APPENDIX A **PATENT PENDING**

Free Drop Impact Analysis Program

Introduction

This program treats a single degree of freedom non-linear impact model of the package. In this analysis, the falling mass is decelerated by a continuously varying force proportional to the effective crush area. The non-linear equation of motion is integrated utilizing an Adams-Moulton, Runge-Kutta algorithm from the time of initial contact with the unyielding surface till the package model comes to rest on the unyielding surface.

The Adams-Moulton, Runge-Kutta algorithm utilized is a standard FORTRAN IV applications subroutine developed at Space Technology Laboratories (now TRW Systems) by Robert Causey and Werner L. Frank, November 30, 1958.

Equation of Motion

The second order differential equation is:

$$\ddot{x} = \frac{-F_x}{M_x} + g \qquad (1)$$

Initial conditions are:

$$\dot{x}_o = \sqrt{2gh} \qquad (2)$$
$$x_o = 0$$

Where: $\ddot{x}$ = the deceleration of the following mass (x is + downward)

$\dot{x}_o$ = initial velocity at contact with surface

x_o = initial displacement

M_x = the displacement varying mass

= initial total mass - mass of crushed media at rest

= $M_o - m_x$

M_o = W/g

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W = Weight (lbs)

g = 386.4 in/sec^2, gravitational constant

F_x = the displacement varying crush force

= $\sigma_{cr} \cdot A_x$

σ_{cr} = crush strength (lbs/in^2) of crush media

A_x = Effective displacement varying area of crush surface (in^2)

m_x = mass of crushed material

= $(\rho/g) \cdot Vol_x$

ρ = wt. density of crush media (lbs/in^3)

Vol_x = Volume of crushed media (in^3)

h = drop height of package (in)

Evaluation of Equation Coefficients

The values for A_x and m_x are particularized for each impact orientation of the rectangular container as follows:

1. Flat drop

$$A_x = \ell \cdot w$$

$$m_x = (\rho/g)\ell w x$$

Where: ℓ = length

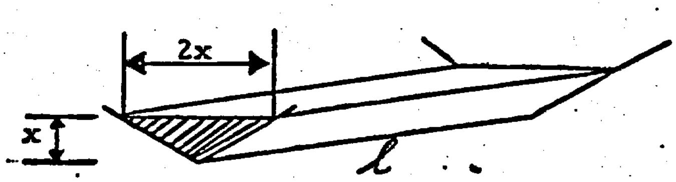
w = width

x = crush depth

2. Edge Drop

$$A_x = 2x\ell$$

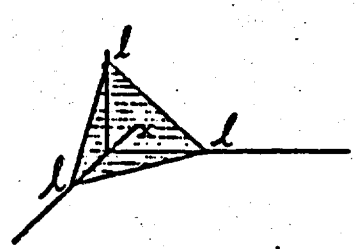
$$m_x = (\rho/g)\ell x^2$$



3. Corner Drop

$$A_x = \frac{\sqrt{3}}{2}\ell^2 = \frac{3\sqrt{3}}{2}x^2$$

$$m_x = (\rho/g)\frac{\sqrt{3}}{2}x^3$$



Note: x = crush depth

= ⊥ distance from corner to plane passing through coordinate axis at

APPENDIX B

PATENT PENDING

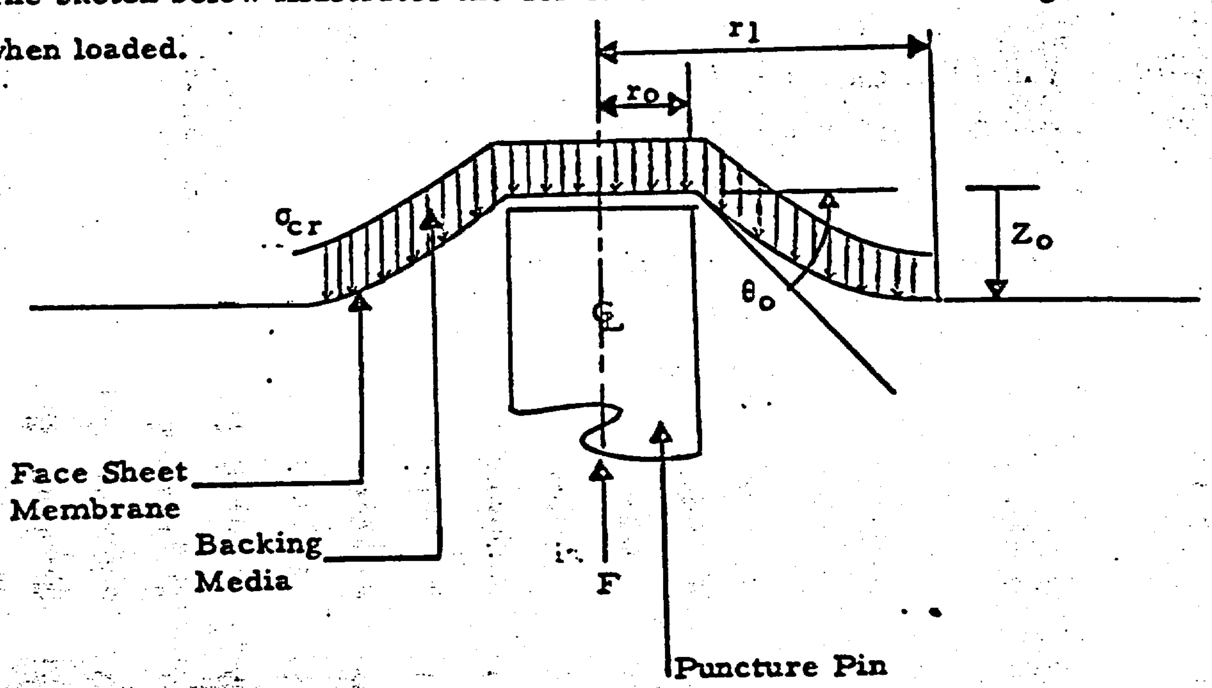
Introduction

This summary report describes the MRI developed computer program, PUNCH, which treats the puncture loading of a supported or backed membrane sheet by a cylindrical pin or puncture column of finite radius. The sheet is considered to have no bending stiffness and to carry all loads in a membrane fashion. The backing or supporting media is considered to be purely plastic and possesses no shear strength.

This analysis program allows evaluation of Department of Transportation and Atomic Energy Commission criteria for puncture loadings of Hazardous Material Transport Containers and Casks as prescribed in 10CFR70, 49CFR171 and AEC Manual 0529.

Membrane Failure Criterion and Basic Total Energy Relations

The sketch below illustrates the deformed membrane and backing media when loaded.



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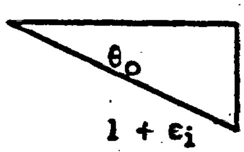
Where: r_o = Radius of Cylindrical Pin
r_1 = Radius of Deformed Region
q_{cr} = Crush strength of backing media
θ_o = Inclination of membrane at edge of pin
Z_o = Total depth of pin penetration.
F = Total force applied by penetrating pin

The membrane fails when the strain exceeds the elongation capability of membrane material. Strain in the membrane is related to two displacements: (1) a general inclination of the draped membrane sheet and (2) a bending of the membrane sheet about the pin edge radius.

The strain due to general inclination, θ_o is:

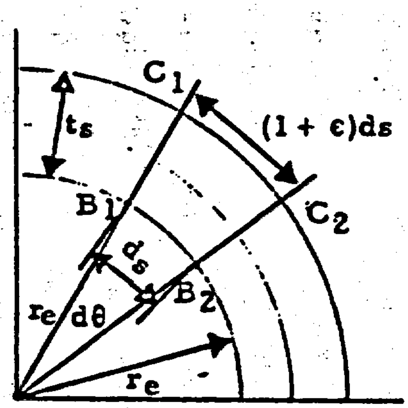


$$\cos \theta_o = \frac{1}{1 + \epsilon_i}$$

$$\epsilon_i = \frac{1 - \cos \theta_o}{\cos \theta_o} \qquad (1A)$$

The above relation implies that the membrane cannot slip with regard to the backing media or puncture pin.

Additional strain occurs due to the bending curvature of the sheet thickness, t_s, about the edge radius of the pin, r_e. Consider a differential segment of the membrane, d_s. Assume no slip on the pin radius.



The strain due to bending about the pin edge radius is:

$$\epsilon_r = \frac{C_1C_2 - B_1B_2}{B_1B_2}$$

$$= \frac{(r_e + t_s)\, d\theta - r_e d\theta}{r_e\, d\theta}$$

$$\epsilon_r = \frac{t_s}{r_e} \qquad (1B)$$

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Strain is assumed to redistribute in the immediate vicinity of the pin edge radius. Specifically, a uniform strain state is assumed to exist either side of the point of tangency of the sheet to the pin edge radius. The total allowable strain in the sheet is thus directly related to gross material elongation potential:

$$\frac{\text{Allowable Elongation \%}}{100} \trianglelefteq \frac{\int_{o}^{\theta_o + 3t_s} (\epsilon i + \epsilon r)\, d\ell}{\int_{o}^{\theta_o + 3t_s} d\ell} \tag{1C}$$

This relation symbolically states that the failure criterion of the membrane is related to the average strain existing from the axis of symmetry (℄ of pin), around the edge radius and beyond for a distance of $3t_s$.

The total force applied by the pin is

$$F_Z = 2\sigma_{su}\, \pi r_o t \sin\theta_o + \pi\, \sigma_{cr}\, r_o^2 \tag{2}$$

Where: σ_{su} = ultimate stress of membrane
t = thickness of membrane

The total energy absorbed by the crushing media is:

$$E = W(h + Z_o^*) \leq \int_{o}^{Z_o^*} F_Z\, dZ \tag{3}$$

Where: Z_o^* is the total depth of pin penetration at membrane failure
h = drop height
W = package weight

The radius of the deformed area of the backing media is obtained from basic equilibruim principles as follows:

$$F_Z = \pi r_1^2 \sigma_{cr}$$
$$r_1 = \sqrt{\frac{F_Z}{\pi \sigma_{cr}}} \tag{4}$$

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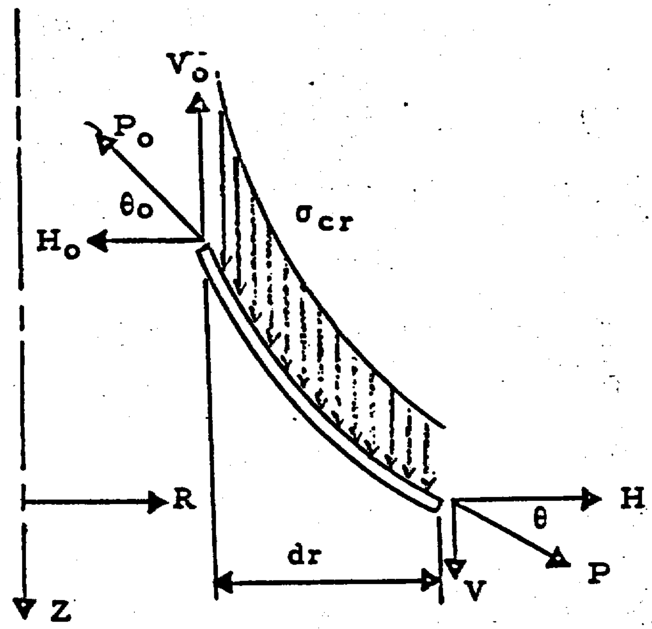
Membrane Equilibrium Equations

The basic equations of motion are obtained by considering the annular differential portion of the membrane shown below.



Equilibrium in the horizontal and vertical directions gives:

$$\frac{d}{dr}\,(P\cos\theta) = 0 \tag{5}$$

$$\frac{d}{dr}(P\sin\theta)\,dr + 2\pi\,\sigma_{cr}\,r\,dr = 0 \tag{6}$$

From (5): $P\cos\theta = H = \text{constant}$

$P = H/\cos\theta$

Then (6) becomes:

$$\frac{d}{dr}\,(H\tan\theta) = -2\pi\,\sigma_{cr}\,r \tag{7}$$

But, $\tan\theta = \frac{dZ}{dr}$, therefore:

$$\frac{d^2Z}{dr^2} = -\omega r \tag{8A}$$

Where: $\omega = \frac{2\pi\,\sigma_{cr}}{H}$ (8B)

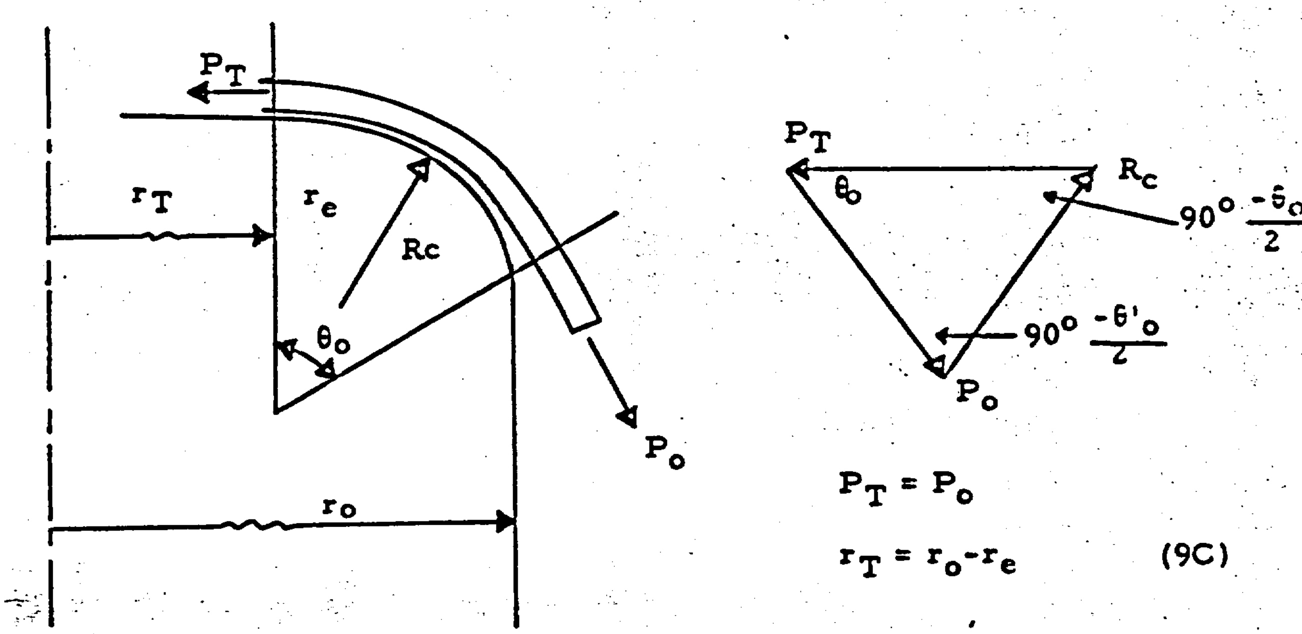
Now, from membrane ultimate strength characteristics we may derive a relation for H in terms of applied force F_Z.

$$H = P_o \cos \theta_o \qquad (9A)$$

But P_o is directly related to the ultimate strength capability of the membrane

$$P = 2\pi r t \sigma_{su} \qquad (9B)$$

The next problem relates to the choice of an appropriate radius value, r. The minimum circle is seen to occur at the top tangent point as the membrane becomes horizontal on the top of the pin.



$$P_T = P_o$$

$$r_T = r_o - r_e \qquad (9C)$$

Substituting (9C), (9B) into (9A) gives:

$$H = 2\pi \sigma_{su} t (r_o - r_e) \cos \theta_o \qquad (9D)$$

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Now, the parameter ω is found by substituting 9D into (8B):

$$\omega = \frac{\sigma_{cr}}{\sigma_{sut}\,(r_o - r_e)\cos\theta_o} \qquad (9E)$$

And from (2):

$$\sin\theta_o = \frac{F_Z - \pi\,\sigma_{cr}\,r_o^2}{2\sigma_{su}\,\pi\,r_{ot}} \qquad (9F)$$

$$\cos\theta_o = [\,1 - \sin^2\theta_o]^{1/2} \qquad (9G)$$

Solution of Equation (8A) is obtained by direct integration:

$$\frac{dZ}{dr} = \frac{-\omega r^2}{2} + c_1 \qquad (10)$$

$$Z = \frac{-\omega\,r^3}{6} + c_1 r + c_2 \qquad (11)$$

Boundary conditions for (10) and (11) are:

$$\underline{r = r_o}: \quad Z = 0 \qquad (12A)$$

$$\frac{dZ}{dr} = \tan\theta_o \qquad (12B)$$

$$\underline{r = r_1}: \quad \frac{dZ}{dr} = 0 \qquad (12C)$$

Substitution of (12B) into (10) gives:

$$c_1 = \tan\theta_o + \frac{\omega\,r_o^2}{2} \qquad (13)$$

Substitution of (12C) into (10) gives:

$$c_1 = \frac{+\omega\,r_1^2}{2} \qquad (14)$$

Equating (13) and (14) requires that:

$$\tan \theta_o = \frac{\omega}{2} (r_1^2 - r_o^2) \qquad (15)$$

Substituting (12A) and (14) into (11) gives:

$$c_2 = \frac{\omega r_o^3}{6} - \frac{\omega r_1^2 r_o}{2} \qquad (16)$$

Finally, upon substitution of (14) and (16) into (11) the equation of the membrane becomes:

$$Z = \frac{\omega}{6} (r_o^3 - 3r_1^2 r_o + 3r_1^2 r - r^3) \qquad (17)$$

The total displacement of the penetrating pin, Z_o, is found by setting $r=r_1$:

$$Z_o = \frac{\omega}{6} (r_o^3 - 3r_1^2 r_o + 2r_1^3) \qquad (18)$$

Where ω is given by Equation (9E).

Computer Program, PUNCH

PUNCH has been written as a FORTRAN IV computer program based upon the relations contained in the foregoing analysis development.

The program has been developed to support design. A built-in program loop continues to cycle until a satisfactory membrane sheet thickness is determined.

Basically the program performs the following steps:

- For each trial thickness the program
  - Computes 20 even increments of load from initial crush to final membrane tear using Equation (2).
  - Checks each incremental load to assure that strain allowable is not exceeded, Equation (1C). If needed the load values are adjusted or reduced in number.

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- Computes corresponding deformed area radius using Equation (4)
- Computes the parameter, ω, using Equation (9E)
- Computes displacements corresponding to the 20 or less increments of load using Equation (18)

- Integrates the force - displacement relation utilizing a trapazoidal rule algorithm to obtain total absorbed energy.
- Compares energy absorbed with the total required energy which must be absorbed, Equation (3).
- If the total energy balance is unsatisfied, the membrane thickness is incremented and the analysis is recycled.

Comparison and Conclusion

For comparative purposes, this computer routine is compared with test data reflected in Figure 2.2 of the Oak Ridge National Laboratory Irradiated Fuel Shipping Cask Design Guide, ORNL-TM-2410, January, 1969. (next page)

Computer results are plotted over Figure 2.2, from ORNL-TM-2410 with substantiating computer output following. In addition to lead backed test data, the program analysis results have been compared in a go/no-go fashion with test data for two MRI developed soft backing media designs The results compare as shown in the below table, substantiating computer results follow.

Design Designation	DOT S. P.	Media Strength (psi)	Thickness (in)		Result
			Test	Analysis	
1. Paper Tiger	6000	30-35	.0359	.0175	No Puncture
2. Super Tiger	pend-ing	100-250 100-250 100 200	.375 .4375 Analysis Only	Test Only .400 .475	Puncture No Puncture - -

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Based upon these check points, PUNCH, appears to deliver reasonable engineering design values for puncture evaluation. Pending further calibration of the program it is recommended that it be applied with a minimum factor of safety on "design only" compliance certifications of +0.10 to +0.25. Furthermore, it is essential to assure in design and fabrication that the membrane material possess minimum ultimate stress and elongation capability as input to the computer program.

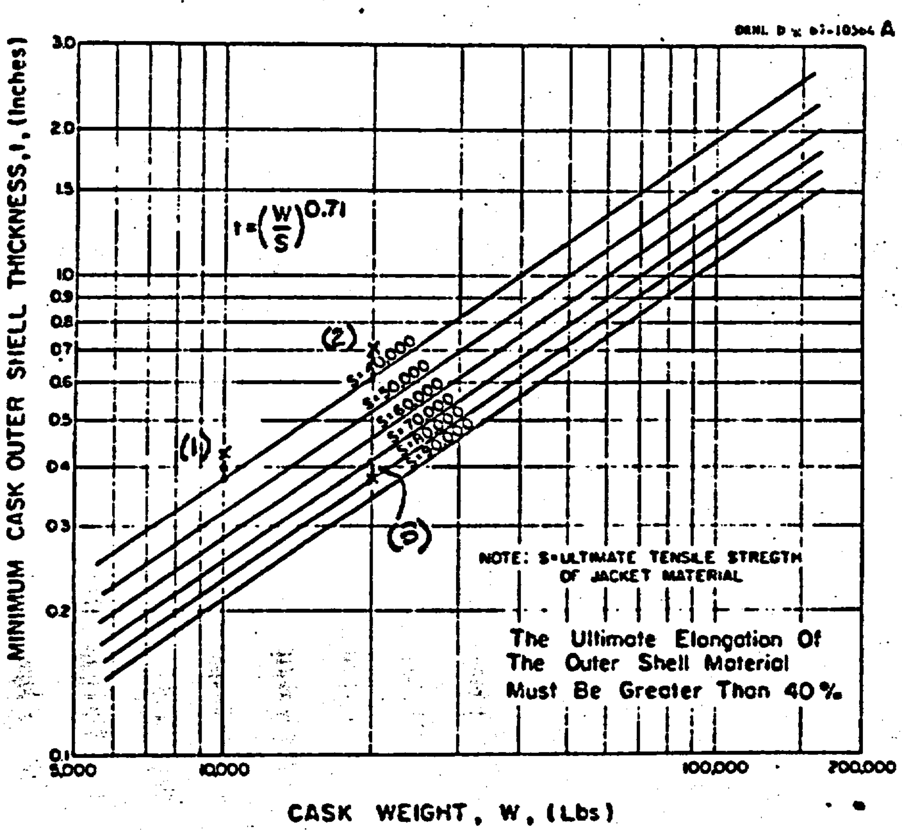

Fig. 2.2. Graph to Estimate Minimum Outer Shell Thickness.
From ORNL TM-2410, January 1969

PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS (1) See Fig ... TM-...

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 10000.

DROP HEIGHT (IN) = 40.

KINETIC ENERGY TO ABSORB (FT-LB) = 33333.

ULTIMATE STRESS OF MEMBRANE (PSI) = 40000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 40.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 2300.

INITIAL & INCREMENTAL THICKNESS OF MEMBRANE SHEET (IN) = .25, .02

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

SHEET THICK (IN)	CRUSH RADIUS (IN)	********** VALUES AT MEMBRANE FAILURE ********** TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.2500	5.221	196950.	1.29	16965.	19.7	44.4	
0.2700	5.359	207504.	1.38	18925.	20.8	44.4	
0.2900	5.493	218057.	1.46	20963.	21.8	44.4	
0.3100	5.625	228611.	1.55	23077.	22.9	44.4	
0.3300	5.753	239165.	1.63	25267.	23.9	44.4	
0.3500	5.879	249718.	1.70	27529.	25.0	44.4	
0.3700	6.002	260272.	1.78	29864.	26.0	44.4	
0.3900	6.122	270825.	1.86	32269.	27.1	44.4	
0.4100	6.240	281379.	1.93	34744.	28.1	44.4	
0.4300	6.356	291932.	2.01	37287.	29.2	44.4	*DESIGN VALUE*

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PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS (2), See Fig 2.2

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 20000.

DROP HEIGHT (IN) = 40.

KINETIC ENERGY TO ABSORB (FT-LB) = 66667.

ULTIMATE STRESS OF MEMBRANE (PSI) = 40000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 40.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 2300.

INITIAL & INCREMENTAL THICKNESS OF MEMBRANE SHEET (IN) = .5,.05

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

********** VALUES AT MEMBRANE FAILURE **********

SHEET THICK (IN)	CRUSH RADIUS (IN)	TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.5000	6.746	328870.	2.26	46709.	16.4	44.4	
0.5500	7.012	355254.	2.43	53918.	17.8	44.4	
0.6000	7.268	381638.	2.60	61512.	19.1	44.4	
0.6500	7.515	408021.	2.76	69476.	20.4	44.4	
0.7000	7.754	434405.	2.91	77801.	21.7	44.4	*DESIGN VALUE*

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PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS (3) SEE FIG 2.2 ORNL TM-2410

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 20000.

DROP HEIGHT (IN) = 40..

KINETIC ENERGY TO ABSORB (FT-LB) = 66667.

ULTIMATE STRESS OF MEMBRANE (PSI) = 70000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 40.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 2300.

INITIAL & INCREMENTAL THICKNESS OF MEMBRANE SHEET (IN) = .3,.02

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

SHEET THICK (IN)	********** VALUES AT MEMBRANE FAILURE ********** CRUSH RADIUS (IN)	TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.3000	6.880	342062.	2.35	50265.	17.1	44.4	
0.3200	7.064	360530.	2.46	55407.	18.0	44.4	
0.3400	7.242	378999.	2.58	60735.	18.9	44.4	
0.3600	7.417	397468.	2.69	66247.	19.9	44.4	
0.3800	7.587	415937.	2.81	71937.	20.8	44.4	*DESIGN VALUE*

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PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS, Paper Tiger, DOT SP [illegible]

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 660.

DROP HEIGHT (IN) = 40.

KINETIC ENERGY TO ABSORB (FT-LB) = 2200.

ULTIMATE STRESS OF MEMBRANE (PSI) = 40000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 40.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 30.

INITIAL & INCREMENTAL THICKNESS OF MEMBRANE SHEET (IN) = .005, .0025

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

SHEET THICK (IN)	CRUSH RADIUS (IN)	********** VALUES AT MEMBRANE FAILURE ********** TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.0050	6.082	3487.	1.83	410.	5.3	44.4	
0.0075	7.141	4806.	2.51	752.	7.3	44.4	
0.0100	8.062	6125.	3.12	1167.	9.3	44.4	
0.0125	3.887	7444.	3.67	1646.	11.3	44.4	
0.0150	9.643	8763.	4.17	2184.	13.3	44.4	
0.0175	10.343	10083.	4.64	2778.	15.3	44.4	*DESIGN VALUE*

0.0357 Actual – No Puncture

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PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS , Superconical

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 45000.

DROP HEIGHT (IN) = 40.

KINETIC ENERGY TO ABSORB (FT-LB) = 150000.

ULTIMATE STRESS OF MEMBRANE (PSI) = 55000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 30.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 100.

INITIAL & INCREMENTAL THICKNESS
OF MEMBRANE SHEET (IN) = .15,.025

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

		********** VALUES AT MEMBRANE FAILURE **********					
SHEET THICK (IN)	CRUSH RADIUS (IN)	TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.1500	18.036	102193.	8.44	48367.	2.3	39.7	
0.1750	19.442	118754.	9.27	61545.	2.6	39.7	
0.2000	20.754	135315.	10.05	75813.	3.0	39.7	
0.2250	21.987	151876.	10.76	91102.	3.4	39.7	
0.2500	23.155	168437.	11.48	107356.	3.7	39.7	
0.2750	24.267	184998.	12.14	124526.	4.1	39.7	
0.3000	25.329	201559.	12.78	142570.	4.5	39.7	
0.3250	26.350	218120.	13.36	161452.	4.8	39.7	
0.3500	27.332	234681.	13.97	181140.	5.2	39.7	
0.3750	28.279	251242.	14.54	201606.	5.6	39.7	
0.4000	29.197	267802.	15.09	222822.	6.0	39.7	*DESIGN VALUES

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PATENT PENDING

*** TRIAL CASE DATA

Su fectiger

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 200.

INITIAL & INCREMENTAL THICKNESS OF MEMBRANE SHEET (IN) = .3,.025

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

********** VALUES AT MEMBRANE FAILURE **********

SHEET THICK (IN)	CRUSH RADIUS (IN)	TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.3000	18.036	204386.	8.44	96733.	4.5	39.7	
0.3250	18.752	220947.	8.86	109630.	4.9	39.7	
0.3500	19.442	237508.	9.27	123091.	5.3	39.7	
0.3750	20.109	254069.	9.66	137095.	5.6	39.7	
0.4000	20.754	270630.	10.05	151627.	6.0	39.7	
0.4250	21.379	287191.	10.42	166668.	6.4	39.7	
0.4500	21.987	303752.	10.78	182205.	6.8	39.7	
0.4750	22.579	320313.	11.13	198224.	7.1	39.7	*DESIGN VALUE*

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PATENT PENDING

APPENDIX C

THAN Thermal Analysis From Reference 6

3.3 Fire Test

The container has been analytically subjected to the required 1475°F fire test for a 30 minute period, using a transient electrical network analogy program (Reference 3). The results of this analysis show for the modified design that the temperature of the payload at no time exceeds 80°F. Figure 2 illustrates the thermal and time history response of the container. The extremely low payload temperatures have been experimentally verified by the previously mentioned Super Tiger development test. Super Tiger employs the same construction technique and was exposed for one hour to temperatures between 1600 and 2000°F. At no time did the payload exceed 150°F (minimum threshold for temperature reading).

The overpack side wall has been subdivided into nine nodes representing the thermal capacitance and conductance through the wall. Each one inch thickness of foam was represented with a node (7 total) with the remaining two used on inner and outer skins. The innerbox was idealized as 2 nodes, one representing the A.N.L. steel box and the other its payload. Figure 3 illustrates both the analytic model used in this analysis and the equivalent electrical analog. The assumed emissivities for this problem are as follows:

Heat Source: $\epsilon = .9$
Outer Container Walls: $\epsilon = .8$
Inner Box Walls: $\epsilon = .8$
Payload: $\epsilon = .8$

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Figure 2

PATENT PENDING

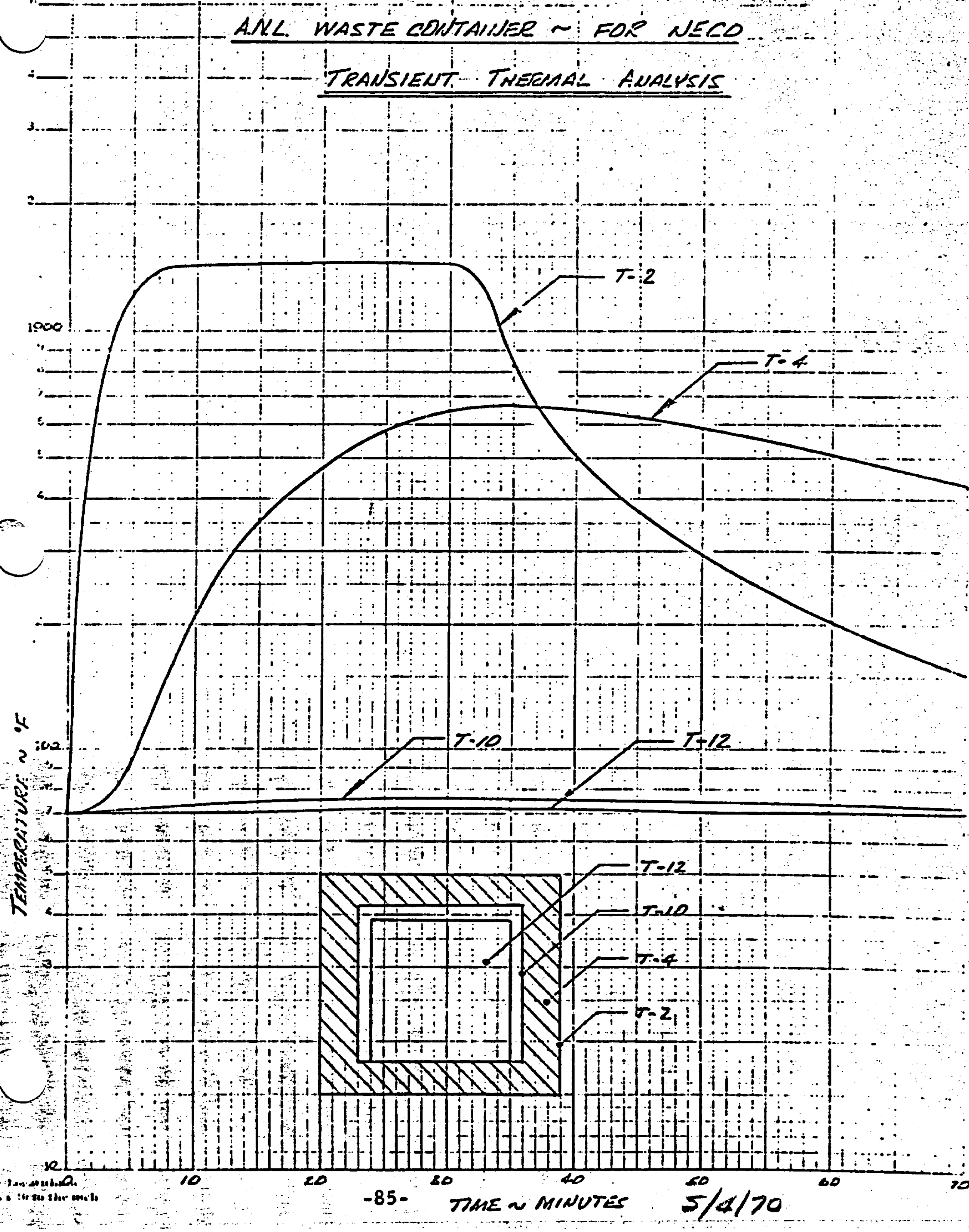
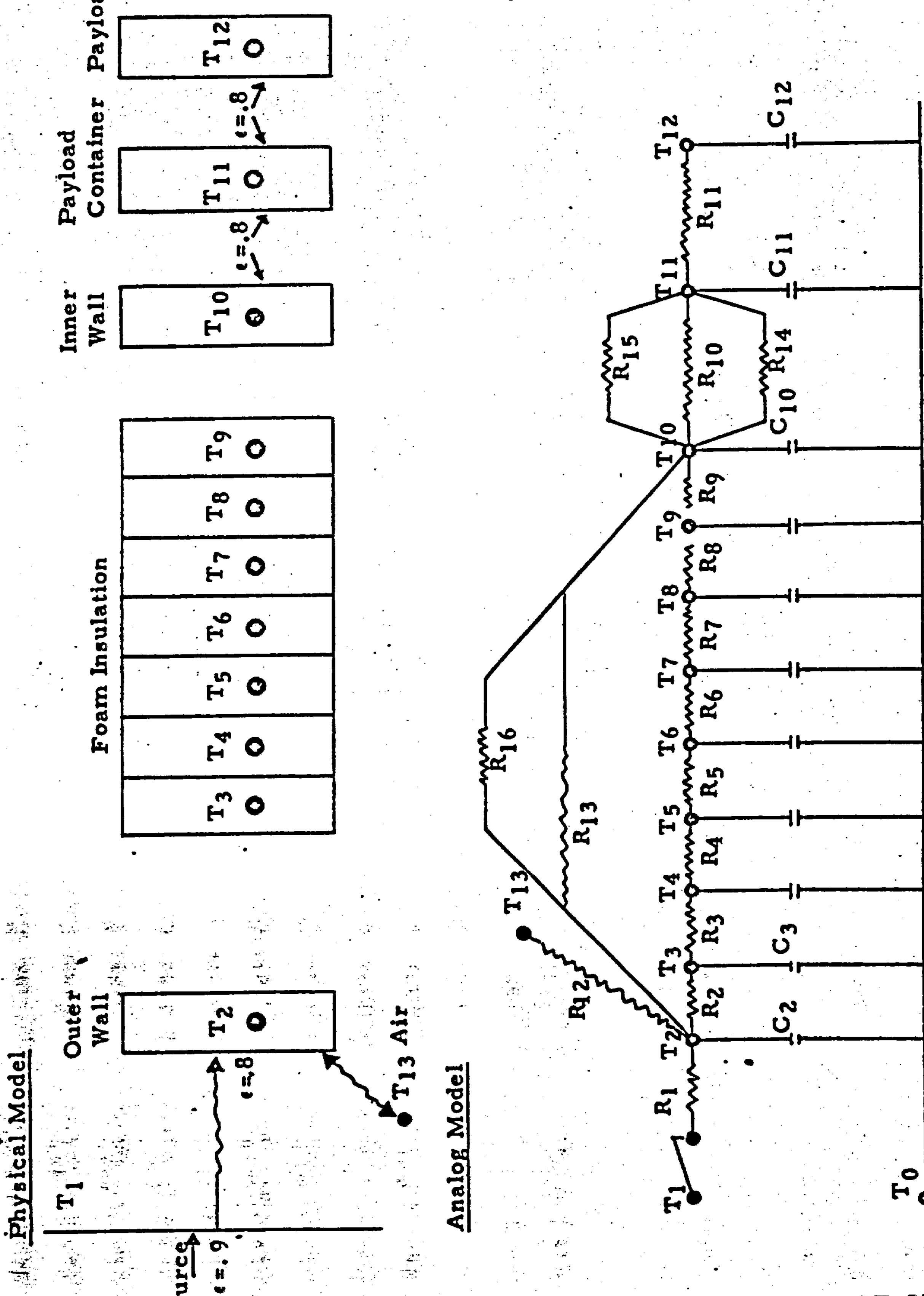


Figure 3

Argonne National Laboratory Waste Container
Thermal Analysis Model



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The model includes the following special features:

- Coupling between the outer wall and the foam consists of a conductance term.
- Foam char adjustment to account for decomposition at temperatures greater than 750°F were incorporated.
- Coupling at the lug pocket consisted of radiation and air conduction.
- Coupling between the inner box wall and the payload consists of a radiant term, and a temperature dependent air conduction term.
- Heat input consists of a programmed source temperature equal to 1475°F acting through a radiant coupling term to the outer box wall. This heat source at 30 minutes drops to a temperature of 70°F.
- At thirty minutes, a free convection and air radiation term is introduced coupling the outer box wall to an air temperature of 70°F. At 3-1/2 hours into test sequence artifical cooling on the outer box wall is introduced. This reduces the outer wall temperature to approximately 70° in about 15 minutes.

The details of this analysis are summarized in the following calculations:

3.3.1 Nodal Capacitances

1. Outer Wall

Weight = 1872 + 300 = 2172 lb.

c = .11 for mild steel

c_2 = (2172)(11) = 238.92 Btu/°R

2. Foam

Weight = 579 + 260 = 839 lbs

c = .2 assumed for foam (80% freon, 20% complex mixture)

$$c_3 \text{ to } c_9 = \frac{(839)(.2)}{7} = 23.97 \text{ Btu/}^\circ\text{R}$$

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3. Inner Wall

Weight = 248.1 lb

$c = .11$

$c_{10} = (248.1)(.11) = 27.29\ Btu/^{\circ}R$

4. Payload Container

Weight = 700 lb

$c = .11$

$c_{11} = (700)(.11) = 77.\ Btu/^{\circ}R$

5. Payload

Weight = 2300 lb

$c = .33$ (assumed)

$c_{12} = (2300)(.33) = 759\ Btu/^{\circ}R$

3.3.2 Conduction Resistors

$$R_{ij} = \frac{\ell_{ij}}{A_{ij}\, k_{ij}}$$

1. Outer Wall to Foam, R_2

R_2 = outer wall + 1/2" foam

$k_{ij} = 25\ Btu/hr\text{-}ft\text{-}^{\circ}F$ (carbon steel)

$$R_{outer\ wall} = \frac{(3/16)}{(249.6)(25)(12)} = 2.504 \times 10^{-6}\ ^{\circ}R/Btu/hr$$

$$= 9.014 \times 10^{-3}\ ^{\circ}R/Btu/sec$$

$$R_{1/2"\ Foam} = \frac{(1/2)(3600)}{(249.6)(.24)} = 30.048\ ^{\circ}R/Btu/sec$$

$R_2 = 30.048 + .009014 = 30.057\ ^{\circ}R/Btu/sec.$

2. Foam Resistors, R_3, R_4, R_5, R_6, R_7, R_8

$$R_{3,4,5,6,7,8} = \frac{(3600)}{(249.6)(.24)} = 60.1\ ^{\circ}R/Btu/sec$$

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3. Foam to Inner Wall, R_9

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$R_9 = 30.05^{\circ}R/Btu/sec$

4. Foam Char Adjustment, R_2 to R_9

To account for decomposition of the foam, the foam resistors are defined as temperature dependent quantities. Up to 750°F the foam resistors have values as given in preceeding paragraphs. Above 750°F the foam resistors take a value equivalent to an air gap of the thickness of the foam node.

$$R_i = \frac{\ell}{A} \frac{1}{k_T}$$

ℓ = 1/12 ft.

A = 249.6 ft^2

°F	°R	k_i[Btu/hr-ft-°F]	$1/k_i$[ft-sec-°F/Btu]	R_i
750	1210	.024891	$.144631 \times 10^6$	48.29
850	1310	.026213	$.137336 \times 10^6$	45.85
1090	1550	.029176	$.123389 \times 10^6$	41.20
1350	1810	.032113	$.112104 \times 10^6$	37.43
1490	1950	.033598	$.107149 \times 10^6$	35.77

5. Payload Container to Payload, R_{11}

Assuming Payload is damp sand or similar material

k_{ij} = .6 Btu/hr-ft-°F] assume
ℓ_{ij} = 2"]

$$R_{11} = \frac{(2/12)(3600)}{(165.4)(.6)} = 6.045\ ^{\circ}R/Btu/sec$$

3.3.3 Complex Coupling Resistors, R_1, R_{12}, R_{13}, R_{10}, R_{14}, R_{15}, R_{16}

1. Radiation Coupling, Inner Wall to Payload Box, R_{10}

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$A_i = 150.78\ ft^2$

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$A_j = 165.4\ ft^2$

$F_{ij} = 1$

$\epsilon_i \quad \epsilon_j = .8$

$\sigma = .4761 \times 10^{-12}\ Btu/sec\text{-}ft^2 - {}^oR^4$

$$k_{ij} = \frac{\sigma A_i}{\left(\frac{1}{\epsilon_i} - 1\right) + \left(\frac{1}{F_{ij}}\right) + \frac{A_i}{A_j}\left(\frac{1}{\epsilon_j} - 1\right)}$$

$$k10 = \frac{(.4761 \times 10^{-12})(150.78)}{\left(\frac{1}{.8} - 1\right) + 1 + \frac{150.78}{165.4}\left(\frac{1}{.8} - 1\right)} = 48.60 \times 10^{-2}\ Btu/sec\text{-}{}^oR^4$$

2. Interface Conductive Coupling, R_{14}

Bottom of Argonne Container to Bottom of Payload, assume 30% contact area and 1/32" height asperities.

$\ell_{ij} = 1/2\ (12\ ga.) + 1/2\ (20\ ga)$

$= 1/2(.1046 + .0359) = .07025''$

$A_{ij} = 58.5 \times 50.5 = 2954.25\ in^2$

$= 20.52\ ft^2$

Conductive Resist: $R_{14_A} = \frac{(.07025)(3600)}{(20.52)(12)(25)} = .041081\ {}^oR/Btu/sec$

Contact Resist: $R_{14_B} = \frac{(1/32)(3600)}{(20.52)(.3)(12)(25)}$ +.060916 $^oR/Btu/sec$

$R_{14} = R_A + R_B = 0.101997\ {}^oR/Btu/sec$

3. Radiant Source to Outer Wall, R_1

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$$k_1 = \frac{(.4761 \times 10^{-12})(249.6)}{\left(\frac{1}{.8} - 1\right) + 1 + \left(\frac{1}{.9} - 1\right)}$$

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$$= 87.313 \times 10^{-12} \text{ Btu/sec} - {}^{\circ}R^4$$

4. **Lug Pocket Radiation Coupling, R_{16}**

$A_i = A_j = 40 \text{ in}^{-2} = .27777 \text{ ft}^2$

$\epsilon_i = \epsilon_j = .8$

$F_{ij} = 1$

$$K_{16} = \frac{(.4761 \times 10^{-12})(.27777)}{\left(\frac{1}{.8} - 1\right) + 1. + (1.)\left(\frac{1}{.8} - 1\right)} = .088166 \times 10^{-12} \text{ Btu/sec-}{}^{\circ}R$$

5. **Temperature Dependent Air Conduction Resistance**

The conductivity assumed for air uses the imperical relation given in section 16 of Reference (6), Table 20.

$$R_i = \frac{i}{A_i k_i} = \frac{i}{A_i} \cdot \frac{1}{k_i}$$

where $k = k_{32} \left(\frac{492 + C}{T + C}\right) \left(\frac{T}{492}\right)^{1.5}$, $\text{Btu/hr/}^{\circ}\text{F/ft}^2$

For Air: $k_{32} = 0.155$

$C = 225$

${}^{\circ}R$	k_i[Btu/hr-ft-°F]	$1/k_i$ [ft-sec-°R/Btu]
530	.013715	$.262486 \times 10^6$
810	.018902	$.190456 \times 10^6$
1050	.022646	$.158968 \times 10^6$
1310	.026213	$.137336 \times 10^6$
1550	.029176	$.123389 \times 10^6$
1810	.032113	$.112104 \times 10^6$
1950	.033598	$.107149 \times 10^6$

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PATENT PENDING

a. Inner Wall to Payload Airgap, R_{15}

$$\left(\frac{\ell}{A}\right)_{top} = \frac{(74.5 - 72.5)\,(12)}{(1)\,(58.5)(50.5)} = .008123$$

$$\left(\frac{\ell}{A}\right)_{side\ 1} = \frac{(52 - 50.5)\,(12)}{(2)\,(1)\,(2)\,(58.5)\,(72.5)} = .001061$$

$$\left(\frac{\ell}{A}\right)_{side\ 2} = \frac{(60-58.5)\,(12)}{(4)\,(50.5)\,(72.5)} = .001229$$

The above are coefficients for parallel resistors

$$R_{15} = \frac{1}{\sum_i \frac{1}{R_i}} = \frac{1}{\frac{1}{.008123} + \frac{1}{.001061} + \frac{1}{.001229}}$$

$$\left(\frac{\ell}{A}\right)_{15} = .000532117/\text{ft.}$$

b. Lifting Lug Pockets, R_{13}

These pockets, or cavities, extend from the container outer wall to the payload.

$\ell = 9.5$ in
$A = 2\text{-}1/2 \times 8 = 20.$ in^2

$$\left(\frac{\ell}{A}\right) = \frac{(9.5)\,(144)}{(20)\,(12)} = 5.7/\text{ft}$$

There are two of these:

$$\left(\frac{\ell}{A}\right)_{13} = \frac{1}{\frac{1}{5.7} + \frac{1}{5.7}} = 2.857/\text{ft.}$$

6. Combined External Air Convection and Radiation

Following application of the simulated 1475 degree fire the outer box wall is assumed to be cooled by combined air convection

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and radiation. The coefficient utilized for this combined equivalent convection loss has been taken from the data presented in Table 11, pages 4-106 and 4-107 of Reference (5).

$$q = (hc + hr)\ A\ \delta T$$

$$h = (hc + hr) \text{ @ } 150^\circ \quad \delta T = 2.40 \text{ (Avg.) Btu/ft}^2\text{-hr/}^\circ\text{F}$$

$$R = \frac{1}{12hA} = \frac{1 \text{ (3600 sec/hr)}}{(2.4 \text{ Btu/ft}^2\text{-hr/}^\circ\text{F})\ (249.6 \text{ ft}^2)}$$

$$= 6.01\ ^\circ\text{F/Btu/sec}$$

This resistor switches in @.5 hr.

Sample output from the computer program, Reference (3), is included in the following pages and to substantiate the plotted results, pages 29 through 35.

3.4 Closing Device

For impact against a cover edge, as shown below in Figure 4, the closure device is loaded by the deceleration of the payload and cover. Assuming that approximately one half of the payload weight reacts against the cover, the total force, P, tending to burst the cover is given by

$$P = (W_c + \frac{W_p}{2})\ G \cos\theta$$

where W_c is the cover weight and W_p is the payload weight. For the subject overpack $\theta = 36^\circ\ 40'$ and $\cos\theta = 0.802$.

PATENT PENDING

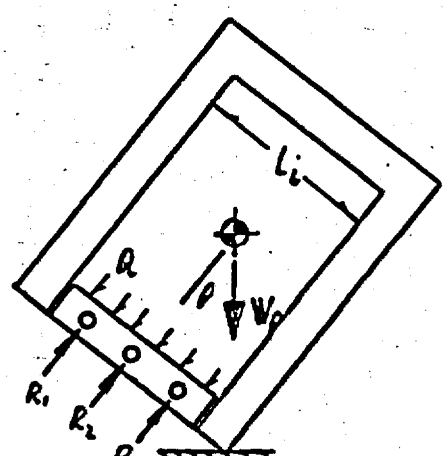

Figure 4

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ARGONNE [illegible] NUCLEAR WASTE CONTAINER, OWNERSHIP, DESIGNER

PRINT CODES

-.0000 .1000+01 -.0000 -.0000 -.0000 -.0000 -.0000 -.0000 -.0000

THERMAL RESISTANCE DATA

RESISTOR	ATTACHING NODES		RESISTANCE DEG.R/BTU/SEC		
1	1	2	.10000+01	RESISTOR DATA **	OUTER RAD. COUPLING
2	2	3	.10000+01		FOAM CONDUCTION
3	3	4	.10000+01		FOAM CONDUCTION
4	4	5	.10000+01		FOAM CONDUCTION
5	5	6	.10000+01		FOAM CONDUCTION
6	6	7	.10000+01		FOAM CONDUCTION
7	7	8	.10000+01		FOAM CONDUCTION
8	8	9	.10000+01		FOAM CONDUCTION
9	9	10	.10000+01		FOAM CONDUCTION
10	10	11	.10000+01		PAYLOAD RAD. COUPLING
11	11	12	.80450+01		PAYLOAD CONDUCTION
12	2	13	.10000+01		EXTERNAL AIR CONV.
13	2	10	.10000+01		LUG POCKET AIR CONDUC
14	10	11	.10200+00		CONTACT RESISTANCE
15	10	11	.10000+01		PAYLOAD AIR CONDUCTIO
16	2	10	.10000+01		LUG POCKET RADIATION

INITIAL TEMPERATURE DATA

NODE	TEMPERATURE (DEG. R)		
1	.19347+04	INITIAL NODE TEMPS.**	SOURCE
2	.52969+03		OUTER WALL
3	.52969+03		FOAM
4	.52969+03		FOAM
5	.52969+03		FOAM
6	.52969+03		FOAM
7	.52969+03		FOAM
8	.52969+03		FOAM
9	.52969+03		FOAM
10	.52969+03		INNER WALL
11	.52969+03		PAYLOAD CONT
12	.52969+03		PAYLOAD
13	.52969+03		EXT AIR SINK

NODE CAPACITANCE DATA

NODE	CAPACITANCE BTU/DEG.R	
1	-.10000+01	NODE CAPACITANCE
2	.23892+03	
3	.23970+02	
4	.23970+02	
5	.23970+02	
6	.23970+02	
7	.23970+02	
8	.23970+02	
9	.23970+02	
10	.27237+02	
11	.77200+02	
12	.75900+03	

PATENT PENDING

PATENT PENDING

```
NODAL DATA SUMMARY

NODE NO.    1      NODE ID     1
CAPACITANCE =    -.1000[illegible] BTU/[illegible]
INITIAL TEMPERATURE =    [illegible] DEG.R

               CONNECTING RESISTORS -      1  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    1      2  .10000+01

NODE NO.    2      NODE ID     2
CAPACITANCE =    .2389200+03 BTU/DEG.R
INITIAL TEMPERATURE =    .5296900+03 DEG.R

               CONNECTING RESISTORS -      5  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    1      1  .10000+01    2      3  .10000+01   12     13  .10000+01
   13     10  .10000+01   16     10  .10000+01

NODE NO.    3      NODE ID     3
CAPACITANCE =    .2337000+02 BTU/DEG.R
INITIAL TEMPERATURE =    .5296900+03 DEG.R

               CONNECTING RESISTORS -      2  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    2      2  .10000+01    3      4  .10000+01

NODE NO.    4      NODE ID     4
CAPACITANCE =    .2337000+02 BTU/DEG.R
INITIAL TEMPERATURE =    .5296900+03 DEG.R

               CONNECTING RESISTORS -      2  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    3      3  .10000+01    4      5  .10000+01

NODE NO.    5      NODE ID     5
CAPACITANCE =    .2337000+02 BTU/DEG.R
INITIAL TEMPERATURE =    .5296900+03 DEG.R

               CONNECTING RESISTORS -      2  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    [illegible]      4  .10000+01    5      6  .10000+01
```

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```
NODE NO.    6      NODE ID     6
CAPACITANCE =     .2397000+02 BTU/DEG.F
INITIAL TEMPERATURE =     .5296900+03 DEG.F

              CONNECTING RESISTORS -     2  TOTAL

   ID  NODE RESISTANCE   ID  NODE RESISTANCE   ID  NODE RESISTANCE

    5      5  .10000+01    6      7  .10000+01

NODE NO.    7      NODE ID     7
CAPACITANCE =     .2397000+02 BTU/DEG.F
INITIAL TEMPERATURE =     .5296900+03 DEG.F

              CONNECTING RESISTORS -     2  TOTAL

   ID  NODE RESISTANCE   ID  NODE RESISTANCE   ID  NODE RESISTANCE

    6      6  .10000+01    7      8  .10000+01

NODE NO.    8      NODE ID     8
CAPACITANCE =     .2397000+02 BTU/DEG.F
INITIAL TEMPERATURE =     .5296900+03 DEG.F

              CONNECTING RESISTORS -     2  TOTAL

   ID  NODE RESISTANCE   ID  NODE RESISTANCE   ID  NODE RESISTANCE

    7      7  .10000+01    8      9  .10000+01

NODE NO.    9      NODE ID     9
CAPACITANCE =     .2397000+02 BTU/DEG.F
INITIAL TEMPERATURE =     .5296900+03 DEG.F

              CONNECTING RESISTORS -     2  TOTAL

   ID  NODE RESISTANCE   ID  NODE RESISTANCE   ID  NODE RESISTANCE

    8      8  .10000+01    9     10  .10000+01

NODE NO.   10      NODE ID    10
CAPACITANCE =     .2729000+02 BTU/DEG.F
INITIAL TEMPERATURE =     .5296900+03 DEG.F

              CONNECTING RESISTORS -     6  TOTAL

   ID  NODE RESISTANCE   ID  NODE RESISTANCE   ID  NODE RESISTANCE

    9      9  .10000+01   10     11  .10000+01   13      2  .10000+01
   14     11  .10250+00   15     11  .10000+01   16      2  .10000+01

NODE NO.   11      NODE ID    11
CAPACITANCE =     .7700000+02 BTU/DEG.F
INITIAL TEMPERATURE =     .5296900+03 DEG.F
```

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```
          CONNECTING RESISTORS -     4  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

   10    10  .10000+01    11    12  .60450+01    14    10  .15200+00
   15    10  .10000+01

NODE NO.   12      NODE ID   12
CAPACITANCE =     .7590000+03 BTU/DEG.R
INITIAL TEMPERATURE =     .5296900+03 DEG.R

          CONNECTING RESISTORS -     1  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

   11    11  .60450+01

NODE NO.   13      NODE ID   13
CAPACITANCE =    -.1000000+01 BTU/DEG.R
INITIAL TEMPERATURE =     .5296900+03 DEG.R

          CONNECTING RESISTORS -     1  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

   12     2  .10000+01
```

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PATENT PENDING

SPECIAL FUNCTION SPECIFICATIONS

RADIATION RESISTOR DATA - FUNCTION 2

RESISTOR	RESISTANCE DEG.R/BTU/SEC	
1	.87317-10	RADIATION RESISTOR & VALUE
10	.48600-10	
16	.88168-11	

TABULAR FUNCTION DATA - FUNCTION 7

DEP. ID	INDEP. ID	TABLE ID	FACTOR	
1	0	1	.10000+01	TABLE 1** SOURCE TIME VS TIME
11	2	2	.29500+01	TABLE 2** [illegible]
15	17	2	.57312+03	[illegible]
12	[illegible]	3	.17000+01	TABLE 3** [illegible]
2	2	4	.50000-02	TABLE 4 ** FLUX CH[illegible]
3	2	4	.10000+01	TABLE 4 ** FLUX CH[illegible]
4	2	4	.10000+01	TABLE 4 ** FLUX CH[illegible]
5	2	4	.10000+01	TABLE 4 ** FLUX CH[illegible]
6	2	4	.10000+01	TABLE 4 ** FLUX CH[illegible]
7	2	4	.10000+01	TABLE 4 ** FLUX CH[illegible]
8	2	4	.10000+01	TABLE 4 ** FLUX CH[illegible]
9	2	4	.50000-02	TABLE 4 ** FLUX CH[illegible]

PRINT SPECIFICATION - FUNCTION 6

CLASS	VARIABLE NO.	PLOTTING FACTOR	
2	1	[illegible]	OUTPUT SPECIFICATION

ALL TEMPERATURES TO BE PRINTED OUT

PROBLEM CONSTANTS

1 OUTPUT TIME INTERVAL : [illegible]

2 TIME INCREMENT BASED ON MINIMUM RC PRODUCT

3 RC TIME MULTIPLIER : [illegible]

4 PROBLEM CUT OFF TIME : [illegible]

5 TRANSIENT PROBLEM

9 INITIAL TIME : [illegible]

OUTPUT VARIABLES BY CLASS

TR NT PROBLEM

PATENT PENDING

TIME = .0000000 SEC.
MINIMUM RC PRODUCT = .0000000 SEC. ---- FOR NODE 0

NO. OF INCREMENTS = -0

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	70.0000000	3	70.0000000	4	70.0000000
5	70.0000000	6	70.0000000	7	70.0000000	8	70.0000000
9	70.0000000	10	70.0000000	11	70.0000000	12	70.0000000
13	70.0000000						

TIME = .6000000+02SEC.
MINIMUM RC PRODUCT = .2763920+01SEC. ---- FOR NODE 10

NO INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	371.1051500	3	81.8531650	4	70.1559220
5	70.0013610	6	70.0000000	7	70.0000000	8	70.0000000
9	70.0001140	10	70.0094140	11	70.0068820	12	70.0000000
13	70.0000000						

TIME = .5999993+03SEC.
MINIMUM RC PRODUCT = .2757491+01SEC. ---- FOR NODE 10

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	1446.6909000	3	757.6222200	4	214.9907000
5	92.2961720	6	72.6970590	7	70.2801740	8	70.1376630
9	70.8472440	10	72.7132260	11	72.6228020	12	70.1121930
13	70.0000000						

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TIME = .1199997+04SEC.
MINIMUM RC PRODUCT = .2757264+01SEC. ----- FOR NODE 10

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	1465.3011000	3	1063.5010000	4	477.7071900
5	199.8394600	6	103.4821540	7	77.4085540	8	72.4202919
9	73.1343760	10	75.3324050	11	75.2305500	12	70.6003870
13	70.0000000						

TIME = .1799994+04SEC.
MINIMUM RC PRODUCT = .2757173+01SEC. ----- FOR NODE 10

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	1467.8426000	3	1162.7200000	4	647.1059700
5	322.4916700	6	163.1246700	7	95.9451440	8	79.6441540
9	76.2808250	10	76.9086050	11	76.7961420	12	71.2681040
13	70.0000000						

TIME = .2399989+04SEC.
MINIMUM RC PRODUCT = .2763681+01SEC. ----- FOR NODE 10

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.3100350	2	498.9976100	3	818.5088000	4	665.5044300
5	391.1502100	6	211.2430900	7	124.0288890	8	89.7212830
9	78.2522950	10	74.7223050	11	74.6954490	12	71.8195870
13	70.0000000						

TIME = .4799966+04SEC.
MINIMUM RC PRODUCT = .2763663+01SEC. ----- FOR NODE 10

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.3100050	2	126.1048980	3	244.4630100	4	364.8884400
5	355.3303600	6	278.2673700	7	194.5690100	8	132.3696200
9	91.7849040	10	75.2621650	11	75.2114330	12	72.4199460
13	70.0000000						

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ENCLOSURE

USAEC - Mr. Donald Nussbaumer
August 28, 1970

PATENT PENDING

1. Description of Cask Contents

In accordance with the requirements of Sec. 71.22 (b) of 10 CFR 71, Subpart B, the materials planned for shipment in the Super Tiger container are described as follows:

(1) Radioactive Constituents - Identification and Maximum Radioactivity

(a) 72 thirty gallon steel drums or 42 fifty-five gallon steel drums conforming to DOT Specification 17H or equivalent of the following materials:

(i) Type A quantities in normal or special form, n.o.s.

(ii) Type B quantities in normal or special form, n.o.s., up to a maximum quantity not to exceed the limits for Type B quantities for each 30 or 55 gallon drum as defined in Section 193.389 of 49 CFR, Subpart (1). The total aggregate quantity shall be constrained by the limitations set forth in Section 173.393 of 49 CFR, Subpart (j).

(iii) 42 fifty-five gallon stainless steel DOT Specification 5B closed-head drums of large quantities of radioactive material, n.o.s., in the form of tritiated heavy water at a concentration not to exceed 15 curies/liter (about 3100 curies per package). Each 55 gallon inner drum may not be filled to more than 98 percent of capacity. The shipper must assure that any necessary administrative arrangements are made as required to maintain temperature control within the carrier vehicle, so as to prevent freezing of the contents. The shipping papers must be properly endorsed to reflect such arrangements.

(iv) 42 fifty-five gallon drums of uranyl nitrate solutions where the U-235 concentration is not more than 5 grams per liter.

(2) Identification and Maximum Quantities of Fissile Constituents

Fissile constituents planned for shipment in the container along with respective quantities are as follows:

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(a) U-233 200 grams/secondary container
(b) Pu-239 200 grams/secondary container
(c) U-235 350 grams/secondary container
(d) Any combination of the above such that the sum of the ratios of the quantity of each to the quantity specified does not exceed unity.

(3) Chemical and Physical Form

The chemical and physical form of the package contents cannot be explicitly defined since the latter will be primarily radioactive wastes.

(4) Maximum Amount of Decay Heat

(a) For Solids:

Considering that the Super Tiger is being used for sole use, and the ambient temperature conditions allow the external temperature to reach 180 degrees F., the other limiting temperature is the temperature at which a time vs. temperature decomposition of the foam begins. Laboratory tests using this type of foam seem to bear out the fact that shrinking occurs prior to decomposition and that shrinking occurs above 350 degrees F., with decomposition taking place above 400 degrees.

Using 350 degrees as the limiting temperature of the internal surface of the foam or steel box, and 180 degrees as the limiting temperature of the external surface of the foam or the external Super Tiger, the temperature difference across 10 inches of foam is 170 degrees F. or 17 degrees per inch of foam thickness. In this thermal gradient, the thermal forces are easily taken up by the foam, and thermal stresses are negligible.

From the technical bulletin put out by the manufacturer of the foam, 6 lbs. per cubic feet foam is listed as having a "K" Factor of 0.148 Btu/hr/sq. ft./in. thickness/degree F. Since the material is 10 inches thick, the heat loss, q, for one square foot of side wall would be:

$$q = \frac{(350 - 180)\ 0.148}{10} \text{ or } 2.52 \text{ Btu/hr/sq. ft.}$$

Since the ends have 35 inches of foam thickness, the temperature gradient would be less, between 5 and 6 degrees per inch of thickness, as well as the heat loss per square foot, or 0.72 Btu/hr/sq. ft.

Being conservative and using the internal surface rather than the average or external surface, the total heat loss of the Super Tiger is the total area of the side walls, which are 14 feet x 6 feet x 4 sides = 336 square feet. This area has a heat loss of 850 Btu/hr. The ends, 6 feet x 6 feet x 2 ends, or 72 square feet, have a heat loss of 50 Btu/hr.

Total heat loss of the Super Tiger is 900 Btu/hr using the interior surface as the method for calculating the overall area. Actually the average area between the inside and the outside is more reasonable, with 14' x 7' x 4 sides, or 392 square feet. Then this heat loss is (392/335) x 850 or about 930 Btu/hr. In the same manner, using the ends as 7' x 7' x 2 ends. the result increases due to 98 square feet rather than 72. Using a factor of (98/72) x 50, the heat loss from the ends are 70 Btu/hr. Therefore, the entire Super Tiger, figured on the average dimensions, totals 1,000 Btu/hr, as opposed to 900 Btu/hr using the inside dimensions. Based on 3.4 Btu per watt, the container has a capacity of 294 watts or derated 20% for a safety factor this amounts to 235 watts per Super Tiger.

Based on a load of 42 drums, each 55 gallon size, the wattage would average out to be about 5.5 watts per drum (55 gallons size), or for a load of 72 drums each 30 gallon size, the wattage would average out to be 3.2 watts per drum (30 gallon size).

Note: With external cooling, this wattage limit could be expanded many times, based on the temperatures listed above. In fact it may be appropriate to review critical or beyond design conditions with addative materials, such as normal ice that liberate 144 Btu/lb. of heat to the heat load upon melting. This means that one pound of ice in melting would compensate for about 42 watts per pound of dry ice. With 1,000 Btu/hr being melted at a the rate of 1,000/144 or about 7 pounds of ice per hour, the thermal problem could be solved for the hauling of materials which may suffer from thermal degradation. This ice could be placed on the floor of the Super Tiger so that conduction takes place in the inner container. During extreme cases, it may be prudent to use dunnage made from aluminum sheets or light plates to increase heat flow from the inner most drums to the heat sink (inner container).

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(b) For Liquids:

For liquids, the maximum internal temperature conditions shall be limited to 200 degrees, and possibly some unstable natural organic polymirs that may be found in nuclear waste. (Normal paper and rags made of natural fiber would not be in this category). Since the temperature difference is reduced to 20 degrees F., the wattage limit, which was 235 watts per Super Tiger for solids, would be (20/170) x 235 or 27.6 watts per Super Tiger containing liquids. Derated this should be used for liquids with internal heat generation only on special occasions, when necessity requires this useage.

(5) Floor Loading Analysis (floor, sides, and ends)

In order to establish on allowable floor loading, that received during actual drop testing should be calculated.

A steel drum resting on a flat surface produces a line contact as shown below:

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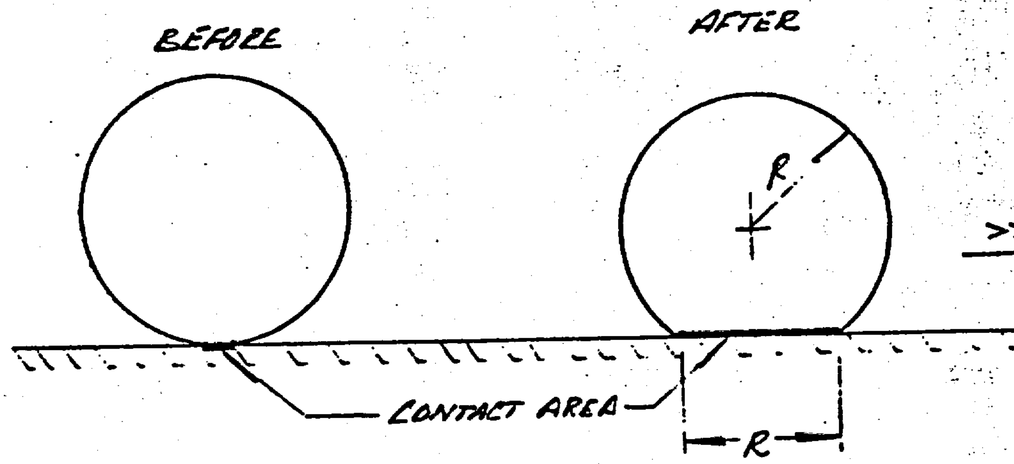

>> 17H C!

On impact, it was found that the line contact was increased to a dimension that never exceed the radius of a drum. Maximum floor loading was reacted over an area no larger than 50% of that available. This was demonstrated in the drop testing and found to produce no detrimental effects to the inner containment vessel. Using a 20% positive Margin of Safety over that shown in test to be safe, it can be concluded that floor loading should at all times be reacted over a minimum of 60 % of the available floor. In this manner, it can be guaranteed that all loads will be less than that experienced in actual drop testing.

We therefore propose the secondary container to be used in:

(a) Any combination of full or empty drums such that the total cavity is filled with said drums.

(b) Any combination of full or empty waste bins such that the total cavity is filled with said bins. (6' x 6' x 4 1/2')

(c) In a & b above and any single container, the maximum floor loading will at all times be distributed over a minimum of 60% of the floor area. Dunnage or internal brasing will be utilized to eliminate secondary impact. Secondary containers will be blocked, as necessary, within the container using timbers, crushable, or inflatable dunnage.

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2. An analysis of Sections 71.33, 71.35 (b), 71.36 (b), and 71.37 of 10 CFR Part 71 for fissile contents specified in Page10 of this enclosure

The fissile material quantities specified in Page10 of this enclosure are such that the material will be in a subcritical configuration in its most reactive chemical and physical form, moderated by water to the most reactive extent and fully reflected on all sides by water.

In addition, the inner container, subsequent to actual testing to meet requirements of Appendix B of 10 CFR Part 71, is leak tight and will not allow liquids to flow in or out. As a back-up safety feature, tests are outlined on Page127 of this enclosure to insure that the mouth of the inner container is water tight after closure.

Based on the above, the requirements of the above mentioned sections of 10 CFR Part 71 are met or are not applicable.

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3. Two tie down techniques can be used. One employees the cable sling approach, while the other utilizes the standard ISO.

Cable Tie down

The Super Tiger can be secured using the system of tie downs shown on Figure I.

A detail drawing of the standard ISO and U.S.A.S.I. corner casting is enclosed. Cable loads for the lower castings are reacted by the shear area denoted Area "A." (See Dwg.)

"A"

$$A = \left(\frac{13}{16}\right)(2\ 1/2) + \left(\frac{7}{16}\right)(2\ 3/16) = 2.985$$

F_s = 36,000 psi (See vendor specification sheet # 1 .30% Maximum Carbon Steel)

Allowable load in double shear/fitting.

$$P_A = (36,000)(2.985)(2)$$

$$P_A = 215,000 \text{ lbs.}$$

"B"

$$A = (1\ 1/8)(2\ 1/4) = 2.53$$

$$P_B = (36,000)(2.53)(2)$$

$$P_B = 182,200 \text{ lbs.}$$

(2 g's Vertical)

Vertical loads are reacted by all eight fittings. Assume all cables act in a direction which is 45° to the applied load.

Load = (2 g's) (45,000 lbs.) = 90,000 lbs.

Since one fitting will react:

cos 45° (182,200) or 128,800 lbs.

$$M.S. = \frac{4\ (128,800)}{90,000} - 1$$

M.S. = + Large

PATENT PENDING

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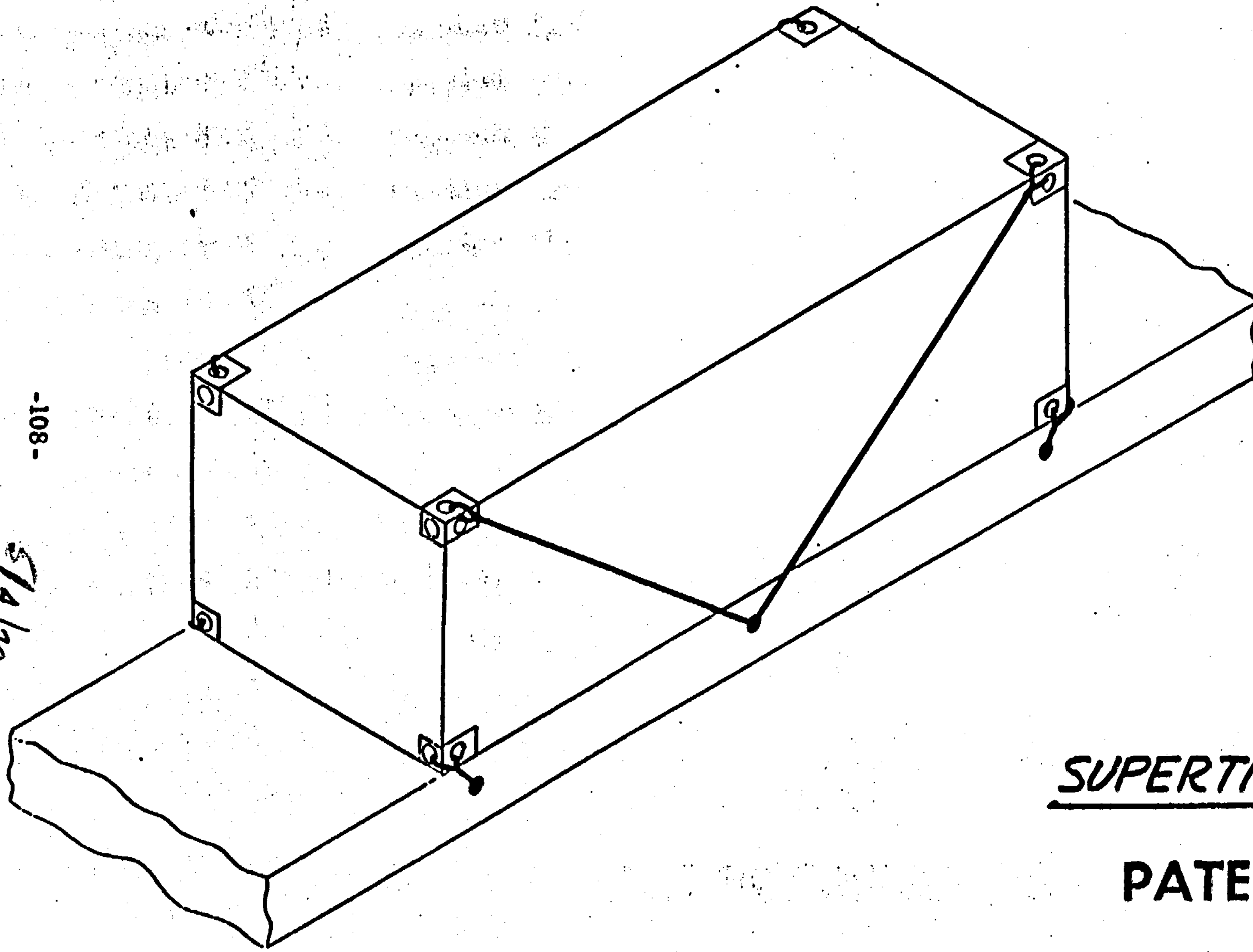

Figure I

SUPERTIGER ~ TIE-DOWNS

PATENT PENDING

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SPECIFICATION #1 - .30% MAXIMUM CARBON STEEL

1.0 CHEMICAL REQUIREMENTS

	MINIMUM/MAXIMUM		EXPECTED
Carbon		.30[1]	.26
Manganese	.50	.70[1]	.65
Silicon	.30	.60	.45
Phosphorus		.05	.03
Sulfur		.05	.03

2.0 PHYSICAL PROPERTIES

	MINIMUM	EXPECTED
Yield, P.S.I.	36,000 →	42,000
Tensile, P.S.I.	70,000	74,000
Elongation, % in 2"	22.0	26.0
Reduction Of Area, %	35.0	44.0
Brinell	180 Max.	

3.0 HEAT TREATMENT

See Specification 600-2 and 600-3
Anneal 1650° F. Furnace cool to 800° F.
Normalize 1650° F. Temper 1100-1300° F.
Must be stress relieved after welding.

4.0 WELDING

See Specification 100-1
Filler Metal ASTM A233-64T Class E-7018
MIL-E-22200/1C Class MIL-7018

5.0 APPROXIMATE EQUIVALENT SPECIFICATIONS

ASTM A27-65 Class 65/35
ASTM A27-65 Class 70/36
ASTM A356-60T Grade 1
ABS Machinery Grade 2
Federal QQ-S-681D Class 65/35
Federal QQ-S-681D Class 70/36
MIL-S-15083B Class CW
MIL-S-15083 B Class 65/35
MIL-S-15083 B Class 70/36
De Laval Code 0113 Steel #9

Note 1: For each reduction of .01% of carbon below the specified maximum, an increase of .04% of manganese is allowed up to 1.0% manganese.

PATENT PENDING

				Specification #1 -- .30% Maximum Carbon Steel	PAGE 1 OF 1
8/14/67	[signature]	[signature]	Rev. 2	DE LAVAL TURBINE INC. 550 — 85TH AVENUE OAKLAND, CALIFORNIA 94621	SPECIFICATION NO. #1
DATE	CHECKED	APPROVED	ALTERATIONS		

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(5 g's Lateral)

Lateral loads are reacted by a minimum of four fittings and again assume a 45° reaction direction:

Load = (5 g's) (45,000 lbs.) = 225,000 lbs.

Capability = 4 (182,200) cos 45° = 515,200 lbs.

$$M.S. = \frac{515,200}{225,000} - 1$$

$$M.S. = +1.29$$

(10 g's Fore and Aft)

These loads are reacted by two upper fittings and two lower fittings:

Load = 10 (45,000) = 450,000 lbs.

Capability = cos 45° [2 (182,200) + 2 (215,000)]

= 561,600 lbs.

$$M.S. = \frac{561,600}{450,000} - 1$$

$$M.S. = +.25$$

Should the fittings experience loads in excess of their capability, the packages integrity will not be jeopardized. Over loading would result in localized tear out or shear failure of a portion of the fitting. Since each fitting is isolated within the triangular cavity formed by the diagonal gusset plate, only localized damage will result. (Ref. Photo 2, Page 5 of Super Tiger Report)

(Lifting Loads):

Lifting of the container would be accomplished with the use of four fittings. Hook and clevis attachments as shown in Annex A will possess capability as calculated for Section "B."

∴ Capability = 4 (182,200) = 728,800 lbs.

Conservatively, assume a 30° sling.

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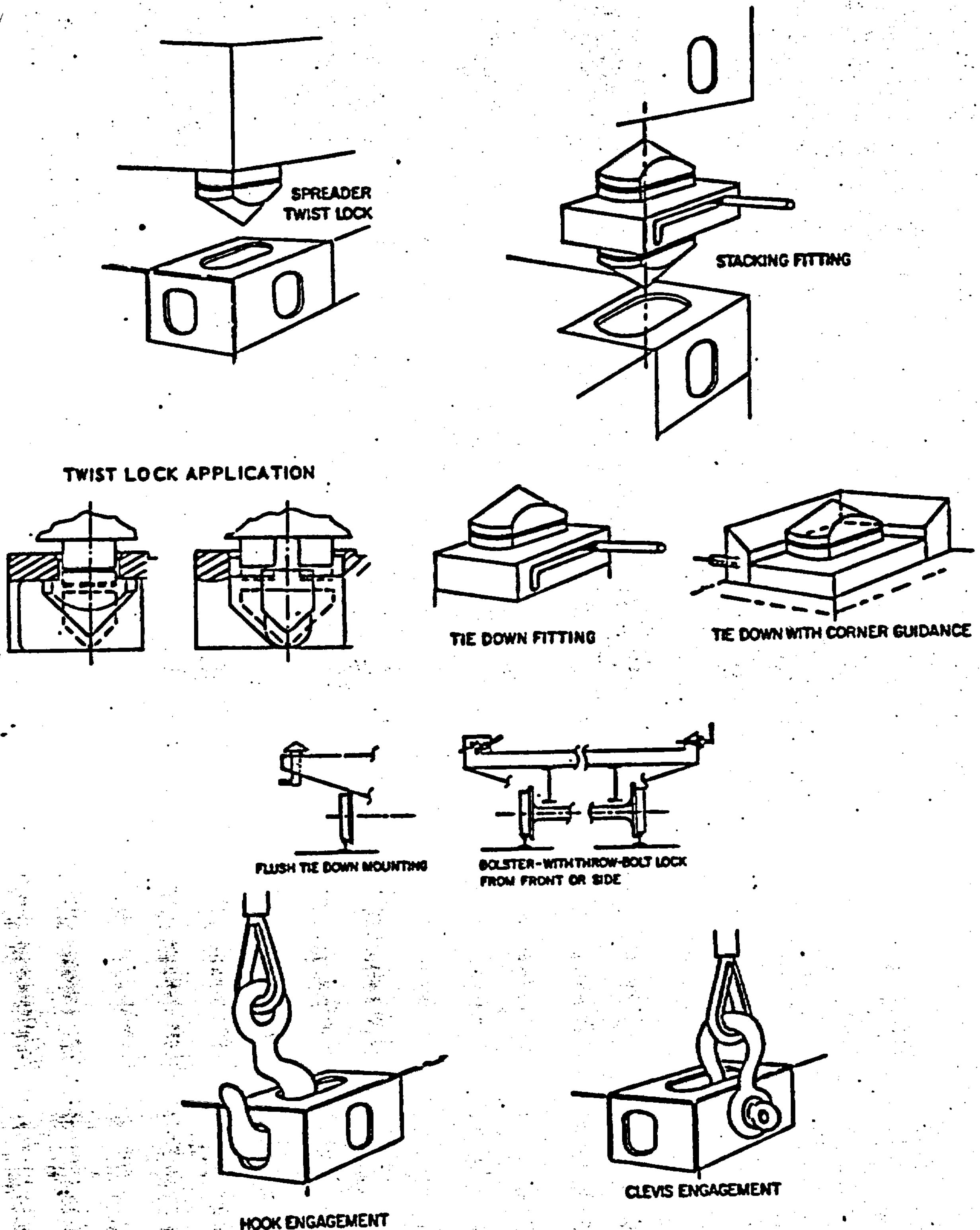
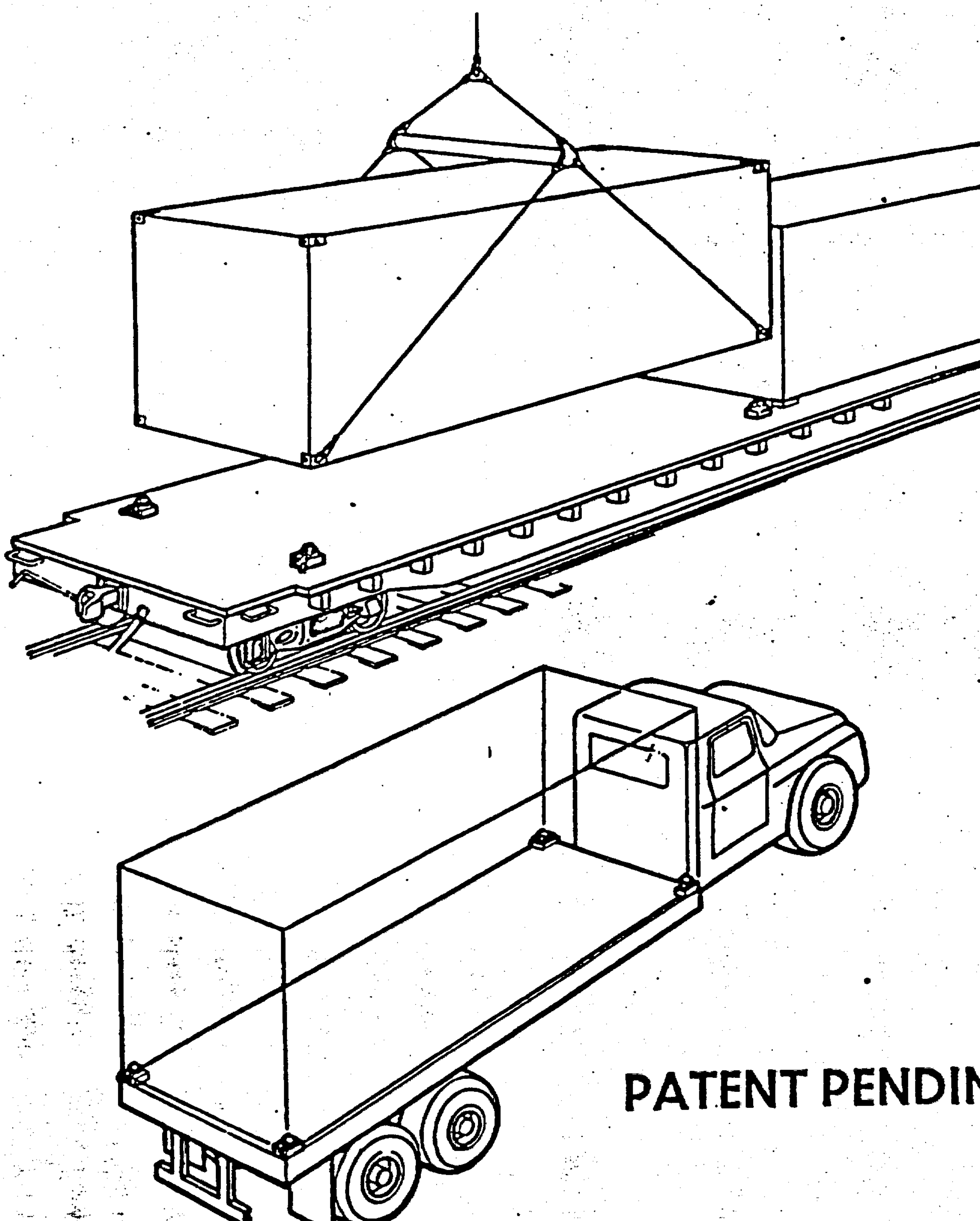
ANNEX A

EXAMPLES OF CORNER FITTING ENGAGING, LIFTING, AND SECURING DEVICES



ANNEX B

EXAMPLE OF USE OF CORNER FITTINGS IN RAILWAY AND ROAD VEHICLE APPLICATIONS



PATENT PENDING

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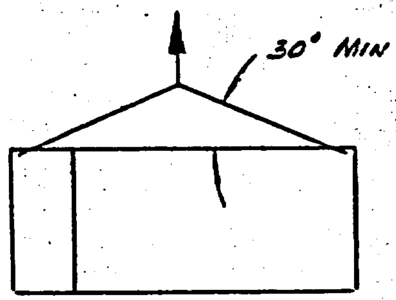

$$M.S. = \frac{(728,800)(\cos 30^o)}{(45,000)(3\ g's)} - 1$$

$$\underline{\underline{M.S. = +Large}}$$

∴ Lifting capability meets requirements listed in Chapter 0529, Page 18,033 II, A, 3.

Standard ISO Tie Downs:

The standard ISO connector fitting consists of a steel rectangular block that mates with bottom fitting hole. (See Annex A and B) Once the container is lowered over the block, the fitting is rotated; thereby, locking it into place. Loads are reacted over considerably more area than that of cable tie down and are, therefore, also structurally adequate.

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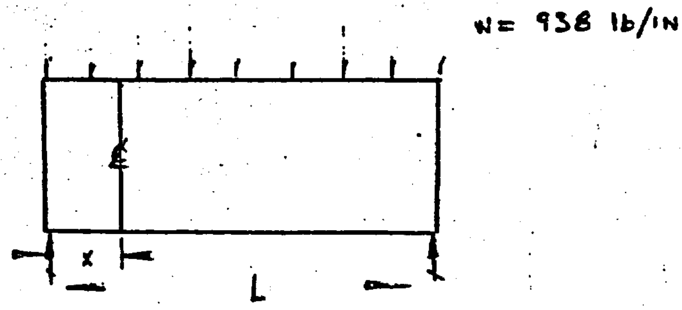
4. The following is an analysis of the Super Tiger's ability to resist the loads of Paragraph 71.32 (a) of 10 CFR 4a Part 71.



A) Bending moment at bolt centerline:

$w = (5)(45,000)/240 = 938$ lb./in.

$x = 35$

$L = 240$

$M_{℄} = wx(L - x)/2$

$M_{℄} = (938)(35)(240 - 35)/2$

$M_{℄} = 3,365,000$ in.-lb.

Conservatively assume only the bottom two bolts react this load:

$P_{bolt} = (3,365,000 \text{ in.-lb.})/(2)(93)$

$P_{bolt} = 18,100$ lbs.

Allowable Bolt Load = 80,700 at 125 ksi

∴ Margin of Safety (Bolts)

$$M.S. = \frac{80,700}{18,100} - 1$$

$M.S. = +$ Large

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B) Max. Shell Bending Moment:

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$$M_{max} = \frac{wL^2}{8}$$

$$M_{max} = (938)(240)^2/8$$

$$M_{max} = 6,753,600 \text{ in.-lb.}$$

Conservatively assume all loads are to be carried by the triangular corner beams. Buckling stability of the corners is provided by the foam and face sheets.

$$\text{Area} = 2\,(11\ 1/2)\,(.1875) + (16.3)\,(.1046)$$

$$\text{Area} = 4.3 + 1.7$$

$$\text{Area} = 6.0 \text{ in.}$$

$$f_c = M/2hA$$

$$f_c = (6,753,600)/4\,(96 - 11\ 1/2)\,(6)$$

$$f_c = 6,660 \text{ psi}$$

$$F_{cy} = 46,500 \text{ psi}$$

Margin of Safety:

$$M.S. = \frac{46,500}{6,660} - 1$$

$$\underline{M.S. = +\text{Large}}$$

Conclusion: The proposed container is capable of safely reacting loads set forth in Paragraph 71.32 (a) of 10 CFR Part 71.

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5. We believe an analysis of the end closure plate for the 25 psi external pressure is not required. From Drawing 121350, Section A-A, Zone F-2, it can be seen that silicone rubber seal 1" x 1/8" thick is clamped between the two mating channels. Additional seal compression is provided by the external pressure itself forcing the cap onto the body. This provides a seal for external pressures; thus assuring that the end closure plate will not experience a pressure rise.

Chuck, as a point of interest to me, was the 25 psi requirement established to protect against submersion to a depth that will produce 25 psi? If so, it is interesting to note that it would require over 17 tons of additional weight to overcome the positive buoyancy of a fully loaded Super Tiger.

At any rate, we believe the presence of the seal will guarantee that no in-leakage and corresponding pressure build-up will take place.

Shear strength of the foam is approximately 200 psi. Those areas which contact the steel shells produce a chilled effect, increasing the density there by increasing the bond strength to levels in excess of 375 psi. An example of this variable density is shown in the photo on Page 117.

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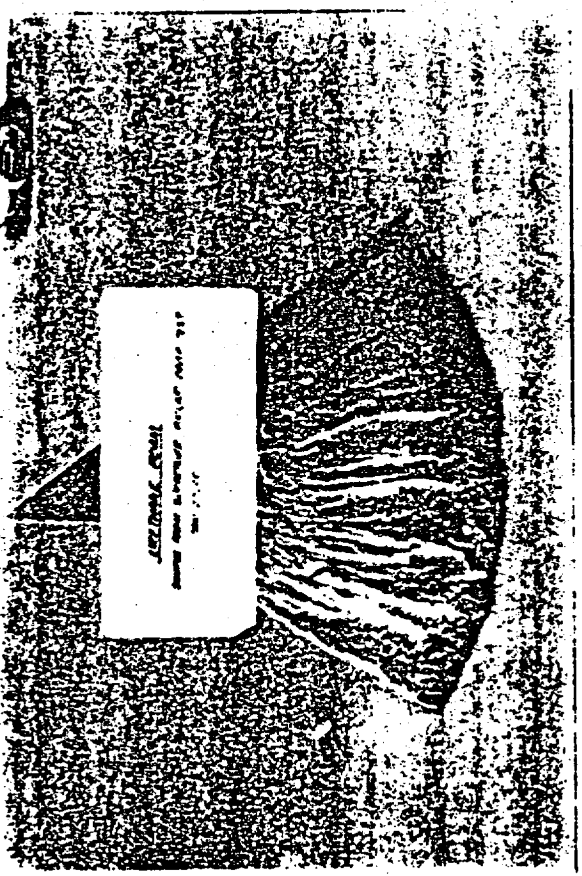

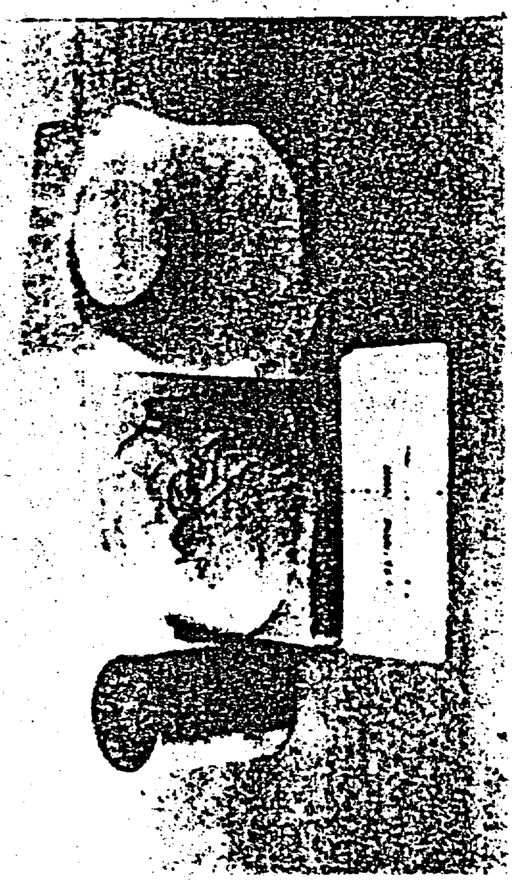

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6. A pressure of .5 atmospheres will produce an internal within the inner container of 7.1 psig.

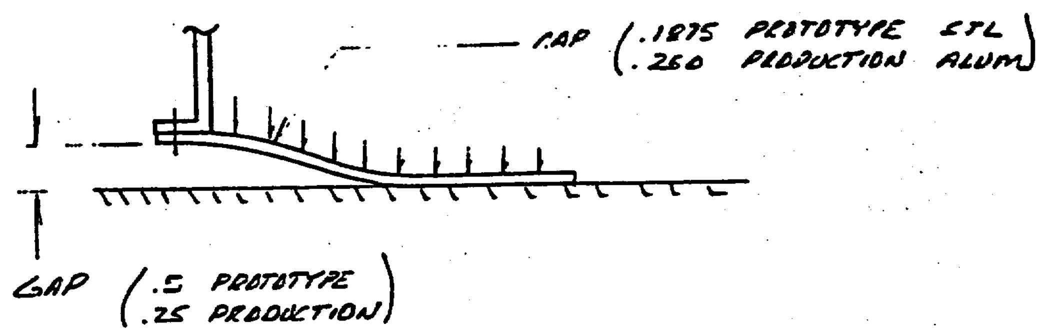
This can easily be reacted by the five container inner walls in the same manner that the 25 psi is reacted externally. Loads on the inner container cover must be treated differently.

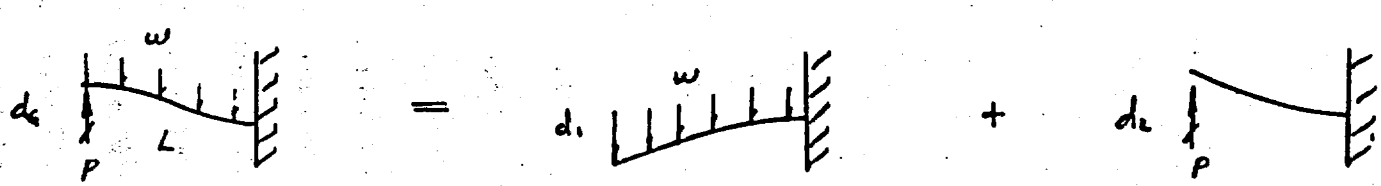
Pressure loads on the cover will cause it to deflect until it contacts the inside of the removable end cap. At this point, the pressure is reacted directly by the end cap.

A) The following analysis evaluates the effect of a 7.1 psi internal pressure on the inner container seal area.

In order to determine deflection experience between the bolts and the corresponding bolt loads and analysis, utilizing super-position techniques must be employed. This will be conducted for the prototype design and again for the production configuration.

<u>Prototype:</u>





$$d_1 = \frac{wL^4}{8EI}$$

$$d_2 = \frac{PL^3}{3EI}$$

$$d_G = \text{Gap}$$

Where:

$w = 7.1$ psi

$I = (.1873)^3 / 12 = .00055$

$E = 3 \times 10^7$ psi

$G = .5$ in.

$$\therefore d_G + \frac{wL^4}{8EI} - \frac{PL^3}{3EI} = 0$$

Solving for P as a function of L:

$$P = 3EI\, d_G\, L^{-3} + 3/8\, wL \qquad \text{(Eq. 1)}$$

Differentiating and set to 0:

$$\frac{dP}{dL} = -3EI\, d_G\, L^{-4} + \frac{w}{8} = 0$$

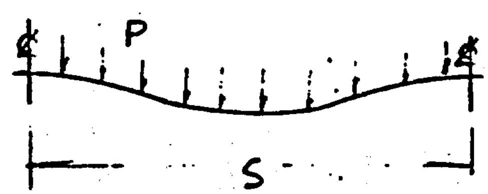
$$L = \sqrt[4]{\frac{72EI\, d_G}{3w}}$$

Solving for L:

L = 13.23 inches (Point at which end plate contacts cap.)

Solving Eq. 1 for P:

P = 46 lb./in.



Seal deflection can be calculated by:

$$d_s = \frac{PS^4}{384EI}$$

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Where:

$P = 46$ lb./in.

$S = 5$ in.

$E = 3 \times 10^7$ psi

$$I = \frac{(2)(.1875)^3}{12} = 1.1 \times 10^{-3}$$

$$d_s = \frac{(46)(5)^4}{(384)(3 \times 10^7)(1.1 \times 10^{-3})}$$

$$d_s = 2.27 \times 10^{-3}$$

Therefore, the seal area will be opened by approximately:

$d_s = .00227$ in.

Bolt load:

$P_b = (46$ lb./in.$)(5$ in.$) = 230$ lbs.

∴ Therefore, with a seal area deflection of less than 3/100 of an inch and bolt load of only 230 lbs., the inner cover is easily capable of reacting the internal pressure load of .5 atmospheres. This was also born out during the post drop and fire test when the inner container was pressurized to approximately 8 psi. Even with the loss of foam from the fire test no damage to the inner container or end cap was noted. Low leak rates due to poor seal installation still prevailed.

Production:

Repeating the same analysis for the production design; from Eq. 2:

$$L = \sqrt[4]{\frac{72\, E I d_b}{3w}}$$

Where:

$E = 10^7$ psi

$d_b = .5$ in.

$w = 7.1$ psi

$I = 2(.25)^3/12 = .0026$

$$L = \sqrt[4]{\frac{72\,(10^7)\,(1.3 \times 10^{-3})\,(.5)}{3\,(7.1)}}$$

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$L = 19.7$ in.

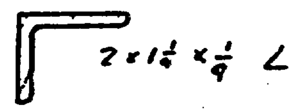
Solving for P:

$$P = \frac{(3)\,(10^7)\,(2.6 \times 10^{-3})\,(.5)}{(19.7)^3} + \frac{3\,(7.1)\,(19.7)}{8}$$

$P \doteq 55$ lbs. /in.

Seal Deflection:

$$d_s = \frac{PS^4}{384\ EI} \qquad I = .089 \text{ in.}^4$$



$$d_s = \frac{(55)\,(10)^4}{(384)\,(10^7)\,(8.9 \times 10^{-2})}$$

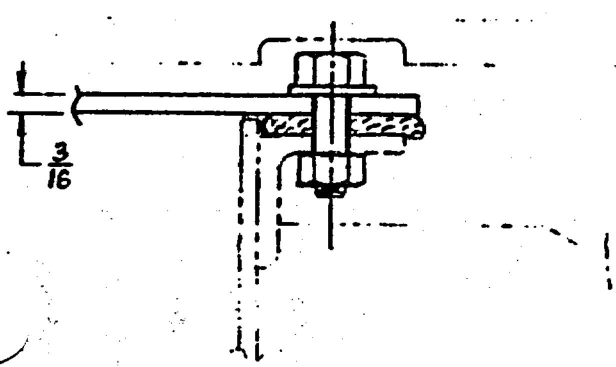
$d_s = .00161$ in.

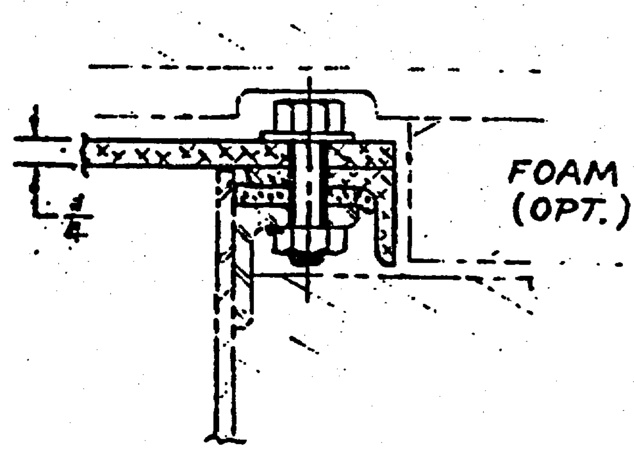
Bolt Load:

$P_b = (55 \text{ lb./in.})\,(100 \text{ in.}) = 550$ lbs.

∴ The seal area deflection of the production configuration is over 30% less than that of the prototype. Expansion being less than 2/1000 of an inch will not jeopardize the sealing integrity. 1/2" diameter bolts are capable of reacting over 15,000 lbs. and are, therefore, adequate.

Conclusion: The seal area configuration of the cover plate was changed from a flat 3/16 steel sheet to a formed 1/4 aluminum plate.





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B) External End Cap Attachment

Presently, ten 1" diameter 120 ksi bolts secure the end cap. Bolt capability based on minimum pitch diameter is:

$$P_{allow} = 81,000 \text{ lb./bolt}$$

For simplicity of calculations, assume that the bolts must carry the full impact load generated by the cargo. From Page 12 of the report, the maximum de-acceleration is 25 g's. Using a maximum payload weight of 30,000 pounds: ← Corner drop.

$$\text{Load} = (30,000 \text{ lbs.})(25 \text{ g's}) = 750,000 \text{ lbs.}$$

$$\text{Capability} = (10 \text{ bolts})(81,000 \text{ lbs.}) = 810,000 \text{ lbs.}$$

$$M.S. = \frac{810,000}{750,000} - 1$$

$$\underline{\underline{M.S. = +.08}}$$

∴ The cap attachment bolts possess sufficient strength to react the total impact de-acceleration; thereby, guaranteeing the integrity of the cap.

Internal pressure load at .5 atmospheres will produce a load of:

$$P = (7.1 \text{ psi})(76)^2 = 41,000 \text{ lbs.}$$

This load can easily be reacted by the 810,000 lb. bolt capability.

The production design differs from that which was tested in the manner in which the bolt load path was directed across the joint. As shown in the sketch below, the two channels forming the joint were bolted through the mating legs. Loads were required to pass from the skin to the outside leg, then in bending up to the web, through the web in tension, back through the inside leg in bending, and out through the bolt--a soft load path. The production design load path is directly across the open channel face to the inside flange. On the bolt, two 3/16 plates flank each bolt. This provides a much stronger load path than that of the prototype design.

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In the interest of safety and increased reliability, the production configuration has been altered so that the 1/2 gap between the plate and end cap has been relaxed to 1/4" maximum. By providing relief holes for the bolt heads, the plywood back-up can be brought up with 1/4" of the plate. Loads will be reacted on the end cap sooner there by producing a lower seal area load yet.

From the comparative EI values and the seal deflection calculations, it is concluded that the production design will provide higher compressive seal pressure than that of the prototype design test. It will provide a pressure tight seal.

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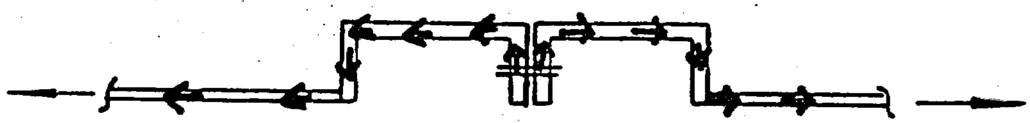
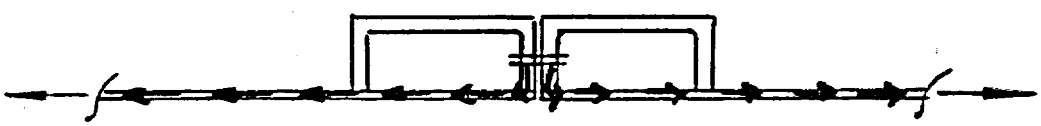
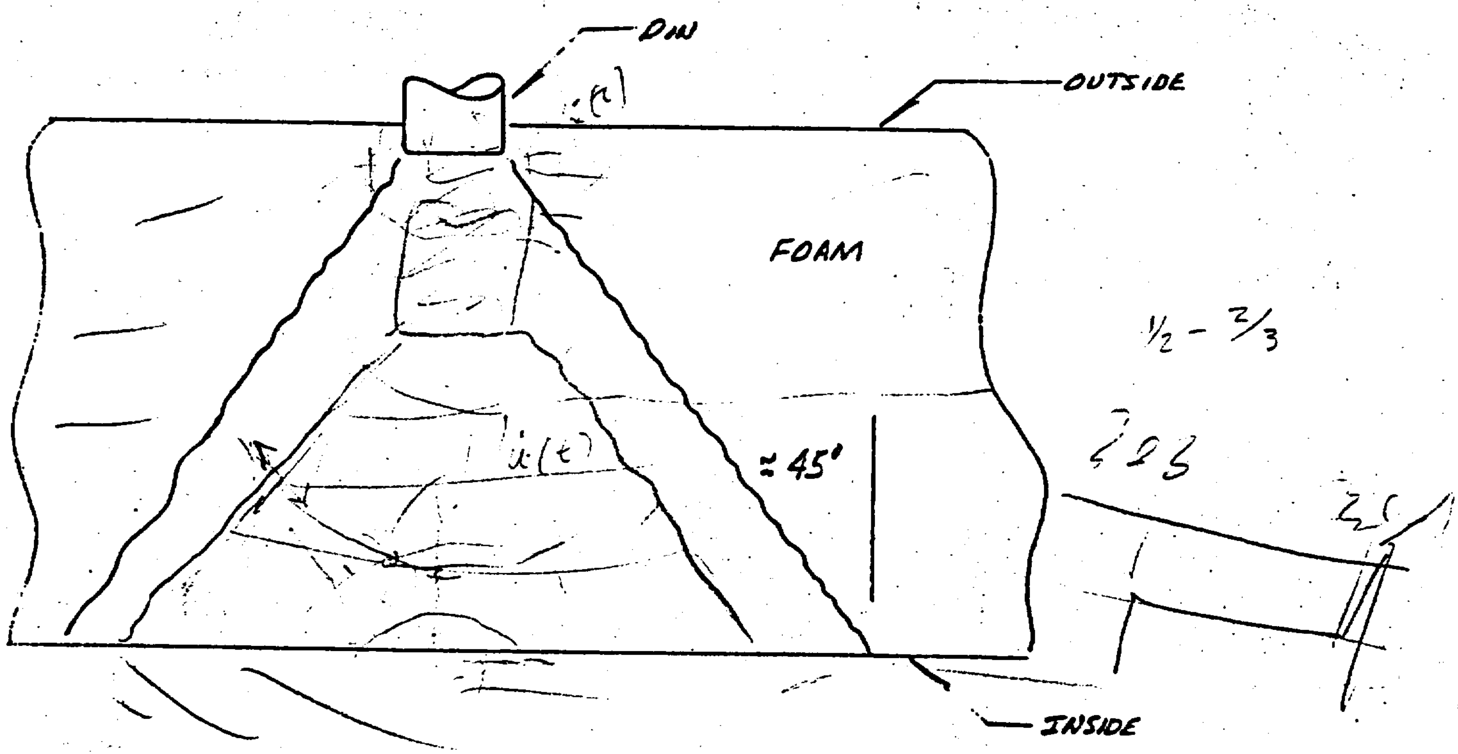




Conclusion: The production design differs over that which was tested by the bolt strength, number and method in which they react their load. The net effect of these changes is a stronger closure than that tested and one capable of reacting all loads and conditions specified in Part 71.

7. The reasoning that led to the conclusion that the 1/8" back-up plates were not required was based on the foams ability (35" thick) to react the puncture loads. Based on the Appendix B analysis, the external skin will puncture. At this point, load is distributed to the foam. Since foam is weaker in tension than compression, it fails on approximately a 45° shear plane.



In actuality, it compresses a cone of foam.

$$\text{Energy} = \left[\text{Vol. (in.}^3)\right]\left[\text{Crush Strength (psi)}\right]$$

$$\text{Energy} = \frac{\pi h^3}{3} F_c$$

$$KE = ws$$

∴ Solving for h:

$$h = \sqrt[3]{\frac{3ws}{\pi F_c}}$$

$$h = \sqrt[3]{\frac{(3)(45,000)(20)}{(\pi)(200)}}$$

$$h = 20.5 \text{ in.}$$

Where:

w = 45,000 lbs.

s = 40 in.

F_c = 200 psi

PATENT PENDING

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∴ Neglecting the energy required to puncture the steel, the pin would penetrate approximately 21 inches of the available 35 inches. This failure mode was demonstrated in tests and a sample showing the failure plane is attached. (See Photo on Page 117.)

Conclusion: It is our opinion that the 1/8" back-up sheets are not required on the ends. They are included on all sides as shown in Drawing 121350.

8. Please find attached, drawings showing fabrication details. The Super Tiger application will not at this time request the scale down option. It will be resubmitted shortly.

PATENT PENDING

9. Test to insure the inner cavity has been properly sealed.

The seal on the internal cavity will be properly sealed when all the bolts have been installed and tightened.

Correct installation calls for bonding the silicon rubber to the cap prior to mating with body. In this manner, the seal will always be firmly attached to cap and mate with the sealing surface on the body.

Seal installation problems originating during prototype testing were the result of hurried assembly. Since the seal was being installed at 3 a.m. prior to the morning of the drop test, not sufficient time was allowed for the seal to adequately adhere to the cap. Therefore, on assembly, silicone rubber actually slipped out of place on the wet adhesion.

Had the adhesive had time to set, the seal would not have moved during assembly and a pressure tight seal would be present. Proper seating is assured with the available clamp-up pressure provided by the 1/2" diameter bolts.

A test which may be conducted on the inner cavity to assure that the silicone seal is properly sealed is described as follows:

1. Load contents into Super Tiger, close cavity cover and secure all bolts.

2. Connect freon aerosol can and hose to Super Tiger check valve fitting as shown in Figure 2.

3. Bleed full contents of can into cavity.

4. Disconnect hose from fitting and install cap.

5. Use standard freon detection device to inspect seal. These are capable of detecting two ounces of leakage per year.

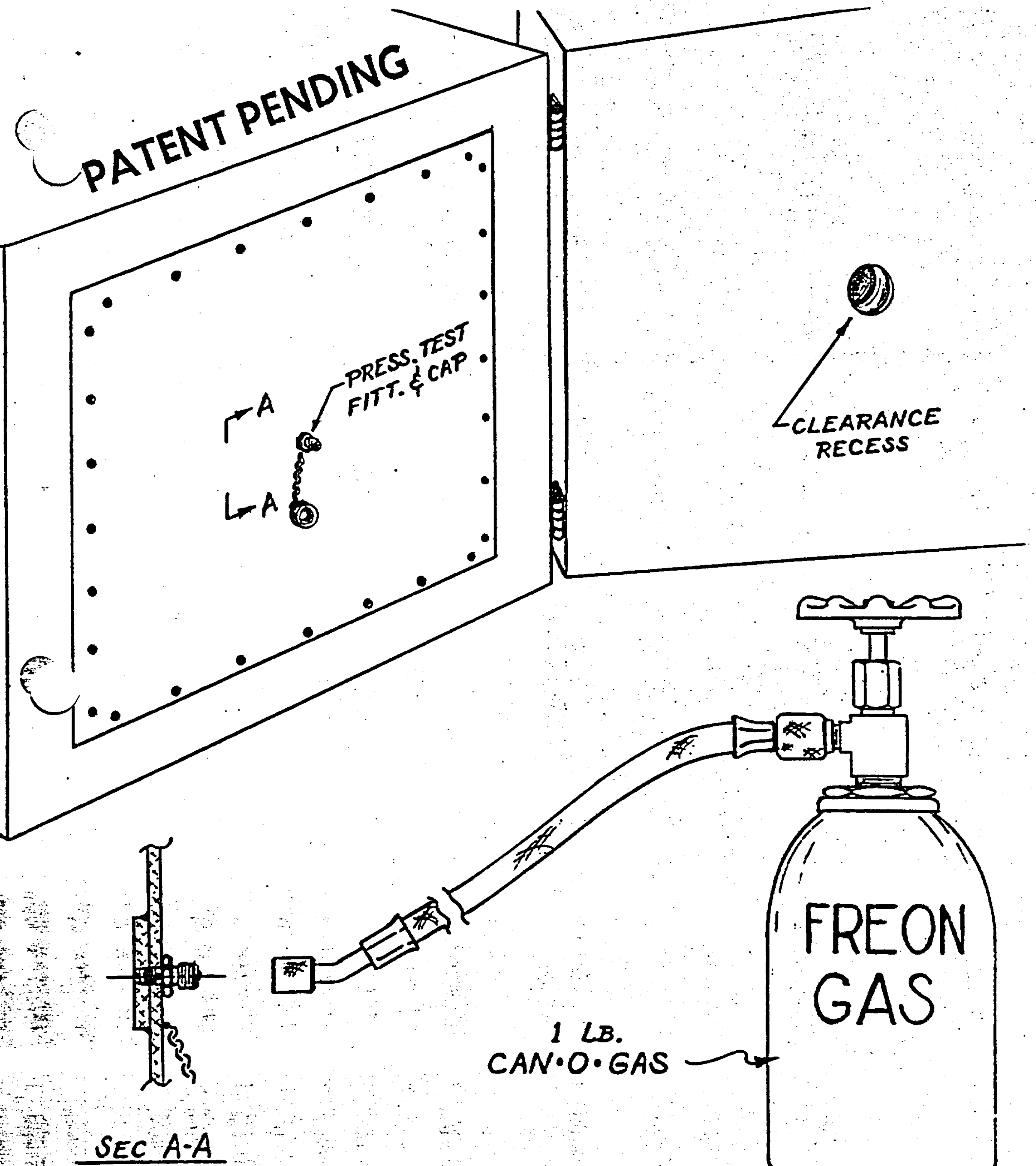
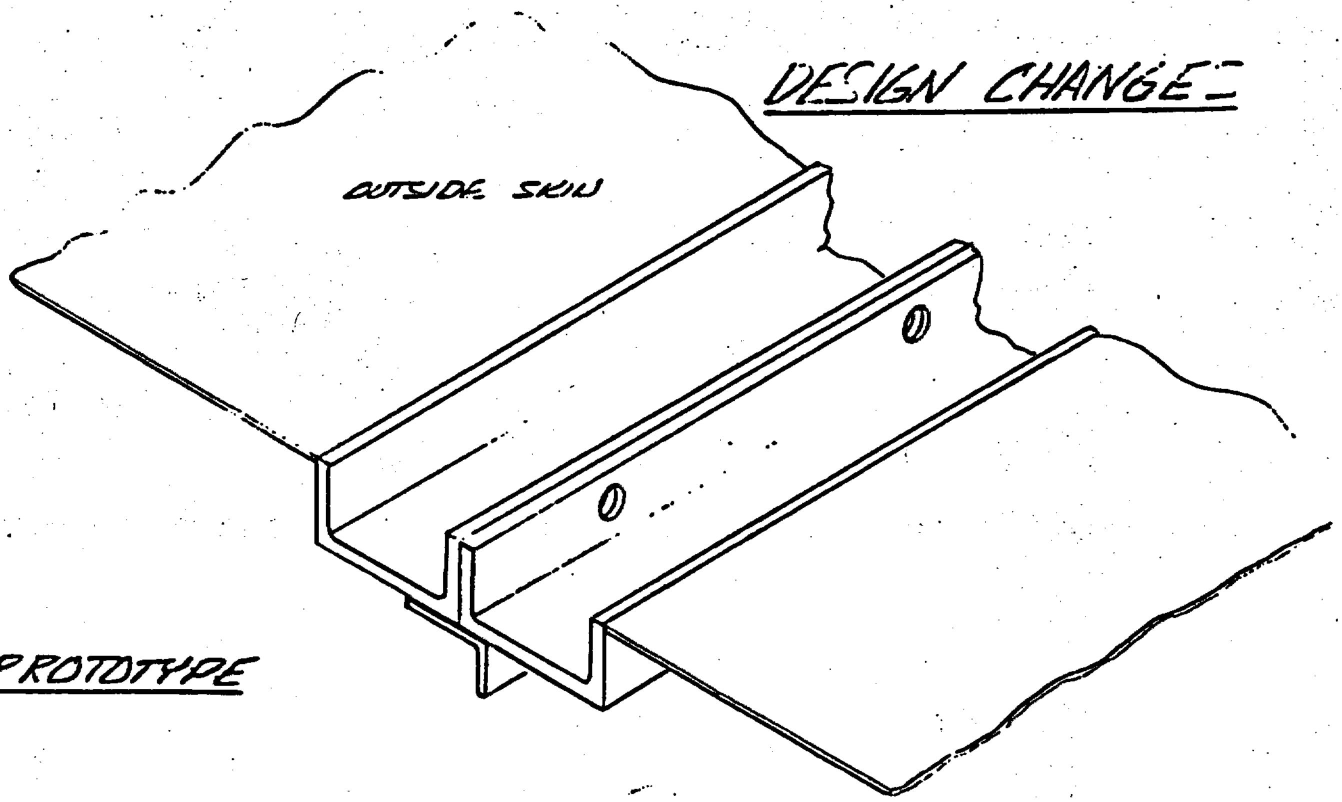

PATENT PENDING
PRESS. TEST FITT. & CAP
A
A
CLEARANCE RECESS
FREON GAS
1 LB. CAN•O•GAS
SEC A-A

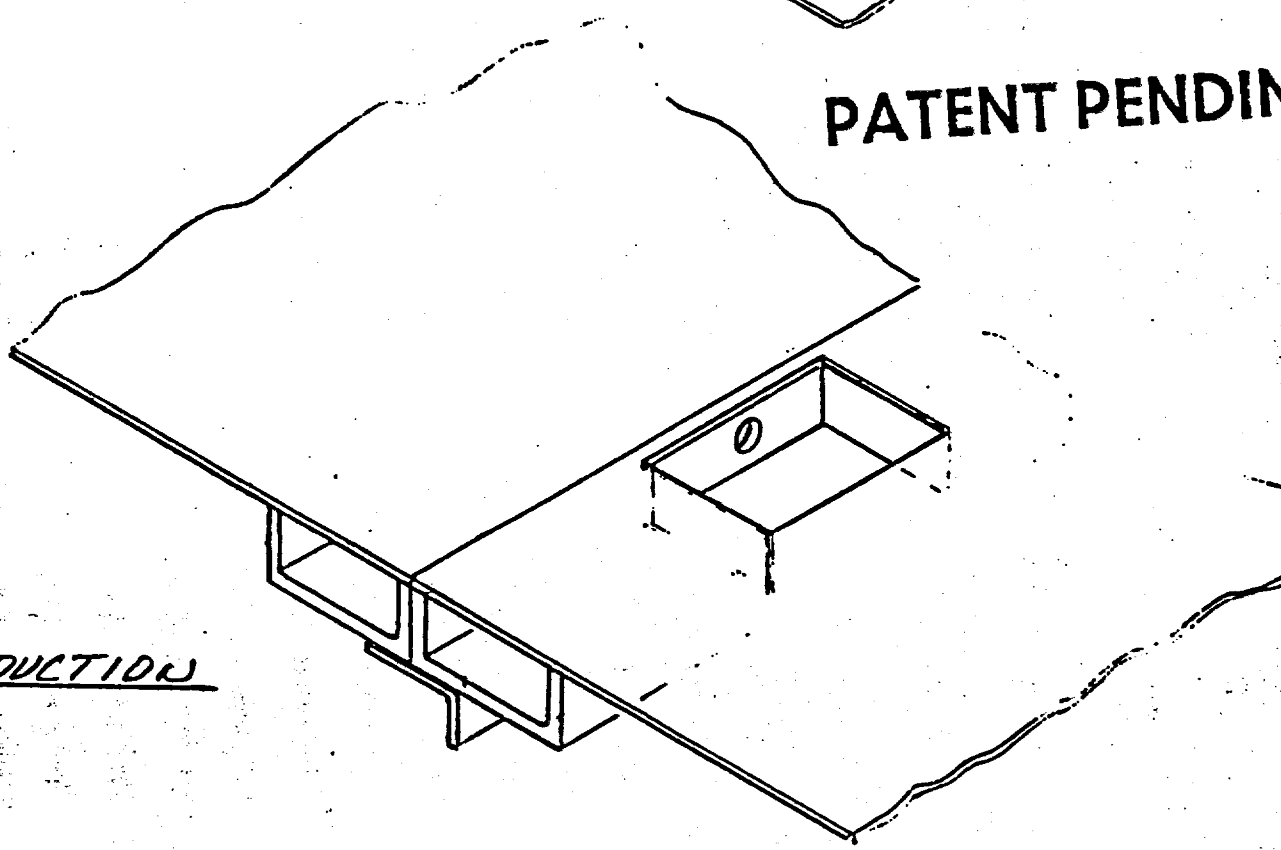
FIGURE NO. 2

A. DESIGN CHANGE –



PROTOTYPE

PATENT PENDING



PRODUCTION

FIGURE 3

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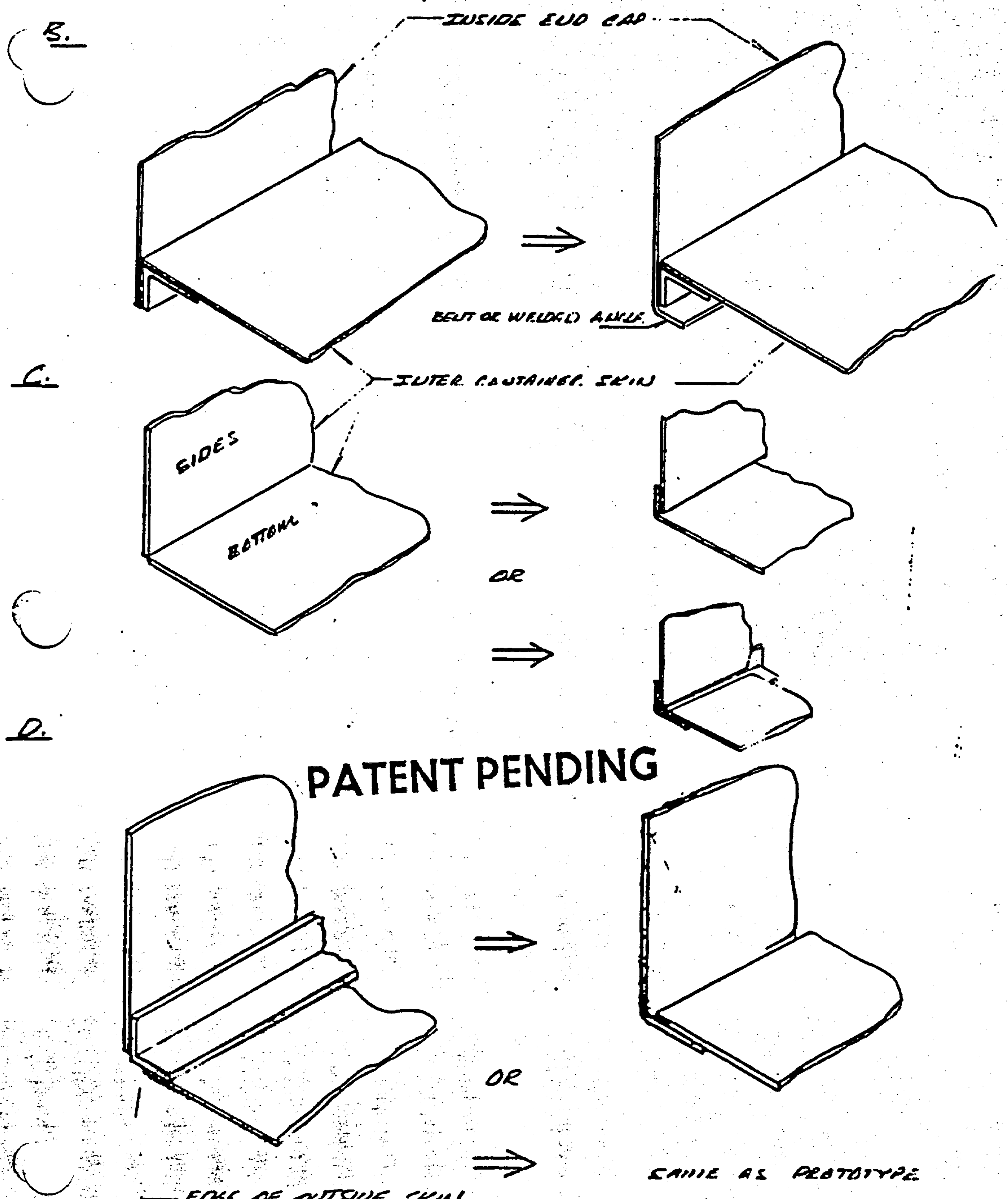

PATENT PENDING

FIGURE 4
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6. If a leak is detected, retighten bolts. If it is still persistant, remove cover, clean seal and inspect surfaces for foreign matter.

7. Repeat steps 2 through 5.

8. If leak persists, install new silicone rubber seal.

10. Design difference between the prototype and production configuration are shown in the following sketches. The two major structural changes involve the internal and external closure area. These have been reviewed analytically in the answer to question 6.

The remaining changes deal with alternate ways of attaching external skin or internal skin along the edges. It is felt that these options do not represent a decrease in the structural integrity over the design tested, but will produce a stronger more reliable configuration easier to fabricate and inspect. Any changes that have been made were made utilizing our best engineering judgment in producing a container of equal and adequate strength.

The last sentence of question 10 deals with the closure analysis shown on Appendix C, Page 93 of the report. Appendix C is an excerpt of Ref. 6, which deals with the analysis of the Argonne National Laboratory Bin (DOT 6272). This analysis was modified and corrected, but has no relevance to the Super Tiger application.

TORNADO DESIGN CONSIDERATIONS

Although this is not part of the requested information, we have corporate interests in using the Super Tiger to haul waste to Project Salt Vault in Lyons, Kansas. Since this area is "Tornado Alley", we have had discussions with Mr. Joe Galway, who is an employee of the ESSA Severe Local Storms Forecast Center located in Kansas City, (816) 374-3426.

In this discussion, it was learned that a Seminar for Architects and Engineers was held at the University of Wisconsin, Milwaukee Division in May of 1970. During this seminar, Mr. Galway presented figures from the ESSA which indicated that buildings designed for tornado loads should have provisions to withstand winds of 200 to 300 miles per hour. Pressure reductions of 200 millibars (1000 millibars equal 29.52 "Hg.) are uncommon; one was measured in Minnesota early in the 20th century. Normal pressure reductions are thought of as being in the order of 3.0"Hg., which is like 0.1 atmospheres.

Mr. Galway did mention that box cars are often turned over and split with the impact of missiles that hit them. He investigated a tornado in Great Falls, Montana, which hit in the 1950's, in which static rail cars on a siding were accelerated up to 70 miles per hour by a tornado moving in the same direction as the rail.

From this information, we feel that the Super Tiger will have a better chance to survive a tornado experience better than any container currently in service for waste hauling. The pressure change or rate of pressure change presents no problem to the desi gn, and if tie downs, compatible with the Super Tiger and ISO systems are used, it prevents this container from being airborne.

This information does point out the fact that a study should be done to prevent accidents from happening. Since they are prevalent in France, Germany, Netherlands, as well as Australia, this severe storm represents a real accident condition.

For information on the A and E Seminar, Contact Dr. Paul A. Seaburg, University of Wisconsin, Milwaukee Division, 600 West Kilborn, Milwaukee, Wisconsin 52303.

PATENT PENDING

THERMAL STRESS CONSIDERATIONS

In previous work, our firm has found that the thermal stress caused by the sudden chilling of a cask can crack the vessel open so that leaking occurs. Since well meaning firemen can actually cause an accident to happen under conditions of extreme heat and mass, we feel that the Super Tiger with the light outer steel skin is able to take this thermal shock without any problems. The rate of cooling using fire hose methods are huge and we feel that the design is more than adequate to take care of this problem.

PATENT PENDING

QUALITY ASSURANCE PROGRAM FOR THE SUPER TIGER

1.0 FOAM PRODUCTION

During discussions dealing with the design and testing of the Super Tiger, the question of Quality Assurance has come up several times; therefore, it is only proper that some of the variables that determine the integrity of the container be included in the report. Some items, such as the formulation of the particular foam, are proprietary items of PPI, and we feel that performance of the material under laboratory testing is all that is required. The formulation includes a basic two component system, using a cell controller, blowing agent, and accelerator (which are all interdependent) as well as the mixture temperature and the steel shell temperature. Since the temperature at which the material reacts is very close to the temperature that the material begins to "char" and destroy itself, we feel that competitors could take advantage of the long effort that our firm has gone through to come up with this formulation. This formulation is stable and will be regulated by appropriate in-house quality control procedures.

From the standpoint of energy absorption, the density of the foam determines the crush strength, and this can be rather well predicted by changing the single variable; namely, the amount of freon that is added to the combination. In order that the material makes a good and lasting bond on the metal skin, two things are important. The first is surface cleanliness and the second is the temperature of the metal skin, which acts as a thermal sink for the exothermic reaction of the foam.

Surface preparation of removal of oils and other foreign material by normal commercial solvents is important. An oily surface can easily prove to be a poor bond for the foam and result in a lack of stress skin strength for the container. In addition to the surface preparation, the steel material should be of a temperature so that the boiling of the freon does not take place at the surface of the metal. By restricting the foam from forming freon bubbles, the material forms a very strong bond on the steel, which has adhesion and shear strengths much higher than the materials with freon bubbles in them. Since this bonding material is 40 to 50 pounds per cubic foot and the strength is proportional to the density, it can be shown that the strength of this bond is as much as ten times stronger than the same material with freon bubbles, resulting in a strong bond between the steel and the foam for the stressed skin effect that is desired.

PATENT PENDING

PROTECTIVE PACKAGING, INC.

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Temperatures as much as 40 degrees lower than the boiling point of the freon seems to cause an undue thermal stress for the foam, taking an undue amount of heat energy out of the material. This produces a good bond initially, but is put under a residual stress level when the steel is warmed up to normal temperatures. Because of this problem, skin temperatures should be limited to between 10 and 15 degrees below the boiling point of the freon. This temperature range fits the 45° to 60° range which is a good ambient range for manufacturing. If this temperature cannot be held with any degree of confidence, a temperature recording device should be put on the container, and the steel heated or cooled as required. Normal "blowing" of carbon dioxide is a good method for cooling, while heating with an open propane gas torch on the side opposite the bond is a good means of heating the metal skin.

In situations where the temperature cannot be maintained, it will be convenient to change to a higher or lower boiling point material, so that difficult conditions can be met. In no instance should the temperature of the skin vary more than 15 degrees F., since when the foam is being poured the range of temperatures is as important as the temperature itself.

Of interest, the internal temperature of the foam will approach 300 degrees in volumes that are furthest from metal conducting paths. This foam requires a time vs. temperature cure time to complete the chemical reaction. Exposure to the atmosphere during this curing process will damage the foam. Cure times of up to ten hours can be expected in the large ends of the Super Tiger with no problem caused by additional pours put on top of the original pour. Insertion of dial thermometers provide a good and accurate method of reading the curing temperature without causing voids or large holes to be cut into the foam. Temperatures in the range of 350 to 400 degrees cause charring during the curing process and reduce the characteristic of the foam by reducing strength. This foam is noticeably darker than the parent material, and should be removed from the container in the event that the material is made in the improper proportions. Good procedures in the blending can usually eliminate this from happening.

The energy that causes charring is due to internal energy generated by the exothermic reaction of the foam. This heat cannot escape to the thermal sink of the metal skin because of the unusually good insulating qualities of the foam itself even when curing. After the foam is cured, the sticky material turns to solid cellular foam, which is rigid and, surprising, more resistant to charring than when in its curing state. Protective Packaging, Inc., has investigated the thermal problems of the

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foaming process, and our opinion is that quality can be assured at the high densities of 8 to 12 pounds per cubic feet, and up to 20 pounds per cubic feet under ideal conditions.

Additional materials, such as a cell controller and a reaction accellerator, are very important in the overall blend. Small portions of this material are used to get the degree of rigid cell structure required. The reaction time is dependent to a great degree on the amount of mechanical stirring or blending energy that can be put into the mixture between the time when the subparts are mixed and the time that they are poured. Stop watch accuracy is not important, but at least 90 seconds of time is needed to "shear" the various materials into one homogenous blend so that the materials are in their proper proportions. Streaking of the material both before and after foaming can easily detect improper mixing.

Part A, one of the two major components, requires a temperature of about 140 degrees F. for proper pour point. So that the mixture point of the two is proper, it is important to keep the other less sensitive component at a constant temperature.

Concern was originally given to the bond between individual pours, but results seemed to indicate that one pour bonds sufficiently to the next. Efficient use of the foam indicates that less material ends up as surface "crust" during larger pours. This is like the raised loaf of bread that is not touched by the bread pan. Since this surface area approaches that of a hemisphere, the minimization of the number of pours, while still maintaining the input of mechanical energy to eliminate streaking of the components, is an absolute production goal that makes for a good product.

Testing the crush strength of the foam is done on a Universal Testing Machine such as that installed at the laboratories of the American Plywood Association in Tacoma, Washington. Samples of the foam are taken on a periodic basis from every fifth pour, and these are checked for density variation. Each sample is then put into the machine and tested to see how it behaves with the other samples. Normally, the only problem occurs when the dinsity of the mixture is changed. Operator error in the measurement of the freon in the mixture is the real source of density changes. This can be corrected easily and in a very predictable way. As an example, cutting the amount of freon in half is cutting the density of the mixture by almost 50%.

1.1 FOAM QUALITY CONTROL DURING INSTALLATION

Refer to PPI Quality Control Document F17, attached.

PATENT PENDING

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PROTECTIVE PACKAGING, INC.

2.0 WELDING PROCEDURES

Good welding techniques and equipment, used by trained personnel is of the utmost importance in the Quality Assurance Program of the Super Tiger production. For the most part, the ductility and the other mechanical properties of the mild steel used in the production of this container are well established. Of prime importance is to have a welding system compatible with the expected performance of the parent steel.

2.1 GENERAL WELDING REQUIREMENTS OF THE SUPER TIGER

Refer to PPI Quality Control Document W13 attached.

3.0 METAL QUALITY CONTROL

To preserve the range of acceptable material that is used on this container, our firm has asked the vendor to supply certified steel that is acceptable to our purchase order qualifications. In addition to this, samples are taken from the incoming sheets in random fashion and tested for strength and ductility. In this way, variabilities that appear in the incoming supply can be "spotted" easily and taken out of inventory and returned to the vendor, rather than being used.

3.1 Refer to PPI Quality Control Document W13 for Steel Requirements.

4.0 OVERALL CONSIDERATIONS

From the information gathered in our preliminary work, it is easy to point out that welding and metal quality control are areas of interest that could be discussed at length. However, they have been studied and reviewed many times in the past, and can be committed to standard production standards.

The foam is a formulation which acts as an adhesive. Therefore, the performance of this material in the many different types of outdoor climates is very important. Since production temperatures are kept in the mid range of the total maximum range of exposure temperatures, the thermal stress is limited when the container sees a winter environment of -50 degrees F. to as much as plus 150 degrees F. in the summer. With the solar loads that usually accompany this high ambient, there is a heat input of up to 150 Btu/hr per square foot of area at right angles to the rays of the sun.

PROPRIETARY DATA

PATENT PENDING

Protective Packaging, Inc.
Quality Control Document
No. F17 Rev. 0
Date: May 4, 1970

FOAMING REQUIREMENTS FOR SUPER TIGER CONTAINER

1.0 SCOPE

This specification covers the requirements for formulation and installation of foam in the Super Tiger Container.

2.0 GENERAL DISCUSSION

Polyurethane foam is a cellular plastic that is formed by the reaction of two liquids. A polyol and a polyisocyanate in the presence of a gas producing agent such as freon.

As a chemical reaction takes place, heat is generated causing the blowing agent to vaporize and form tiny bubbles. The creation of these bubbles generates foam which expands to its full height in less than five minutes. The net result of the chemical reaction is one giant cross linked molecule of cellular plastic containing entrapped bubbles of freon gas.

The cellular structure of rigid urethane gives it exceptional strength for its light weight. Compressive strength can be varied from 25 psi to over 500 psi through alteration of formulation. The closed cell in addition to contributing to the strength also seals the foam against penetration of gases or liquid. Gas contained in the cells not only shapes the cells but also contributes greatly to its thermal insulating capabilities.

Rigid urethane foam is the most efficient insulating material available. It has twice the insulating ability of the next best material, polystyrene foam. It is possible to have k factors of .1 Btu/hr/ft^2 per ^oF/inch.

For the Super Tiger a special formulation of fire retarded rigid polyurethane foam is used. This foam, designated U-2333, is poured in place and allowed to expand between the two steel shells. Since, on expanding, foam rigidly bonds to all surfaces, the inside and outside shells are forced to work together forming a stress skin type design.

Foam densities can be regulated thereby varying the crush strength. In this design, higher density foam is placed in the ends and along all edges.

PATENT PENDING

3.0 CONTROL CONDITIONS AND METHOD OF INSTALLATION

3.1 Maintain pour point temperature of Component "A" to 140 degrees F, plus or minus 5 degrees F, and make provision for stirring prior to reading, so that average temperatures are reflected rather than local hot or cold spot temperatures.

3.2 Maintain the metal temperatures of the "skin" between 45 and 60 degrees F. Insulation of the skin from concrete floors should be considered if temperatures are too low.

3.3 Make provisions in small clean containers for the additives of accellerator, cell controller and freon. This should be done in three different size cups to eliminate duplication of one material at the expense of omitting another. Measurement should be made to 5% accuracy on a balance scale, by weight in oz. and lb., so that this accurate measurement can be put on the cylindrical wall of the cup in such fashion as to make weight and corresponding volumentric duplication easy and accurate. Care should be taken to provide open areas for this material at a temperature so that boiling of the freon does not occur as well as evaporation of the other components.

3.4 Provide timer and shear blades on a motor driven long shaft electric drill or other high speed device that rotates at 1750 rpm and is capable of adding energy to the misture at a rate of one fourth horsepower per 60 pounds of mixture or one horsepower per 240 pounds of mixture. Mixing shall last at least 90 seconds. Streaking of the finished foam is a recognized indicator that mixing is done in an improper manner. If this happens, mix in smaller batches or provide more energy by increasing the speed of the mixer. In-put energy can be checked by reading with a commercial ammeter. (Amprobe is a commercial device for this purpose).

3.5 Density of the foam should be checked during every pour at the start of the run for range, streaking, and internal char. To accomplish this, take material halfway through the pour, and make a "bun" of approximately four cubic feet in a standrad fiberboard box provided for that purpose. Let this sample cure for two hours and cut into the bun with an ordinary carpenters' crosscut saw for a sample in the middle approximately 6 inches on a side, so that a cube is formed. The density should be calculated on a weight per cubic foot basis and compared with the desired density. If the pour is 0.5 lb. per cubic foot less or 1.0 lb. per cubic feet more than the required amount according to the design values, the amount of freon should be adjusted to make the proper density. If streaking is obvious, the pour should be made over, with no changes in the mixture, and the density taken again. Sample should be numbered and put away in a storage box for later testing. Changing indications should be "flagged" at once.

PATENT PENDING

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3.6 To make sure that the cured foam is meeting the minimum crush strengths required by the design, cut the sampel acquired above into 1 inch cubes and test in a Universal Testing Machine. These samples should be numbered in the same system and sequence as the original samples so that the errors can be located and corrected.

3.7 In the event that charring has occurred in any sample, take effort to measure the actual pour to determine the temperature at least 12 inches inside the foam "bun." Indications of excessively high temperature inside of the pour will normally produce charring. If temperatures below 300 degrees F. are read, the pour is fine. Higher readings indicate closer control of the mixture, especially when pouring high density foam above 8 lb. per cubic foot.

3.8 An alternative method of mixing and pouring the foam other than the "batch" method as described above is to continuously pour using a high quality foaming machine. The same control standards described above will be adhered to.

4.0 FOAM SPECIFICATION

All foams used within the Super Tiger shall meet the dynamic crush strengths set forth below:

Foam Type	Dynamic Crush Strength
A	100 psi (+ 30 psi, - 0 psi)
B	200 psi (+60 psi, - 0 psi)

Dynamic crush strengths to be measured at 530 in./sec.

PATENT PENDING

Protective Packaging, Inc.
Quality Control Document
No. W13 Rev. 0
Date: May 4, 1970

PATENT PENDING

WELDING AND STEEL REQUIREMENTS FOR SUPER TIGER CONTAINER

1.0 SCOPE

This specification covers the requirements for welding all metal joints on the Super Tiger container. It also calls out the requirements for selecting the steel material.

2.0 GENERAL DISCUSSION

The entire outer and inner shell is fabricated from very ductile Hot Rolled AISI Low Carbon steel plate. The elongation of this material allows it to be bent flat on itself in any direction at room temperature without visible carcks.

Steel shall be of a good commercial quality hot rolled sheets that are low carbon, open hearth steel that is rimmed, capped or semi-killed to prevent piping so a smooth surface sheet will be produced.

All welding shall be performed by qualified welders using low hydrogen welding electrodes conforming to the proper series of the EXX16, EXX18, or EXX28 Classifications of the Specification for Mild Steel Arc-Welding Electrodes (ASTM Designation: A 233), unless otherwise specified in the basic specification. The electrodes shall be protected from moisture pickup during storage and use. The welds shall be sound, the weld metal being thoroughly fused to all surfaces and edges without undercutting or overlap.

3.0 STEEL SPECIFICATION

Specifications for general requirements for delivery of rolled steel plates shapes sheet piling, and bars for structural use are provided with ASTM A 6-67 or the equivalent to ASME SA-6.

The pertinent portion of specification is attached.

4.0 WELDING ROD AND WIRE SPECIFICATION

This specification prescribes requirements for covered mild steel electrodes for shielded metal or welding of carbon and low alloy steels. ASTM A 23-64 T (ASME SA-233) shall apply. Welding wire shall be in accordance with ASTM-A 559-65T, Case E 70T-1. The pertinent portion of the specification is attached.

.0 WELDING

PATENT PENDING

Welding shall be in accordance with AWS DI 0-66 Code. AISC Specification Section 24 and Section 25 shall apply.

6.0 FABRICATION

Fabrication will be conducted in accordance with AISC Specification Part V Section 33 and 34. Internal container will be demonstrated to be water tight prior to acceptance.

EXTERNAL PRESSURE

PATENT PENDING

"Packaging shall be adequate to assure that the containment vessel will suffer no loss of its contents if subjected to an external pressure of 25 psig."

Where Packaging is defined as: "Packaging means one or more receptacles and wrappers and their contents, excluding fissile material and other radioactive material, but including absorbent material, spacing structures, thermal insulation, radiation shielding, devices for cooling and absorbing mechanical shock, external fittings, neutron moderators, non-fissile neutron absorbers, and other supplementary equipment".
(As per AEC Appendix 0529, Paragraph 12,040)

The proposed "Package" does insure that the containment vessel will suffer no loss of contents when subjected to an external pressure of 25 psi. Since the design incorporates a unit-body construction technique, it must be concluded that the external shell, as well as the internal shell, act as the containment vessel. By structurally joining these two elements with a closed cell rigid polyurethane foam they are forced to act as one body with the inherent stress skin advantages. From PPI Drawing 32106 ZN F2 it can be seen that a silicone rubber seal is employed to isolate the internal structure from the direct application 25 psig external pressure.. The reliability of this seal is guaranteed by:

1. Procedural inspection prior to end cap assembly.

2. Seating pressure of 10-1 inch diameter bolts combined with effective pressure acting on the lid. This produces a seating stress well in excess of the 200 psi minimum as stated in "ASME Boiler and Pressure Vessel Code Section VIII, Unfired Pressure Vessels".

This combined with the analysis shown in the original report Section 4.4, Page 19, 20 and 21 verifies the Super Tiger ability in meeting the external pressure requirement.

It might be interesting to examine what would result if the seal was non-existant.

As an academic point of interest the intercontainer cover will be backed by dunnage. This will insure that inward cover deflection will be restricted to a minimum. For general information, actual unsupported, pressure limitations of the cap can be found using diaphram plate deflections. Roark treats this under Chapter 10, Section 59 of the fourth addition.

$$\frac{Sb^2}{Et^2} = 277$$

$$\frac{Wb^4}{Et^4} = 1,770$$

Where: $S = 30,000$ psi
$b = 76$ inches
$E = 10^7$ psi
$t = 1/4$ inch

Solving for W (allowable pressure)
$W = 2.07$ psi

This is a somewhat conservative number since the analysis is only valid in the elastic range. Actual ultimate pressure capabilities will exceed this lastic prediction up to a range of approximately 5 to 10 psi. Should a failure ctually take place the cover would fail locally (i.e., cracks, etc.) allowing internal venting. Hole sizes would be small. Secondly, once pressure had equalized, the spring back nature of the cap will tend to close the holes created. At this point, contents would be required to escape from the internal secondary container, through the receeded cracks in the inter-cover and then past the defective seal. As shown in the attached figure, the path through which the contents must pass is complicated and very confined. As an example, clamp-up of the cap seal by bolts restricts the maximum possible opening to less than 1/16 of an inch. The net result of this hypothetical case is that in order to have even a very small release of contents, all the following must take place:

1. Leak in external seal.
2. No dunnage to support cap.
3. Structural failure in inter-lid.
4. No spring back to close cracks in lid.
5. Faulty secondary container allowing loose material in the Super Tiger.
6. Contents must leak through cracks and around 5 corners.
7. Pass through small gap between mating channels, (less than 1/16 inch).

Quality Control procedures established by PPI for construction and loading would guard against the occurance of any of the above.

It is therefore concluded that the proposed design is capable of containing the contents when subjected to 25 psig external pressure. Even in the event of a hypothetical failure of the seal it is questionable whether any material, even a very small quantity, could be released.

PATENT PENDING

FIGURE WITHHELD UNDER 10 CFR 2.390

SECTION A-[illegible]

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SUPERTIGER CORNER COLUMN STABILITY

PATENT PENDING

-ing lifting and stacking operations the container will undergo axial compression ...s. These loads are reacted by column stability of the corners. Conservatively assume the corners to form a pin-ended column of a length equal to unsupported edges. Using Euler's load formula, the critical allowable load is:

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

Where: $E = 3 \times 10^7$ psi

$I = 88.1$ inch^4 (See attached calc.

$A = 7.686$ inch^2

$L = 205$ inches

$$P_{cr} = \pi^2 \frac{(3 \times 10^7)(88.1)}{(205)^2}$$

$$P_{cr} = 618,462 \text{ lbs.}$$

The allowable compressive load based on yield strength is:

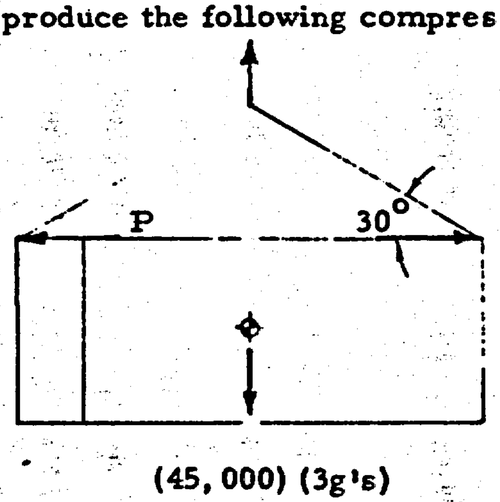
$$P_y = (46,000 \text{ psi})(7.686 \text{ inch}^2)$$

$$P_y = 353,000 \text{ lbs.}$$

Therefore, the corners will fail in compressive yield prior to buckling.

Compressive Loads:

A 30° lifting sling will produce the following compressive loads:



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$$P = \frac{(45,000 \text{ lbs.})(3 \text{ g's})}{(2 \text{ sides})(\tan 30^\circ)}$$

$$P = 117,000 \text{ lbs.}$$

Margin of Safety:

$$M.S. = \frac{353,000}{117,000} - 1$$

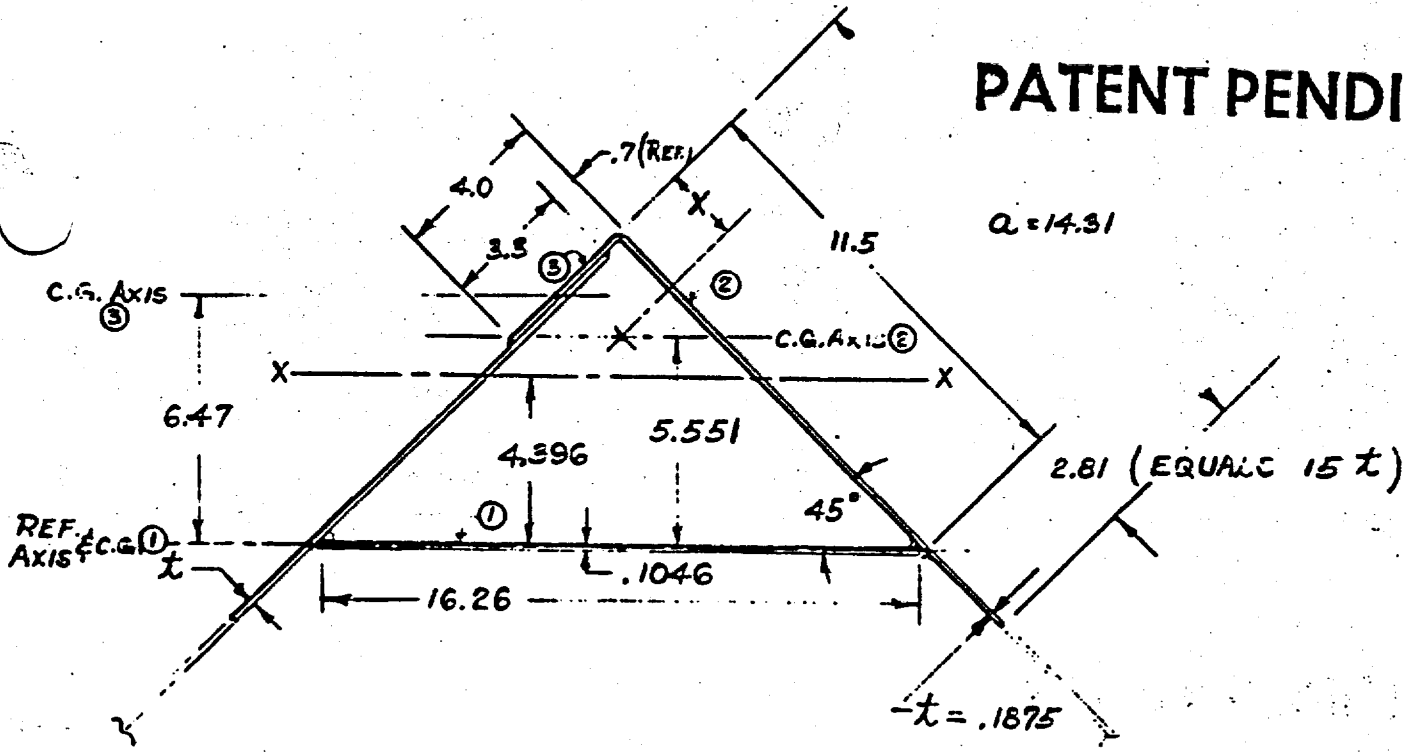
$$M.S. = + \text{Large}$$

PATENT PENDING

Conclusion:

The Super Tiger is capable of reacting the loads experienced during lifting with a 30° sling.

PATENT PENDING



PART	AREA	y	Ay	$I_{c.g.}$	d	Ad^2	$I_{c.g.} + Ad^2 = \downarrow$
①	1.701	0	0	.00155	4.396	32.872	32.874
②	5.366	5.551	29.787	45.072	1.155	7.158	52.230
③	.619	6.469	4.004	.2922	2.073	2.670	2.962
$\Sigma A \rightarrow$	7.686	$\Sigma Ay \rightarrow$	33.791			$I_{x-x} =$	88.1 IN.^{4}

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A} = \frac{33.791}{7.686} = 4.396 \text{ IN.}$$

PART ①

AREA $= .1046(16.26) = 1.701$ IN.^{2}

$$I_{c.g.} = \frac{16.26(.1046)^3}{12} = 0.00155 \text{ IN.}^4$$

PART ③

AREA $= .1875(3.3) = .619$ IN.^{2}

$$I_{c.g.} = \frac{b h (t^2 \sin^2 a + h^2 \cos^2 a)}{12} \quad \text{For . . F.}$$

$$= \frac{.1875(3.3)\left[(.1875)^2(.707)^2 + (3.3)^2(.7\ldots)\right]}{12}$$

$= .2922$ IN.^{4}

PART ②

AREA $= .1875(14.31)\,2 = 5.366$ IN.^{2}

$$X = \frac{a^2 + (a-t)t}{2(2a-t)} = 3.649 \text{ IN.}$$

$$I_{c.g.} = \frac{b t^3 + b^3 t + 3 b t (a - 4X + 2t)^2 + t^4 + 6 t^2 (2X - t)^2}{12}$$

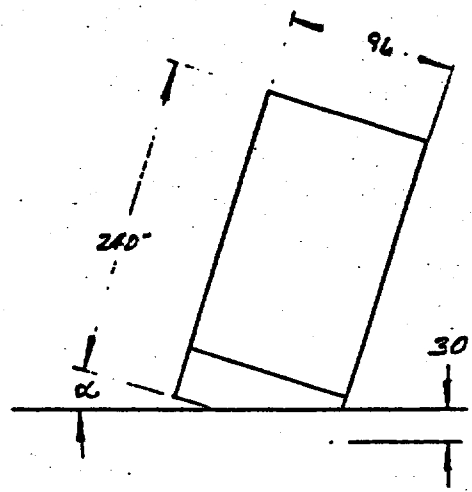
FORMULA FORM ... HUDSON'S ENG. MAN. A

$$= \frac{14.123(.1875)^3 + (14.123)^3 .1875 + 3(14.123).1875\left[14.31 - 4(3.649) + 2(.1875)\right]^2 + (.1875)^4 + 6(.1875)^2\left[2(3.649) - .1875\right]^2}{12}$$

$= 45.072$ IN.^{4}

SUPER TIGER BOLT CLOSURE ANALYSIS **PATENT PENDING**

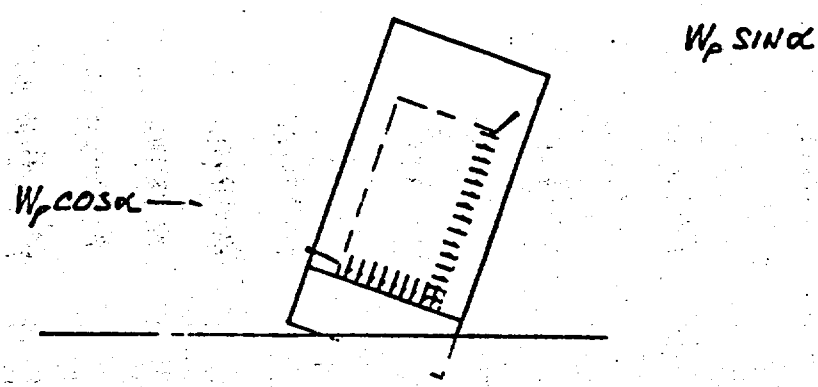
Maximum bolt loads will be generated during an edge drop onto the container end. From page 16 of the report the maximum expected crush depth of 30 inches will produce an acceleration of 24.9 g's.



$$\tan \alpha = 96/240 = .40$$

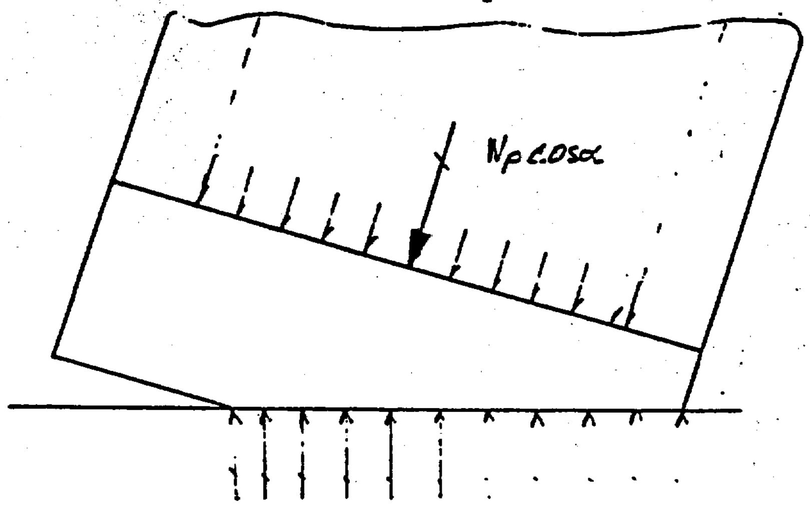
$$\alpha = 22^{\circ}$$

Assume that the axial component at the payload is reacted directly on the cap and the lateral load is reacted along the side of the upper body.



PATENT PENDING

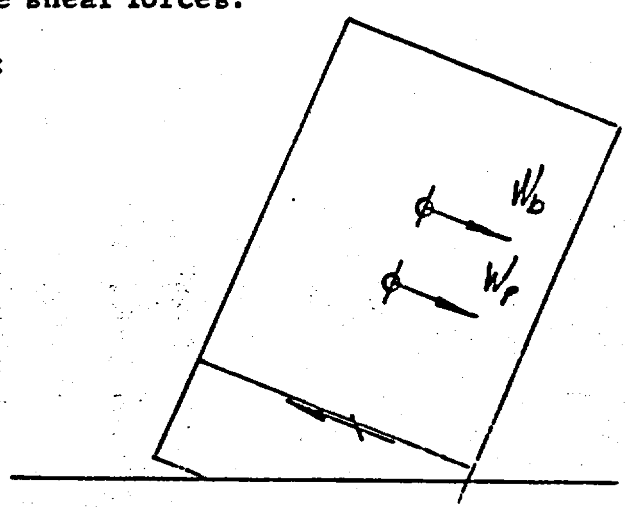
Since the non linear acceleration assures the maximum load is experienced at the end of the compression stroke all the payload component load will be reacted in direct compression through the cap. This can be seen graphically from the sketch below that shows the center of pressure of the payload to fall within the load reacting area of the cap.



Had the cap been rigid and not an energy absorbing cushion the impact force would not have been distributed over the large foot print. This would result in a tendency of the cap to pivot about the corner under the payload induced force, placing the cap bolts in tension. Again this is not the case here where the payload forces are reacted in direct compression.

The closure bolts must react the over turning moment introduced by the lateral weight component of the payload (W_p sin α) and the upper container in addition to the shear forces.

A. Shear Loads:



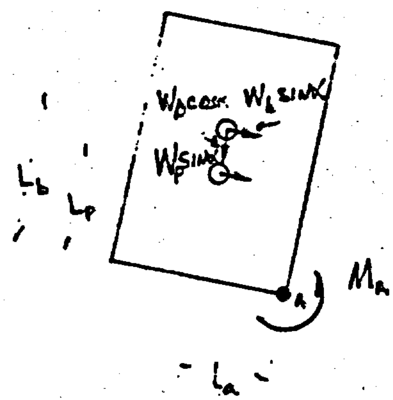
$$P_s = (W_p + W_b) \sin \alpha \ (g's)$$

$$P_s = (30,000 + 12,000)(.375)(24.9)$$

$$P_s = 392,000 \text{ lbs. or } 39,200 \text{ lb. / bolt}$$

B. Tension Loads: **PATENT PENDING**

Interface bending moment is given by:



$M_a = 0$

$$M = \left[W_p \sin\alpha \ L_p + W_b \sin\alpha \ L_b + W_b \cos\alpha \ L_a\right] \text{ g's}$$

Where: $W_p = 30,000$

$W_b = 12,000$ lbs.

$L_p = 88$ inches

$L_b = 115$ inches

$L_a = 48$ inches

$\alpha = 22^\circ$

$g = 24.9$

$$M_a = \left[(30,000)(.375)(88) + (12,000)(.315)(115) + (12,000)(.927)(-48)\right] 24$$

$M_a = 24.241 \times 10^6$ in-lbs

PROTECTIVE PACKAGING, INC.

 5/4/70

Therefore the closure bolts are structurally adequate to react to all loads.

It should be noted that this is a conservative number since the shear load could have been reacted by:

1. Dowels:

$$P_d = \left[\frac{\pi}{4} (1)^2 (46,000) \right] 4$$

$$\underline{P_d = 144,000 \text{ lbs.}}$$

2. Angle (See page 28, Figure 3 of Amendment)

$$P_a = (3/16)(92)(2)(46,000)$$

$$\underline{P_a = 155,000 \text{ lbs.}}$$

3. Friction:

Bolt Clamp-up is about 40,000 lbs. based on 400 in-lb torque

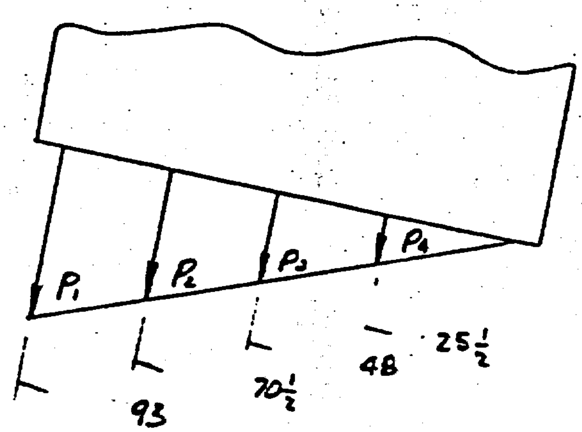
$$P_f = (10)(40,000)(1/3)$$

$$\underline{P_f = 134,000 \text{ lbs.}}$$

Total of: 433,000 lbs.

PATENT PENDING

Assuming a triangular bolt load distribution:



M_a = $(93P_1 + 70.5\ P_2 + 48\ P_3 + 25.5\ P_4)\ 2$

P_1 = $(93^2 + 70.5^2 + 48^2 + 25.5^2) = 93\ M_a/2$

P_1 = $(93)\ (24,241,000)\ /2\ (16573.5)$

P_1 = 68,012 lbs.

<u>Margin of Safety:</u>

Bolt Stresses:

$f_t = 68012\ /\ (\pi/4)\ (1)^2$

f_t = 86612 psi

$f_s = 39200\ /\ (\pi/4)\ (1)^2$

f_s = 49920 psi

Combined Stress:

$$S = f_t\ /\ 2 \pm \sqrt{\left(\frac{f_t}{2}\right)^2 + f_s^{\ 2}}$$

S = 109,406 psi

Margin of Safety:

$$M.S. = \frac{120,000}{109,406} - 1$$

M.S. = + .095

PATENT PENDING

 PATENT PENDING

The following analysis, combined with the actual drop test results, will verify the break-away plate placement as shown in PPI Drawing 32106, Figure 1.

40 inch puncture Test No. 1 and Test No. 2 verified the proposed placement at the center and near one edge and is documented on page 36 through 51 of the original report. Placement along the overall length will be determined by the following analysis.

Since impact at any point other than directly over the c.g. will cause rotation, the net pin impact force will be reduced. Impact magnitude will be a function both mass moment of inertia and the load application point away from the c.g.

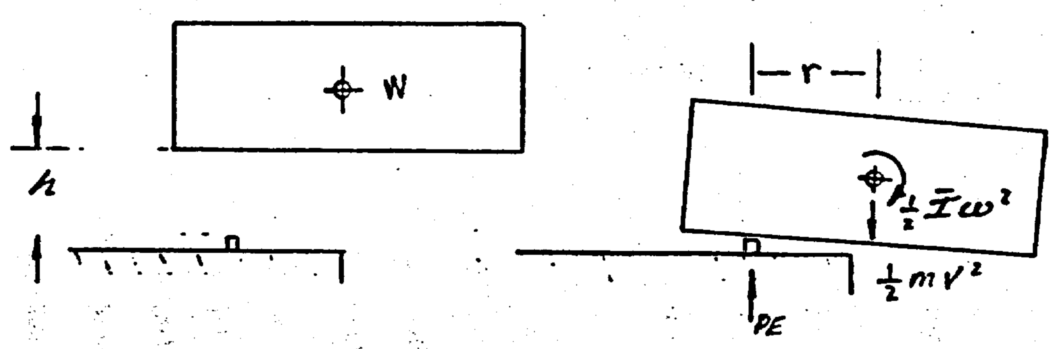
Using conservation of momentum and energy principles, impact energies can be calculated. We shall define the impact energy at an arbitrary pin location as:

Energy absorbed at pin,

$$\overline{PE} = \text{Force} \times \text{Crush Depth}$$

and using:

Conservation of Energy



Σ Energy = 0

$$Wh = \overline{PE} + \frac{1}{2} m v_1^2 + \frac{1}{2} \bar{I} \omega^2$$

$$v_1 = r\omega$$

$$Wh = \overline{PE} + \frac{1}{2} \omega^2 (mr^2 + \bar{I}) \qquad \text{(Eq 1)}$$

Conservation of Momentum

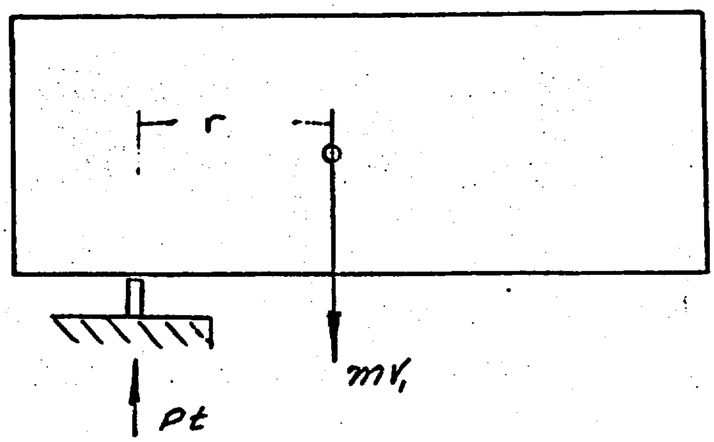
Σ Syst Momenta $\rightarrow$ Syst Ext Imp. = Syst Momenta

($+$ | Components

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 1

PATENT PENDING



$$mv_o = Pt + mv_1$$

Where: $t = 2E/v_o$

$v_1 = r\omega$

$$mv_o = \frac{2\overline{P}E}{v_o} + mr\omega$$

Solving for ω^2

$$\omega = (mv_o - \frac{2\overline{P}E}{v_o})\frac{1}{mr}$$

$$\omega = (\frac{v_o}{r} - \frac{2}{mv_o r}\overline{P}E)$$

$$\omega^2 = (\frac{v_o^2}{r^2} - \frac{4\overline{P}E}{mr^2} + \frac{4}{m^2 v_o^2 r^2}\overline{P}E^2) \qquad \text{(Eq 2)}$$

Solving simultaneous equations Eq 1 and 2:

$$Wh = \overline{P}E + \frac{1}{2}(mr^2 + I)(\frac{v_o^2}{r^2} - \frac{4}{mr^2}\overline{P}E + \frac{4}{m^2 v_o^2 r^2}\overline{P}E^2)$$

5/4/70

Substitute and solve the quadratic equation for PE: **PATENT PENDING**

Where: $m = 45000 / 32.2 = 1400$

$v = 14.62$ fps

$h = 40$ inches

$$I = \frac{1}{12} m(a^2 + b^2)$$

$$I = \frac{1}{12}\left(\frac{30000}{32.2}\right)(64 + 196) + \frac{1}{12}\frac{15000}{32.2}(64 + 400)$$

$I = 38198$

$r = 6$ ft. (End of Breakaway Plates)

$W = 45000$ lbs.

$$(45000)(40) / 12 = PE + \frac{1}{2}\left[(1400)(36) + (38198)\right]\left[\frac{(14.62)^2}{(6)^2} - \frac{4}{(1400)(36)} PE + \frac{4}{(1400)^2(14.62)^2(36)} PE^2\right]$$

$$150000 = PE + 44299\,(5.93734 - .00007936\,PE + 2.6522 \times 10^{-10}\,PE^2)$$

$$1.174875 \times 10^{-5}\,PE - 2.51601\,PE + 113,018 = 0$$

$$PE = \frac{+2.51601 \pm \sqrt{(2.51601)^2 - 4(1.174875 \times 10^{-5})(11.3018 \times 10^4)}}{2(1.174875 \times 10^{-5})}$$

$$= \frac{2.51601 - 1.00947}{2(1.174875 \times 10^{-5})}$$

PE = 64115 ft. - lbs.

It is therefore apparent that the magnitude of the load is greatly dependent on the point of impact and its proximity to the containers center of gravity. At locations other than the c.g. the containers energy is not totally absorbed by the pin area, but is partially transformed into rotational energy about is c.g. Also, a secondary energy component related directly to the linear velocity of the c.g. is present. The net result is that as the pin moves away from the c.g., puncture loads are greatly reduced.

Substitute and solve the quadratic equation for PE for a point 3.5 ft. from the center:

Where: $m = 45000 / 32.2 = 1400$

$v = 14.62$ fps

$h = 40$ inches

$$I = \frac{1}{12} m(a^2 + b^2)$$

$$I = \frac{1}{12}\left(\frac{30000}{32.2}\right)(64 + 196) + \frac{1}{12}\ \frac{15000}{32.2}(64 + 400)$$

$I = 38198$

$r = 3.5$ (End of Breakaway Plates)

$W = 45000$ lbs.

$$(45000)(40) / 12 = PE + \frac{1}{2}\left[(1400)(12.25) + (38198)\right]\left[\frac{(14.62)^2}{(3.5)^2} - \frac{4}{(1400)(3.5)^2} PE + \frac{4}{(1400)^2(14.62)^2(3.5)^2} PE\right]$$

$$150000 = PE + 27674(17.4485 - .000233\ PE + 7.7942 \times 10^{-10}\ PE^2)$$

$$2.1481389 \times 10^{-5}\ PE^2 - 5.454575\ PE + 332870 = 0$$

$$PE = \frac{5.454575 - 1.072543}{2(2.1481389 \times 10^{-5})}$$

PE = 102317.5 ft. - lbs.

PATENT PENDING

Skin strength capability is related to the thickness squared (t^2) per Timoshenko, "Theory of Plates and Shells". Since combined skin thickness of (3/16 + 1/8 + 1/8) exists at the center:

$$t_c^2 = (.1875)^2 + (.125)^2 + (.125)^2$$

$$t_c^2 = .066$$

Based on the foregoing energy calculation, the required thickness at a point 6 ft. from the c.g. would be:

$$t_5^2 = (.066)(64115) / 150000$$

$$t_5^2 = .0282$$

$$t_5 = .16796 \text{ inch}$$

The margin of safety, based on the proposed design of no breakaway plate beyond 6 feet, is as follows:

$$M.S. = \frac{.1875}{.16796} - 1$$

$$M.S. = + .116$$

Based on the foregoing energy calculation, the required thickness at a point 3.5 ft. from the c.g. would be:

$$t_5^2 = (.066)(102317) / 150000$$

$$t_5^2 = .0450$$

$$t_5 = .2122$$

The margin of safety, based on the proposed design of no breakaway plate beyond 3.5 feet, is as follows:

$$M.S. = \frac{.1875 + .125}{.2122}$$

PATENT PENDING

$$M.S. = + .473$$

It is felt that these margin of safety calculations are conservative since they use the strength at the C.G. location as a base and assume a zero margin of safety. It was shown in tests that the skin at the C.G. location does not tear. It, therefore, has capability in excess of the applied load. The amount of additional capability is not known, but could be significant due to technique of "break-away". This technique allows the external skin to fail. On penetration of the external skin the internal plates break-away and are allowed to mold over the pin end. This greatly increases the effective area, thereby absorbing more energy than the external skin along. This was demonstrated in scale testing and documented in the report. The conclusion is that the capability in excess of that which it was tested too does exist at the C.G. resulting in actual margins greater than that calculated.

Conclusion:

Loads experienced at a point 3.5 and 6 feet away from the c.g. are sufficiently low to be fully reacted by the steel skin.

The analysis shows that when the pin is off-set from the c.g., the c.g. continues to travel in the same direction. It has kinetic energy of translation as well as kinetic energy of rotation.

It has been shown that the proposed design is capable of reacting the 40 inch puncture loads at the:

1. c.g. (by test).
2. Container edge (by test).
3. fore or aft of c.g. (by analysis).

APPENDIX C. CONTAINMENT OF RADIOACTIVE MATERIALS

Contents

WRD-LA-244

Westinghouse Electric Corporation
Water Reactor Divisions
Box 355
Pittsburgh Pennsylvania 15230

November 20, 1980

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety & Safeguards
Division of Fuel Cycle & Material Safety
Washington, D.C. 20555

Attention: Mr. Charles E. MacDonald, Chief
Transportation Branch

Dear Mr. MacDonald:

Subject: Exemption From 10 CFR 71.42(b)(3), Super Tiger Shipping Container, Certificate of Compliance No. 6400

The Westinghouse Electric Corporation hereby requests an exemption from the requirements of 10 CFR Part 71.42(b)(3) for the Model 6400 Shipping Package, Certificate of Compliance No. 6400, Docket 71-6400, in accordance with the attached information.

Please find enclosed a check in the amount of $2,800 as payment of the minor amendment fee per the requirements of 10 CFR Part 170.

If you have any questions regarding this matter, please write me at the above address or telephone me on Area Code 412 373-4652.

Very truly yours,

WESTINGHOUSE ELECTRIC CORPORATION

Ronald P. DiPiazza

Ronald P. DiPiazza, Manager
NES License Administration

/kk

Attachments

TREATMENT, PACKAGING, AND SAFETY ASSESSMENT FOR TRANSPORTING LARGE EQUIPMENT WASTE

WESTINGHOUSE NUCLEAR FUEL DIVISION
PLUTONIUM FUELS DEVELOPMENT LABORATORY

NOVEMBER 20, 1980

TABLE OF CONTENTS

1. INTRODUCTION

Within the scope of the Westinghouse plan to decontaminate and decommission its plutonium fuel laboratories, various treatment and packaging methods are employed for the many categories of waste generated. These methods are required to assure that the wastes will be transported and disposed of in a safe manner and in compliance with all government regulations.

The current Westinghouse work effort is concentrated in the treatment and packaging of large equipment waste. Wastes, such as glove boxes, hoods, duct work, filter housings, furnaces, etc., would undergo treatments of decontamination and fixation, packaged rigidly in strong tight fiberglass reinforced polyester (FRP) coated plywood boxes, and transported to a disposal site in a Model 6400 overpack (Super Tiger). Specific restrictions, however, have been placed on shipment of these wastes unless it is shown that a minimum of two barriers of confinement are provided within the waste package to prevent release of contamination.

The following discussion shows that the methods employed by Westinghouse in treating and packaging large equipment waste will prevent the release of plutonium when the entire package is subjected to normal and accident conditions incident to transportation. Based on this information, an exemption is requested from the requirements of 10 CFR 71.42.

2. TREATMENT

In preparation for packaging large equipment waste in FRP-coated plywood boxes, decontamination and fixation treatments are used. Prior to these treatments, smaller equipment items, utilities, and other extraneous items are cleaned and removed. As a result, treatment of contaminated areas within the large equipment can proceed effectively and with minimum obstruction.

A. DECONTAMINATION

Description

If required, surfaces are decontaminated using wash and rinse techniques. A decontamination cleaner is applied followed by water rinses. After each wash and rinse step, the surfaces are allowed to dry, and smear surveys are taken and documented. When it has been determined that contamination levels are stabilized at levels as low as can be reasonably achieved, a fixation treatment is employed.

Results

The decontamination cleaner is designed for removal of loose (smearable) contamination. It is neutral and nonflammable. Glove boxes in which were processed large quantities of powders have been decontaminated to smearable levels averaging 20,000 to 75,000 dpm/100 cm^2. The smear paper used for surveys showed little discoloration, indicating that the decontamination treatment is effective in removing residual material from contaminated surfaces.

B. FIXATION

Description

Either a formulated coating or a rigid polyurethane foam may be used as a fixative to render any remaining residual surface contamination in a "nonrespirable" or "not readily dispersible" form. Either fixative may be applied to a specific large equipment item. This fixative provides one of the two barriers for confinement of removable contamination.

Spray methods are used to apply the fixative to all affected surfaces. After the coating is dried or the foam is set, smear surveys are taken on the applicable surfaces and recorded. In compliance with safeguards requirements, each waste item is then assayed nondestructively to verify that large quantities of SNM are not present.

Results

Smear Surveys

Significant decreases in the levels of removable contamination due to these fixation techniques were documented. These decreases ranged from a factor of two to a factor of several hundred, depending on the initial level of contamination. The average reduction factor was between ten and twenty. Removable surface contamination results after fixation are comparable to the contamination levels allowed on the exterior surfaces of shipping packages under DOT and NRC regulations. For example, the allowable surface contamination on packages shipped by "exclusive use of vehicle" is 2,200 dpm/100 cm^2 for plutonium and 22,000 dpm/100 cm^2 for uranium (49 CFR 173.397). In comparison, the loose contamination on the interior surfaces of the glove boxes after fixation has ranged from an average of 650 to 5,500 dpm/100 cm^2. The maximum observed value was < 25,000 dpm/100 cm^2.

Nondestructive Assays

Nondestructive assays performed after decontamination have shown that an average of less than one gram of plutonium remains in each glove box. One gram of this plutonium is equivalent to 1.3 curies. The upper limit defined in 10 CFR 71.4(q) for Type B quantities of plutonium is 20 curies.

3. EFFECTIVENESS OF DECONTAMINATION AND FIXATION

Several decontaminated and fixed glove boxes were separated from the plant ventilation system and moved to storage. Air sampling was routinely employed during these operations and, in all cases, no airborne contamination was detected.

In one specific case, removal of a section of a glove box was required for eventual packaging. During this operation, an area located at the top of the glove box was removed with a reciprocating saw. No release of contamination was detected by air sampling during and after sawing operations.

These results are significant because:

a. This glove box was used to process plutonium powders for approximately ten years.

b. The integrity of the fixation coating was not disturbed during the sawing operation when fines were generated.

c. Air sampling was conducted continuously for 154 minutes at the exposed opening of the glove box.

Based on these results, the fixation technique was successful as a barrier in preventing contamination release.

4. PACKAGING

Prior to packaging the decontaminated and fixed large equipment waste, an inspection shall be made to assure that: a) all sharp or protruding objects have been removed or blunted; and b) pipe caps, gasketed blind flanges, covers, etc. have been installed where required.

PACKAGE DESCRIPTION

The waste item shall be placed into a strong tight plywood box. The box shall be coated with a layer of fiberglass reinforced polyester (FRP) and banded with steel straps. The size of the box varies for each waste item.

The FRP-coated plywood boxes will be constructed of 1-inch exterior-type plywood with 4x4-inch interior supporting studs on the sides and ends, and double 2x6-inch interior supporting studs on the top and bottom. The FRP coating will be 0.125 inch nominal thickness throughout; including the exterior edges. Skids shall be provided on the bottom of the boxes for handling. The box shall be assembled using adhesive and either box nails or staples. The FRP-coated boxes shall be banded with 1-inch minimum steel straps. These straps will be placed horizontally and also vertically between the skids.

After the waste item is placed in the FRP-coated box, the void space shall be foamed to give the waste item a "cocoon-type" configuration. This foam provides the second barrier for confinement of removable contamination. This foam also serves as a rigid cushion to prevent movement of the waste item in the plywood box during transport.

The inner package described above will be placed in a Model 6400 overpack (Super Tiger) for transportation.

5. PACKAGE SAFETY EVALUATION

GENERAL

The treatment and packaging methods described in the previous sections of this request were designed to provide protection against a release of radioactive material during normal conditions of transport (10 CFR 71, Appendix A) and during hypothetical accident conditions (10 CFR 71, Appendix B). The Super Tiger was originally designed as a Type B overpack, and will satisfy only those requirements discussed below. For the purposes of this exemption request, the Super Tiger overpack is assumed to provide protection for the inner waste package; no credit is taken for leak tightness. The surface fixation and the packaging of large equipment waste provide the multiple barriers against release of contamination.

SAFETY ASSESSMENT - 10 CFR 71 REQUIREMENTS

Normal Conditions of Transport - Appendix A

Item 1. Heat--Direct sunlight at an ambient temperature of 130°F in still air.

Response--The heat conditions will not affect the FRP-coated box or its contents (reference thermal section under hypothetical accident conditions).

Item 2. Cold--An ambient temperature of -40°F in still air and shade.

Response--There is no adverse effect on the foam, the coating, the plywood, or the FRP materials at -40°F.

Item 3. Pressure--Atmospheric pressure of 0.5 times standard atmospheric pressure.

Response--The FRP-coated plywood box is designed to withstand pressure loadings averaging 544 $lbs./ft^2$ or ∿ 3.8 psi. At a pressure of 0.5 atmosphere (1,058 $lbs./ft^2$ or 7.35 psi), the allowable stress factor is exceeded by a factor of nearly two as specified in the Uniform Building Code. Although the safety factor within the values given in the Building Code are not known, it is assumed that at least a factor of two exists. Therefore, the FRP-coated plywood box would retain its integrity under a pressure of 0.5 atmosphere. It may further be assumed that the rigid foam and fixation coating will function as barriers for preventing contamination release under such environmental pressure changes.

Item 4. Vibration--Vibration normally incident to transport.

Response--The inner package structure of the FRP-coated box and the dunnage surrounding it preclude any adverse affects during transport.

Item 5. Water Spray--A water spray sufficiently heavy to keep the entire exposed surface of the package except the bottom continuously wet during a period of 30 minutes.

Response--The water spray will not affect the inner package (reference water immersion section under hypothetical accident conditions).

Item 6. Free Drop--Between 1-1/2 and 2-1/2 hours after the conclusion of the water spray test, a free drop through the distance specified below onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

FREE FALL DISTANCE

Package Weight (Pounds)	Distance (Feet)
Less Than 10,000	4
10,000 to 20,000	3
20,000 to 30,000	2
More Than 30,000	1

Response--(Reference free drop section under hypothetical accident conditions.)

Item 7. Corner Drop--A free drop onto each corner of the package in succession, or in the case of a cylindrical package onto each quarter of each rim, from a height of 1 foot onto a flat essentially unyielding horizontal surface. This test applies only to packages which are constructed primarily of wood or fiberboard, and do not exceed 110 pounds gross weight, and to all Fissile Class II packagings.

Response--Not applicable. Packages exceed 110 pounds.

Item 8. Penetration--Impact of the hemispherical end of a vertical steel cylinder 1-1/4 inches in diameter and weighing 13 pounds, dropped from a height of 40 inches onto the exposed surface of the package which is expected to be most vulnerable to puncture. The long axis of the cylinder shall be perpendicular to the package surface.

Response--(Reference puncture section under hypothetical accident conditions.)

Item 9. Compression--For packages not exceeding 10,000 pounds in weight, a compressive load equal to either 5 times the weight of the package or 2 pounds per square inch multiplied by the maximum horizontal cross section of the package, whichever is greater. The load shall be applied during a period of 24 hours, uniformly against the top and bottom of the package in the position in which the package would normally be transported.

Response--This test is not applicable since the Super Tiger exceeds 10,000 pounds.

Hypothetical Accident Conditions - Appendix B

Item 1. Free Drop--A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

Response--The Super Tiger overpack confines the inner waste package after a free fall drop of 30 feet. If the integrity of the inner package is not maintained, containment of contamination is provided by the techniques previously described in Sections 2 and 3 of this exemption request.

Item 2. Puncture--A free drop through a distance of 40 inches striking, in a position for which maximum damage is expected, the top end of a vertical cylindrical mild steel bar mounted on an essentially unyielding horizontal surface. The bar shall be 6 inches in diameter, with the top horizontal and its edge rounded to a radius of not more than one-quarter inch, and of such a length as to cause maximum damage to the package, but not less than 8 inches long. The long axis of the bar shall be perpendicular to the unyielding horizontal surface.

Response--Previous Super Tiger testing demonstrated that the overpack satisfies the requirements of the 40-inch puncture test.

Item 3. Thermal--Exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 1,475°F for 30 minutes with an emissivity coefficient of 0.9, assuming the surfaces of the package have an absorption coefficient of 0.8. The package shall not be cooled artificially until 3 hours after the test period unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hours.

Response--Fire testing conducted on the Super Tiger demonstrated that the inner contents did not exceed 150°F when the outer overpack was exposed to temperatures between 1,600° and 2,000°F for one hour. By analysis, the inner contents would not exceed 80°F when exposed to the 1,475°F for 30 minutes as required by Appendix B.

The fixation coating, used as the first barrier on the waste equipment surfaces, becomes tacky between 300° and 400°F when exposed to direct flame. Since this condition is not projected, the surface fixative within the inner package will remain intact.

The rigid foam, used as the second barrier against contamination release, is not affected by exposure to the heat shown in Super Tiger testing. Tests were conducted by an independent laboratory at the request of the foam manufacturer on samples having dimensions of 4"x4"x1" (sample size was per Military Spec.). At 158°F for 14 days, slight curvatures, but very little distortions were detected on the samples. Since the foam will adhere to the equipment surfaces, no adverse effects are expected.

Breakdown of the foam's chemical structure occurs slowly between 400°F and 500°F. Since temperatures in this range were not indicated inside the Super Tiger during fire testing, the foam will remain intact.

Temperatures in the range of 80°-150°F will not affect the integrity of the plywood box and its FRP coating. Plywood will start to char around 400°F, and, with the addition of FRP coating, its fire-resistant properties are greatly enhanced. The FRP-coated plywood box assures that the barriers preventing release of contamination will remain intact.

Item 4. Water Immersion (fissile material packages only)--Immersion in water to the extent that all portions of the package to be tested are under at least 3 feet of water for a period of not less than 8 hours.

Response--Assuming that (1) the Super Tiger overpack is not leak tight and (2) the FRP-coated plywood box with the waste item is immersed in water, then: The fiberglass reinforced polyester coating will protect the package.

Further assuming that the integrity of the FRP coating and plywood is breached and the water contacts the foam "cocoon" of the waste item, testing by the foam manufacturer indicates that water penetrates only 1/16 inch into the rigid closed-cell foam. Tests were performed on 4x4x1-inch thick samples immersed in dyed water for 96 hours.

Finally, water will not affect the fixation coating on the waste equipment surface.

Since the foam and coating barriers are both resistant to water immersion, it is conservative to assume that particulate material will not penetrate these barriers.

6. CONCLUSIONS

A. The methods used by Westinghouse for decontaminating large equipment waste is successful in reducing contamination to low levels.

B. Fixation methods using either formulated coatings or rigid foam as barriers to prevent the release of contamination from low-level decontamination will meet the conditions required in 10 CFR 71(b)(3).

C. By packaging decontaminated and fixed waste in high integrity plywood boxes which are coated with FRP laminate and banded with steel straps, the strength of these inner packages will be enhanced in the event of a transport accident.

TREATMENT, PACKAGING, AND SAFETY ASSESSMENT FOR TRANSPORTING WASTE

WESTINGHOUSE NUCLEAR FUEL DIVISION
PLUTONIUM FUELS DEVELOPMENT LABORATORY

AUGUST 7, 1980

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1. INTRODUCTION

In a previous document, "Treatment, Packaging, and Safety Assessment for Transporting Large Equipment Waste," November 20, 1980, Westinghouse's packaging descriptions were presented for large equipment items. This document expands this description to the packaging methods for other package contents, and for the use of either a fiberglass reinforced polyester (FRP) coated plywood box or a steel box of corrugated construction as the secondary package.

The following discussion shows that the methods employed in treating and packaging waste items provides multiple barriers to prevent the release of plutonium when the entire package is subjected to the normal and hypothetical accident conditions described in Appendices A and B of 10 CFR 71. Based on this evaluation, an exemption from the special requirements of 10 CFR 71.42 is requested.

2. TREATMENT

Waste items will be treated in a similar manner to that described in the November 20, 1980, document, i.e., decontamination by wash and rinse techniques (as required) followed by the application of a fixative. These items will then be enclosed in two heat-sealed 12-mil thick PVC bags. Items with internal surfaces that are not easily accessible will have the openings sealed with mechanical fittings or have the contaminant fixed by foaming within the cavities. External surfaces of these items will be treated as described.

The decontaminate and fix techniques used for hard waste items are not adaptable to some waste, such as soft waste or glove box filters where smear techniques would not be effective and the completeness of the fixative application would be suspect. These items will be enclosed in two heat-sealed 12-mil thick PVC bags and packaged within a DOT Specification 17H or 17C steel drum (maximum size of 55 gallons). Each drum will have a sealed plastic liner and will be equipped with a standard drum closure.

Contaminated liquids are another waste category where decontamination and fixation techniques are not applicable. These wastes will be solidified in concrete in either:

a. A 30-gallon drum which is sealed in a plastic bag and centered and supported in a DOT Specification 17H or 17C 55-gallon steel drum by absorbent material, or

b. In one-gallon (or smaller) bottles which are enclosed in two heat-sealed 12-mil thick PVC bags and placed in a DOT Specification 17H or 17C 55-gallon steel drum.

Each drum will have a sealed plastic liner and will be equipped with a standard drum closure.

3. SECONDARY PACKAGING

The decontaminated and fixed waste items or the DOT specification steel drums described in Section 2 of this document will be placed in either a tight-fitting 1" thick plywood box as described in the November 20, 1980, document or in a tight-fitting 3/16" thick steel box. The steel box will be of corrugated construction with a gasketed lid bolted in place.

The space between the box and the waste packages or drums will be filled with foam to a minimum thickness of 1". Void spaces between the waste packages or between the drums will be filled with foam to a minimum thickness of 1/2".

The packages described above will be placed in a Model 6400 overpack (Super Tiger) for transportation.

4. PACKAGE SAFETY EVALUATION

In the November 20, 1980, document, the plywood box package was shown to satisfy the requirements for normal conditions of transport (10 CFR 71, Appendix A) and for hypothesized accident conditions (10 CFR 71, Appendix B). That discussion is applicable to the corrugated steel box as well. The combination of treatment and packaging of the various waste materials, and the placement of the waste packages or drums into a secondary package, including foaming of the waste package or drum in place, would prevent the loss of contents if the shipment were subjected to the external pressure loading specified by 10 CFR 70.32(b).

5. CONCLUSIONS

A. The treatment and packaging methods for the waste material described provide effective confinement barriers to prevent the release of contamination which satisfies the conditions for exemptions from the requirements of 10 CFR 71.42.

B. Both the corrugated steel box and the fiberglass reinforced polyester coated plywood box provide an effective secondary package for the waste packages or drums.

APPENDIX D. NUCLEAR CRITICALITY SAFETY EVALUATION

Contents

Nuclear Materials and Equipment Corporation   Apollo, Pennsylvania 15613   Telephone 412-842-0111   Cable

DOCKET NO. 70-364   Extra

September 17, 1971

United States Atomic Energy Commission
4915 St. Elmo Place
Bethesda, Maryland 20014

Attention: Mr. Donald A. Nussbaumer, Chief
Fuel Fabrication and Transportation Branch

Subject: DOT SP 6400
Loading of "Super Tiger" with Waste Drums

References: (1)RFP-1411, ATMX-600 Railcars for Radioactive Waste Shipments

(2)Mechanics Research, Inc. Report No. C2378, "Engineering Evaluation of the Super Tiger Overpack Designed for the Shipment of Large Quantities of Hazardous Materials."

Dear Mr. Nussbaumer:

We wish approval to deliver to a carrier, as a Fissile Class I shipment, a "Super Tiger", DOT SP 6400, which is loaded according to the following specifications:

1. Forty-two 17C or 17H fifty-five gallon containers.

   i. Each container is limited to a maximum of 200g fissile fuel and a maximum of 200 pounds of graphite.

   ii. The material is process wastes which are (1)sludges which have been hardened with speedi-dry, oil-dry, cement, or equivalent, and (2)line-generated wastes which are insulation, glass, washables, contaminated equipment, and miscellaneous residues.

   iii. The maximum thermal decay energy is two watts per drum.

and/or

2. Crates 19A, 19B or equivalent or those meeting Spec. 7A general packaging.

   i. The contents of each crate are similar to the line generated wastes described above but the size prevents putting the items in drums. This includes equipment, hoods, glove boxes, pipe, lumber, etc.

ii. Each crate is limited to a fissile fuel content less than 5g/ft.^{3}.

3. The drums and crates are lined with sheet plastic having a minimum thickness of 5 mils.

4. Drums and crates are packaged in the Super Tiger in accordance with MRI report C2378. The bases for allowing us to use this loading are the following:

The contents of the inside of the Super Tiger are unaffected by all accident conditions as shown in report C2378, "Engineering Evaluation of the Super Tiger Overpack Designed for the Shipment of Large Quantities of Hazardous Materials." (This report was submitted February 4, 1971, with docket 70-337 as Appendix Q.)

Each drum and crate that will be loaded into the Super Tiger has the same criticality limits as those approved for the ATMX-600 railcar which is a DOT SP 5948.

The usable volume of the Super Tiger is smaller than the usable volume of the railcar. Consequently, the Super Tiger, when loaded, is less reactive than the railcar. This means the criticality analysis which was done for the ATMX railcar (RFP-1411) is applicable to the Super Tiger and the Super Tiger can be shipped as a Fissile Class I shipment. The transport index will be determined by external radiation levels.

Very truly yours,

Edward K. Reitler

Edward K. Reitler, Jr., Manager
Health, Safety, and Licensing

/drk

70-364

EXTRA

Nuclear Materials and Equipment Corporation
a subsidiary of Babcock & Wilcox

609 North Warren Avenue, Apollo, Pa. 15613
Telephone: (412) 842-0111

January 6, 1972

United States Atomic Energy Commission
4915 St. Elmo Place
Bethesda, Maryland - 20014

Attention: Mr. Donald A. Nussbaumer, Chief
Fuel Fabrication and Transportation Branch
Division of Materials Licensing

Subject: Our Application Dated 17 September, 1971, Loading of "Super Tiger" With Waste Drums.

References: Your letter dated 18 November 1971

Dear Mr. Nussbaumer:

The following is in answer to the questions you raised in your letter dated 18 November 1971:

AEC Question 1: A nuclear safety analysis to demonstrate that criticality will not occur as a consequence of damage to the inner containers. The analysis should consider whether the contents of a sufficient number of damage containers could be accidently expelled and assembled to cause criticality. Damage to the containers is shown in the Unabridged Report C2378, "Engineering Evaluation of the Super Tiger Overpack for the Shipment of Large Quantities of Hazardous Materials", submitted May 28, 1971 as Appendix Q to Docket No. 70-337.

Answer 1: It is not necessary for NUMEC to present a new nuclear safety analysis for the following reasons:

1. The Super Tiger package (Forty two 17C or 17H fifty five gallon containers each limited to a maximum of 200 grams of fissile fuel and a maximum of 200 pounds of graphite) is safe from nuclear criticality based on a Rocky Flats report RFP-1411 (Ref. 3, p. 27-30) which demonstrates the safety of a similar package of at least 250 undamaged drums containing a maximum of 200 grams Pu-239 per drum.

2. The drums used by NUMEC are either 16 gage or 18 gage thick. The report C2378 for Super Tiger overpack (Ref. 2, p. 63-65) shows that during an impact test, 22 gage drums showed considerable deformation and some drums had reuptured seams through which liquid had escaped whereas 16 gage drums with removable covers experienced little or no deformation. It is argued that a plastic drum liner would provide assurance against spillage from any drums. NUMEC waste containers have a plastic drum liner and in addition, do not carry any liquids;

solid waste is less liable to escape. Drums of about 19 gage thicknesses have been reported to be undamaged by Rocky Flats (Ref. 3) based on an engineering evaluation of Mr. F. E. Adcock (Ref. 4) for 19 gage drums contained in the AMTEX railroad car; therefore, damage to 16 or 18 gage drums in the Super Tiger overpack is not credible.

3. The crates are inherently safe from criticality since it contains no more than 5 grams of fissile fuel per cubic foot of the crates. This is an ever safe concentration and is very low compared to the drum concentration of about 28 gms/cu.ft. The contents of each crate are essentially large sized, line generated contaminated waste. This does not create an accountability problem for criticality and in unlikely event of its getting expelled, the waste would retain its distributed contamination, far from causing criticality. The crates can be intermixed with the drum lattice since it leads to a less reactive arrangement as per the Rocky Flats report (Ref. 3, p. 30).

AEC Question 2: Confirmation that the maximum decay heat generation per package will be in agreement with the conditions for the Super Tiger package or a thermal analysis which substantiates the revised thermal loading.

Answer 2: Numec proposes the shipment of two types of drum loadings, identified in the following tables as Type 1 and Type 2. From those tables it is shown that the Fuel Type 1 loading of the "Super Tiger" is safe providing no more than 35 drums loaded with Type 1 Fuel are loaded into the "Super Tiger". Drums loaded with Fuel Type 2 are safe when 42 drums (a maximum loading) are put into the Super Tiger. The contents of the drums have been determined by Gamma-Spectroscopy barrel-scan.

Very truly yours,

Edward Reitler

E. K. Reitler, Manager
Health, Safety and Licensing

/amc

Attachments

TABLE1: Plutonium Fuel*

Isotope	% per gm of Pu	
	Type 1	Type 2
Pu - 238	0.109	----
Pu - 239	88.280	90.80
Pu - 240	9.410	8.30
Pu - 241	1.410	0.61
Pu - 242	0.191	0.04
Am - 241	0.600	0.25

*Amount of Am - 241 is obtained from the β-decay of Pu - 241. Decay time of about 6 years is assumed prior to shipment in Super Tiger.

TABLE 2: Isotopes Versus Energy Release*

Isotope	At.wt. A	Half life τ, years	Mev/decay $Q_{\alpha,\beta,\gamma}$	Total Energy Release Q_T, watt/gm
Pu-238	238.050	86	5.592(α-decay)	5.80×10^{-1}
Pu-239	239.052	24400	5.243(α-decay)	1.91×10^{-3}
Pu-240	240.054	6580	5.255(α-decay)	7.06×10^{-3}
Pu-241	241.056	13.2	0.0208(β-decay)	1.39×10^{-2}
Pu-241	241.057	458	5.640(α-decay)	1.08×10^{-1}

$$*Q_T = 2.121 \times 10^3 \frac{Q_\alpha}{A\tau} \quad \text{Watts/gm}$$

where Q_α = Energy per disintegration, Mev

A = Atomic wt.

τ = Half life, years

TABLE 3: Typical Decay Heat from NUMEC Fuel

(1) Fuel Type 1:

Isotope	Q_T watt/gm	gm - fraction of isotope	Heat Load Q, watt/gm of Pu
Pu-238	5.80×10^{-1}	0.0011	0.638×10^{-3}
Pu-239	1.91×10^{-3}	0.8828	1.686×10^{-3}
Pu-240	7.06×10^{-3}	0.0941	0.664×10^{-3}
Pu-241	1.39×10^{-2}	0.0141	0.196×10^{-3}
Am-241	1.08×10^{-1}	0.0060	0.648×10^{-3}
		Total	3.832×10^{-3} watt/gm of Pu

∴ Watt/drum = $3.832 \times 10^{-3} \times 200 = 0.7665$

35 drums will produce 26.83 watts

(2) Fuel Type 2:

Isotope	Q_T	gm-fraction	Q
Pu-239	1.91×10^{-3}	0.9087	1.736×10^{-3}
Pu-240	7.06×10^{-3}	0.0823	0.581×10^{-3}
Pu-241	1.39×10^{-2}	0.0061	0.083×10^{-3}
Am-241	1.08×10^{-1}	0.0025	0.270×10^{-3}
		Total	2.670×10^{-3}

∴ Watts/drum = $2.670 \times 10^{-3} \times 200 = 0.5346$

42 drums will produce 22.45 watts

REFERENCES

Ref. 1: A.E.C.'s letter to NUMEC (Att: Mr. E. K. Reitler, Jr.), dated November 18, 1971 (DML:CEM 70-364) for an amendment to SNM-414 for Super Tiger Package.

Ref. 2: "Engineering Evaluation of the Super Tiger Overpack Designed for the Shipment of Large Quantities of Hazardous Materials," Report C2378, Protective Packaging, Inc., May 4, 1970.

Ref. 3: "ATMX-600 Railcars for Radioactive Waste Shipments," RFP-1411, January 7, 1970.

Ref. 4: Engineering Evaluation--"No. 741 First Stage in ICC-17C 55 Gallon Drums," F.E.Adcock, Rocky Flats Division, The Dow Chemical Company, December 4, 1967.

Ref. 5: Letter to Mr. Nussbaumer of A.E.C. from Mr. E. K. Reitler, Jr. of NUMEC on September 17, 1971 for DOT SP 6400, "Loading of Super Tiger With Waste Drums".

Ref. 6: Personal communication with Mr. H. D. Warren of LRC-A for decay energy release.

Ref. 7: C. M. Lederer, J. M. Hollander and I. Perlman, "Tables of Isotopes", Sixth Edition.