NuPac
NUCLEAR
PACKAGING, INC.
1733 SO. FAWCETT • TACOMA, WASHINGTON 98402 • (206) 572-7775

November 30, 1978 (NRC PUBLIC DOCUMENT ROOM)

Mr. Charles E. MacDonald, Chief
Transportation Branch
Division of Materials & Fuel Cycle Facility Licensing
United States Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Model No. CN6-80B Packaging
Docket No. 71-9116

Dear Mr. MacDonald:

In response to your letter of July 5, 1978, please find enclosed eight (8) copies of the information requested.

Should you require additional information, please do not hesitate calling.

Thank you.

Sincerely yours,

NUCLEAR PACKAGING, INC.

Larry J. Hansen

LJH/dmm

Enclosures

FEE EXEMPT
add'l info

7812180290

11390

INSTRUCTIONS FOR INCORPORATING REVISION 1 AMENDMENTS

TO MODEL CN6-80B APPLICATION, DATED SEPTEMBER 12, 1978

Insert new page ii	Remove old page ii
Insert new page iii	Remove old page iii
Add new page 1-9a	
Add new page 1-9b	
Add new page 1-9c	
Insert new page 1-21	Remove old page 1-21
Add new page 1-21a	
Insert new page 1-28	Remove old page 1-28
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Add new page 1-42c	
Add new page 1-42d	
Add new page 1-42e	
Add new page 1-42f	
Insert new page 1-43	Remove old page 1-43
Add new page 143-a	
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Instructions - Continued

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Insert new page 1-47	Remove old page 1-47
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Insert new page 1-48	Remove old page 1-48
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Insert new page 1-53	Remove old page 1-53
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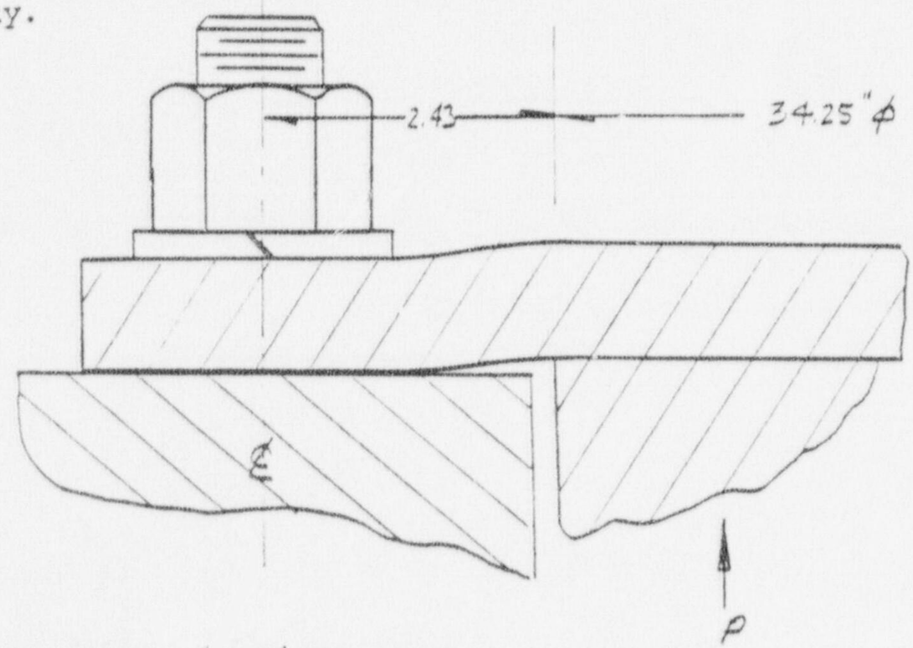
Insert new Dwg. No. BC-20-201D, Rev. A	Remove old Dwg. No. BC-20-201D

Loads from the lifting lugs are distributed to the secondary lid where they are reacted by the eight 1 inch diameter Grade 5 studs. The secondary lid must react these loads by plate bending. From the sketch below it can be seen that the bolts tend to "fix" one end of the plate while the attachment to the two 4 inch plates provides the other fixity.



Bending stress is given as:

$$f_b = 6P(L/2)/\ Dt^2$$

$$= (6)(57500)(3)(2.43/2)/\ (34.25)(1)^2$$

$$= 11686 \text{ psi}$$

$$M.S. = 36000/11686 - 1$$

$$M.S. = +2.08$$

If for conservatism the same analysis was repeated assuming no fixity of the bolts the stress would be; $f_b = 20934$ psi

$$M.S. = 36000/20934 - 1$$

$$M.S. = +.71$$

Lifting loads from the lugs are distributed into the top plate and the lower four inch plate by means of plug welds adjacent to each lug as well as a full perimeter weld. Conservatively assume only the plug welds as being effective. Ultimate capacity of the plug weld is given as:

$$P_u = F_{tu}A$$

$$= (55000 \text{ psi})(\pi)(1)^2/4$$

$$= 43197 \text{ lbs./plug weld}$$

or

$$= 129591 \text{ lbs./lug}$$

This load is (129591/57500 or) 2.25 times greater than the maximum 3g load condition. At loads greater than this the 1" thick top plate will locally shear from the lug out to the adjacent studs. This will leave the primary seal area uneffected and have no

detrimental effects on the packages ability to react other requirements of the subpart.

Therefore, it can be concluded that the lifting points are more than capable of reacting a load equal to three times the package weight.

1.6.5 Water Spray

Since the package exterior is constructed of steel, this test is not required.

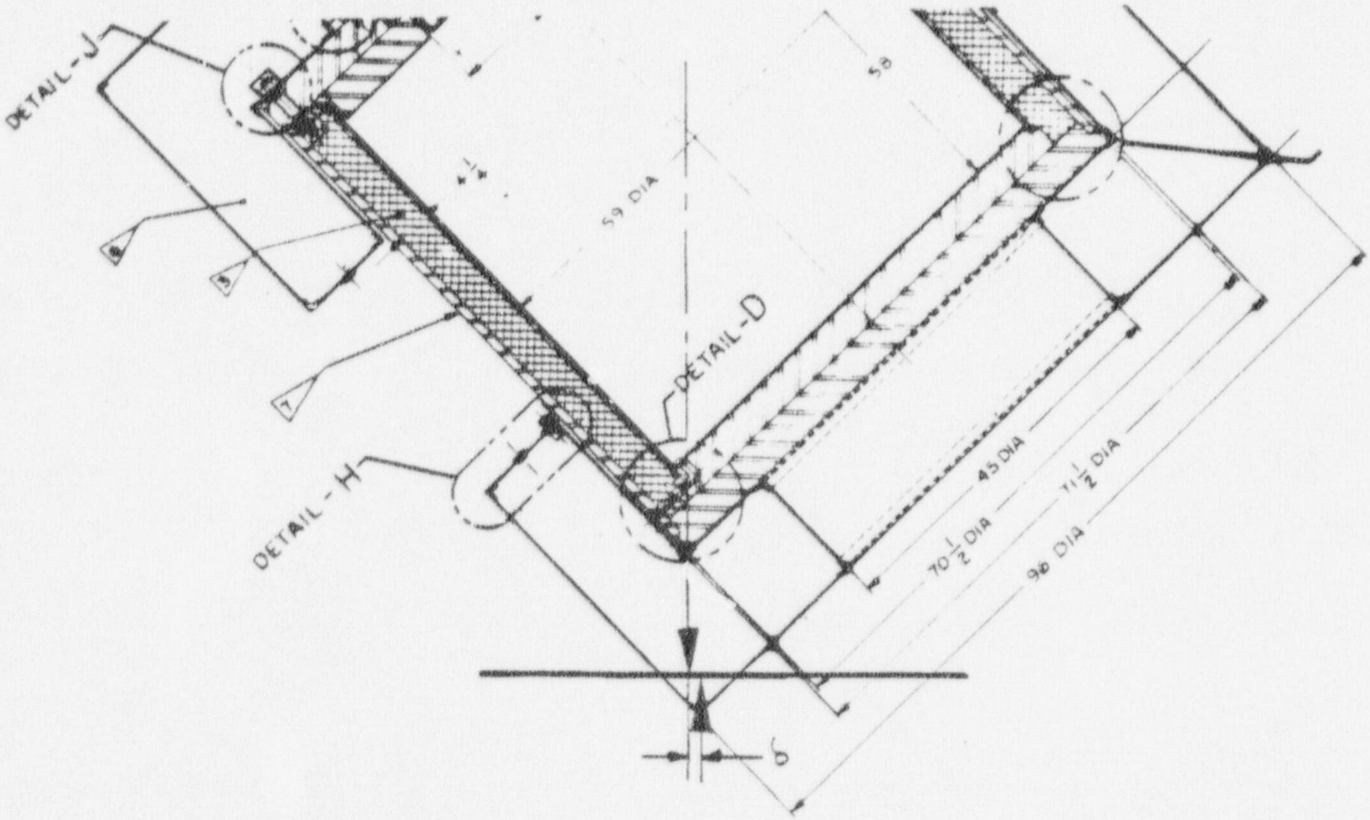
1.6.6 Free Drop

The Model CN6-80B package with payload weighs 57,500 lbs. Appendix A.6 of 10 CFR 71 prescribes a drop height of one (1) foot for packages in excess of 30,000 lbs. The overpack, designed to protect the cask under a 30' hypothetical free drop, effectively cushions and protects the cask from all "normal" free drop effects.

None-the-less, for additional conservatism, the analysis present in the Type "A" submittal for the CN6-80, as found in Section 1.6.6, page 1-13 through 1-19, demonstrates the adequacy of the cask to survive a one (1) foot drop by itself (without any assistance from the overpack).

The overpacks are attached to the cask body by means of 8-1 inch diameter bolts. Flat end drop condition will place the over pack in direction compression. The attachments will not experience loading. For the side drop condition tolerances around the attachment fixture allow the overpack to shift slightly until it can react loads in direct compression.

From the figure below it can be seen that the corner drop condition will produce a negative rotation, or compression load, on the overpack. Again for this condition the attachments remain essentially unloaded. Therefore, it can be concluded that the overpack will not produce loads on its attachments that will effect its ability to meet other sections of 10CFR71.



1.6.7 Corner Drop

This requirement is not applicable since the Model CN6-80B packaging is fabricated of steel.

1.6.8 Penetration

From previous container tests, as well as engineering judgment

Total equivalent wt.

$$WT = 2210 \text{ lbs} + 1812 \text{ lbs}$$

$$WT = 4022 \text{ lbs}$$

Bolt Loads

$$P = (4022 \text{ lbs})(128 \text{ g})/8 \text{ bolts}$$

$$P = 64352 \text{ lbs/bolt}$$

As shown in Section 1.4.3, the tensile strength of the secondary lid studs is 64745 lbs. Thus, the margin of safety is:

$$MS = 64745/64352 - 1$$

$MS = +.01$ Secondary Lid Closure Studs.

Shear out capacity of the threaded hole for a 1" diameter stud can be found from the following equation. (Ref ASA B1.1-1960 by ASME)

$$A_n = \pi N L_e D_s (1/2N + .5773(D_s - E_n))$$

WHERE:

A_n = Internal shear area

N = Number of threads per inch= (8)

L_e = Length of thread engagement= (1 in.)

D_s = Min. major diameter of external thread= (.9830 in.)

E_n = Max. pitch diameter of internal thread= (.9276 in.)

$A_n = \pi(8)(1)(.983)(.0625 + .5773(.9830-.9276))$

$A_n = 2.31\ in^2$ per inch of length

Ultimate shear out capacity is then given as

$P = F_{su}A_n$

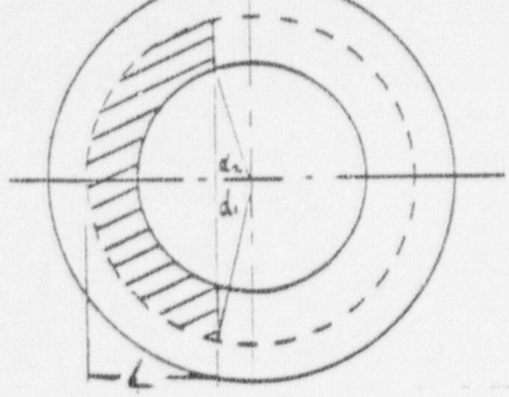
$= (36000\ psi)(2.31\ in^2)$

$= 83160$ lbs. per inch of depth

A hole drilled and tapped to a depth of one inch into the lid will possess a capacity equal to that at the Grade 5 stud. From the drawing it can be seen that each of the secondary lid studs are located in holes 2 inches deep. Therefore, it can be concluded that the studs will not shear out prior to developing their full tension capability.

Conclusion: It is therefore safe to conclude that the package can safely react the maximum loads for a 30 foot end drop without detrimental effects.

The projected area is calculated as follows:



From the print out shown on page 1-43, column 9, it can be seen that 90% of the impact area is experiencing a compressive stress between 4000 psi @ 70% strain and 1000 psi @ 7% strain. The 10% is experiencing compressive stresses greater than 4000 psi. Therefore it will be conservative to assume that the average stress felt across the impact area will be 2000 psi or greater.

The lid will experience a compressive force across this projected area. Conservatively assume that the nominal 1000 psi foam crush strength will be felt over this area. The area is given by:

$$A = r_1^2 \left(\alpha_1 - \frac{\sin 2\alpha_1}{2}\right) - r_2^2 \left(\alpha_2 - \frac{\sin 2\alpha_2}{2}\right)$$

Where:

$r_1 = 35.3$ in.

$r_2 = 22.5$ in.

$\alpha_1 = 79.92^\circ$

$\alpha_2 = 74.14^\circ$

$A = 986.71 \text{ in.}^2$

The overpack reaction will be:

$R = AF_{cr}$

$= (986.7\ in^2)(2000psi)$

$= 1,973,400$ lbs.

This load will be applied of the centroid of the area. Distance to the centroid is given as:

$\bar{x} = 2 \sin \alpha (R_o{}^3 - R_1{}^3)/3 \quad (R_o{}^2 - R_1{}^2)$

(Per Handbook of "Formulas for Stress & Strain" by Ungar)

Where:

$\alpha = 79.9^\circ$

$R_o = 35.3$ in.

$R_1 = 22.5$ in.

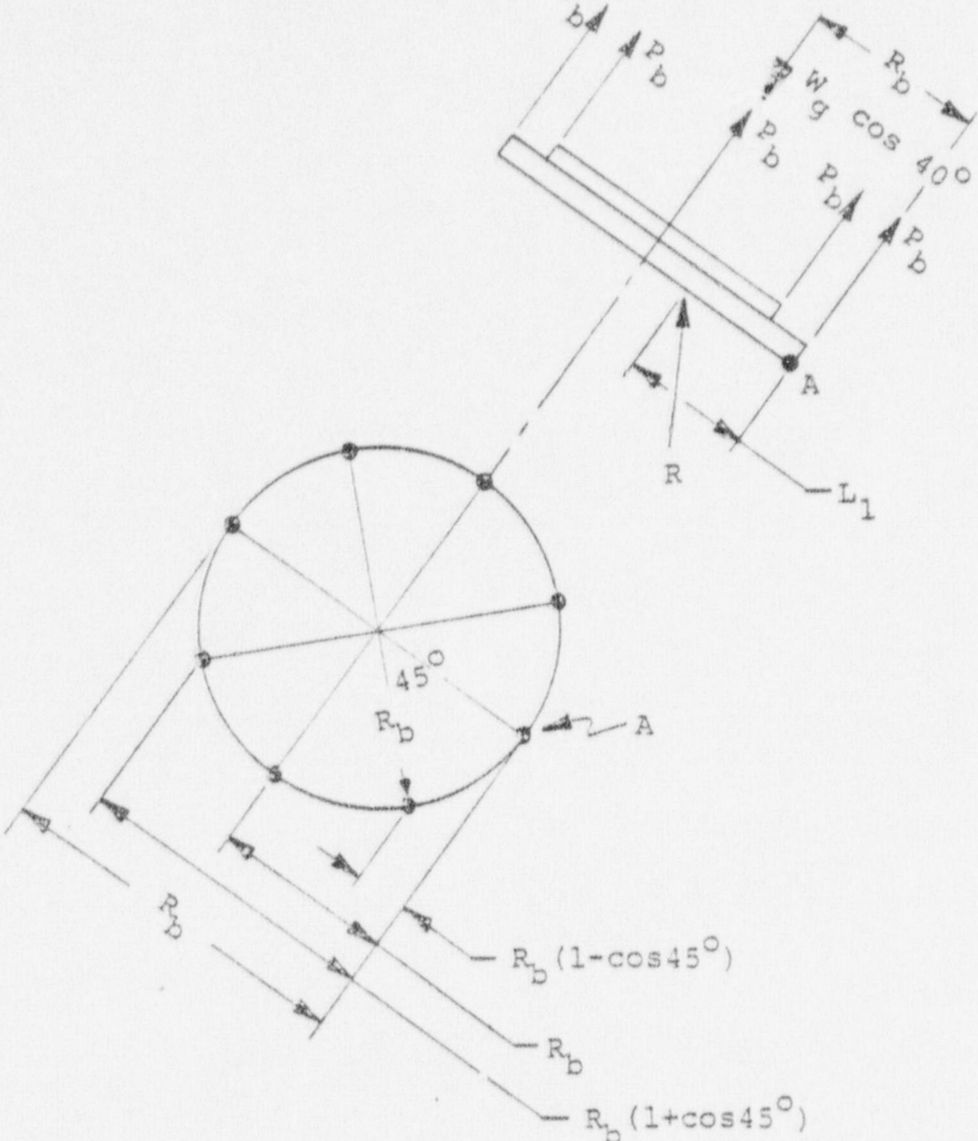
$\bar{x} = 2(\text{Sin } 79.9^\circ)(35.3^3 - 22.5^3)/3(1.39)(35.3^2 - 22.5^2)$

$\bar{x} = 20.66$ in.

$L_1 = d/2 - \bar{x}$

$= 70.25/2 - 20.66$

$= 14.46$ in.



$$\Sigma M_A = 0$$

$$W g R_b \cos 40^\circ = R L_1 \cos 40^\circ + P_b \left[2R_b(1-\cos 45^\circ) + 2R_b + 2R_b(1+\cos 45^\circ) + R_b \right]$$

Where:

W = (Payload + Lid + Overpack)

= (7500 lbs. + 7600 lbs. + 3000 lbs.)

= 18100 lbs.

g = 80.4 g's (Max.)

R_b = 65.5/2 in. = 32.75 in.

R = 1,973,400 lbs.

L_1 = 14.46 in.

$$(18100)(80.4)(32.75)\text{Cos } 42.7^\circ = (1,973,400)(14.46)\text{Cos } 42.7^\circ + (2)(32.75)P_b(1-\text{Cos } 45^\circ+1+1+\text{Cos } 45^\circ+.5)$$

$$35,025,375 = 20,971,000 + 229.25$$

$$P_b = 61,305 \text{ lbs. per bolt}$$

Therefore, the maximum bolt load will be 61,305 lbs. Capacity of the high strength 1-1/4 in. bolt is 95,248 lbs. The Margin of Safety is:

M.S. = 95,248/61,305-1

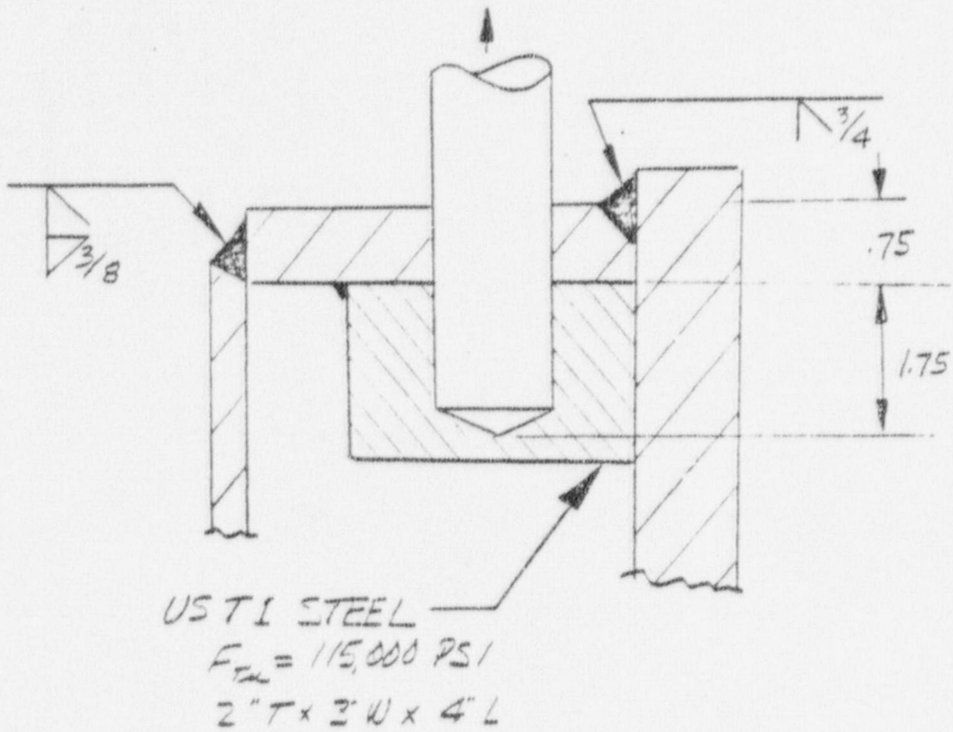
M.S. = +.55 Closure System

This number is conservative since the average compressive stress acting across the lid face will be substantially greater than the nominal 2000 psi assumed here. The higher foam compressive stress reduces the load that must be reacted by the primary studs. Secondly, the effective area will be considerably larger than that assumed. Foam does have the ability to distribute loads out over a larger footprint. This will also increase the load carried by the overpack. Thirdly, a major portion of the overpack weight will be reacted directly onto the impact surface thus reducing the load experienced by the primary studs.

Each stud is threaded into the top closure ring and high strength doubler. Total thread engagement includes .75 inches for the closure ring and 1.75 inches into the doubler. Recommended thread engagement is that equal to the thickness of a heat treated nut of the same tensile strength as the stud. Minimum thickness for a 1 1/4 NC Heavy Hex Nut is 1.250 in. (Max.), per Machinery Handbook. Since the doubler is manufactured from a material of greater strength than the stud, the following conservative margin of safety can be calculated.

M.S. = 1.75 in./1.25 in. -1

<u>M.S. = +.40</u>



Tear out or shear strength at the closure ring is calculated as follows. Conservatively assume that the closure ring welds are effective only out 4 inches on either side of the stud center line.

$P_w = F_{su} A_{weld}$

Where:

$F_{su} = 35{,}000$ psi

$A_{weld} = \left[(3/4)(.707)+(3/8)\right] 8$

$= 7.24 \text{ in}^2$

$P_w = (35{,}000 \text{ psi})(7.24 \text{ in}^2)$

$P_w = 253{,}470$ lbs.

Margin of Safety

M.S. = 253,470/61,305 -1

M.S. = + Large

Therefore, it can be concluded that both the stud and its attachments are capable of reacting the loads.

The secondary lid studs are also loaded by these impact accelerations. The problem is considerably simpler to evaluate because the overpack does not bear upon this secondary lid. The stud loads are evaluated as:

$P_s = (W)(a_g)(\text{Cos } \theta)/N$

CASE NR. 1
Minimum Properties
45"ϕ void

PACKAGE WEIGHT	=	57500.	(LBS)
PACKAGE EXTERNAL LENGTH	=	104.00	(IN)
PACKAGE EXTERNAL DIAMETER	=	96.00	(IN)
PACKAGE EXTERNAL HOLE DIA	=	45.60	(IN)
PAYLOAD ENVELOPE LENGTH	=	74.00	(IN)
PAYLOAD ENVELOPE DIAMETER	=	70.25	(IN)
DROP HEIGHT	=	30.00	(FT)
ORIENTATION ANGLE	=	.7454	(RADIAN
NOMINAL CRUSH STRESS	=	0.00	(PSI)

STRAIN VS STRESS TABLE

PT	STRAIN	STRESS
1	0.00	0.00
2	.05	650.00
3	.07	850.00
4	.10	950.00
5	.20	1000.00
6	.25	1050.00
7	.30	1150.00
8	.40	1260.00
9	.45	1400.00
10	.50	1600.00
11	.60	2250.00
12	.70	3850.00
13	.75	5300.00
14	.80	7400.00
15	.90	13800.00
16	.95	18500.00
17	.99	24000.00

CRUSH DEPTH (IN)	** CRUSH PLANE ** AREA (IN2)	VOLUME (IN3)	**** IMPACT **** FORCE (LBS)	ACCEL. (G)	****** ENERGY ****** KINETIC (IN-LB)	STRAIN (IN-LB)	RATIO (SE/KE)	DISTRIBUTION OF STRAIN RATIOS BY PERCENT OF CONTACT AREA LE.70	GT.70 LE.80	GT.80 LE.90	GT.90 LE.95	GT.95
1.00	31.6	8.	8178.	.1	20757500.	2045.	.000	100.00	0.00	0.00	0.00	0.00
1.50	57.8	30.	22383.	.4	20786250.	9687.	.000	100.00	0.00	0.00	0.00	0.00
2.00	88.6	67.	43878.	.8	20815000.	26253.	.001	100.00	0.00	0.00	0.00	0.00
2.50	123.4	120.	71032.	1.2	20843750.	54981.	.003	100.00	0.00	0.00	0.00	0.00
3.00	161.5	191.	102936.	1.8	20872500.	98473.	.005	100.00	0.00	0.00	0.00	0.00
3.50	202.7	282.	138872.	2.4	20901250.	158925.	.008	100.00	0.00	0.00	0.00	0.00
4.00	246.7	394.	178228.	3.1	20930000.	238200.	.011	100.00	0.00	0.00	0.00	0.00
4.50	293.1	529.	220797.	3.8	20958750.	337956.	.016	100.00	0.00	0.00	0.00	0.00
5.00	341.9	688.	266532.	4.6	20987500.	459788.	.022	100.00	0.00	0.00	0.00	0.00
5.50	392.8	872.	315633.	5.5	21016250.	605329.	.029	100.00	0.00	0.00	0.00	0.00
6.00	445.7	1081.	368335.	6.4	21045000.	776322.	.037	100.00	0.00	0.00	0.00	0.00
6.50	499.4	1318.	424643.	7.4	21073750.	974565.	.046	100.00	0.00	0.00	0.00	0.00
7.00	556.8	1582.	484257.	8.4	21102500.	1201791.	.057	100.00	0.00	0.00	0.00	0.00
7.50	614.9	1875.	547013.	9.5	21131250.	1459609.	.069	100.00	0.00	0.00	0.00	0.00
8.00	674.5	2198.	612969.	10.7	21160000.	1749604.	.083	100.00	0.00	0.00	0.00	0.00
8.50	735.4	2550.	680625.	11.8	21188750.	2073003.	.098	100.00	0.00	0.00	0.00	0.00
9.00	797.7	2933.	752307.	13.1	21217500.	2431236.	.115	100.00	0.00	0.00	0.00	0.00
9.50	861.2	3348.	822012.	14.3	21246250.	2824916.	.133	100.00	0.00	0.00	0.00	0.00
10.00	925.9	3795.	897525.	15.6	21275000.	3254700.	.153	100.00	0.00	0.00	0.00	0.00
10.50	991.7	4274.	972675.	16.9	21303750.	3722250.	.175	100.00	0.00	0.00	0.00	0.00
11.00	1058.5	4787.	1052881.	18.3	21332500.	4228639.	.198	100.00	0.00	0.00	0.00	0.00
11.50	1126.3	5333.	1141537.	19.9	21361250.	4777244.	.224	100.00	0.00	0.00	0.00	0.00
12.00	1194.9	5913.	1228475.	21.4	21390000.	5369747.	.251	100.00	0.00	0.00	0.00	0.00
12.50	1264.3	6528.	1325312.	23.0	21418750.	6008194.	.281	100.00	0.00	0.00	0.00	0.00
13.00	1334.6	7178.	1434727.	25.0	21447500.	6698204.	.312	100.00	0.00	0.00	0.00	0.00
13.50	1405.5	7863.	1557588.	27.1	21476250.	7446283.	.347	100.00	0.00	0.00	0.00	0.00
14.00	1477.1	8584.	1682754.	29.3	21505000.	8256368.	.384	100.00	0.00	0.00	0.00	0.00
14.50	1549.3	9340.	1828872.	31.8	21533750.	9134275.	.424	99.34	.66	0.00	0.00	0.00
15.00	1622.1	10133.	1994158.	34.7	21562500.	10090032.	.468	97.17	2.83	0.00	0.00	0.00
15.50	1695.3	10962.	2197892.	38.2	21591250.	11138045.	.516	95.86	4.14	0.00	0.00	0.00
16.00	1769.0	11828.	2421005.	42.1	21620000.	12292769.	.569	94.99	5.01	0.00	0.00	0.00
16.50	1843.1	12731.	2678859.	46.6	21648750.	13567735.	.627	92.08	7.40	.52	0.00	0.00
17.00	1917.6	13672.	2988858.	52.0	21677500.	14984664.	.691	89.88	7.70	2.42	0.00	0.00
17.50	1992.4	14649.	3336936.	58.0	21706250.	16566113.	.763	88.21	7.77	4.01	0.00	0.00
18.00	2067.4	15664.	3765612.	65.5	21735000.	18341750.	.844	87.23	7.91	4.86	0.00	0.00
18.50	2142.7	16717.	4257707.	74.0 [handwritten: 80.1]	21763750.	20347580.	.935	84.97	9.33	5.53	.18	0.00
19.00	2218.2	17807.	4812600.	83.7	21792500.	22615155.	1.038	82.35	8.67	7.00	1.98	0.00
19.50	2293.8	18935.	5473362.	95.2	21821250.	25186647.	1.154	80.12	8.99	7.39	3.50	0.00
20.00	2369.5	20101.	6225279.	108.3	21850000.	28111307.	1.287	78.61	9.04	7.68	2.85	1.82

CASE NR. 2
MINIMUM PROPERTIES
NO VOID.

PACKAGE WEIGHT = 57500. (LBS)
PACKAGE EXTERNAL LENGTH = 104.00 (IN)
PACKAGE EXTERNAL DIAMETER= 96.00 (IN)
PACKAGE EXTERNAL HOLE DIA= 1.00 (IN)
PAYLOAD ENVELOPE LENGTH = 74.00 (IN)
PAYLOAD ENVELOPE DIAMETER= 70.25 (IN)

DROP HEIGHT = 30.00 (FT)
ORIENTATION ANGLE = .7454 (RADIAN

NOMINAL CRUSH STRESS = 0.00 (PSI)

STRAIN VS STRESS TABLE

PT	STRAIN	STRESS
1	0.00	0.00
2	.05	650.00
3	.07	850.00
4	.10	950.00
5	.20	1000.00
6	.25	1050.00
7	.30	1150.00
8	.40	1260.00
9	.45	1400.00
10	.50	1600.00
11	.60	2250.00
12	.70	3850.00
13	.75	5300.00
14	.80	7400.00
15	.90	13800.00
16	.95	18500.00
17	.99	24000.00

CRUSH DEPTH (IN)	** CRUSH PLANE ** AREA (IN2)	VOLUME (IN3)	**** IMPACT **** FORCE (LBS)	ACCEL. (G)	****** ENERGY ****** KINETIC (IN-LB)	STRAIN (IN-LB)	RATIO (SE/KE)	DISTRIBUTION OF STRAIN RATIOS BY PERCENT OF CONTACT AREA LE.70	GT.70 LE.80	GT.80 LE.90	GT.90 LE.95	GT.95
1.00	31.6	8.	8179.	.1	20757500.	2045.	.000	100.00	0.00	0.00	0.00	0.00
1.50	57.9	30.	22389.	.4	20786250.	9687.	.000	100.00	0.00	0.00	0.00	0.00
2.00	88.6	67.	43878.	.8	20815000.	26253.	.001	100.00	0.00	0.00	0.00	0.00
2.50	123.4	120.	71032.	1.2	20843750.	54981.	.003	100.00	0.00	0.00	0.00	0.00
3.00	161.5	191.	102935.	1.8	20872500.	98473.	.005	100.00	0.00	0.00	0.00	0.00
3.50	202.7	282.	138872.	2.4	20901250.	158925.	.008	100.00	0.00	0.00	0.00	0.00
4.00	246.7	394.	178223.	3.1	20930000.	238200.	.011	100.00	0.00	0.00	0.00	0.00
4.50	293.1	529.	220797.	3.8	20958750.	337956.	.016	100.00	0.00	0.00	0.00	0.00
5.00	341.9	688.	266532.	4.6	20987500.	459788.	.022	100.00	0.00	0.00	0.00	0.00
5.50	392.8	872.	315633.	5.5	21016250.	605329.	.029	100.00	0.00	0.00	0.00	0.00
6.00	445.7	1081.	368335.	6.4	21045000.	776322.	.037	100.00	0.00	0.00	0.00	0.00
6.50	500.4	1318.	424643.	7.4	21073750.	974566.	.045	100.00	0.00	0.00	0.00	0.00
7.00	556.9	1592.	484257.	8.4	21102500.	1201791	.057	100.00	0.00	0.00	0.00	0.00
7.50	614.9	1875.	547013.	9.5	21131250.	1459609.	.069	100.00	0.00	0.00	0.00	0.00
8.00	674.5	2198.	612969.	10.7	21160000.	1749604.	.083	100.00	0.00	0.00	0.00	0.00
8.50	735.4	2559.	682259.	11.9	21188750.	2073411.	.098	100.00	0.00	0.00	0.00	0.00
9.00	797.7	2933.	755394.	13.1	21217500.	2432824.	.115	100.00	0.00	0.00	0.00	0.00
9.50	861.7	3348.	832715.	14.5	21246250.	2829852.	.133	100.00	0.00	0.00	0.00	0.00
10.00	925.9	3705.	914721.	15.9	21275000.	3266711.	.154	100.00	0.00	0.00	0.00	0.00
10.50	991.7	4274.	1001880.	17.4	21303750.	3745861	.176	100.00	0.00	0.00	0.00	0.00
11.00	1058.5	4797.	1094439.	19.0	21332500.	4269941.	.200	100.00	0.00	0.00	0.00	0.00
11.50	1126.3	5333.	1193094.	20.7	21361250.	4841824.	.227	100.00	0.00	0.00	0.00	0.00
12.00	1194.9	5913.	1298435.	22.6	21390000.	5464707.	.255	100.00	0.00	0.00	0.00	0.00
12.50	1264.3	6529.	1411145.	24.5	21418750.	6142103.	.287	100.00	0.00	0.00	0.00	0.00
13.00	1334.6	7178.	1536179.	26.7	21447500.	6878934.	.321	100.00	0.00	0.00	0.00	0.00
13.50	1405.5	7863.	1670177.	29.0	21476250.	7680523.	.358	100.00	0.00	0.00	0.00	0.00
14.00	1477.1	8586.	1823098.	31.7	21505000.	8553841.	.398	100.00	0.00	0.00	0.00	0.00
14.50	1549.3	9340.	1988943.	34.6	21533750.	9506852.	.441	99.42	.58	0.00	0.00	0.00
15.00	1622.1	10133.	2174062.	37.8	21562500.	10547603.	.489	97.52	2.48	0.00	0.00	0.00
15.50	1695.3	10962.	2395401.	41.7	21591250.	11689969.	.541	96.39	3.61	0.00	0.00	0.00
16.00	1769.0	11828.	2636834.	45.9	21620000.	12948028.	.599	95.67	4.33	0.00	0.00	0.00
16.50	1843.1	12731.	2930167.	51.0	21648750.	14339778.	.662	93.23	6.32	.44	0.00	0.00
17.00	1917.6	13672.	3268581.	56.8	21677500.	15889465.	.733	91.42	6.53	2.05	0.00	0.00
17.50	1992.4	14649.	3641503.	63.3	21706250.	17616986.	.812	90.09	6.54	3.38	0.00	0.00
18.00	2067.4	15664.	4093066.	71.2	21735000.	19550628.	.899	89.28	6.64	4.08	0.00	0.00
18.50	2142.7	16717.	4615163.	80.3	21763750.	21727685.	.998	87.44	7.78	4.61	.15	0.00
19.00	2218.2	17807.	5192177.	90.3	21792500.	24179520.	1.110	85.34	7.20	5.83	1.64	0.00
19.50	2293.8	18935.	5882459.	102.3	21821250.	26948220.	1.235	83.57	7.41	6.04	2.96	0.00
20.00	2369.5	20191.	6686959.	116.3	21850000.	30090531.	1.377	82.50	7.40	6.21	2.33	1.49

80A

CASE NR. 3
MAXIMUM PROPERTIES
45"ϕ VOID

PACKAGE WEIGHT	=	57500. (LBS)
PACKAGE EXTERNAL LENGTH	=	104.00 (IN)
PACKAGE EXTERNAL DIAMETER	=	96.00 (IN)
PACKAGE EXTERNAL HOLE DIA	=	45.00 (IN)
PAYLOAD ENVELOPE LENGTH	=	74.00 (IN)
PAYLOAD ENVELOPE DIAMETER	=	70.25 (IN)
DROP HEIGHT	=	30.00 (FT)
ORIENTATION ANGLE	=	.7454 (RADIAN
NOMINAL CRUSH STRESS	=	0.00 (PSI)

STRAIN VS STRESS TABLE

PT	STRAIN	STRESS
1	0.00	0.00
2	.05	850.00
3	.07	1000.00
4	.10	1050.00
5	.20	1200.00
6	.25	1300.00
7	.30	1350.00
8	.40	1500.00
9	.45	1620.00
10	.50	1800.00
11	.60	2550.00
12	.70	4400.00
13	.75	6100.00
14	.80	8350.00
15	.90	15300.00
16	.95	20500.00
17	.99	25600.00

CRUSH DEPTH (IN)	** CRUSH PLANE ** AREA (IN2)	VOLUME (IN3)	**** IMPACT **** FORCE (LBS)	ACCEL. (G)	****** ENERGY ****** KINETIC (IN-LB)	STRAIN (IN-LB)	RATIO (SE/KE)	DISTRIBUTION OF STRAIN RATIOS BY PERCENT OF CONTACT AREA LE.70	GT.70 LE.80	GT.80 LE.90	GT.90 LE.95	GT.95
1.00	31.6	9.	12692.	.2	20757500.	3173.	.000	100.00	0.00	0.00	0.00	0.00
1.50	57.8	30.	31525.	.5	20786250.	14227.	.001	100.00	0.00	0.00	0.00	0.00
2.00	88.6	67.	57693.	1.0	20815000.	36532.	.002	100.00	0.00	0.00	0.00	0.00
2.50	123.4	120.	89423.	1.6	20843750.	73311.	.004	100.00	0.00	0.00	0.00	0.00
3.00	161.5	191.	126147.	2.2	20872500.	127203.	.006	100.00	0.00	0.00	0.00	0.00
3.50	202.7	282.	167576.	2.9	20901250.	200634.	.010	100.00	0.00	0.00	0.00	0.00
4.00	246.7	394.	213486.	3.7	20930000.	295899.	.014	100.00	0.00	0.00	0.00	0.00
4.50	293.1	529.	263875.	4.6	20958750.	415239.	.020	100.00	0.00	0.00	0.00	0.00
5.00	341.9	688.	318699.	5.5	20987500.	560883.	.027	100.00	0.00	0.00	0.00	0.00
5.50	392.8	872.	377943.	6.6	21016250.	735044.	.035	100.00	0.00	0.00	0.00	0.00
6.00	445.7	1081.	441212.	7.7	21045000.	939332.	.045	100.00	0.00	0.00	0.00	0.00
6.50	500.4	1318.	508187.	8.9	21073750.	1177182.	.056	100.00	0.00	0.00	0.00	0.00
7.00	556.8	1582.	578045.	10.1	21102500.	1448965.	.069	100.00	0.00	0.00	0.00	0.00
7.50	614.9	1875.	653591.	11.4	21131250.	1757039.	.083	100.00	0.00	0.00	0.00	0.00
8.00	674.5	2198.	732093.	12.7	21160000.	2103520.	.099	100.00	0.00	0.00	0.00	0.00
8.50	735.4	2550.	811898.	14.1	21188750.	2489519.	.117	100.00	0.00	0.00	0.00	0.00
9.00	797.7	2933.	896128.	15.6	21217500.	2916524.	.137	100.00	0.00	0.00	0.00	0.00
9.50	861.2	3349.	977487.	17.0	21246250.	3384928.	.159	100.00	0.00	0.00	0.00	0.00
10.00	925.9	3795.	1065275.	18.5	21275000.	3895519.	.183	100.00	0.00	0.00	0.00	0.00
10.50	991.7	4274.	1152772.	20.0	21303750.	4450130.	.209	100.00	0.00	0.00	0.00	0.00
11.00	1058.5	4787.	1245475.	21.7	21332500.	5049693.	.237	100.00	0.00	0.00	0.00	0.00
11.50	1124.3	5333.	1347408.	23.4	21361250.	5697913.	.267	100.00	0.00	0.00	0.00	0.00
12.00	1194.0	5913.	1446719.	25.2	21390000.	6396444.	.299	100.00	0.00	0.00	0.00	0.00
12.50	1264.3	6528.	1557323.	27.1	21418750.	7147454.	.334	100.00	0.00	0.00	0.00	0.00
13.00	1334.6	7178.	1662689.	29.3	21447500.	7957455.	.371	100.00	0.00	0.00	0.00	0.00
13.50	1405.5	7863.	1822289.	31.7	21476250.	8833697.	.411	100.00	0.00	0.00	0.00	0.00
14.00	1477.1	8584.	1964746.	34.2	21505000.	9780456.	.455	100.00	0.00	0.00	0.00	0.00
14.50	1549.3	9340.	2130827.	37.1	21533750.	10804349.	.502	99.34	.66	0.00	0.00	0.00
15.00	1622.1	10133.	2319356.	40.3	21562500.	11916895.	.553	97.17	2.83	0.00	0.00	0.00
15.50	1695.3	10962.	2553674.	44.4	21591250.	13135153.	.608	95.86	4.14	0.00	0.00	0.00
16.00	1769.0	11828.	2807847.	48.8	21620000.	14475533.	.670	94.99	5.01	0.00	0.00	0.00
16.50	1843.1	12731.	3098872.	53.9	21648750.	15952213.	.737	92.08	7.40	.52	0.00	0.00
17.00	1917.6	13672.	3449207.	60.0	21677500.	17589232.	.811	89.84	7.70	2.47	0.00	0.00
17.50	1992.4	14649.	3840263.	66.8	21706250.	19411599.	.894	88.21	7.77	4.01	0.00	0.00
18.00	2067.4	15664.	4320463.	75.1	21735000.	21451780.	.987	87.23	7.91	4.86	0.00	0.00
18.50	2142.7	16717.	4869028.	84.7	21763750.	23749153.	1.091	84.07	9.33	5.53	0.00	0.00
19.00	2219.2	17807.	5489014.	95.5	21792500.	26338664.	1.209	82.35	8.67	7.00	.18	0.00
19.50	2293.8	18935.	6228895.	108.3	21821250.	29268141.	1.341	80.12	8.99	7.30	1.08	0.00
20.00	2369.5	20101.	7056995.	122.7	21850000.	32589613.	1.493	78.61	9.06	7.68	3.85	1.82

Case Nr. 4
Maximum Properties
No void.

PACKAGE WEIGHT = 57500. (LBS)
PACKAGE EXTERNAL LENGTH = 104.00 (IN)
PACKAGE EXTERNAL DIAMETER= 96.00 (IN)
PACKAGE EXTERNAL HOLE DIA= 1.00 (IN)
PAYLOAD ENVELOPE LENGTH = 74.00 (IN)
PAYLOAD ENVELOPE DIAMETER= 70.25 (IN)

DROP HEIGHT = 30.00 (FT)
ORIENTATION ANGLE = .7454 (RADIAN

NOMINAL CRUSH STRESS = 0.00 (PSI)

STRAIN VS STRESS TABLE

PT	STRAIN	STRESS
1	0.00	0.00
2	.05	850.00
3	.07	1000.00
4	.10	1050.00
5	.20	1200.00
6	.25	1300.00
7	.30	1350.00
8	.40	1500.00
9	.45	1620.00
10	.50	1800.00
11	.60	2550.00
12	.70	4400.00
13	.75	6100.00
14	.80	8330.00
15	.90	15300.00
16	.95	20500.00
17	.99	25600.00

CRUSH DEPTH (IN)	** CRUSH PLANE ** AREA (IN2)	VOLUME (IN3)	**** IMPACT **** FORCE (LBS)	ACCEL. (G)	****** ENERGY ****** KINETIC (IN-LB)	STRAIN (IN-LB)	RATIO (SE/KE)	DISTRIBUTION OF STRAIN RATIOS BY PERCENT OF CONTACT AREA LE.70	GT.70 LE.80	GT.80 LE.90	GT.90 LE.95	GT.95
1.00	31.6	8.	12692.	.2	20757500.	3173.	.000	100.00	0.00	0.00	0.00	0.00
[illegible]	57.9	30.	31525.	.5	20786250.	14227.	.001	100.00	0.00	0.00	0.00	0.00
[illegible]	88.6	67.	57693.	1.0	20815000.	36532.	.002	100.00	0.00	0.00	0.00	0.00
[illegible]	123.4	120.	89423.	1.6	20843750.	73311.	.004	100.00	0.00	0.00	0.00	0.00
[illegible]	161.5	191.	126147.	2.2	20872500.	127203.	.006	100.00	0.00	0.00	0.00	0.00
[illegible]	202.7	282.	167576.	2.9	20901250.	200634.	.010	100.00	0.00	0.00	0.00	0.00
[illegible]	246.7	394.	213486.	3.7	20930000.	295899.	.014	100.00	0.00	0.00	0.00	0.00
4.50	293.1	529.	263875.	4.6	20958750.	415239.	.020	100.00	0.00	0.00	0.00	0.00
5.00	341.9	688.	318699.	5.5	20987500.	560883.	.027	100.00	0.00	0.00	0.00	0.00
5.50	392.8	872.	377943.	6.6	21016250.	735044.	.035	100.00	0.00	0.00	0.00	0.00
6.00	445.7	1081.	441712.	7.7	21045000.	939832.	.045	100.00	0.00	0.00	0.00	0.00
6.50	500.4	1318.	508187.	8.8	21073750.	1177182.	.056	100.00	0.00	0.00	0.00	0.00
7.00	556.8	1582.	578945.	10.1	21102500.	1448965.	.069	100.00	0.00	0.00	0.00	0.00
7.50	614.9	1875.	653591.	11.4	21131250.	1757999.	.083	100.00	0.00	0.00	0.00	0.00
8.00	674.5	2198.	732093.	12.7	21160000.	2103520.	.099	100.00	0.00	0.00	0.00	0.00
8.50	735.4	2553.	814616.	14.2	21188750.	2490198.	.118	100.00	0.00	0.00	0.00	0.00
9.00	797.7	2933.	901220.	15.7	21217500.	2919156.	.138	100.00	0.00	0.00	0.00	0.00
9.50	861.2	3349.	992333.	17.3	21246250.	3392545.	.160	100.00	0.00	0.00	0.00	0.00
10.00	925.9	3795.	1088251.	18.9	21275000.	3912691.	.184	100.00	0.00	0.00	0.00	0.00
10.50	991.7	4274.	1189525.	20.7	21303750.	4482135.	.210	100.00	0.00	0.00	0.00	0.00
11.00	1058.5	4787.	1296639.	22.6	21332500.	5103675.	.239	100.00	0.00	0.00	0.00	0.00
11.50	1126.3	5333.	1410237.	24.5	21361250.	5780394.	.271	100.00	0.00	0.00	0.00	0.00
12.00	1194.9	5913.	1531165.	26.6	21390000.	6515745.	.305	100.00	0.00	0.00	0.00	0.00
12.50	1264.3	6529.	1660512.	28.9	21418750.	7313564.	.341	100.00	0.00	0.00	0.00	0.00
13.00	1334.6	7178.	1804479.	31.4	21447500.	8179912.	.381	100.00	0.00	0.00	0.00	0.00
13.50	1405.5	7863.	1957659.	34.0	21476250.	9120445.	.425	100.00	0.00	0.00	0.00	0.00
14.00	1477.1	8584.	2133516.	37.1	21505000.	10143240.	.472	100.00	0.00	0.00	0.00	0.00
14.50	1549.2	9340.	2322960.	40.4	21533750.	11257359.	.523	99.42	.58	0.00	0.00	0.00
15.00	1622.1	10133.	2535335.	44.1	21562500.	12471933.	.578	97.52	2.48	0.00	0.00	0.00
15.50	1695.3	10962.	2790681.	48.5	21591250.	13863438.	.639	96.39	3.61	0.00	0.00	0.00
16.00	1768.0	11828.	3066871.	53.3	21620000.	15267825.	.706	95.67	4.33	0.00	0.00	0.00
16.50	1843.1	12731.	3400583.	59.1	21648750.	16884689.	.780	93.23	6.32	.44	0.00	0.00
17.00	1917.6	13672.	3784300.	65.8	21677500.	18680909.	.862	91.42	6.53	2.05	0.00	0.00
17.50	1992.4	14549.	4264739.	11.2 73.1	21706250.	20678169.	.953	90.08	6.54	3.38	0.00	0.00
18.00	2067.4	15664.	4711643.	81.9	21735000.	22907366.	1.054	88.98	6.64	4.08	0.00	0.00
18.50	2142.7	16717.	5295269.	92.1	21763750.	25408977.	1.167	87.46	7.78	4.61	.15	0.00
19.00	2218.2	17907.	5940591.	103.3	21792500.	28217927.	1.295	86.34	7.20	4.81	1.64	0.00
19.50	2293.8	19035.	6714645.	116.8	21821250.	31381737.	1.438	83.57	7.43	6.04	2.96	0.00
20.00	2369.5	20101.	7603057.	132.2	21850000.	34961162.	1.600	82.53	7.40	6.28	2.33	1.49

Therefore, it can be concluded that the studs static allowable capabilities will not be lower under shock or dynamic loading.

Lateral or shear loads resulting from the corner drop condition are reacted by the deep stepped lid. The two lid plates are tied together by way of two welds with a total capacity of:

$$A = (59)(\pi)(1/2)(\sin 45^{\circ})+(34.75)\pi(1/2)(\sin 45^{\circ})$$

$$A = 6.55 \text{ in}^2 + 38.6 \text{ in}^2 = 104.1 \text{ in}^2$$

$$P_s = F_s A$$

$$= (35000 \text{ psi})(104.1 \text{ in}^2)$$

$$= 3,644,500 \text{ lbs capacity}$$

Shear loads will be:

$$F = \left[64000 \text{ lbs} - 7600 \text{ lbs (lid)} - 3000 \text{ lb(O.P.)}\right] \cos 40^{\circ} \text{ (80.4 g's)}$$

$$F = 3,288,000 \text{ lbs (Maximum)}$$

Margin of Safety

M.S. = 3,644,500/3,288,000 -1

M.S. = +.11

Therefore, the stepped lid can safely react all lateral loads resulting from corner drop impact conditions.

1.7.1.3 Free Drop Impact Analysis, Side Drop

Detrimental effects resulting from a side drop are limited to the closure areas. Both primary and secondary lids are deeply stepped and manufactured from solid steel plates. The side impact

loads produce lateral shear forces that are reacted in direct compression of the lapped joint. Bolts securing the secondary lid are not required to react this shear force since the radial clearance with their hole is greater than that of their stepped lid. i.e., lid bottoms out before bolts contact.

In order to determine the amount of deformation that would be experienced by a side impact it was conservatively assumed that only the projected length of the cask on the overpack would be effective. Therefore, the overpacks effective length would be 44 inches.

The impact acceleration forces are determined by use of a NUPAC developed computer program called SYDROP (Side Drop - Cylinders). SYDROP was developed to consider the strain hardening in a crushable foam overpack. The general approach, output, and assumptions parallel

those discussed in Section 1.7.1.2 for the corner impact program CYDROP.

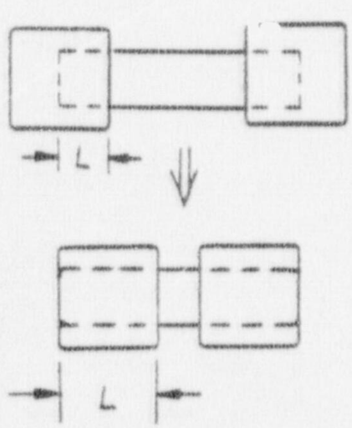
Two cases are analyzed - minimum foam properties and maximum foam properties given in Figure 1 of Section 1.3 above. Key results are summarized below with computer results following:

Case	Deflection (in)	Energy Absorption Margin	Impact Acceleration *
Minimum Properties	10.0	+0.53	108.6g
Maximum Properties	9.5	+0.95	101.7g

*Interpolated at KE=SE.

As for the corner impact case, the impact acceleration values are relatively independent of material properties but show a tendency for slightly higher final impact accelerations with the "softer" minimum properties cases.

In an effort to evaluate the effect of that part of the overpack that extends beyond the end of the cask an additional SYDROP run was made. For this case the effective package length was assumed to be equal to the total length of both overpacks.



CN6-80 SHIELDED CASK - OVERPACK, MAXIMUM PROPERTIES

PACKAGE WEIGHT = 57500. (LBS)
PACKAGE EXTERNAL LENGTH = 44.00 (IN)
PACKAGE EXTERNAL DIAMETER = 96.00 (IN)
PAYLOAD DIAMETER = 70.25 (IN)
DROP HEIGHT = 30.00 (FT)

STRAIN VS STRESS TABLE

PT	STRAIN	STRESS
1	0.00	0.00
2	.05	850.00
3	.07	1000.00
4	.10	1050.00
5	.20	1200.00
6	.25	1300.00
7	.30	1350.00
8	.40	1500.00
9	.45	1620.00
10	.50	1800.00
11	.60	2550.00
12	.70	4400.00
13	.75	6100.00
14	.80	8350.00
15	.90	15300.00
16	.95	20500.00
17	.99	25600.00

[illegible]-SHIELDED CASK + OVERPACK, MAXIMUM PROPERTIES

CRUSH DEPTH (IN)	** [illegible] ** AREA ([illegible])	VOLUME ([illegible])	**** IMPACT **** FORCE (LBS)	ACCEL. (G)	****** ENERGY ****** KINETIC (IN-LB)	STRAIN (IN-LB)	RATIO (SE/KE)	DISTRIBUTION OF STRAIN RATIOS BY PERCENT OF CONTACT AREA LE.70	GT.70 LE.80	GT.80 LE.90	GT.90 LE.95	GT.95
[illegible]	[illegible]	[illegible]	[illegible]	11.8	20757500.	179257.	.008	100.00	0.00	0.00	0.00	0.00
1.50	1057.?	[illegible]	[illegible]	[illegible]	20786250.	577141.	.028	100.00	0.00	0.00	0.00	0.00
2.00	1204.5	1454.	1175043.	20.4	20815000.	1105591.	.053	100.00	0.00	0.00	0.00	0.00
2.50	1345.6	2254.	1379375.	24.0	20843750.	1744080.	.084	100.00	0.00	0.00	0.00	0.00
3.00	1480.7	2990.	1587259.	27.6	20872500.	2485739.	.119	100.00	0.00	0.00	0.00	0.00
3.50	1589.1	3777.	1788079.	31.1	20901250.	3320799.	.159	100.00	0.00	0.00	0.00	0.00
4.00	1698.1	4541.	1973915.	34.3	20930000.	4275522.	.204	100.00	0.00	0.00	0.00	0.00
4.50	1795.7	5443.	2155322.	37.5	20958750.	5302832.	.253	100.00	0.00	0.00	0.00	0.00
5.00	1877.1	6325.	2340250.	40.7	20987500.	6426725.	.306	100.00	0.00	0.00	0.00	0.00
5.50	1963.1	7286.	2534361.	44.1	21016250.	7645377.	.364	100.00	0.00	0.00	0.00	0.00
6.00	2046.0	8288.	2745424.	47.7	21045000.	8965323.	.426	100.00	0.00	0.00	0.00	0.00
6.50	2122.5	9333.	2985105.	51.9	21073750.	10397978.	.493	100.00	0.00	0.00	0.00	0.00
7.00	2196.5	10412.	3260813.	56.9	21102500.	11961733.	.567	100.00	0.00	0.00	0.00	0.00
7.50	2267.3	11576.	3620221.	63.1	21131250.	13686262.	.648	100.00	0.00	0.00	0.00	0.00
8.00	2335.0	12675.	4093493.	71.2	21160000.	15616570.	.738	100.00	0.00	0.00	0.00	0.00
8.50	2399.0	13869.	4705684.	81.8	21188750.	17816553.	.841	100.00	0.00	0.00	0.00	0.00
9.00	2462.6	15076.	5432235.	96.2	21217500.	20375943.	.960	100.00	0.00	0.00	0.00	0.00
9.50	2533.?	16322.	6652184.	11?.7	21246250.	23422048.	1.102	78.67	21.33	0.00	0.00	0.00
10.00	2584.?	17533.	8123095.	141.1	21275000.	27113368.	1.274	70.67	29.33	0.00	0.00	0.00
10.50	2634.?	19003.	9969787.	173.4	21303750.	31634059.	1.485	64.67	22.67	12.67	0.00	0.00
11.00	2683.8	20233.	12308434.	214.1	21332500.	37203603.	1.744	60.00	16.67	23.33	0.00	0.00
11.50	2743.2	21531.	15242312.	265.1	21361250.	44091293.	2.064	56.67	13.33	30.00	0.00	0.00
12.00	2793.0	22877.	18904066.	328.8	21390000.	52628102.	2.460	53.33	12.00	17.33	17.33	0.00
12.50	2843.	24187.	23414141.	407.2	21418750.	63207836.	2.951	50.67	10.67	14.00	11.33	13.33

181.7

CN6-80 SHIELDED CASK - OVERPACK, MINIMUM PROPERTIES

PACKAGE WEIGHT = 57500. (LBS)
PACKAGE EXTERNAL LENGTH = 44.00 (IN)
PACKAGE EXTERNAL DIAMETER = 96.00 (IN)
PAYLOAD DIAMETER = 70.25 (IN)
DROP HEIGHT = 30.00 (FT)

STRAIN VS STRESS TABLE

PT	STRAIN	STRESS
1	0.00	0.00
2	.05	650.00
3	.07	850.00
4	.10	950.00
5	.20	1000.00
6	.25	1050.00
7	.30	1150.00
8	.40	1260.00
9	.45	1400.00
10	.50	1600.00
11	.60	2250.00
12	.70	3850.00
13	.75	5300.00
14	.80	7400.00
15	.90	13800.00
16	.95	18500.00
17	.99	24000.00

[illegible] SHIELDED CASK A [illegible], MINIMUM PROPERTIES

CRUSH DEPTH (IN)	** CONTACT AREA ** AREA (IN2)	VOLUME (IN3)	**** IMPACT **** FORCE (LBS)	ACCEL. (G)	****** ENERGY ****** KINETIC (IN-LB)	STRAIN (IN-LB)	RATIO (SE/KE)	DISTRIBUTION OF STRAIN RATIOS BY PERCENT OF CONTACT AREA: LE.70	GT.70 LE.80	GT.80 LE.90	GT.90 LE.95	GT.95
1.00	917.7	771.	563740.	9.4	20757500.	135047.	.007	100.00	0.00	0.00	0.00	0.00
1.50	1047.9	1061.	811473.	14.1	20786250.	474753.	.023	100.00	0.00	0.00	0.00	0.00
2.00	1206.4	1516.	1017113.	17.7	20815000.	931899.	.045	100.00	0.00	0.00	0.00	0.00
2.50	1345.6	2256.	1180420.	20.5	20843750.	1481287.	.071	100.00	0.00	0.00	0.00	0.00
3.00	1460.9	2959.	1330893.	23.1	20872500.	2109111.	.101	100.00	0.00	0.00	0.00	0.00
3.50	1593.6	3727.	1488677.	25.0	20901250.	2814004.	.135	100.00	0.00	0.00	0.00	0.00
4.00	1690.1	4541.	1659623.	28.8	20930000.	3600831.	.172	100.00	0.00	0.00	0.00	0.00
4.50	1785.7	5409.	1816816.	31.6	20958750.	4469592.	.213	100.00	0.00	0.00	0.00	0.00
5.00	1877.1	6325.	1969646.	34.3	20987500.	5416308.	.258	100.00	0.00	0.00	0.00	0.00
5.50	1963.3	7286.	2137108.	37.2	21016250.	6442996.	.307	100.00	0.00	0.00	0.00	0.00
6.00	2044.0	8289.	2333643.	40.6	21045000.	7560584.	.359	100.00	0.00	0.00	0.00	0.00
6.50	2122.5	9333.	2563883.	44.6	21073750.	8785065.	.417	100.00	0.00	0.00	0.00	0.00
7.00	2196.5	10410.	2824076.	49.2	21102500.	10133280.	.480	100.00	0.00	0.00	0.00	0.00
7.50	2267.2	11526.	3150302.	54.8	21131250.	11628122.	.550	100.00	0.00	0.00	0.00	0.00
8.00	2334.0	12676.	3561227.	61.9	21160000.	13305776.	.629	100.00	0.00	0.00	0.00	0.00
8.50	2399.0	13860.	4098062.	71.3	21188750.	15220349.	.719	100.00	0.00	0.00	0.00	0.00
9.00	2462.4	15076.	4818821.	83.8	21217500.	17449570.	.822	100.00	0.00	0.00	0.00	0.00
9.50	2523.5	16322.	5781144.	100.5 (handwritten: 108.6)	21246250.	20099561.	.946	100.00	0.00	0.00	0.00	0.00
10.00	2580.7	17599.	7064245.	122.9	21275000.	23310998.	1.096	78.67	21.33	0.00	0.00	0.00
10.50	2636.7	18903.	8744065.	152.1	21303750.	27262986.	1.289	70.67	29.33	0.00	0.00	0.00
11.00	2691.8	20235.	10875466.	189.1	21332500.	32167869.	1.509	64.67	22.67	12.67	0.00	0.00
11.50	2743.2	21591.	13550714.	235.7	21361250.	38274413.	1.792	60.00	16.67	23.33	0.00	0.00
12.00	2793.0	22977.	16837645.	292.8	21390000.	45871563.	2.145	56.67	13.33	30.00	0.00	0.00
12.50	2843.0	24387.	21017125.	365.5	21418750.	55335196.	2.583	53.33	12.00	17.33	17.33	0.00
								50.67	10.67	14.00	11.33	13.33

From the print out it can be seen that the maximum deformation will only be 7.75 in. vs. 9.25 for cask No. 1. Also the maximum acceleration at the end of the impact stroke is 99 g's vs. 108.6 g's. (Ref. pg. 1-44 a)

Therefore, it can be concluded that the overhanging section of the overpack will absorb some portion of the energy. It is conservative to neglect this contribution and use the maximum acceleration figures calculated and referenced above.

As noted earlier, the secondary lid bolts do not react these shear loads due to the stepped lid design. The following analysis is provided to demonstrate what margin it safely would exist if they were required to react these loads.

Load per bolt is:

$$P = (2000 \text{ lbs Lid})(109 \text{ g's})/8 \text{ bolts}$$

$$P = 27250 \text{ lbs (shear)}$$

Bolt capacity is:

$$R = (115{,}000 \text{ psi})(.563 \text{ in}^2)(60\%)$$

$$R = 38847 \text{ lbs}$$

CN6-80 PACKAGE OVERPACK -- MAXIMUM EFFECTIVE LENGTH

PACKAGE WEIGHT = 57500. (LBS)
PACKAGE EXTERNAL LENGTH = 74.00 (IN)
PACKAGE EXTERNAL DIAMETER = 96.00 (IN)
PAYLOAD DIAMETER = 70.25 (IN)
DROP HEIGHT = 30.00 (FT)

STRAIN VS STRESS TABLE

PT	STRAIN	STRESS
1	0.00	0.00
2	.05	650.00
3	.07	850.00
4	.10	950.00
5	.20	1000.00
6	.25	1050.00
7	.30	1150.00
8	.40	1260.00
9	.45	1400.00
10	.50	1600.00
11	.60	2250.00
12	.70	3850.00
13	.75	5300.00
14	.80	7400.00
15	.90	13800.00
16	.95	18500.00
17	.99	24000.00

CN6-80 PACKAGE OVERPACK -- MAXIMUM EFFECTIVE LENGTH

CRUSH DEPTH (IN)	++ CRUSH PLANE ++ AREA (IN2)	VOLUME (IN3)	**** IMPACT **** FORCE (LBS)	ACCEL. (G)	****** ENERGY ****** KINETIC (IN-LB)	STRAIN (IN-LB)	RATIO (SE/KE)	DISTRIBUTION OF STRAIN RATIOS BY PERCENT OF CONTACT AREA LE.70	GT.70 LE.80	GT.80 LE.90	GT.90 LE.95	GT.95
1.00	1442.5	964.	714521.	15.9	20757500.	228630.	.011	100.00	0.00	0.00	0.00	0.00
1.50	1762.1	1768.	1364750.	23.7	20786250.	798448.	.038	100.00	0.00	0.00	0.00	0.00
2.00	2029.3	2717.	1710599.	29.7	20815000.	1567285.	.075	100.00	0.00	0.00	0.00	0.00
2.50	2262.8	3791.	1985251.	34.5	20843750.	2491248.	.120	100.00	0.00	0.00	0.00	0.00
3.00	2472.1	4976.	2238320.	38.9	20872500.	3547141.	.170	100.00	0.00	0.00	0.00	0.00
3.50	2663.0	6260.	2503698.	43.5	20901250.	4732643.	.226	100.00	0.00	0.00	0.00	0.00
4.00	2839.1	7636.	2789512.	48.5	20930000.	6055943.	.289	100.00	0.00	0.00	0.00	0.00
4.50	3003.2	9097.	3055554.	53.1	20958750.	7517209.	.359	100.00	0.00	0.00	0.00	0.00
5.00	3156.9	10638.	3312587.	57.6	20987500.	9109244.	.434	100.00	0.00	0.00	0.00	0.00
5.50	3301.9	12253.	3594228.	62.5	21016250.	10835948.	.516	100.00	0.00	0.00	0.00	0.00
6.00	3439.2	13939.	3924763.	68.3	21045000.	12715696.	.604	100.00	0.00	0.00	0.00	0.00
6.50	3569.7	15691.	4311985.	75.0	21073750.	14774883.	.701	100.00	0.00	0.00	0.00	0.00
7.00	3694.1	17507.	4757820.	82.7	21102500.	17042334.	.808	100.00	0.00	0.00	0.00	0.00
7.50	3813.0	19384.	5298387.	99.0 92.1	21131250.	19556386.	.925	100.00	0.00	0.00	0.00	0.00
8.00	3926.9	21319.	5987654.	104.1	21160000.	22377897.	1.058	100.00	0.00	0.00	0.00	0.00
8.50	4036.2	23310.	6892196.	119.9	21188750.	25597859.	1.208	100.00	0.00	0.00	0.00	0.00
9.00	4141.4	25355.	8104381.	140.9	21217500.	29347003.	1.383	100.00	0.00	0.00	0.00	0.00
9.50	4242.6	27451.	9722834.	169.1	21246250.	33803807.	1.591	78.67	21.33	0.00	0.00	0.00
10.00	4340.2	29597.	11880777.	206.6	21275000.	39204710.	1.843	70.67	29.33	0.00	0.00	0.00
10.50	4434.4	31791.	14705927.	255.8	21303750.	45851385.	2.152	64.67	22.67	12.67	0.00	0.00
11.00	4525.5	34031.	18290556.	318.1	21332500.	54100506.	2.536	60.00	16.67	23.33	0.00	0.00
11.50	4613.6	36316.	22789837.	396.3	21361250.	64370604.	3.013	56.67	13.33	30.00	0.00	0.00
12.00	4698.9	38644.	28317857.	492.5	21390000.	77147528.	3.607	53.33	12.00	17.33	17.33	0.00
12.50	4781.5	41014.	35346983.	614.7	21418750.	93063738.	4.345	50.67	10.67	14.00	11.33	13.33

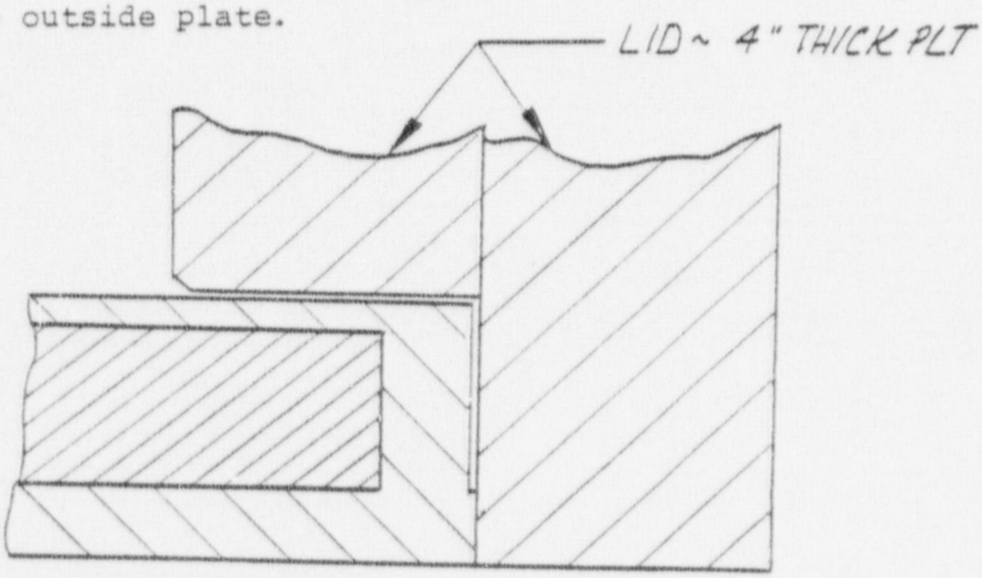
Margin of Safety

M.S. = R/P -1

M.S. = 38847/27250 -1

<u>M.S. = +0.43</u>

From the drawing and the sketch below it can be seen that the lid is flush with the outside diameter of the cask. Lateral loads from the lid are reacted in direct bearing on the 4 inch thick plate while lateral loads from the cask body are distributed along its length. Therefore, the actual shear loads carried across the joint for side drop conditions are very small. They become limited primarily to acceleration loads of the inside lid plate on its attachment welds to the outside plate.



The loads are:

$$P = (\pi/4)(59)^2(4)(.283\ lbs/in^3)(108.6\ g's)$$

$$P = 336,000\ lbs$$

The weld area is:

$$A = 59(\pi)(.50)\ \sin 45^\circ$$

$$A = 65.5\ in^2$$

Stress:

$$f_s = 336,000\ lbs/65.5\ in^2$$

$$f_s = 5128\ psi$$

Margin of Safety on plate to plate attachment is:

$$M.S. = 35,000\ psi/5128\ psi - 1$$

<u>M.S. = +Large</u>

Conclusion:

From the above it can be concluded that under the most conservative conditions the package will maintain 3 inches of foam in the compressed area. Impact loads will not produce detrimental effects on closure system since all loads are carried in direct compression across the deeply stepped joints. Therefore, the side drop of 30 feet will not produce detrimental effects to the package.

1.7.2 Puncture

A 40 inch drop onto a 6 inch diameter pin can occur in three separate regions of the package, i.e., overpack area, ends and side walls between overpack.

Since the overpack is backed by side wall or end type construction, any impact in this region would be less severe.

Using ORNL-NSIC-68 for the side wall evaluation, the required shell thickness for puncture integrity can be calculated as:

$$t = (W/S)^{.71}$$

Where:

$S = 58000$ psi

$W = 57500$ lb.

$t = (57500/58000)^{.71}$

$t = 0.994$ inches

The Margin of Safety for side puncture is:

M.S. = 1.00/.994 -1 (Cask No. 001 Only)

M.S. + +0.01

From Fig. 2.3 of the ORNL-NSIC-68 on the following page, it can be seen that two test points for carbon steel fall below the established design curve. If a line was drawn between these two points it would produce an E/S ratio of 35 for a 1.0 inch thick plate. Using the package energy level the required mechanical properties of the external skin should be:

$$E/S = 35$$

$$S = E/35$$

$$= (57500)(40)/35$$

$$= 65714 \text{ psi}$$

Certified mechanical properties for Cask No. 001 are recorded as:

$$F_t = 66800 \text{ psi}$$

Margin of Safety

$$M.S. = 66800 \text{ psi}/65714 \text{ psi} - 1$$

$$\underline{M.S. = +.017}$$

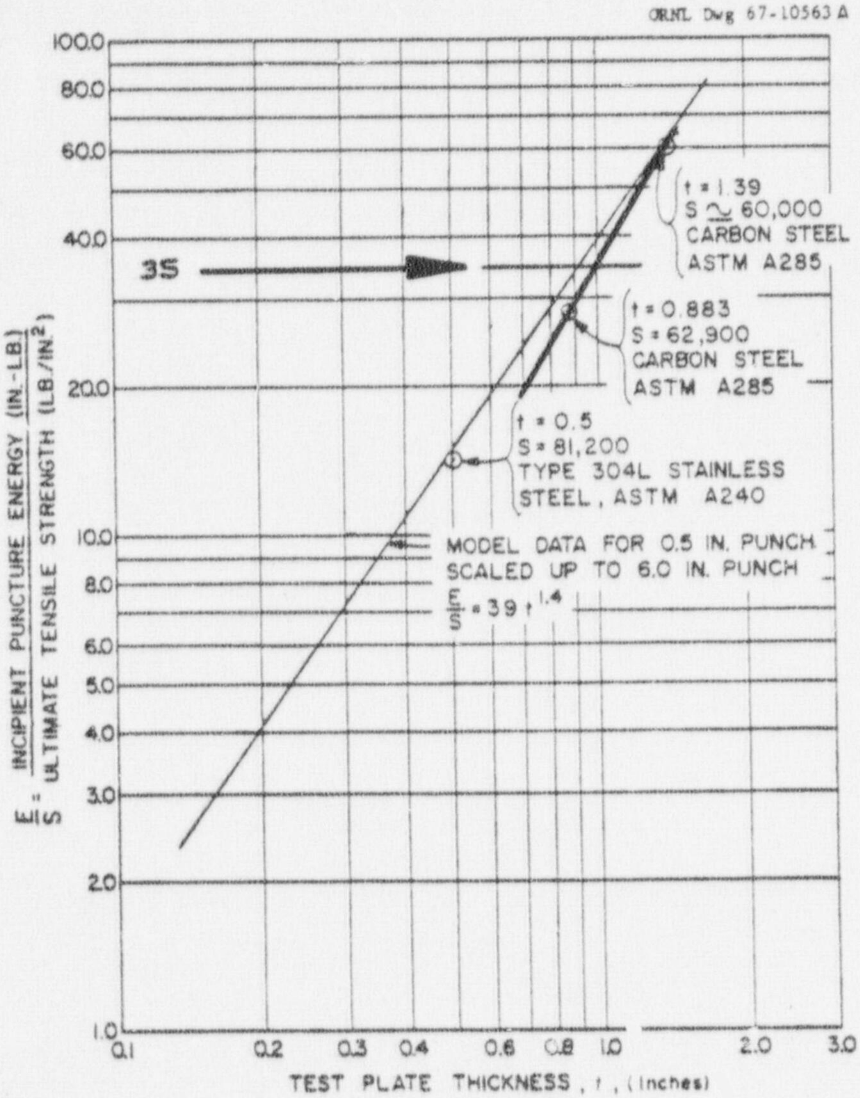


Fig. 2.3. Puncture Test Data for Lead-Backed Plates.

For subsequent casks, Serial No. 002 and beyond, the external skin will be increased to a thickness of 1 1/8 inches. Using the lower design curve, drawn between the two test points, E/S = 42 for a plate thickness of 1 1/8 inches.

Using minimum allowable mechanical properties for A-36 the incipient puncture energy is:

$$E = 42\ S$$

$$= 42\ (58000\ psi)$$

$$= 2,436,000\ in/lbs$$

Margin of Safety

$$M.S. = 2,436,000/(57500)(40) - 1$$

$$\underline{M.S. = +.06}$$

Therefore, it can be concluded that the Serial No. 001 cask is acceptable since it was manufactured from steel with actual material properties of 66,800 psi. Future casks, Serial No. 002 and beyond, will be manufactured from 1 1/8 inch thick steel plate.

End impact evaluation of the CN6-80B package is based upon a detail non-linear finite element analysis which conservatively assumed only one of the two lapped end plates deformed inelastically to absorb the full kinetic energy of impact. That is, the energy absorbed by the smaller second plate was conservatively ignored. The CN6-80B evaluation employed an axi-symmetric "ANSYS" finite element solution which considered both large deflection of the circular plate and bi-linear characteristics of its mild steel material.

The CN6-80B evaluation model consisted of 52 nodes and 36 iso-parametric quadrilaterals (STIF42) representing an axi-symmetric plate of four inches thickness and 68¼" in diameter, as shown in Figure 1.7.2-1. The plate model was loaded by applying a series of prescribed displacements at a location corresponding to the contact perimeter of the 6" diameter puncture pin. At the outer diameter of the plate, the forces induced by this prescribed displacement were reacted in an axial fashion. No radial constraints were imposed upon the model except at the axis of symmetry. The conventional bi-linear properties of mild steel used in this analysis corresponded to a 36 ksi yield and 58 ksi rupture at a conservative 10% strain value.

The st ..ctural behavior of the plate at maximum pin penetration is shown in Figure 1.7.2-2. Figure 1.7.2-2 illustrates both deformed plate shape and effective strains for each of the 36 finite elements.

On an effective strain basis, the worst severely strained element possesses a rupture margin of greater than + 1.13; thus, no puncture occurs.

Maximum pin penetration (deformation of plate) was determined by plotting the load deformation characteristics of node 2 (the puncture pin diametrical location) as shown in Figure 1.7.2-3. Integrating this load-deformation relation, as shown in Figure 1.7.2-4, produces a description of plate strain energy versus deformation depth.

The kinetic energy relation of the dropped cask is also plotted on figure 1.7.2-4. The intersection of these two energy relations defines the defomation depth at which the strain energy (or work done on the plate) equals the available kinetic energy. At this deformation depth, 2.48 inches, the deformation is arrested and can proceed no further.

From Figure 1.7.2-3 the maximum load will be:

$$F = 2\pi \text{ (188,000 lbs)}$$

$$F = 1.18 \times 10^6 \text{ lbs}$$

For puncture conditions directly on the lid, loads would be trasmitted from the secondary lid to the primary lid by way of the seal spacer block. Compressive stress on the block is calculated as follows:

f_b = Impact Force, F/Effective Area, A

where:

$F = 1.18 \times 10^6$ lbs (Pg. 1-51)

$A = (34^2 - 32\frac{1}{2}^2)\ \pi/4$

$= 78.34\ in^2$

$f_b = 1.18 \times 10^6/78.34$

$f_b = 15,060$ psi

Margin of Safety

M.S. = 36,000 psi/15,060 psi -1

M.S. = +1.4

Therefore, it can be concluded that the lid and support ring can react the pin impact loads.

FIG. 1.7.2-1
ANSYS*
FLASK END PLATE FINITE ELEMENT
MODEL FOR PIN IMPACT

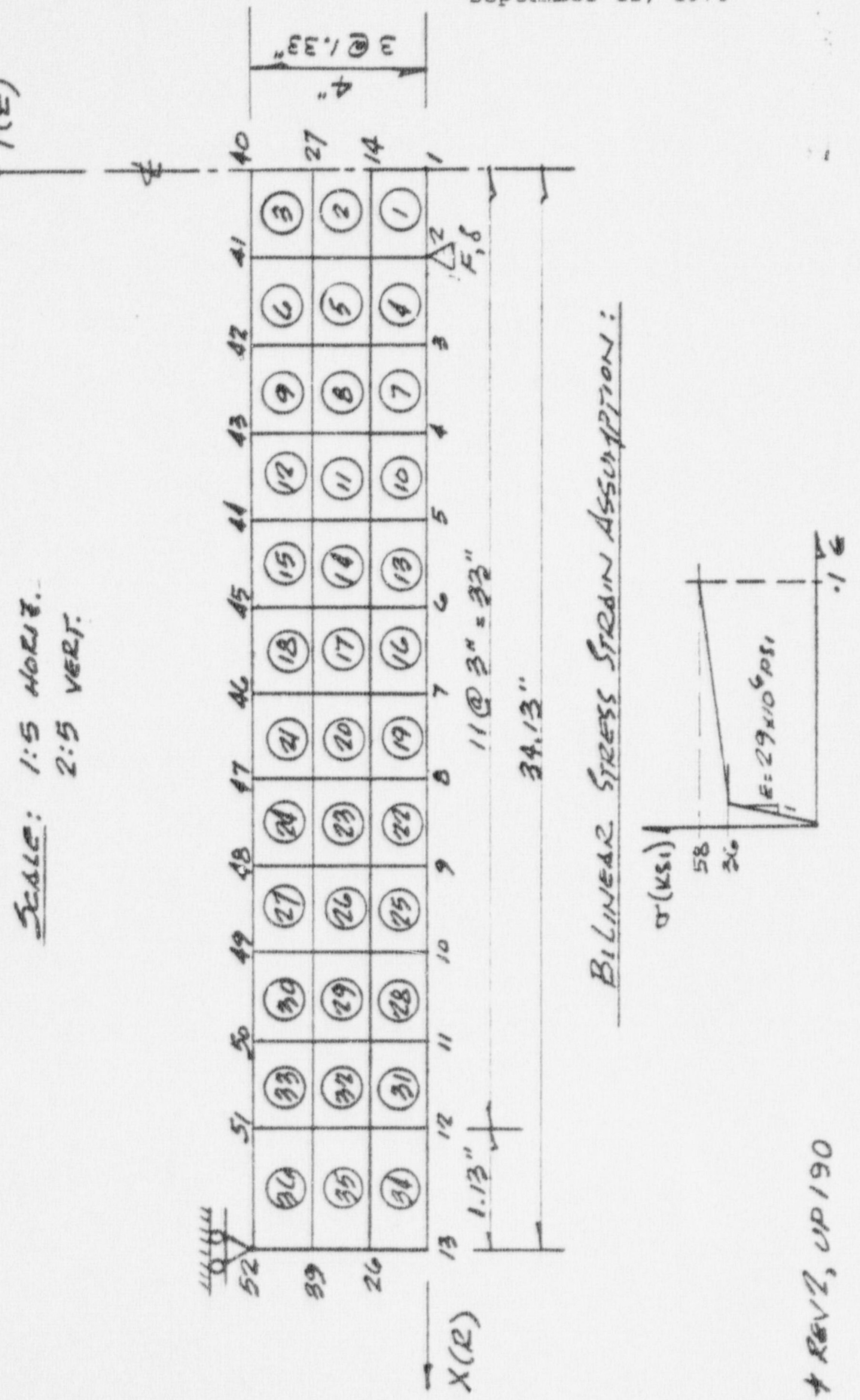
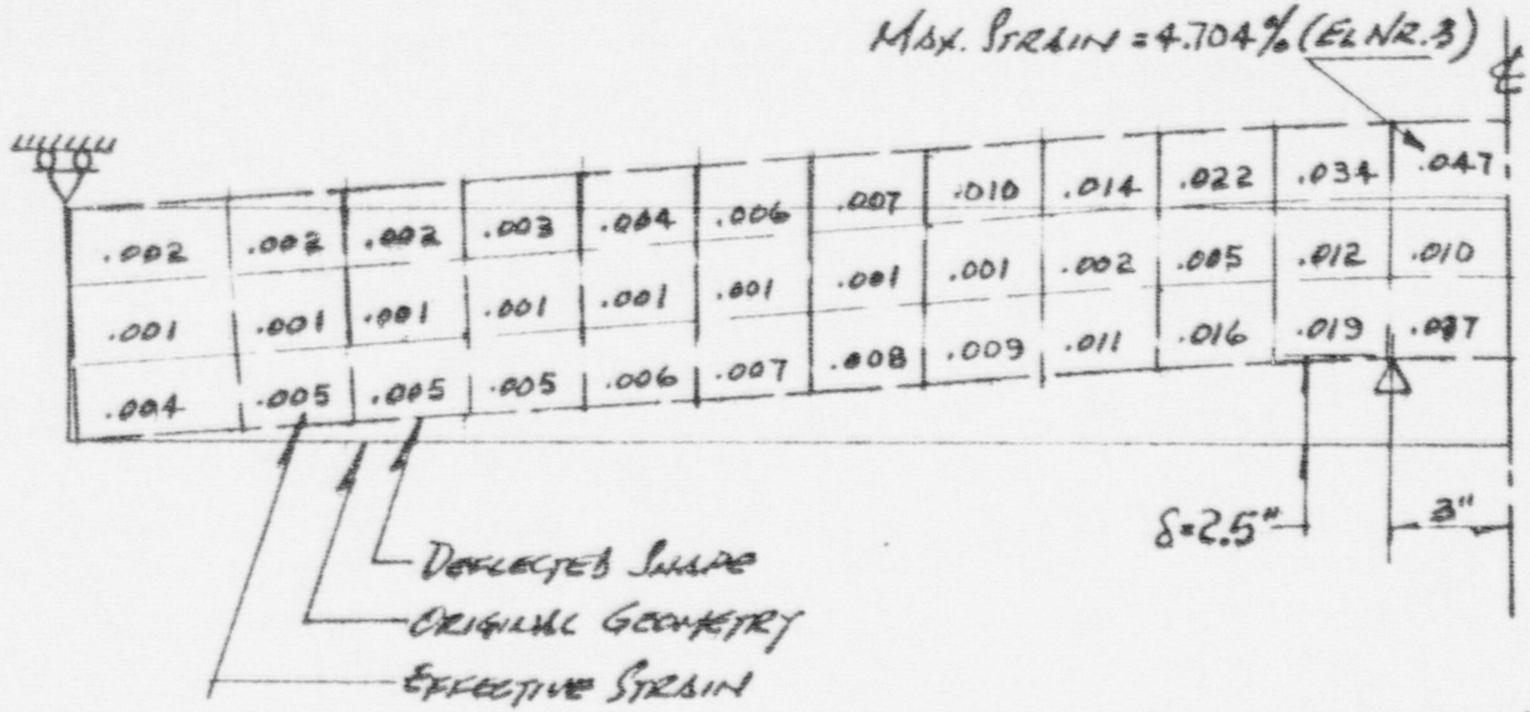


FIG. 1.7.2-2
ANSYS RESULTS
AT A PIN DEFLECTION = 2.5" *
(MAX. PIN DEFLECTION = 2.48") **

SCALE: 1:10 DEFLECTION



NOTES:

* ANSYS LOAD STEP 6

** MAX. PIN STROKE & PLATE DEFLECTION

ALLOW. STRAIN = 10%

$$\text{RUPTURE M.S.} \geq \frac{10.}{4.704} - 1 \geq +1.13$$

MAX. STRAIN %

Revision 1
September 12, 1978

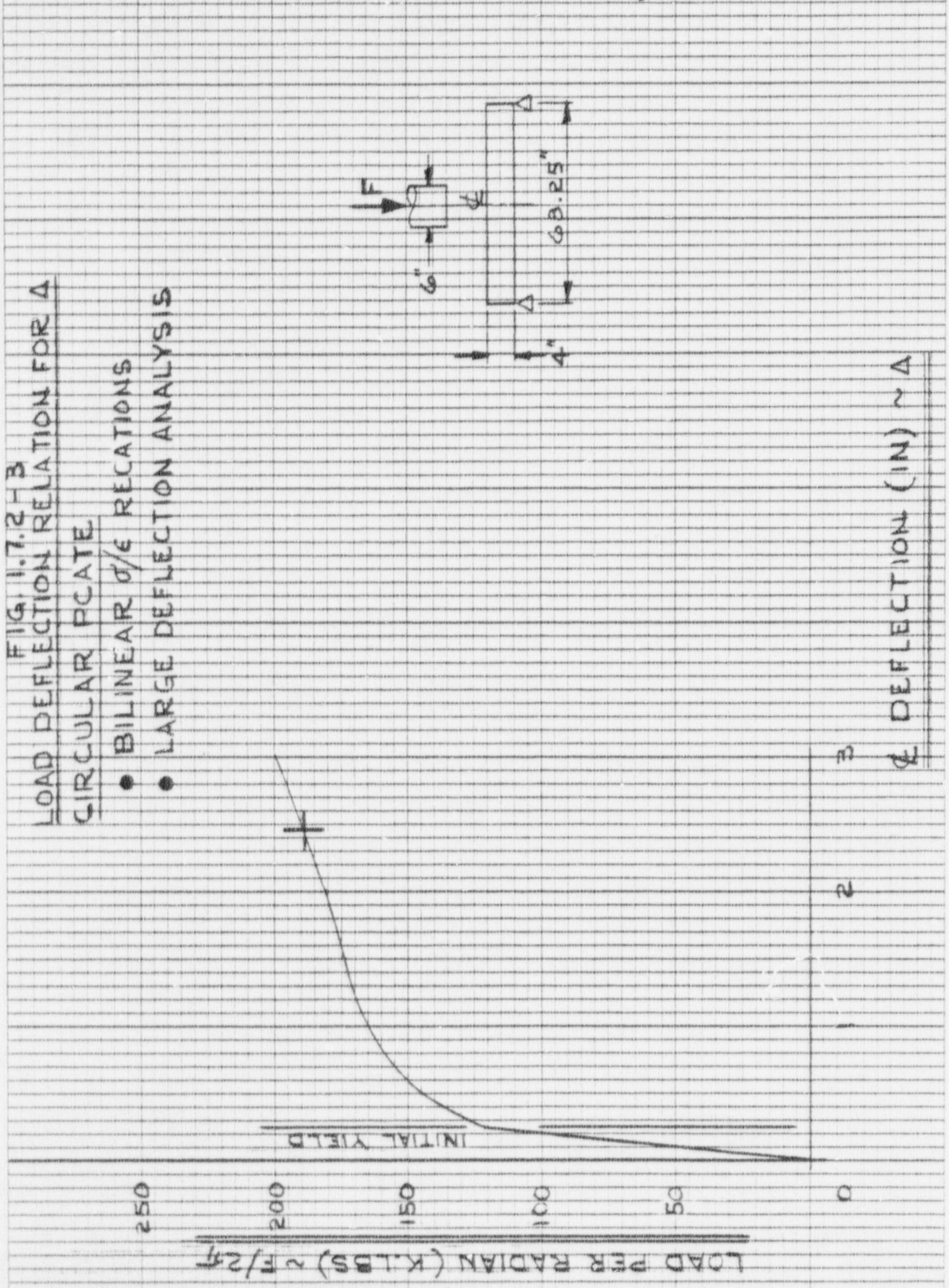
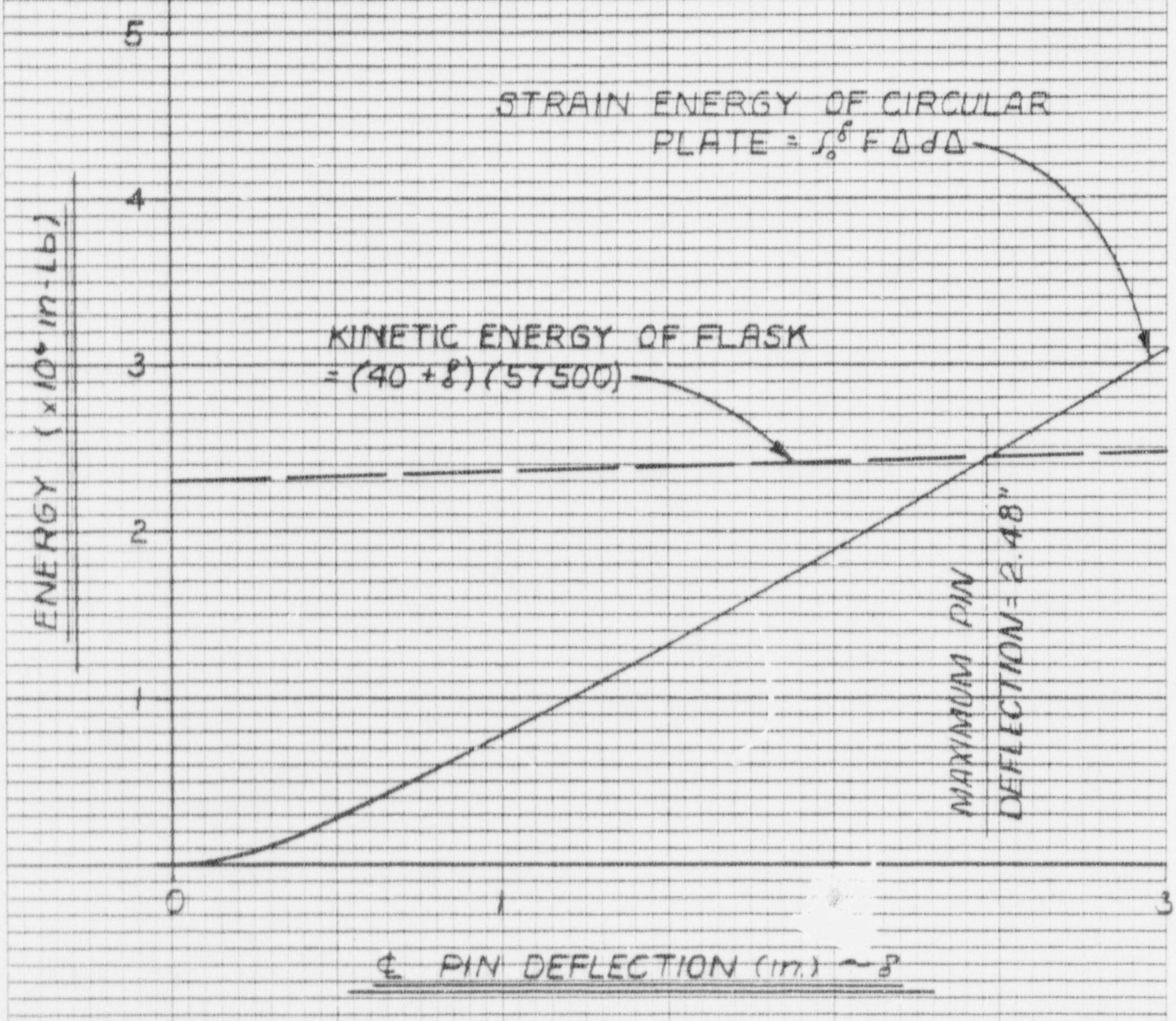


FIG. 1.7.2-3
LOAD DEFLECTION RELATION FOR Δ
CIRCULAR PLATE
• BILINEAR σ/ε RELATIONS
• LARGE DEFLECTION ANALYSIS
F
6"
℄
63.25"
4"
INITIAL YIELD
250
200
150
100
50
0
1
2
3
LOAD PER RADIAN (K.LBS) ~ F/2π
℄ DEFLECTION (IN) ~ Δ

ENERGY VS DEFLECTION
RELATIONS FOR CN6-80 CASK
IMPACT ON CIRCULAR END
PLATE

FIG. 1.7.2-4



1.7.3 Thermal

The hypothetical thermal accident analysis of the CN6-80B package is fully described in Section 2.5.

1.7.3.1 Summary of Pressures and Temperatures

The results described in Section 2.5 are summarized below:

Item	Value	See Section
Primary Seal Temperature	227°F	2.5.3
Secondary Seal Temperature	450°F	2.5.3
Inner Lid Surface	457°F	2.5.3
Inner Upper Shield Surface	188°F	2.5.3
Inner Mid Shield Surface	300°F	2.5.1
Internal Pressure	11.59 psig	2.5.4

1.7.3.2 Differential Thermal Expansion

Not applicable

1.7.3.3 Stress Calculations

See Section 2.5.5

1.7.3.4 Comparison with Allowable Stresses

See Section 2.5.5

1.7.4 Water Immersion

Not Applicable

1.7.5 Summary of Damage

As a result of the above assessment, it is concluded that should the Model CN6-80B package be subjected to the hypothetical accident conditions, no radioactive material would be released from the package.

1.8 Special Form

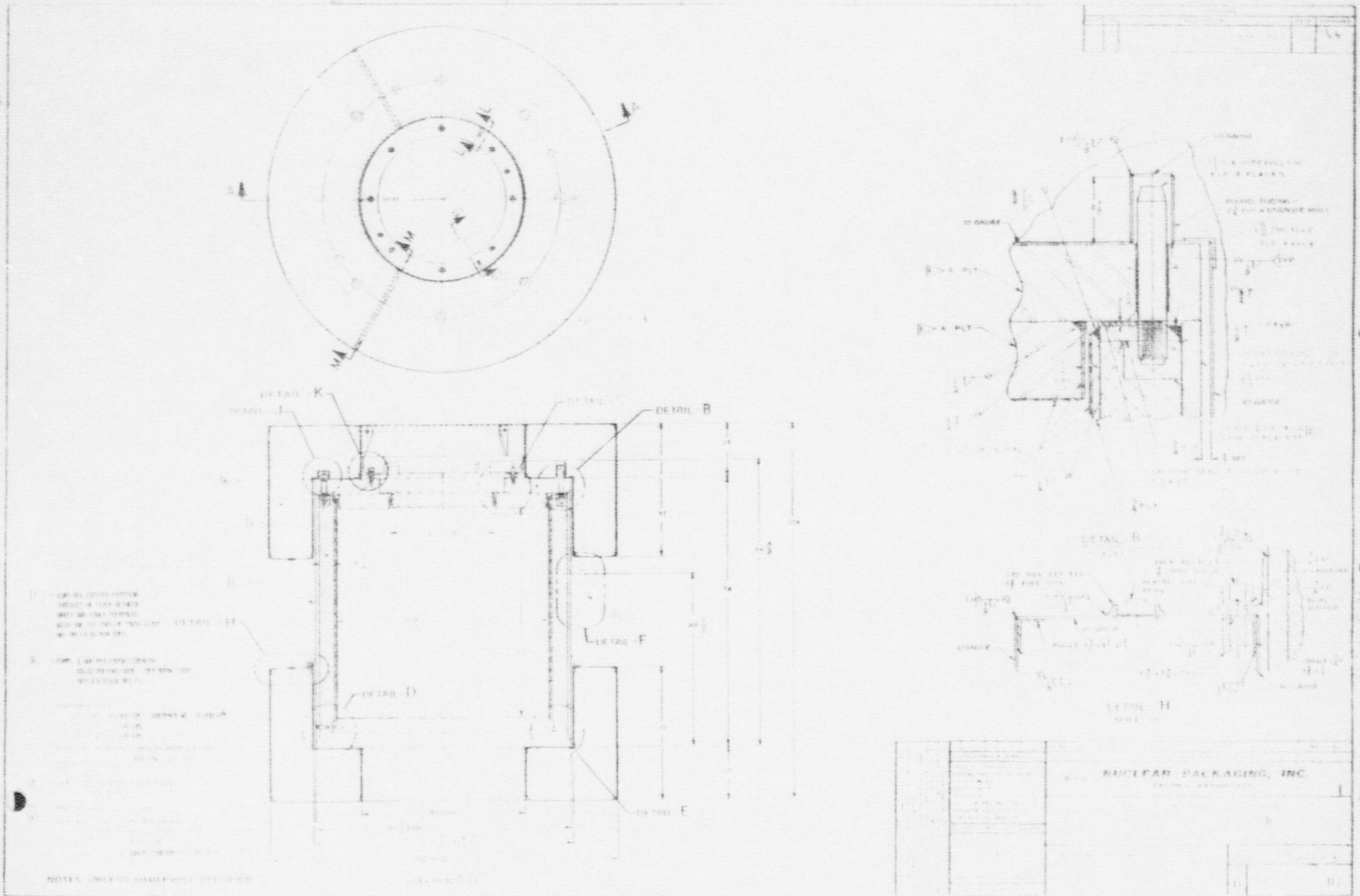
Since no special form is claimed, this section is not applicable.

1.9 Fuel Rods

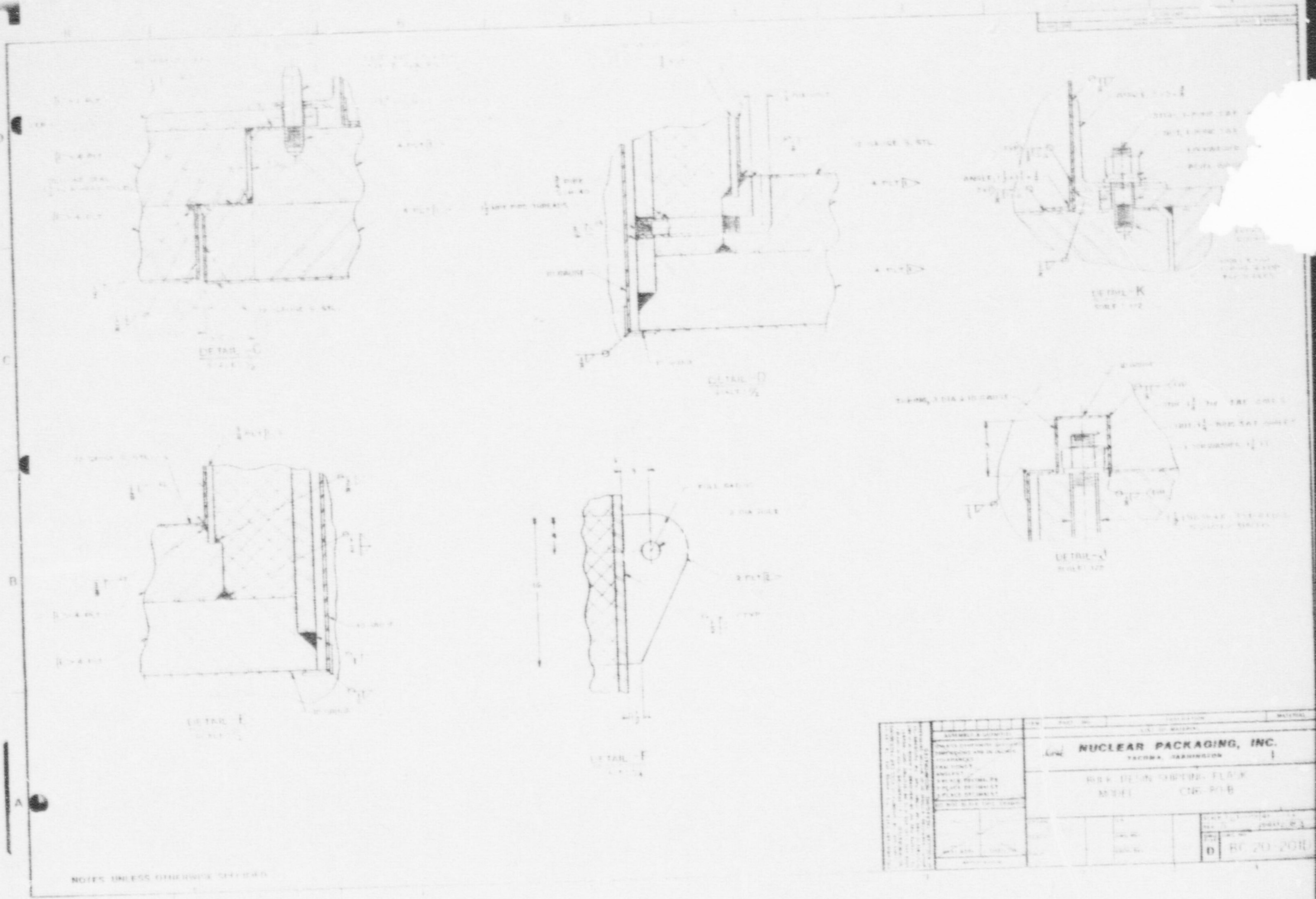
Not applicable.

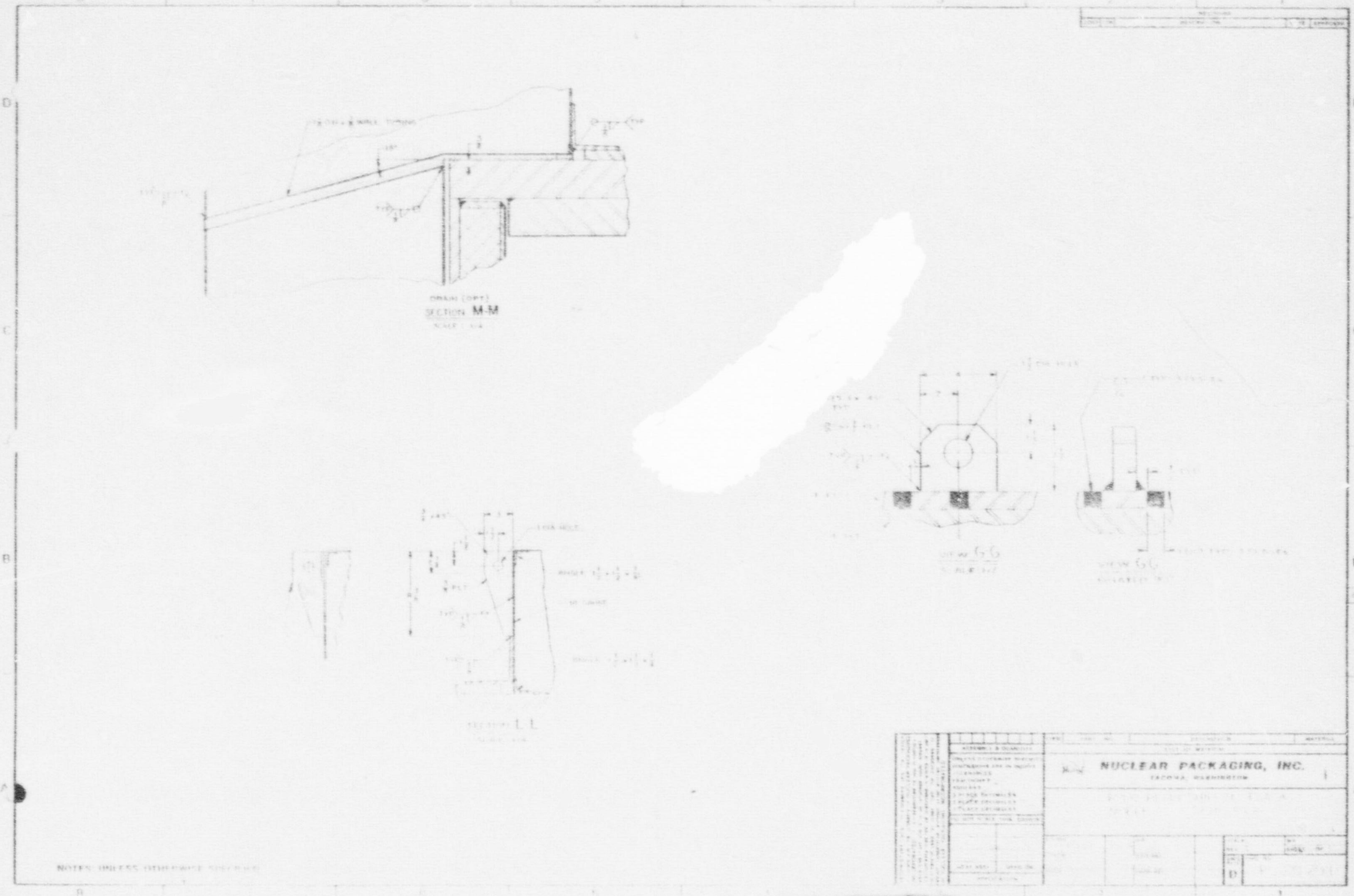
1.10 Appendix

1.10.1 General Arrangement drawing of Model CN6-80B packaging.



DETAIL K
DETAIL J
DETAIL B
DETAIL F
DETAIL D
DETAIL E
DETAIL H
DETAIL B
DETAIL H
NOTES: UNLESS OTHERWISE SPECIFIED
NUCLEAR PACKAGING, INC.


DETAIL C
DETAIL D
DETAIL K
DETAIL E
DETAIL F
DETAIL J
NOTES UNLESS OTHERWISE SPECIFIED
NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON
MODEL
CNS-80-B
D
BC 20-201D



SECTION M-M
VIEW G-G
VIEW G-G
SECTION L-L
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