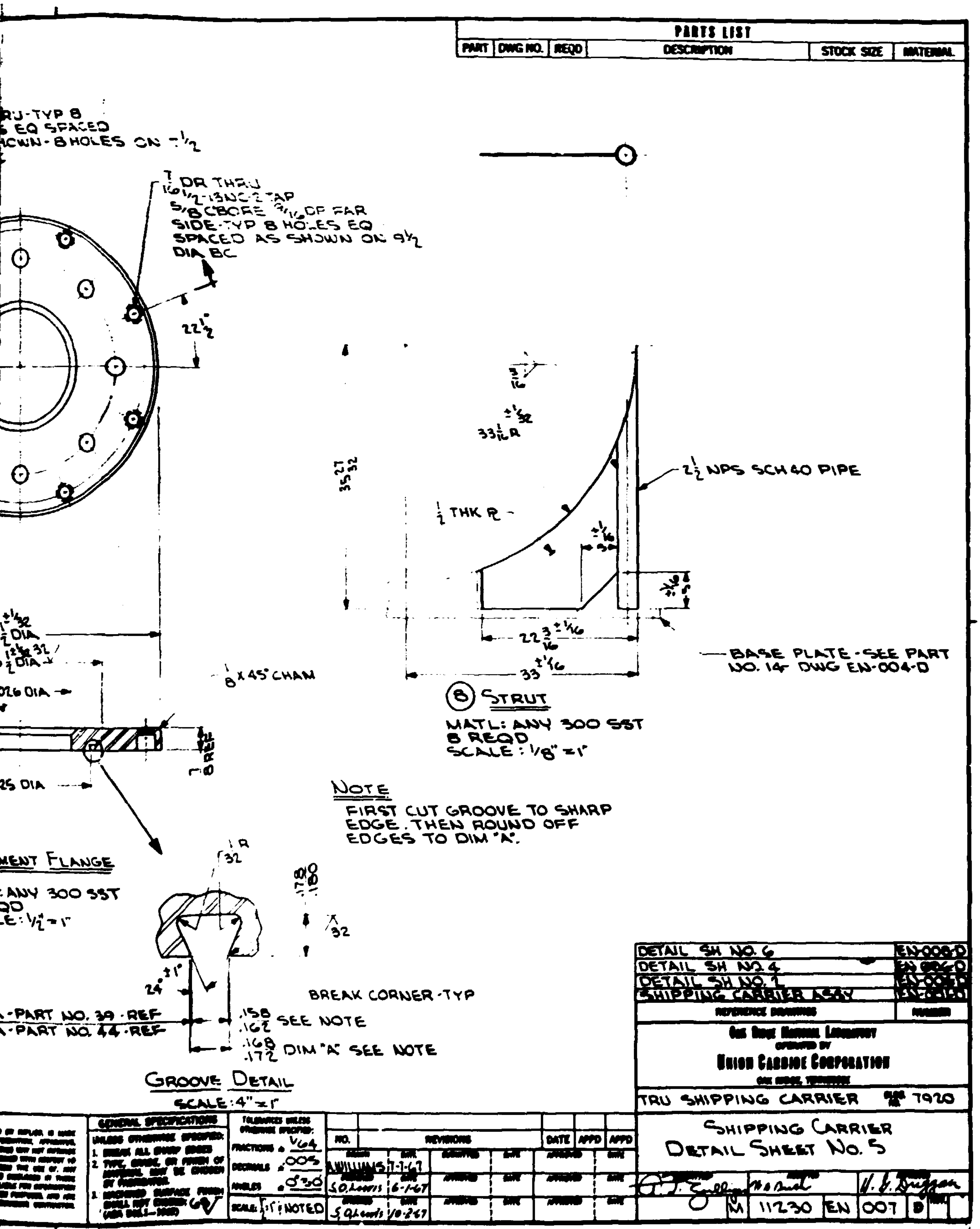
MATL: ANY 300 SST & NOTED
2 REQD
SCALE: 1"=1"

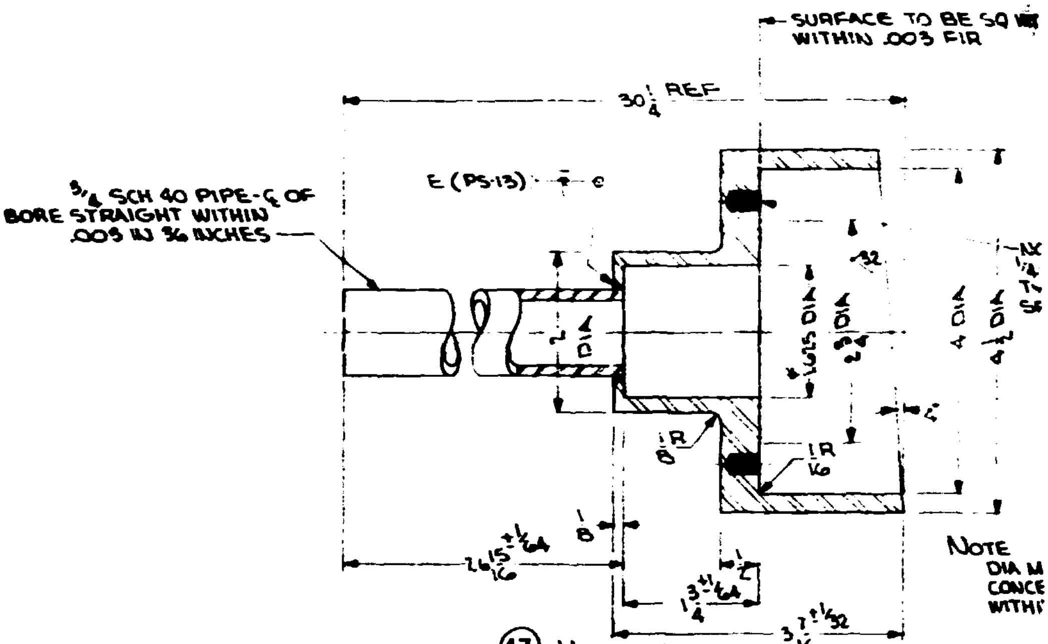


㊴ ADJUSTMENT FLANG

MATL: ANY 300 S
2 REQD
SCALE 1/2"=1"

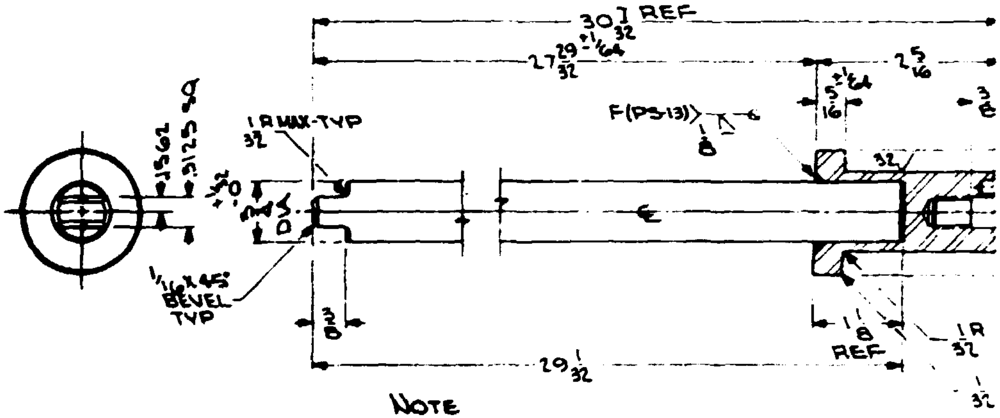
5.525 DIA - PART NO.
3.150 DIA - PART NO.


PARTS LIST
PART
DWG NO.
REQD
DESCRIPTION
STOCK SIZE
MATERIAL
RU-TYP 8
EQ SPACED
OWN-8 HOLES ON 1/2
7/16 DR THRU 1/2-13NC-2 TAP 5/8 CBORE 9/16 DP FAR SIDE-TYP 8 HOLES EQ SPACED AS SHOWN ON 9 1/2 DIA BC
22 1/2°
3/16
33 1/16 R ±1/32
35 27/32
2 1/2 NPS SCH 40 PIPE
1/2 THK R
±1/16
22 3/16 ±1/16
33 ±1/16
BASE PLATE-SEE PART NO. 14 DWG EN-004-D
1/8 X 45° CHAM
8 STRUT
MATL: ANY 300 SST
8 REQD
SCALE: 1/8" = 1"
NOTE
FIRST CUT GROOVE TO SHARP EDGE. THEN ROUND OFF EDGES TO DIM 'A'.
MENT FLANGE
ANY 300 SST
QD
LE: 1/2" = 1"
1/32 R
.170 .180
32
24° ±1°
BREAK CORNER-TYP
-PART NO. 39-REF
-PART NO. 44-REF
.158 .162 SEE NOTE
.168 .172 DIM 'A' SEE NOTE
GROOVE DETAIL
SCALE: 4" = 1"
26 DIA
25 DIA
DETAIL SH NO. 6 EN-008-D
DETAIL SH NO. 4 EN-006-D
DETAIL SH NO. 1 EN-003-D
SHIPPING CARRIER ASSY EN-001-D
REFERENCE DRAWINGS
NUMBER
Oak Ridge National Laboratory
operated by
Union Carbide Corporation
Oak Ridge, Tennessee
TRU SHIPPING CARRIER 7920
SHIPPING CARRIER DETAIL SHEET No. 5
GENERAL SPECIFICATIONS
TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 0°30'
SCALE: AS NOTED
REVISIONS
DATE
APPD
NO.
A. Williams 7-1-67
S. O. Lewis 6-1-67
S. O. Lewis 10-2-67
G. T. Eng
H. O. Bush
W. G. Duggan
M 11230 EN 007 D



(47) HOUSING

MATL: ANY 300 SST
2 REQD
SCALE: 1"=1"



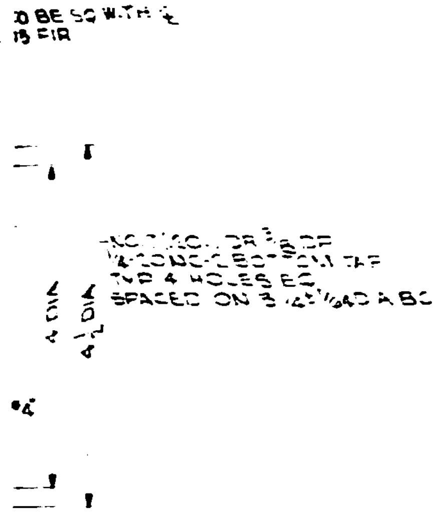
NOTE
ALL DIAMETERS CONCENTRIC WITH ℄
WITHIN .003 FIR

(48) EXTENSION BAR

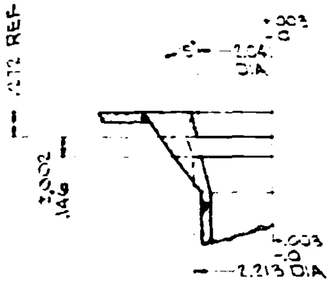
MATL: ANY 300 SST
2 REQD
SCALE: 1"=1"

NOTE:
FINAL MACHINE AFTER WELDING

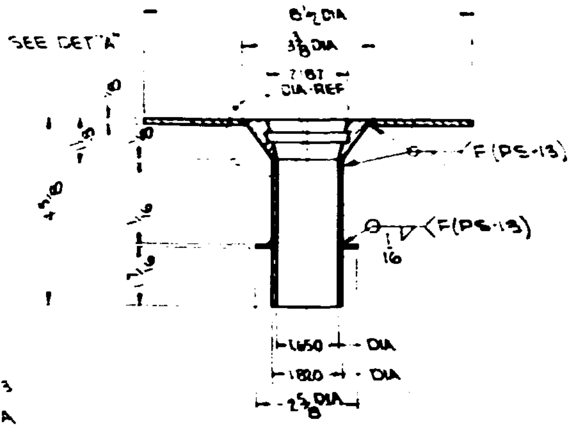
PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



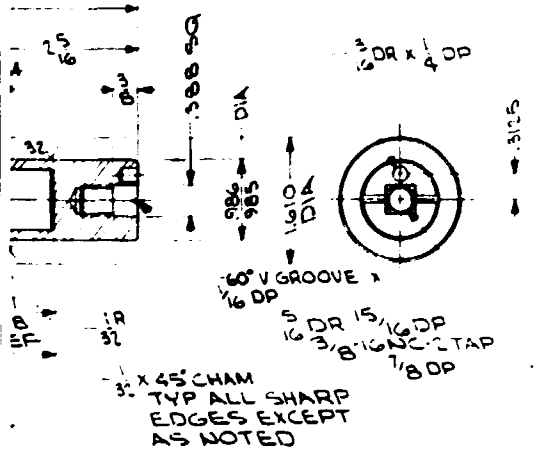
NOTE
DIA MARKED (*) TO BE
CONCENTRIC WITH ℄
WITHIN .003 FIR



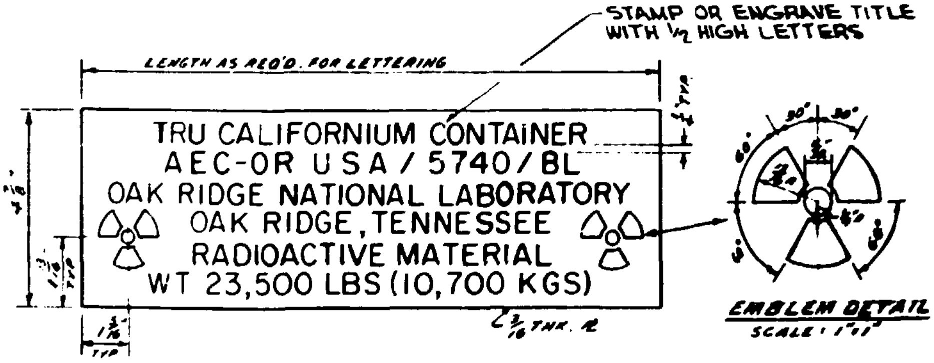
DETAIL "A"
SCALE: 1"=1"



(58) ADAPTER
MATL: ANY 300 SST
1-REQD
SCALE: 1/2"=1"



1/32 x 45° CHAM
TYP ALL SHARP
EDGES EXCEPT
AS NOTED



(60) NAME PLATE
MAT'L.: ANY 300 SST
1 REQ'D.
SCALE: 1/2"=1"

GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: 125 (ASA B46.1-1962)

TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ± 1/32
DECIMALS ± .005
ANGLES ± 0°30'
SCALE: NOTED

NO.	REVISIONS	DATE	APPD	APPD
1	CHG'D. NAME PLATE-PART 60	[illegible]	[illegible]	[illegible]

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
A. WILLIAMS	7-12-67				
DESIGNED	DATE	APPROVED	DATE	APPROVED	DATE
S Q Lewis	6-1-67				
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE
S Q Lewis	10-6-67				

REFERENCE DRAWINGS	NUMBER
SHIPPING CARRIER ASSY	EN-00[illegible]

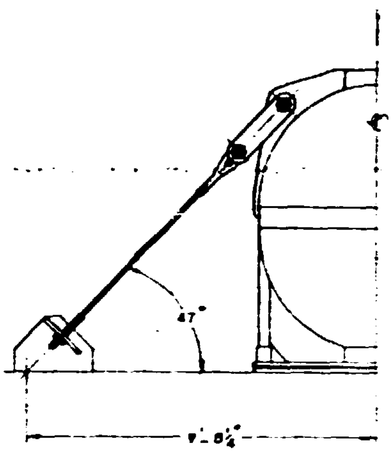
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

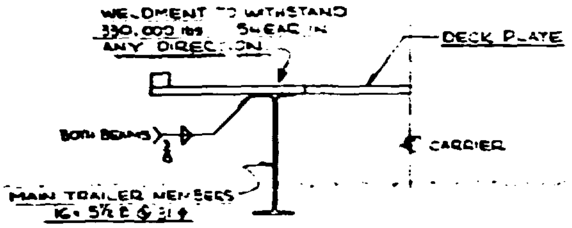
TRU SHIPPING CARRIER 7920

SHIPPING CARRIER
DETAIL SHEET NO. 6

G. T. Gilligan · W. B. Burch · H. G. Duggan

M 11230 EN 008 D 1

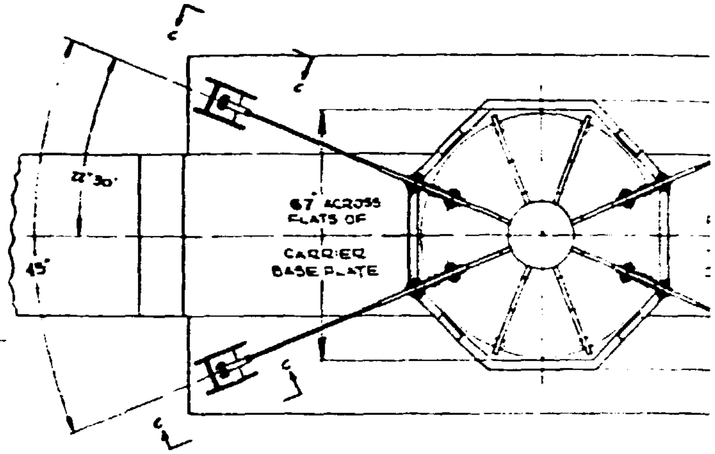


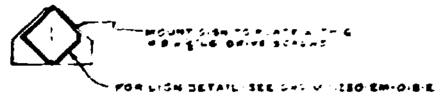


~ NOTE ~

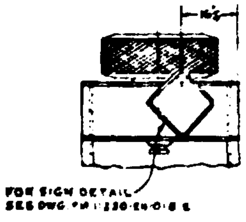
TIE DOWN CABLE ANCHORS TO BE EQ SP AS SHOWN FROM CENTER OF LOAD DISTRIBUTION DECAL 22°30' OFF TRAILER LENGTH CENTERLINE 4 REQ'D

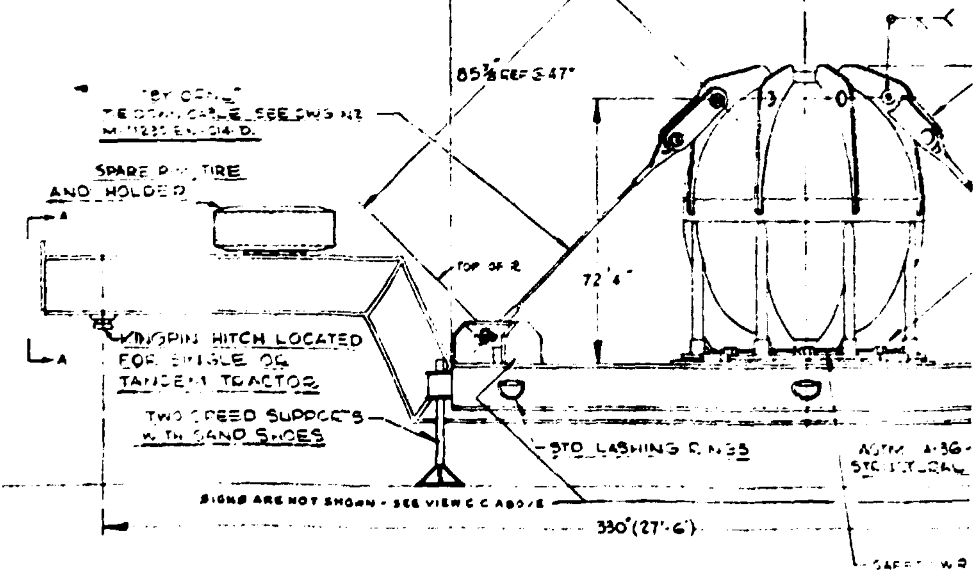
TIE DOWN ANCHORS SHALL BE WELDED TO THE MAIN STRUCTURAL MEMBERS OF THE TRAILER.





VIEW C-C

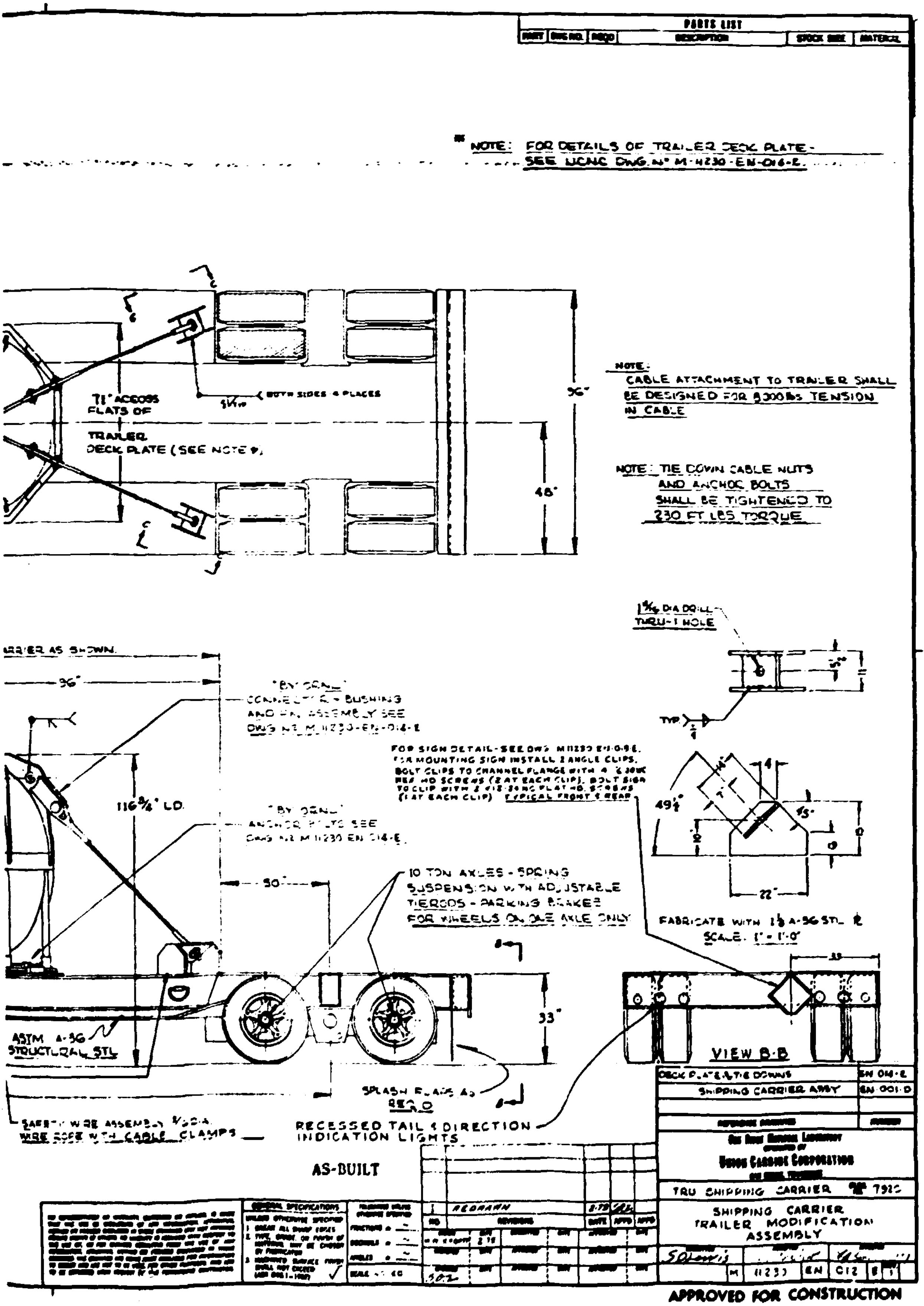




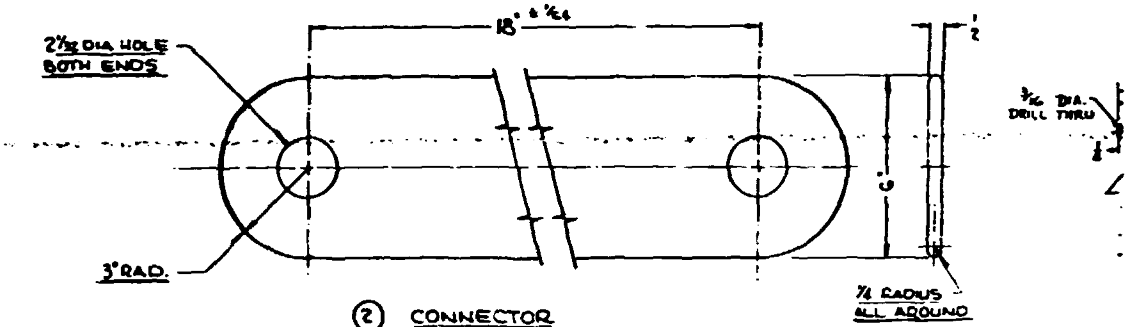
VIEW A-A

TRAILER WT APPROX 13740 lbs (6230 Kg)
SHIPPING CARRIER WT APPROX. 23500 lbs (10700 Kg)
SCALE: 1/4" = 1'-0"

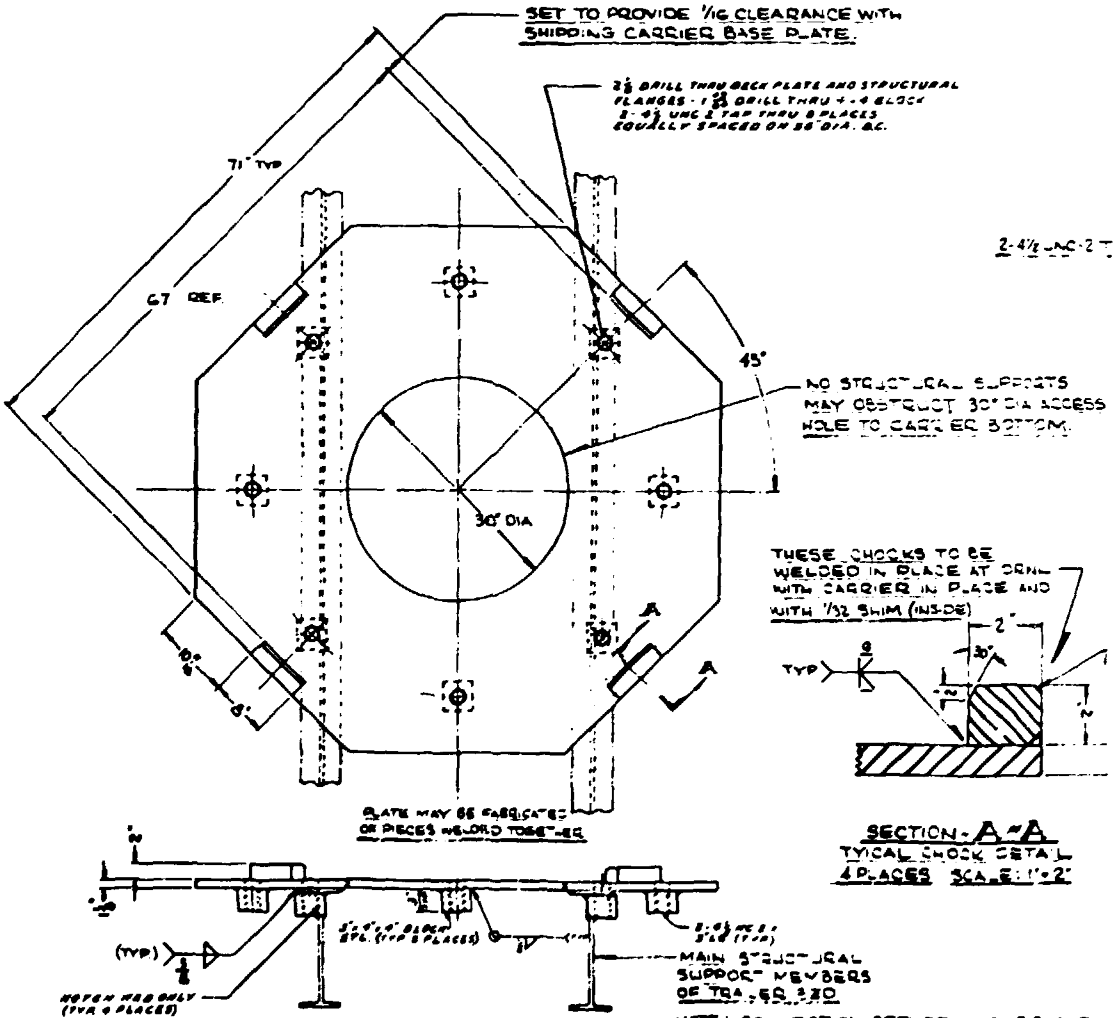
PAINT NOTE: PAINT ALL STEEL WITH ONE COAT OF RUST INHIBITIVE PRIMER AND TWO COATS OF MACHINERY GRAY OIL BASE PAINT.



APPROVED FOR CONSTRUCTION



② CONNECTOR
MAT'L : STEEL
Nº REQ'D - 8 SCALE: 1" = 2"



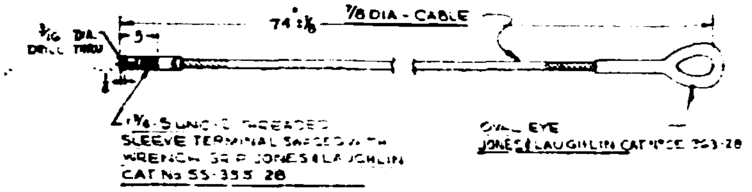
SECTION - A - A
TYPICAL CHOCK DETAIL
4 PLACES SCALE: 1" = 2"

⑧ TRAILER DECK PLATE
MAT'L : STEEL
Nº REQ'D - 1 SCALE: 1" = 6"

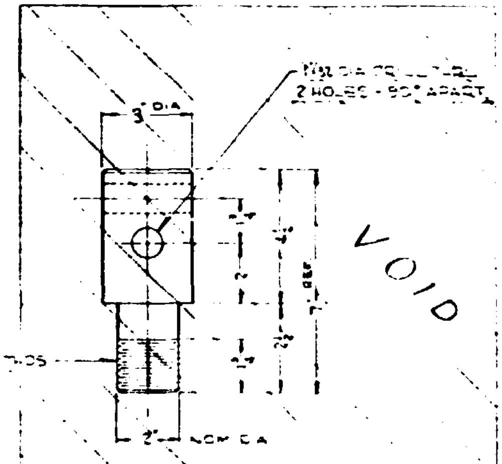
NOTE: CONNECTION BETWEEN PT Nº 8 AND STRUCTURAL MEMBERS OF TRAILER SHALL BE APPROVED BY ORNL

PARTS LIST

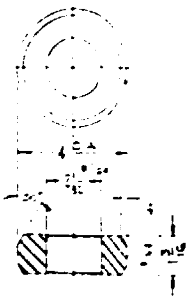
PART	DWG. NO.	REQ'D	DESCRIPTION	STOCK SIZE	MATERIAL
1	THIS DWG.	4	TIE DOWN CABLE ASSEMBLY		STEEL
2		8	CONNECTOR 72" R		STEEL
3		8	PIN		STEEL
4		16	2-4½ UNC-2 HEX NUT		STEEL
5		16	COTTER PIN 9/32 DIA - 3" LONG		STEEL
6		4	BUSHING		STEEL
7		8	ANCHOR BOLTS		STEEL
8		1	DECK PLATE 1" THICK		STEEL
9		8	1¼-UNC-2 HEX NUT		STEEL



① TIE DOWN CABLE
MAT'L STEEL
No REQ'D - 4 SCALE: NONE

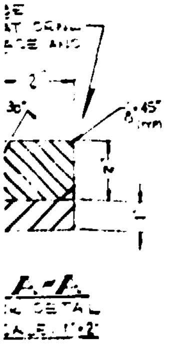


⑦ ANCHOR BOLT
MAT'L: STEEL
No REQ'D - 8 SCALE 1"=2"

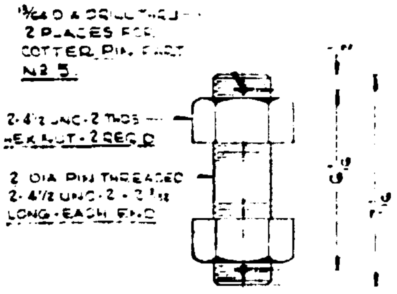


⑥ BUSHING
MAT'L: STEEL
No REQ'D - 4
SCALE 1"=2"

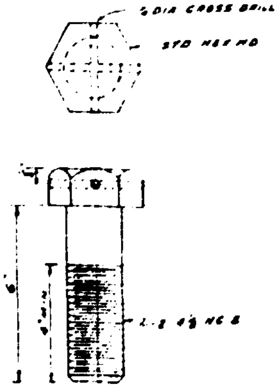
SUPPORTS
...TO... ACCESS
BOTTOM



A - A
DETAIL
SCALE 1"=2"



③④ PIN ASSEMBLY
MAT'L - MILD STEEL
No REQ'D - 8 SCALE 1"=2"



⑦ ANCHOR BOLT
SCALE 1"=2" No REQ'D 8
MAT'L STL SAE GRADE 5

...T No 3 AND
...OF TRAILER
BY ...

TRAILER MODIFICATION ASSEMBLY	EN-012-E
SHIPPING CARRIER ASSY	EN 001-D
REFERENCE DRAWINGS	NUMBER

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

TRU SHIPPING CARRIER 7320

SHIPPING CARRIER
TRAILER MODIFICATION
TIE DOWN DETAILS

S. Davis

M 11233 EN 014 E 1

GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR
3. MACHINED SURFACE FINISH SHALL NOT EXCEED √

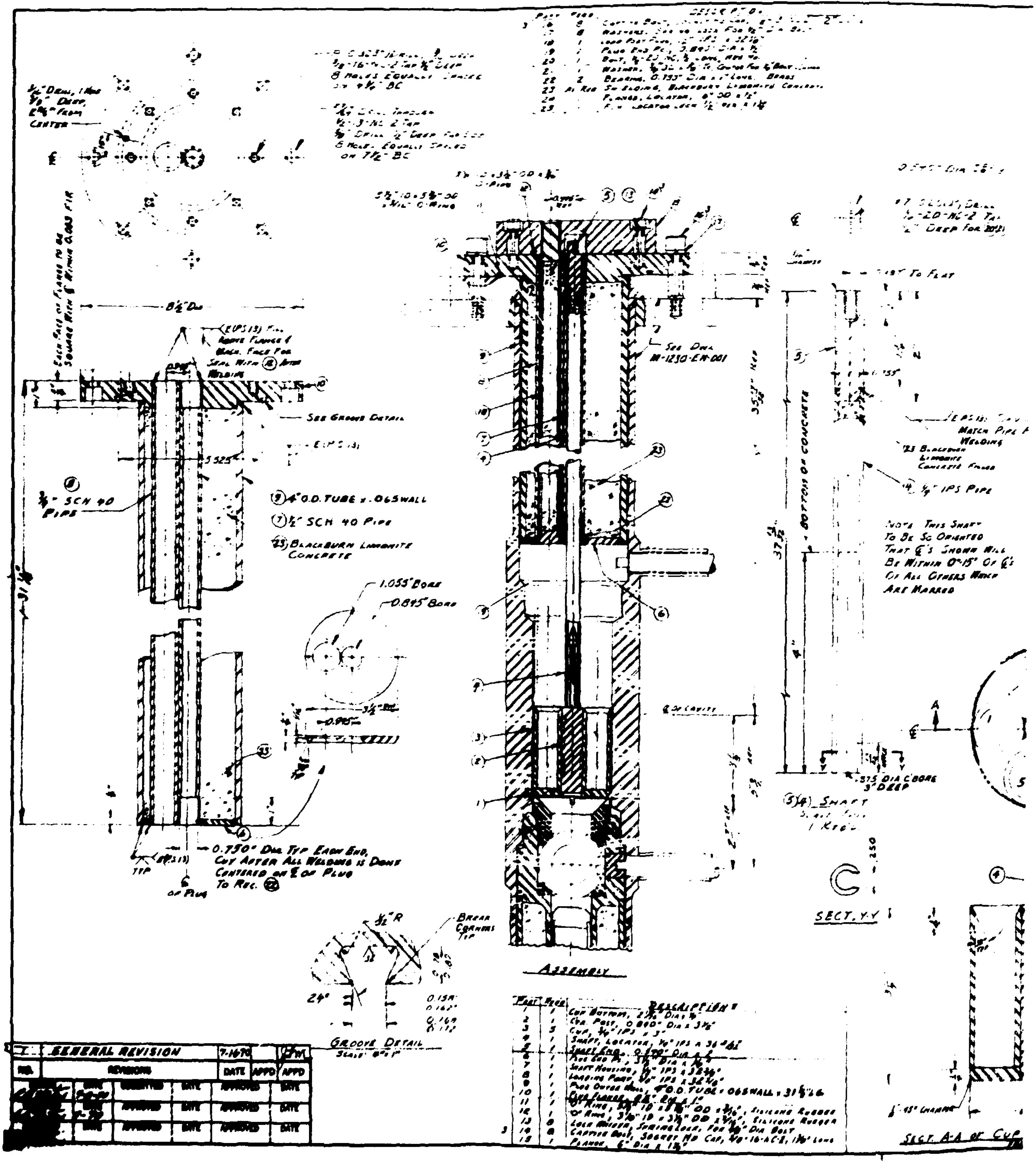
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ±
DECIMALS ±
ANGLES ± 1°
SCALE

REDRAWN 2-19
NO REVISIONS DATE APPD APPD

AS BUILT

APPROVED FOR CONSTRUCTION

MICROFILMED

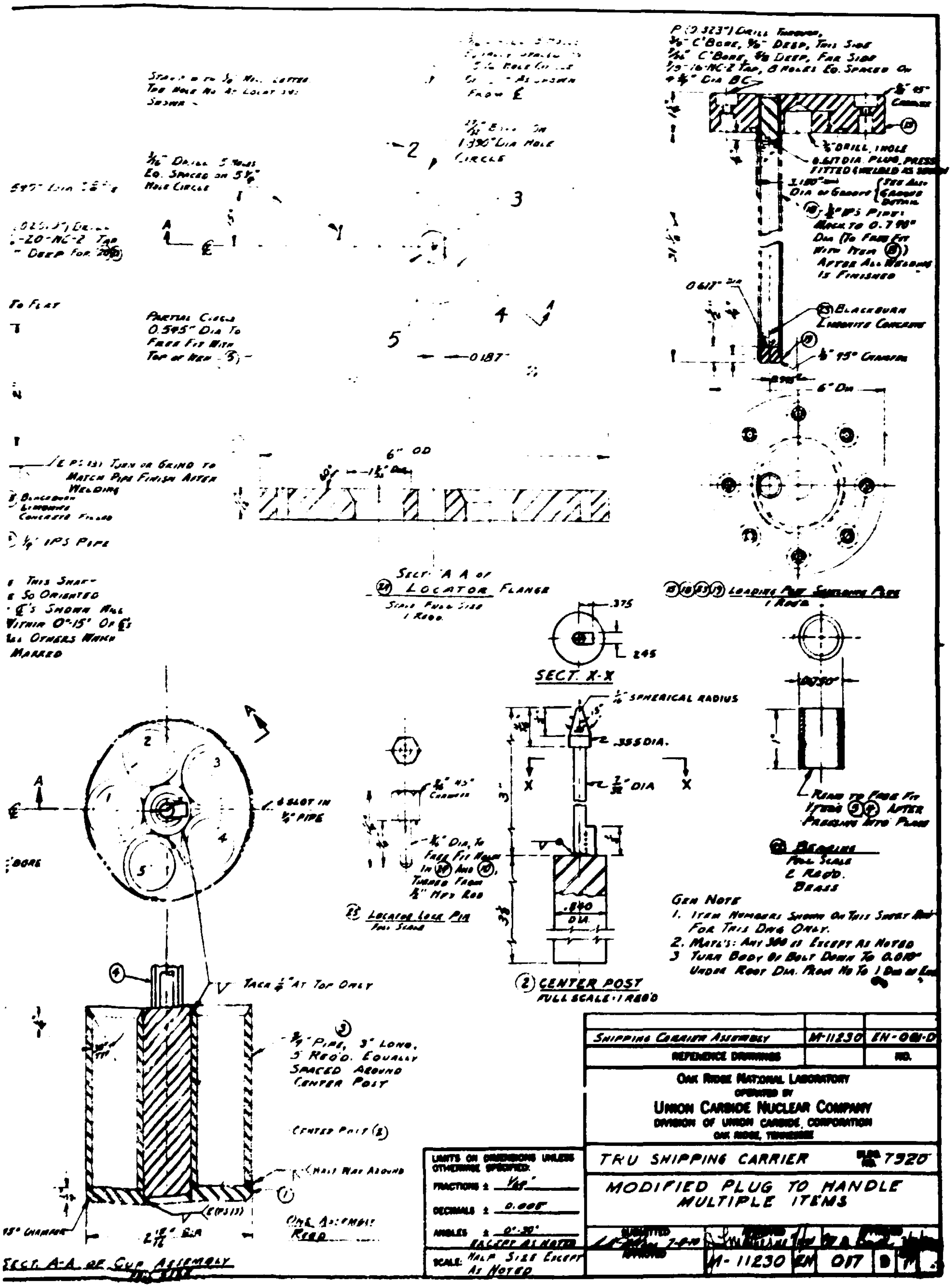


Part	Req'd	Description
16	8	Capture Bolt, [illegible]
17	8	Washers, [illegible] For 1/2" Dia Bolt
18	1	Load Post Form, [illegible] IPS x 32 1/16"
19	1	Plug End Pc., 3.843" Dia x 1/2
20	1	Bolt, 1/4-20-NC, 1/2 Long, Hex Hd.
21	1	Washer, [illegible] For 1/4" Bolt [illegible]
22	2	Bearing, 0.753" Dia x 1" Long, Brass
23	As Req	Shielding, Blackburn Limonite Concrete
24	[illegible]	Flange, Locator, 6" OD x 1/2"
25	[illegible]	Pin, Locator, [illegible] 1/2" Dia x 1 1/2

Part	Req'd	Description
1	1	Cup Bottom, 2 3/16 Dia x 1/4
2	1	Ctr. Post, 0.840" Dia x 3 1/8"
3	5	Cup, 1/2" IPS x 3"
4	1	Shaft, Locator, 1/4" IPS x 36 [illegible]
5	1	Shaft End, 0.[illegible]" Dia x [illegible]
6	1	Plug End Pc., 3 1/2" Dia x [illegible]
7	1	Shaft Housing, 1/2" IPS x 32 3/4"
8	1	Loading Port, 3/4" IPS x 32 1/8"
9	1	Plug Outer Wall, 4" O.D. TUBE x .065 WALL x 31 1/2" Lg.
10	1	Plug Flange, 8 1/2" Dia x 1"
11	1	"O" Ring, [illegible] ID x [illegible] OD x 1/16", Silicone Rubber
12	1	"O" Ring, 3 1/2" ID x 3 3/4" OD x 1/16", Silicone Rubber
13	8	Lock Washer, Springlock, For 5/8" Dia Bolt
14	8	Capture Bolt, Socket Hd Cap, 5/8-16-NC-2, 1 1/4" Long
15	1	Flange, 6" Dia x 1 1/2"

NO.	REVISIONS	DATE	APPD	APPD
1	GENERAL REVISION	7-16-70	[illegible]	

	DATE	CHECKED	DATE	APPROVED	DATE
[illegible]	[illegible]				
[illegible]	[illegible]	APPROVED	DATE	APPROVED	DATE
[illegible]	DATE	APPROVED	DATE	APPROVED	DATE



Gen Note
1. Item Numbers Shown On This Sheet Are For This Dwg Only.
2. Mat'l's: Any 300 SS Except As Noted
3. Turn Body Of Bolt Down To 0.010" Under Root Dia. From Hd To 1 Dia of End

Shipping Carrier Assembly	M-11230	EN-061-D
REFERENCE DRAWINGS		NO.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

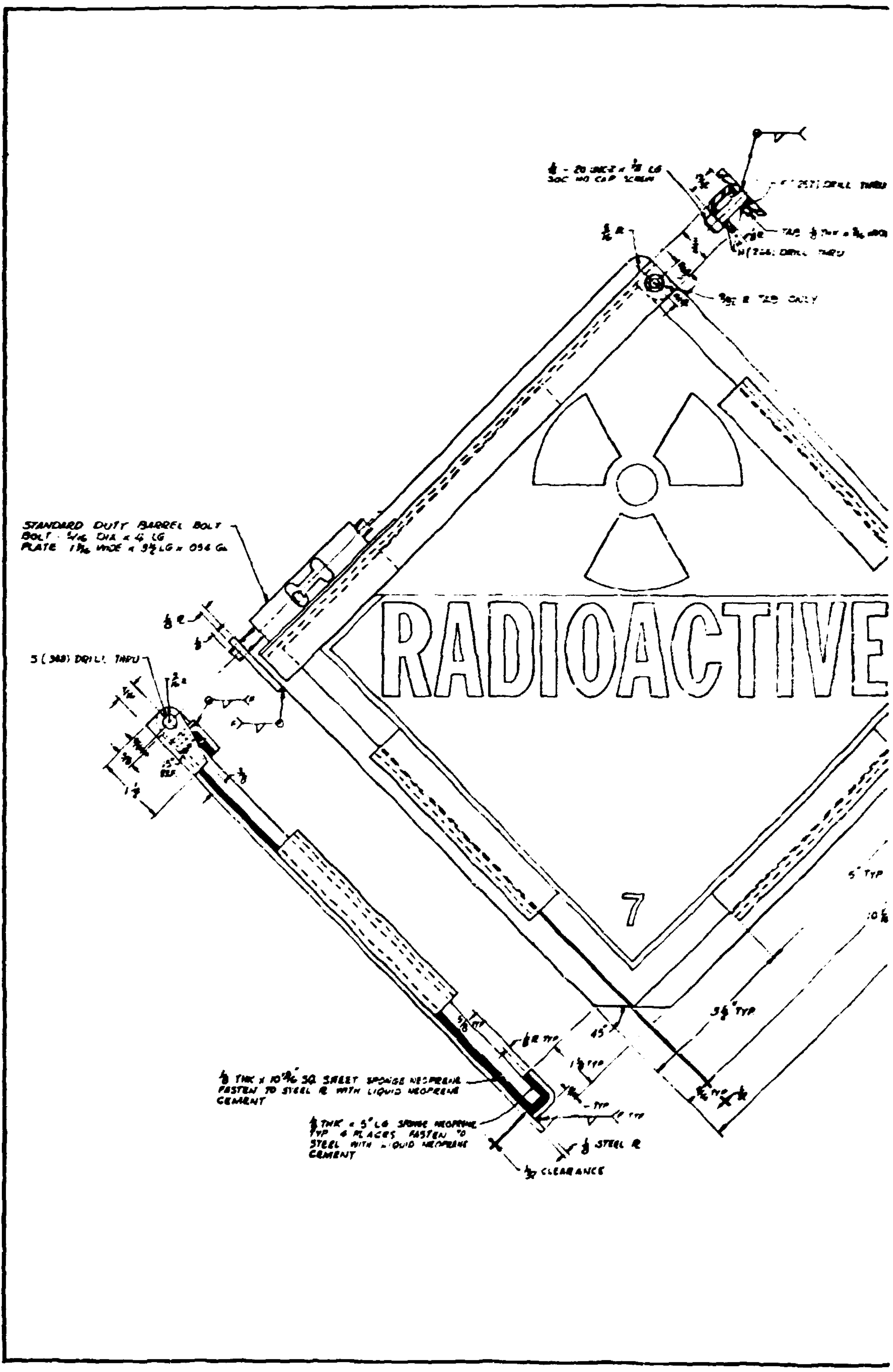
TRU SHIPPING CARRIER — BLDG. NO. 7920

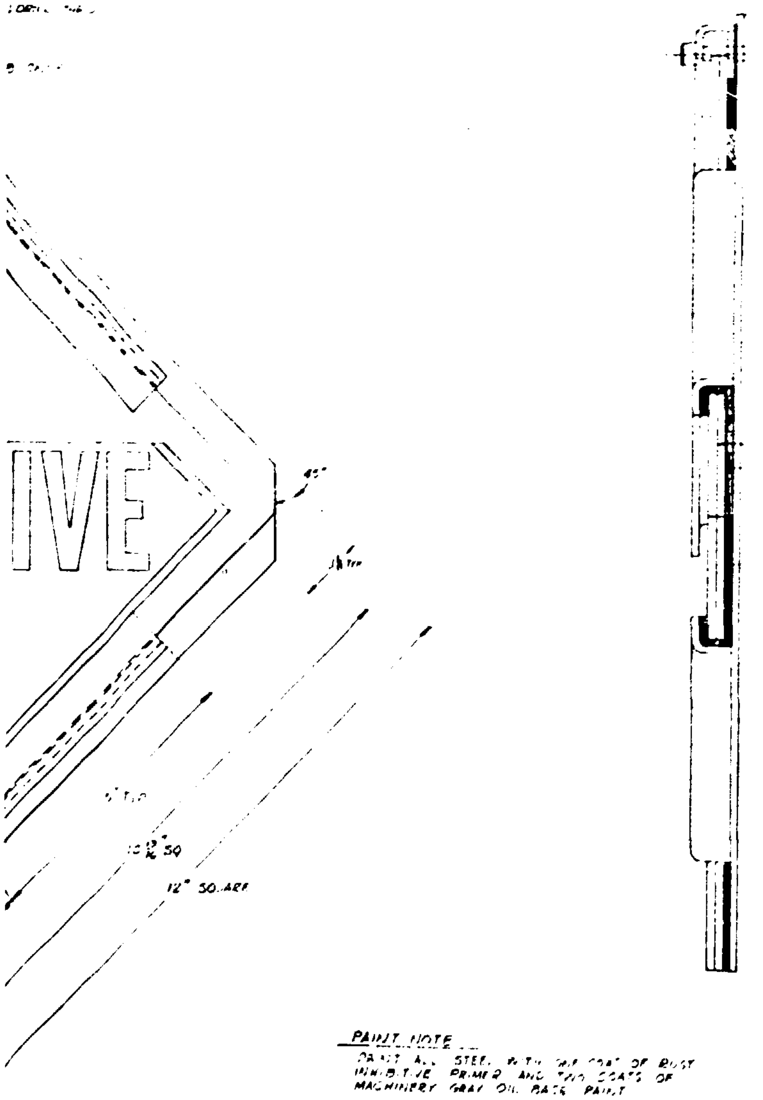
MODIFIED PLUG TO HANDLE MULTIPLE ITEMS

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED:
FRACTIONS ± 1/64"
DECIMALS ± 0.005"
ANGLES ± 0°-30'
EXCEPT AS NOTED
SCALE: Half Size Except As Noted

SUBMITTED 7-8-70
APPROVED

M-11230 EN 017 D


1/4 - 20 UNC-2 x 1/2 LG
SOC HD CAP SCREW
F (.257) DRILL THRU
TAP 1/4 THK x 5/16 ...
1/8 R
H (.266) DRILL THRU
1/16 R
9/32 R TIE ONLY
STANDARD DUTY BARREL BOLT
BOLT 5/16 DIA x 4 LG
PLATE 1 5/16 WIDE x 3 1/2 LG x .094 Ga
1/8 R
5 (.348) DRILL THRU
RADIOACTIVE
7
45° REF
1 1/4
5/8 TYP
1/8 R TYP
1 1/2 TYP
45°
3 1/8 TYP
5" TYP
10 1/8
1/8 THK x 10 3/16 SQ SHEET SPONGE NEOPRENE
FASTEN TO STEEL R WITH LIQUID NEOPRENE
CEMENT
1/8 THK x 5" LG SPONGE NEOPRENE
TYP 4 PLACES FASTEN TO
STEEL WITH LIQUID NEOPRENE
CEMENT
1/8 STEEL R
1/32 CLEARANCE
TYP



TRIM STANDARD CLASS 7 RADIOACTIVE LABEL TO 9 1/2 SQUARE AND LAMINATE BETWEEN [illegible] X 10 1/2 SQUARE PLEXIGLAS

PAINT NOTE
PAINT ALL STEEL WITH ONE COAT OF RUST INHIBITIVE PRIMER AND TWO COATS OF MACHINERY GRAY OIL BASE PAINT

SHIPPING CARRIER TRAILER ASSY	EN 012-E

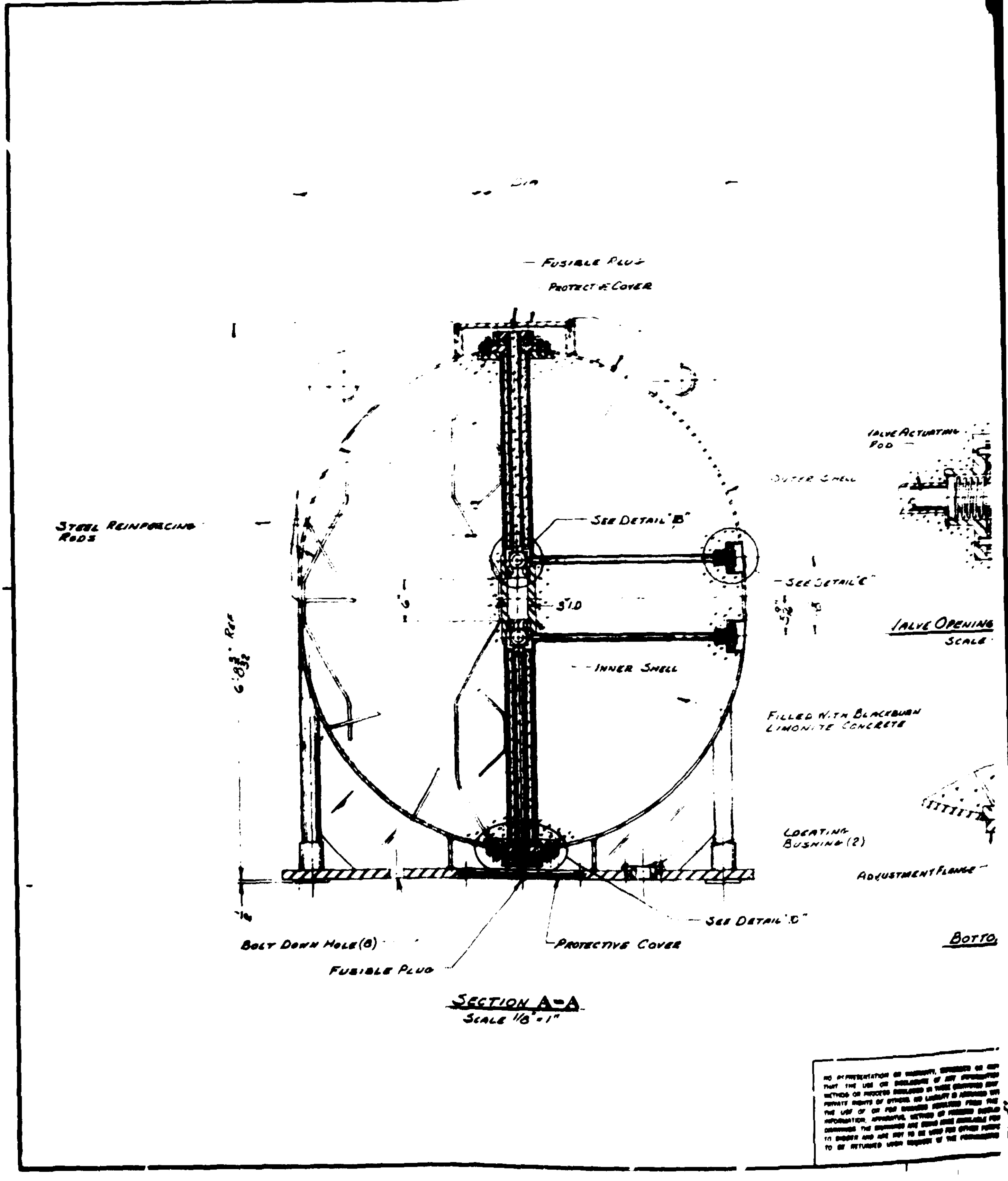
Oak Ridge National Laboratory
Union Carbide Corporation

TRU SHIPPING CARRIER 1980

SHIPPING CARRIER
TRAILER MODIFICATIONS
RADIOACTIVE SIGN MOUNTING BRACKET

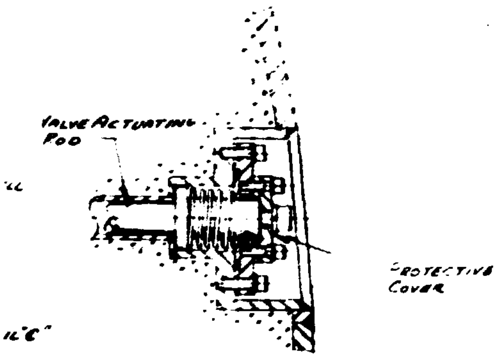
S.O.

M 11230 EN 018 E

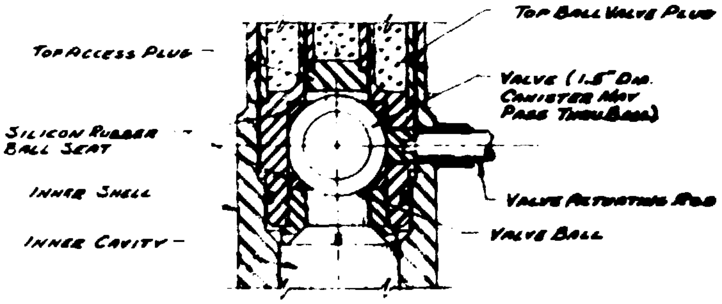


SECTION A-A
SCALE 1/8" = 1"

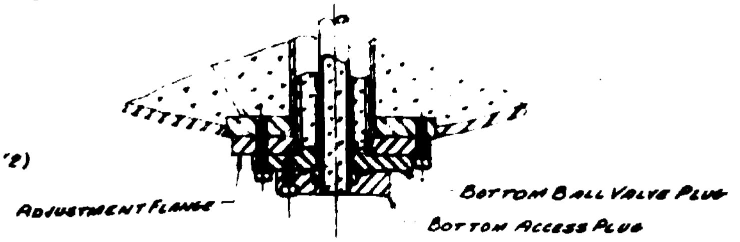
PLAN
SCALE 1/8"=1'



VALVE OPENING DEVICE DETAIL "C"
SCALE 1/8"=1'



BALL VALVE DETAIL "B"
SCALE 1/8"=1'



BOTTOM CLOSURE DETAIL "D"
SCALE 1/8"=1'

TRU SHIPPING CARRIER ASSEMBLY	M11810-[illegible]
REFERENCE DRAWINGS	NUMBER

Oak Ridge National Laboratory
Operated by
Union Carbide Corporation
Oak Ridge, Tennessee

TRU SHIPPING CARRIER 7980

TRU-10 TON CALIFORNIUM
SHIPPING CONTAINER

NO.	REVISIONS	DATE	APPD	APPD
1	GENERAL REVISIONS	3-16-66	[illegible]	

TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ±
DECIMALS ±
ANGLES ±
SCALE: AS NOTED

DRAWN R P Oliver DATE 1-26-66

M 12166 CD 019 D

9.2 Appendix B: Approval Documents

This appendix includes copies of the following:

DOE Form [illegible]
[illegible]
10 CFR 71

U.S. DEPARTMENT OF ENERGY

CERTIFICATE OF COMPLIANCE

For Radioactive Materials Packages

1a. Certificate Number	1b. Revision No.	1c. Package Identification No.	1d. Page No.	1e. Total No. Pages
5740	2	USA/5740/BL (DOE-OR)	1	2

2. PREAMBLE

2a. This certificate is issued to satisfy Sections 173.393a, 173.394, 173.395, and 173.396 of the Department of Transportation Hazardous Materials Regulations (49 CFR 170-189).

2b. The packaging and contents described in item 5 below, meets the safety standards set forth in Subpart C of Title 10, Code of Federal Regulations, Part 71, "Packaging of Radioactive Materials for Transport and Transportation of Radioactive Material Under Certain Conditions."

2c. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application

(1) Prepared by (Name and address)

Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37830

(2) Title and identification of report or application

Safety Analysis Report for Packaging (SARP) of the Oak Ridge National Laboratory TRU Californium Shipping Container.

Report ORNL-5409/R1

(3) Date

November 1979

4. CONDITIONS

This certificate is conditional upon the fulfilling of the requirements of Subpart D of 10 CFR 71, as applicable, and the conditions specified in item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Fissile Class, Other Conditions, and References

(a) Packaging

(1) Model: ORNL TRU Californium Shipping Container

(2) Description: A 304L stainless steel encased concrete shipping cask

The outer shell consists of two ½-in. thick, 66-in. diameter hemispherical heads joined by a 6-in. cylindrical section. The cylindrical cavity has a 1-in. thick stainless steel wall and is 3-in. diameter x 6-in. long. Shielding consists of 30-in. of Blackburn limonite concrete having a density of ~175 lb/ft^3. Upper and lower level ball valves located at the end of concrete-filled plugs define, isolate, and seal the cavity. Both of these plugs which utilize O-ring seals are bolted in place and are protected with a gasketed cover plate. Fusible plugs in the cover plates and the shell will melt to permit steam release in event of thermal exposure.

The top ball valve and plug may be replaced by other plugs for multiple source shipments. Sources are contained in DOT Specification 2R or special-form containers.

The cask is mounted onto a 1-in. thick steel base plate by eight steel 2½-in. NPS Schedule 40 pipe struts. The cask is transported on its own special trailer. The gross weight of the cask is 23,500 lb.

6a. Date of Issuance October 26, 1979

6b. Expiration Date

FOR THE U.S. DEPARTMENT OF ENERGY

7a. Address (of DOE Issuing Office)

U. S. Department of Energy
Post Office Box E
Oak Ridge, Tennessee 37830

7b. Signature, Name, and Title (of DOE Approving Official)

William H. Travis, Director
Safety & Environmental Control Division

(3) Drawings:

The package and special trailer are constructed in accordance with Oak Ridge National Laboratory (ORNL) Drawings M-11230-EN-001-D through 008-D, 012-E, 014-E, 017-D, 018-E, and M-12166-CD-019-D.

(b) Contents

(1) Type and Form of Material

The contents consist of isotopes of Americium (Am), Curium (Cm), Berkelium (Bk), Californium (Cf), Einsteinium (ES), and Fermium (Fm) as a solid (metal, oxide, oxysulfate, or dry salt) that is contained in a DOT Specification 2R inner container(s) or in a special form capsule(s).

(2) Maximum Quantity of Material Per Package

3g. (large quantity).

(3) Other Limitations

(1) Maximum heat load - 5W.

(2) External radiation dose rates - limited to DOT Regulations, 49 CFR 173.393.

REQUEST FOR NUCLEAR SAFETY REVIEW

ORNL
CRITICALITY COMMITTEE

NSR [illegible]54

EXPIRATION DATE
November, 1975*

This request covers operations with fissile material in a control area and/or fissile material transfers that originate within the control area. The control area supervisor shall complete the blocks below and describe the process and/or operations to be performed, emphasizing the provisions for nuclear criticality safety on the reverse side of this page. This request shall be approved by the Radiation Control Officers of the originating Division and the Division(s) to which fissile material will be transferred.

TITLE, CONTROL AREA, AND SUMMARY OF BASIC CONTROL PARAMETERS

(To be completed by the Control Area Supervisor)

TITLE (FOR REFERENCE PURPOSES): [illegible] Californium [illegible] Container

DATE OF REQUEST: 7/1[illegible]7

DATE REVIEW REQUIRED: 7/[illegible]7

CONTROL AREA: Not applicable

CODE NO.:

BUILDING ROOM:

DIVISION: Chem. Tech.

TYPE AND FORM OF MATERIAL		Oxide or salt containing [illegible]
ISOTOPIC ENRICHMENT (WT. %)		up to 100% [illegible]
QUANTITY OF FISSILE ISOTOPES	PER ISOLATED BATCH OR UNIT	Not applicable
	TOTAL IN CONTROL AREA	Not applicable
	TOTAL TO BE PROCESSED	Not applicable
Concentration or Density of Fissile Material		See other side.
Spacing of Fissile Units		Not applicable
Proximity and Type of Neutron Reflectors or Adjacent Fissile Material		Not applicable
Limit on Moderation		Not applicable
Limit on Neutron Absorbers		Not applicable
Limit on Volume or Dimensions of Containers		Size of inner container [illegible]

THIS REQUEST (MODIFIES, REPLACES) NSR-S NO.: None

RECOMMENDATIONS

(To be completed by the Criticality Committee)

This endorsement is based on our present understanding of the operation (whether acquired verbally or in writing) and is subject to review and cancellation.

This request is approved subject to the following considerations:

1. The fissile mass limits are well below the estimated minimum critical masses of these actinide isotopes under conditions of optimal moderation and reflection.*
2. The fissile isotopes will be transported as salts, oxides, or metals, mixed, in some cases, with nonfissionable diluents. These conditions tend to further increase the minimum critical mass within this cask.
3. The massive neutron shield of the cask will preclude interaction with other fissile units

*A.H.Clark, "Critical Masses of Fissile Transplutonium Isotopes, ANS Transactions, Vol. 12, No. 2 (Dec. 1969)

R. G. Affel [illegible] 74
CHAIRMAN, CRITICALITY COMMITTEE DATE

UCN-5917
(3 9-70)

PROVISIONS FOR NUCLEAR CRITICALITY SAFETY

(To be completed by the Control Area Supervisor)

Provisions for nuclear criticality safety shall be described below in accordance with Appendices II and III of the AEC Manual Chapter 0530. This shall include brief descriptions of the process and/or all operations to be performed, plans and procedures for the operations for nuclear criticality safety, and the basic control parameters. Please attach 11 copies of referenced drawings and documents.

The cask is a 6 ft. 6 in. stainless steel sphere shielded by [illegible] in. of Blackburn limonite concrete whose density is 175 lb/cu ft.

The inner cavity used for shipment of the material is 3 in. ID by 6 in. high and is described in ORNL-TM-[illegible]505. It is used to ship large quantities of Group I radionuclides in normal form including any radioisotope of Am, Cm, Bk, Cf, Es, and Pu as a solid metal, oxide, or dried chloride, nitrate or other salt, the maximum quantity of any of the above radionuclides limited to [illegible] grams.

ORNL
CRITICALITY COMMITTEE

NSR 750

EXPIRATION DATE
November, 1979*

RADIATION CONTROL OFFICER	DIVISION	CONTROL AREA SUPERVISOR	BUILDING 4500N
RADIATION CONTROL OFFICER	DIVISION	RADIATION CONTROL OFFICER John B Rush	DIVISION CTD

*The expiration date for this NSR has been extended to November 1984.

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

April 11, 1975

To: B. B. Klima
L. B. Shappert
M. C. Jurgensen

From: Transportation Committee

Subject: Approval of SARP of the ORNL TRU Californium Shipping Container

The ORNL Transportation Committee has reviewed your submission of the subject SARP to fulfill the requirements (internal review) of paragraph B of AEC Immediate Action Directive 5201-3. Particular attention was given the five areas of structural integrity, thermal resistance, radiation shielding, nuclear criticality safety, and quality assurance.

The results of the evaluation show that the container meets the requirements of AECM 0529 and the SARP is approved for submission to the ERDA for request of a Certificate of Compliance for approval of the cask for use for offsite shipments of fissile and radioactive materials.

E. M. King

E. M. King, Chairman
Transportation Committee

EMK:bb

cc: Transportation Committee

9.3 Appendix C: Computer Program for 30-ft Drop Onto the Top and Bottom of the TRU Californium Shipping Container - Program 1014 Cask

Derivation of Equations

The model shown in Fig. 9.1 illustrates the general case of a cask equipped with an energy absorber which deforms in pure compression. If the force-deformation curve for the absorber is taken as shown in Fig. 9.2, the expression

$$\Delta U_n = F_n(X_n - X_{n-1}) = F_n\delta_n \tag{9.1}$$

represents the energy expended as the cask moves from X_o to X_n and deforms the absorber an amount δ_n. It follows that

$$U'_n = \sum_{n=0}^{n'=n} \Delta U = \sum_{n=0}^{n} \quad {}^{n} \, .$$

The summation may be simplified by taking δ constant and satisfying the expression.

$$N\delta = X_n. \tag{9.2}$$

The deformation X_n may be written

$$X_n = \epsilon_n L = N\delta. \tag{9.3}$$

Solving for ϵ_n, we have

$$\epsilon_n = N\delta / L. \tag{9.4}$$

There is an expression, $\sigma_i = f(\epsilon_i)$, where σ = stress, psig, and ϵ = strain, in. in., for the material from which the energy absorber is constructed. The force F can then be determined from the following expression:

$$F = \sigma A, \tag{9.5}$$

where

A = original cross-sectional area of the energy absorber, in.^{2}.

These relationships form the basis for the attached computer program. The absorber deformation is increased in steps of constant magnitude. Strain, stress, and force are computed for value of deformation and the energy for the step determined. The energy is added to the sum of that from previous steps and compared with the cask potential energy. When the dissipated energy equals the potential energy, the computations are complete.

The program is currently supplied with stress-strain equations.

ORNL DWG 75-82

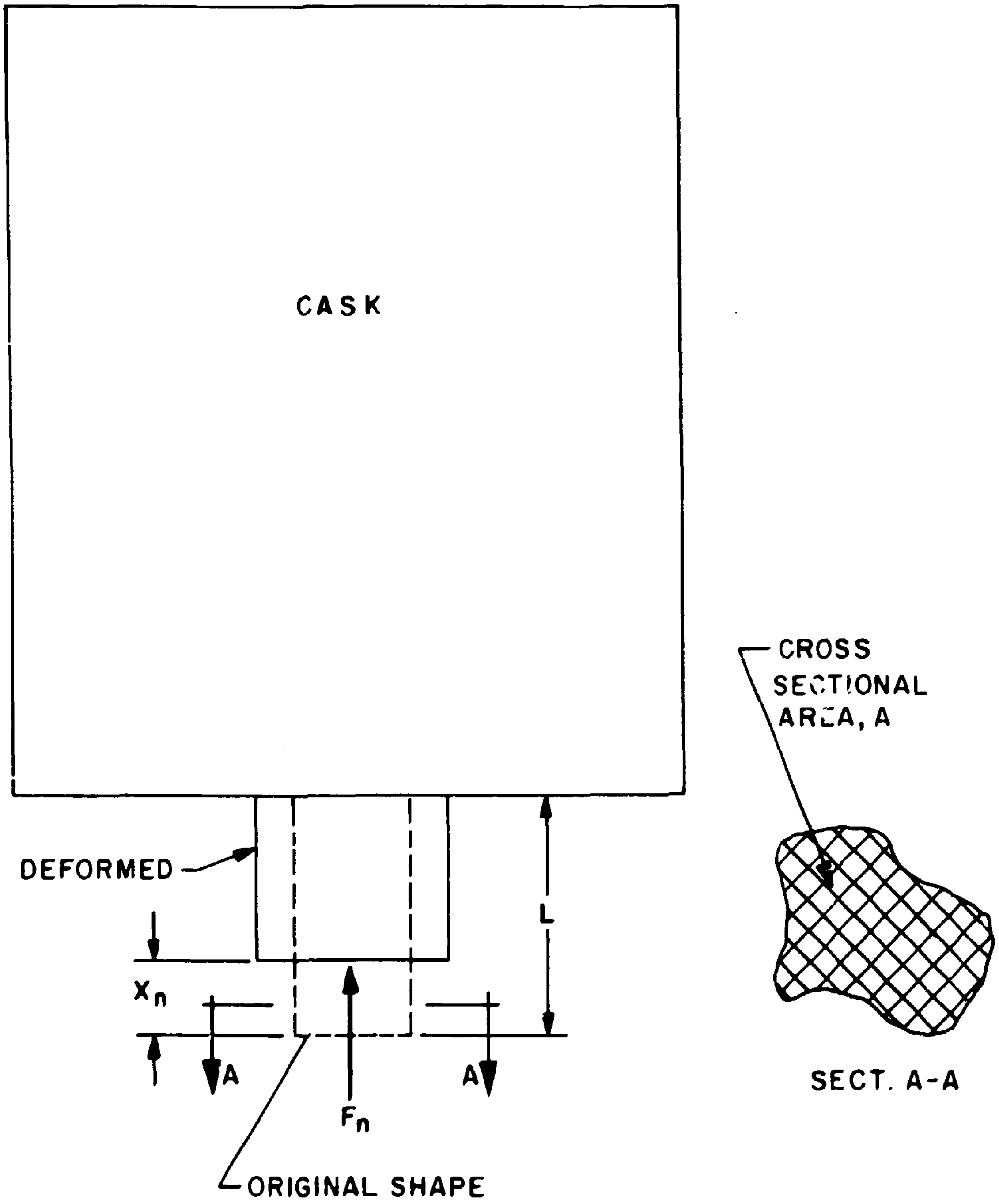


Fig. 9.1. Cask model.

ORNL DWG 75-83

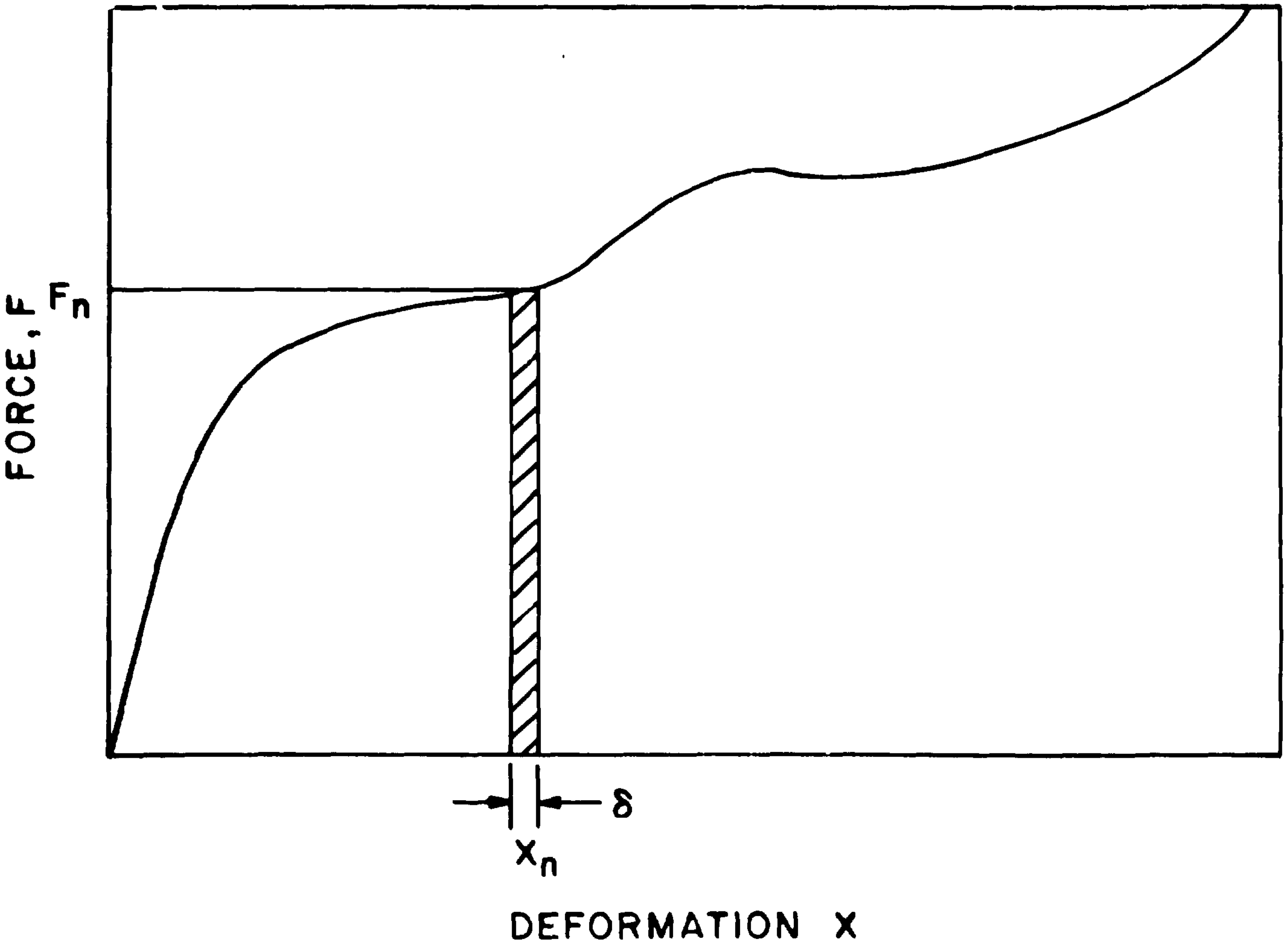


Fig. 9.2. General force deformation diagram.

$$\sigma = f(\epsilon).$$

for stainless steel and mild steel. The program can be used for absorbers having any cross-sectional shape. It is equipped to compute the area for tubular absorbers (see Fig. 9.3a) and for rectangular absorbers having a constant thickness (see Figs. 9.3b and 9.3c). In the case of the tubular absorber, the radius and thickness depth must be inserted in statement numbers 70, 71, and 72. For a rectangular absorber, the thickness, depth, and length must be inserted as statement numbers 71, 72, and 73. For absorbers of other geometry, the area must be computed by hand in input in statement 74. Those statements not applicable must be left as 0.0. In addition, the cask weight in pounds must be input in statement 80, the drop material height in inches in statement 81, and the material in statement 88. The material in input is SST for 300 annealed series stainless steel and STL for mild steel. If a finer or coarser mesh is desired, the value of DE in statement 60 may be decreased or increased. The 1000 format should be altered to identify the cask.

A glossary of terms used in the 1000 format is listed below:

AMATL = Material absorber is made of
WT = Weight of cask
TLEN = Length of absorber
RAD = Radius of absorber
THK = Thickness of absorber
DEPH = Depth of absorber
DL = Incremental change in absorber depth
AREA = Area of absorber before impact

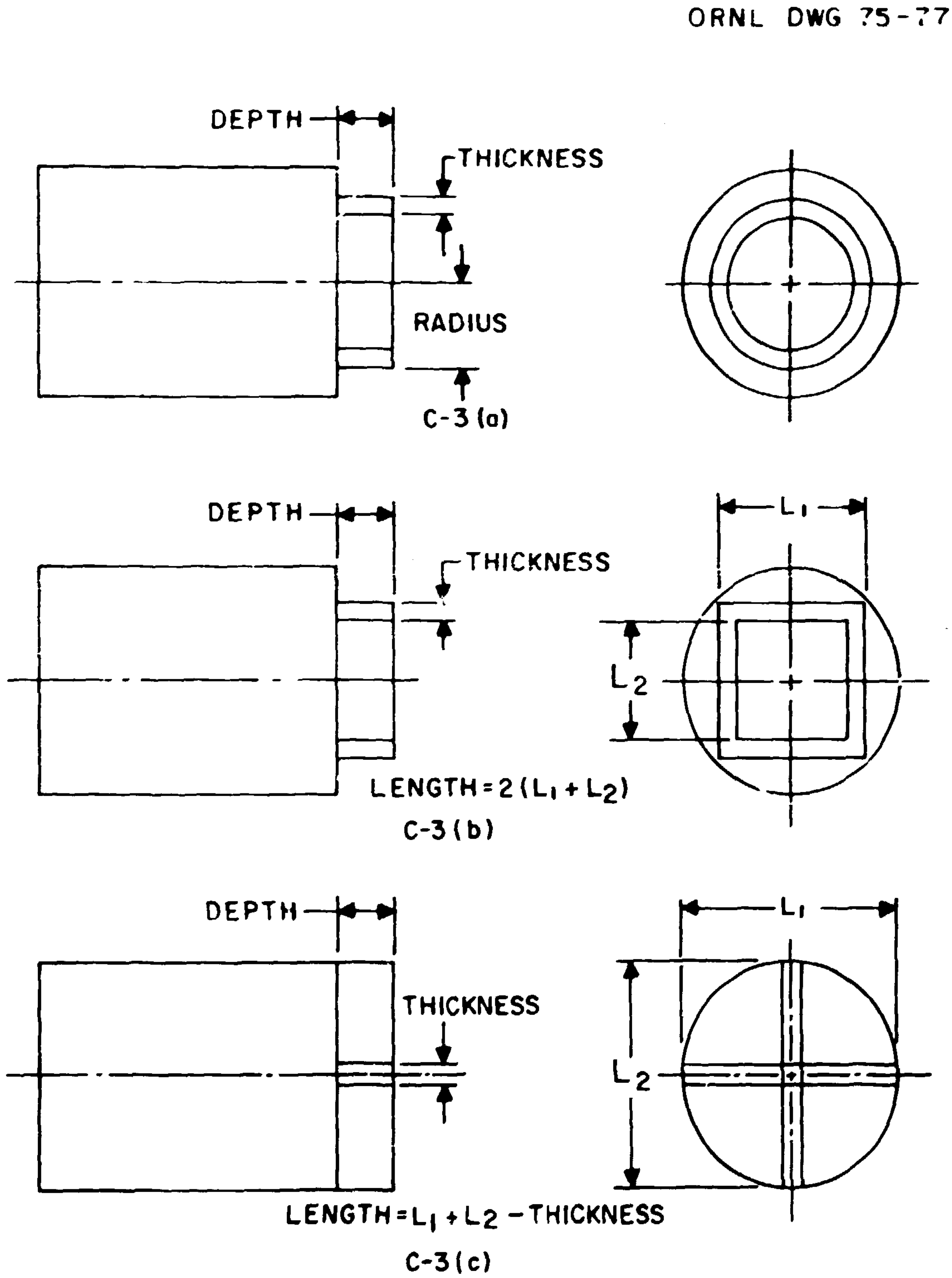


Fig. 9.3. Energy absorber configurations.

```
**FTN,L,M,R,G,A.
C                          PROGRAM 1014 CASK
C THIS PROGRAM COMPUTES THE RESPONSE OF A RIGID CASK EQUIPPED WITH AN ENERGY,
C ABSORBER WHICH DEFORMS IN PURE COMPRESSION CODED BY JOHN EVANS PE ,OAK RIDGE
C NATIONAL LABORATORY, JUNE 1974
      DIMENSION  DE(200),S(200),DEF(200),DU(200),FORC(200),ENER(200),
     2 ACC(200)
 1000 FORMAT(1H ,8X,'O. R. N. L. 10 TON SHIPPING CASK')
 1001 FORMAT (1H0)
 1002 FORMAT(1H ,1X,49H*************************************************,
     1       55H*******************************************************,
     2       14H**************)
 1003 FORMAT(1H ,23X,24HENERGY ABSORBER GEOMETRY)
 1004 FORMAT(1H ,12X,6HRADIUS,3X,9HTHICKNESS,3X,5HDEPTH,4X,6HLENGTH,5X,
     1    4HAREA)
 1005 FORMAT(1H ,F18.3,4F10.3)
 1006 FORMAT (1H ,16X,33HCASK GEOMETRY AND TEST CONDITIONS)
 1007 FORMAT(1H ,12X,11HCASK WEIGHT,3X,11HDROP HEIGHT,3X,9HPOTENTIAL,
     1       X, 6HENERGY)
 1008 FORMAT(1H ,F21.1,F14.1,F17.1)
 1009 FORMAT (1H , 1X,12HACCELERATION,2X,11HDEFORMATION,6X 5HFORCE,6X,
     1    6HSTRESS,6X,6HSTRAIN,8X,6HENERGY)
 1010 FORMAT (1H , 5X,3HX G,10X,6HINCHES, 9X,4HLBS.,7X,4HPSI., 9X,
     1    5HIN/IN,9X,5HLB-IN)
 1011 FORMAT (1H ,F10.1,F13.3,F16.1,F12.1,F11.3,F12.1)
      DO 7, I=1,200
      DE(I)=0.0
      S(I)=0.0
      DEF(I)=0.0
      DU(I)=0.0
      FORC(I)=0.0
      ENER(I)=0.0
    7 ACC(I)=0.0
      SST=1.0
      STL=2.0
      ALUM=3.0
   60 EE=.005
      DS=0.0
   88 AMATL=SST
   70 RAD=8.375
   73 TLEN=0.0
   74 AREA=0.0
   72 DEPH=4.
   71 THK=1.25
   80 WT=23200.
      DL=EE*DEPH
      PHI=3.14159265
      IF(RAD .GT. 0.) AREA=2.*RAD*PHI*THK
      IF(TLEN .GT. 0.) AREA=TLEN*THK
      IF(AMATL.NE.2.0) GO TO 6
C   MILD STEEL COEFFICIENTS
      A=-4.36337724E+02
      B=3.52674012E+06
      C=-5.84344912E+07
      D=8.44752080E+08
      E=-1.00790838E+10
      F=8.32241264E+10
```

```
      G=-4.42875864E+11
      H=1.50685484E+12
      O=-3.25535392E+12
      P=4.31754272E+12
      Q=-3.20487884E+12
      R=1.01910658E+12
      AA=0.5
      AB=345000.
      AC=73000.
    6 CONTINUE
      IF(AMATL.NE.1.0) GO TO 5
C    STAINLESS STEEL COEFICIENTS
      A=-6.60046824E+02
      B=3.27884020E+06
      C=-1.74360075E+08
      D=5.78280072E+09
      E=-9.29116096E+10
      F=8.46509048E+11
      G=-4.79173280E+12
      H=1.75760146E+13
      O=-4.20115552E+13
      P=6.33579656E+13
      Q=-5.48432768E+13
      R=2.07901540E+13
      AA=0.35
      AB=642000.
      AC=50300.
    5 CONTINUE
      IF(AMATL.NE.3.0) GO TO 12
      A=-2.37529992E+02
      B=8.77222216E+05
      C=-2.10395908E+07
      D=7.92526976E+08
      E=-1.19710816E+10
      F=9.28522728E+10
      G=-4.24976496E+11
      H=1.21919694E+12
      O=-2.22403424E+12
      P=2.51118460E+12
      Q=-1.60332062E+12
      R=4.43286884E+11
      AA=0.5
      AB=209100.
      AC=27900.
   12 CONTINUE
      DO 20 N=1,2
      HT=24.0
      IF(N .EQ. 2) HT=360.
      UT=WT*HT
      SUMU=0.0
      DS=0.
      DO 1 I=1,200
      DE(I)=DS
      DEF(I)=DE(I)*DEPH
      IF(DS.GT.AA) GO TO 21
      S(I)=A+(B*DS)+(C*DS*DS)+(D*(DS**3.))+(E*(DS**4.))+(F*(DS**5.))+
     1 (G*(DS**6.))+(H*(DS**7.))+(O*(DS**8.))+(P*(DS**9.))+
```

```
     2 (Q*(DS**10.))+(R*(DS**11.))
21    CONTINUE
      IF(DS.LE.AA) GO TO 22
      STRS=(AB*DS)+AC
22    CONTINUE
      FORC(I)=S(I)*AREA
      ACC(I)=FORC(I)/WT
      DU(I)=FORC(I)*DL
      SUMU=SUMU+DU(I)
      ENER(I)=SUMU
      DS=DS+EE
      IF(ENER(I).GE.UT)  GO TO 2
 1    CONTINUE
 2    CONTINUE
      J=I
      WRITE (6,1002)
      WRITE (6,1002)
      WRITE (6,1001)
      WRITE (6,1000)
      WRITE (6,1001)
      WRITE (6,1002)
      WRITE (6,1002)
      WRITE (6,1001)
      WRITE  (6,1003)
      WRITE (6,1001)
      WRITE (6,1004)
      WRITE (6,1001)
      WRITE(6,1005),RAD,THK,DEPH,TLEN,AREA
      WRITE (6,1001)
      WRITE (6,1002)
      WRITE (6,1001)
      WRITE (6,1006)
      WRITE (6,1001)
      WRITE (6,1007)
      WRITE (6,1001)
      WRITE (6,1008)WT,HT,UT
      WRITE (6,1001)
      WRITE (6,1002)
      WRITE (6,1002)
      WRITE (6,1001)
      WRITE (6,1009)
      WRITE (6,1001)
      WRITE (6,1010)
      WRITE (6,1001)
      DO 10 I=1,200
      WRITE(6,1011),ACC(I),DEF(I),FORC(I),S(I),DE(I),ENER(I)
      IF(I.GE.J) GO TO 11
10    CONTINUE
11    CONTINUE
      WRITE (6,1001)
      WRITE (6,1001)
      WRITE (6,1002)
      WRITE (6,1002)
      WRITE (6,1002)
      WRITE (6,1002)
      WRITE (6,1002)
      WRITE (6,1002)
```

```
      WRITE (6,1001)
      WRITE (6,1001)
      CALL QWIKPL(DEF,ACC,J,'LINEAR','J.H.EVANS$')
      CALL QWIKPL(DEF,ENER,J,'LINEAR','J.H.EVANS$')
      CALL QWIKPL(ACC,ENER,J,'LINEAR','J.H.EVANS$')
   20 CONTINUE
      STOP
      END
```

9.4 Appendix D: Typical Operating and Inspection Procedures for TRU Californium Shipping Container

Form TRU-5740-1

SHIPMENT PREPARATION SUMMARY

AEC-OR USA/5740/BL

DATE: ______________________ TRU SHIPMENT No.: ____________

The following elements of shipment preparation have been properly completed, copies of the indicated forms are attached.

__________ Loading Procedure (TRU-5740-)

__________ Trailer Inspection Report (TRU-5740-)

__________ Inspection Engineering Department Review

__________ Final H.P. Survey at TRU

__________ Form UCN-TX-4623 Prepared

FORM TRU-5740-5
Page 1 of 2

TRU CALIFORNIUM SHIPPING CONTAINER
UNLOADING PROCEDURE
INCOMING SHIPMENTS
MULTIPLE BASKET ITEMS OR SINGLE SHIPMENT ITEMS

AEC-OR USA/5740/BL

Date: ____________________

Material Received: ____________

No. Packages: ______________

Type Packages: _____________

Shipper: ________________

Radiation Data: H.P. Representative: ____________________

	Contact	6 ft
Gamma, mrem/hr	_____	_____
Neutrons, mrem/hr	_____	_____
Total, mrem/hr	_____	_____
Contamination	_____	dpm, alpha
	_____	dpm, beta-gamma

	Date	By	
1.	_____	_____	Carrier moved from trailer into Bldg. 7920.

Items 2 through 13 require H.P. surveillance.

	Date	By	
2.	_____	_____	Remove top cover plate.
3.	_____	_____	Remove bolts from top valve actuator rod assy. Pull assy. out 1 inch.
4.	_____	_____	Remove top plug — top loading port shield remains attached to top plug.

FORM TRU-5740-5
Page 2 of 2

Date **By**

5. ______ ______ Complete pre-move check on TDF:

   A. Air, water, power disconnected: ______

   B. Transfer line disconnected: ______

   C. Slug chute closed - handle removed: ______

   D. Valve in TDF closed: ______

6. ______ ______ Move TDF to station above carrier.

7. ______ ______ Open valve in bottom of TDF.

8. ______ ______ Lower proper tool from TDF into carrier — engage basket or single item and lift into TDF.

9. ______ ______ Close bottom valve on TDF.

10. ______ ______ Move TDF back to upper station.

11. ______ ______ H.P. survey carrier to determine that carrier is empty.

12. ______ ______ Clean all carrier parts. Store in plastic bags.

13. Contamination levels after cleaning — dpm alpha

    Top plug: ______

    Carrier internals: ______

    Spacers: ______

14. ______ ______ Remove old shipping labels from carrier.

15. ______ ______ Cover open top of carrier with plastic or blotter paper.

16. ______ ______ Reinstall top valve actuator rod assy. and tighten bolts.

FORM TRU-5740-7
Page 1 of 3

MULTIPLE SHIPMENT LOADING PROCEDURE
TRU CALIFORNIUM CONTAINER
AEC-OR USA/5740/BL

Date: ____________________
Material to be Shipped: __________
TRU Shipment No.: ____________
Number of Packages: ___________
Type Packages: ____________

	Date	By	
1.	_____	_____	Contamination levels after cleaning carrier components.
2.	_____	_____	Transfer multiple shipping basket to decontamination facility (TDF).
3.	_____	_____	Load and record package positions:
4.	_____	_____	Disconnect air, water, power, and transfer line from TDF.
5.	_____	_____	Check that valve in slug chute is closed.

Step 1:

	dpm, alpha
Top loading port shield	________
Top plug	________
Basket	________
Carrier internals	________

Step 3:

		dpm alpha smear
Position No. 1	______	______
Position No. 2	______	______
Position No. 3	______	______
Position No. 4	______	______
Position No. 5	______	______

FORM TRU 5740-7
Page 2 of 3

	Date	By	
6.			Remove handle from slug chute valve.
7.			Check that valve in bottom of TDF is closed.
8.			Have riggers move TDF to load-out station.
9.			Open valve in bottom of TDF.
10.			With H.P. surveillance, lower loaded basket into carrier cavity.
11.			Move TDF back to Cell 1 position.
12.			Check condition of sealing surfaces and O-ring on top inner plug.
13.			Put top inner plug into carrier, being certain to orient shaft to engage basket.
14.			Torque top inner plug bolts to 100 in. lbs.
15.			Check sealing surfaces and O-ring on top loading port shielding plug.
16.			Install top loading port shield plug.
17.			Torque top loading port shield plug bolts to 80 in. lbs.
18.			Check condition of surfaces and gasket on outer cover plate. Comments: ______________
19.			Install outer cover plate with lock washers in place. Torque bolts to 100 in. lb.
20.			1. General condition of carrier: ______ 2. Old shipping labels removed: ______

21. Radiation Data — Obtain and Record — H.P. Representative: ____________

	Contact	**6 ft**	**Driver**
Gamma, mrem/hr	______	______	______
Neutrons, n_i, mrem/hr	______	______	______
n_f, mrem/hr	______	______	______
Total, mrem/hr	______	______	______

Contamination ______ dpm, alpha

______ dpm, beta-gamma

Date **By**

22. ______ ______ Shipping letter included: ____________________

    1. Inside carrier top cover: ________________
    2. Inside trailer tool box: ________________

23. ______ ______ Carrier moved to trailer.

24. ______ ______ Install anchor bolts. Torque to 230 ft-lb.

25. ______ ______ Install anchor bolt safety wires.

26. ______ ______ Install cables.

27. ______ ______ H.P. transfer tag attached to carrier.

28. Trailer tool box check list:

    1. Source lifting tool: ____________
    2. Index plate: ________________
    3. Tool box locked: ______________

FORM TRU-5740-8
Page 1 of 2

TRU TEN-TON CALIFORNIUM SHIPPING CONTAINER
BIENNIAL INSPECTION CHECK LIST

CONTAINER

1. Inspection of Welds (Visual):

Welds on spherical body: ____________________

Welds on top fins: ____________________

Welds on bottom fins: ____________________

Baseplate welds: ____________________

Welds needing more inspection: ____________________

____

2. Fusible Plugs:

Top cover plate: ____________________

Bottom cover plate: ____________________

Concrete pour opening: ____________________

3. Pressure Check:

__________ Remove top cover plate.

__________ Remove bottom cover plate.

__________ Check that bolts on top inner plug are torqued to 100 in. lbs.

__________ Check that bolts on bottom inner plug are torqued to 100 in. lbs.

__________ Connect 15 psig air supply, gage, and exhaust valve and filter assembly to quick disconnects in top.

__________ Apply 15 psig pressure to cavity and close inlet valve.

__________ After 30 min observe pressure: _____ psig.

__________ If pressure has dropped, check test equipment for leaks using soap solution.

If test equipment is o.k., check top and bottom O-ring seals.

Top: _____ o.k., _____ leak

Bottom: _____ o.k., _____ leak

__________ Release air pressure from system.

__________ Obtain H.P. assistance.

__________ Remove top and/or bottom inner plug.

__________ Inspect O-ring and sealing surfaces. Comments: _____

____

____

After making needed repairs, obtain another copy of this form and repeat pressure test.

OAK RIDGE NATIONAL LABORATORY RADIOACTIVE MATERIALS PACKAGING INFORMATION

THIS FORM IS REQUIRED FOR ALL SHIPMENTS GREATER THAN 1 MILLICURIE ALPHA OR 5 CURIES BETA-GAMMA SOLID, LIQUID, OR GAS AND ALL EMPTY RETURNABLE CONTAINERS

General Information

1. Origin (Division ____ 2. Destination ____
3. Method of Transport ____ 4. Weight ____
5. Special Instructions ____
____ Special Instructions Complied by ____

Radioactive Contents

1. All major activities in curies and/or grams ____
____
2. Specify (a) Normal Form ☐ (b) Special Form ☐ Special Form No. ____
(c) Fissile ☐ (d) Non-Fissile ☐
3. Radioactive Material Form: Solid ☐ Liquid ☐ Gas ☐
4. Heat Load (watts): Calculated ____ Estimated ____ By ____

Shipping Container

1. AEC Certificate of Compliance No. AEC-OR-USA ____
2. DOT Specification No. ____ 3. Nuclear Safety Review No. ____
4. Container determined proper for contents by ____ Date ____

Internal Container

1. Internal Containment: Glass Bottle ☐ Plastic Bottle ☐ "2R" ☐ Conoseal ☐
Welded Capsule (specify capsule material) ☐ ____
Other (explain) ☐ ____
2. Contamination level on internal container: Estimated ____ Smeared ____
3. Radiation level from internal container: Measured ____ Calculated ____
4. Gaskets or seals (valves) properly installed ____ By ____
5. Leak tests of internal container ____ By ____

External Container

1. Moderator and neutron absorber present for fissile material? Yes ☐ ☐ By ____
2. External container examination ____ Yes ☐ ☐ By ____
3. Gaskets or seals properly installed ____ Yes ☐ ☐ By ____
4. Leak test ____ Yes ☐ ☐ By ____
5. Bolts torqued to ____ ft lbs By ____
6. Tie down to skid checked ____ Yes ☐ By ____
7. Tamper seal installed ____ Yes ☐ ☐ By ____
8. Lid eye bolt removed and wired to the outside of the carrier Yes ☐ By ____

Radiation Survey

1. Surface contamination level: Alpha ____ dpm, β-γ ____ dpm
2. External radiation level ____ mrem/hr @ contact
3. Domestic shipments ____ mrem/hr @ 3 ft from surface
4. Foreign shipments ____ mrem/hr @ 1 meter from center
5. Health Physics Surveyor ____ Date ____

Truck Tie-Down and Shoring

1. Tie-down and shoring checked by (Inspection Engineering) ____

Shipment Approved By ____
Date ____

TX-4623 (Revised 9/74)

10. REFERENCES

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17. E. D. Clayton, "The Nature of Fission and the Criticality Process" (from Protactinium to Californium and Beyond), "*Proceedings of Short Course on Nuclear Criticality Safety*, Taos, New Mexico, May 7-11, 1973, USAEC TID-26286 (1974), p.1.

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