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05/06/85

NUCLEAR
PACKAGING, INC.

NOTICE

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25223

Table of Contents

APPLICATION FOR NRC CERTIFICATE OF COMPLIANCE AUTHORIZING SHIPMENT OF NUCLEAR MATERIAL IN NUPAC MODEL OH-142 PACKAGING

0.0 GENERAL INFORMATION

0.1 Introduction

The Model OH-142 packaging has been developed by Nuclear Packaging, Inc. as a safe means of transporting Type "B" and large quantity levels of radioactive materials in all forms other than liquids. Fissile radioactive material is limited to those exempt quantities licensed under 10 CFR 71.9 and IAEA Safety Series No. 6, Section VI. Authorization is sought for shipment by cargo vessel, motor vehicle and rail.

Radioactive material is contained within a heavy gauge cylindrical inner container or "liner". The containment vessel itself is a shielded lead and steel cask surrounding the liner. Protection from the normal conditions of transport and hypothetical accident conditions is provided by shock or impact limiters placed peripherally around the top and bottom of the shield.

0.2 Package Description

0.2.1 Packaging

0.2.1.1 General Description

The Model OH-142 packaging is a reusable insulated and shock absorbing shipping package designed to protect radioactive material from normal conditions of transport and hypothetical accident conditions.

0.2.1.2 Materials of Construction, Dimensions, & Fabricating Methods

General Arrangement drawings of the Model OH-142 packaging are included in Appendix 1.10.1. They show the overall dimensions as well as the material.

The packaging system consists of a pair of circular shock or impact limiters placed peripherally around the top and bottom of a circular shield. Each impact limiter has an external shell fabricated from ductile low carbon steel which allows them to undergo large deformations without fracturing. All joints are arc welded with full penetration welds to assure structural integrity.

The volume between the inner and outer shell of the overpack is

filled with a shock-and-thermal-insulating material consisting of rigid polyurethane foam having a density of approximately twenty pounds per cubic foot. The insulating material is poured into the cavity between the two shells and allowed to expand, completely filling the void. Here it bonds to the shells creating a unitized construction for the packaging. Mechanical properties of these materials are further described in Section 1.0 below.

For the Mark O design (baseline), the lower impact limiter is an integral part of the shield body and is secured by means of eight 1 3/4 inch diameter ratchet binders (160,000 lbs. each). A 24 inch diameter secondary lid is located in the center of the primary lid. It is secured by means of eight 7/8 inch diameter bolts. Both are fabricated from two thicknesses of 3 inch thick steel plate. A 29 inch or 16 inch diameter secondary lid is provided as options. The 29 inch lid design employs eight one-inch diameter bolts instead of the 7/8 inch bolts.

The shield body consists of an external 1-1/8 inch (1.0 inch on units manufactured from A516 gr. 70) thick outer and 1/2 inch thick inner carbon steel shell. Three and half inches of lead is located between the two for shielding.

Lifting lugs and tiedowns are a structural part of the package.

The Mark I configuration differs from the above in that the 24 inch diameter secondary lid has been eliminated and replaced by 6 small 19 inch diameter lids. A central 16" diameter lid (as in the Mark O design) may also be used with the Mark I configuration.

The Mark II configuration differs from the baseline design in that the package bottom has been made identical to the existing top. The 24 inch secondary lid (29 inch diameter optional secondary lid) is not included in the bottom. The package will be almost totally symmetrical about the horizontal center line.

The lower impact limiter in the Mark II version is retained in place by ratchet binders which are attached to the upper impact limiters in 8 locations. This causes the lower and upper impact limiters to be pulled toward each other and against the ends of the cask effectively securing them in place. This arrangement allows the removal of both the lower and upper impact limiter for top or bottom loading.

The lower impact limiter in the Mark I version is fully welded to the cask outer shell and bottom. This version can only be top loaded.

Material on the Mark II is A516 and uses 1" plate on the external skin vs. the 1 1/8" A-36 used on the baseline package.

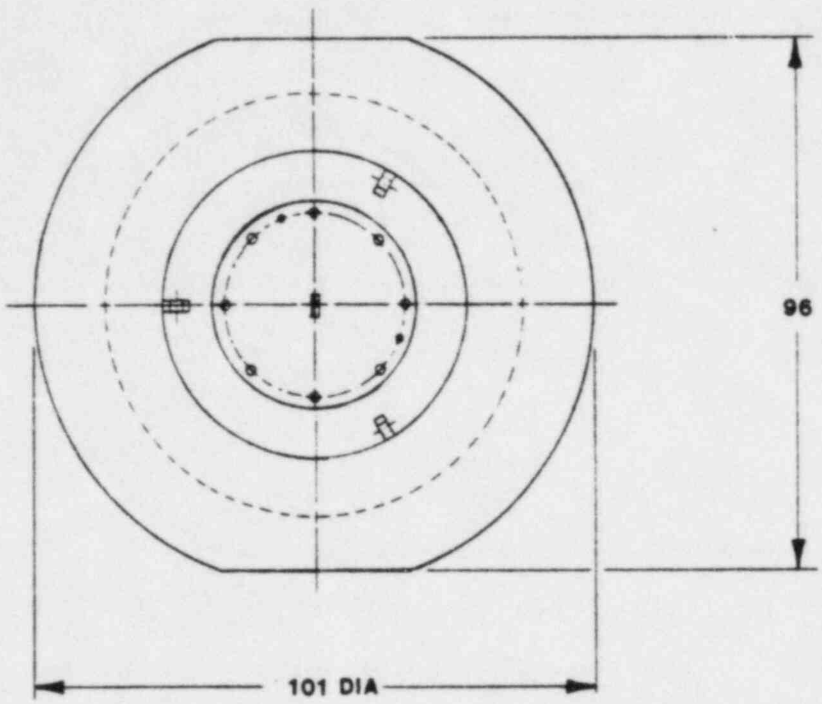
In all other respects the Mark I and II are identical with the baseline configuration.

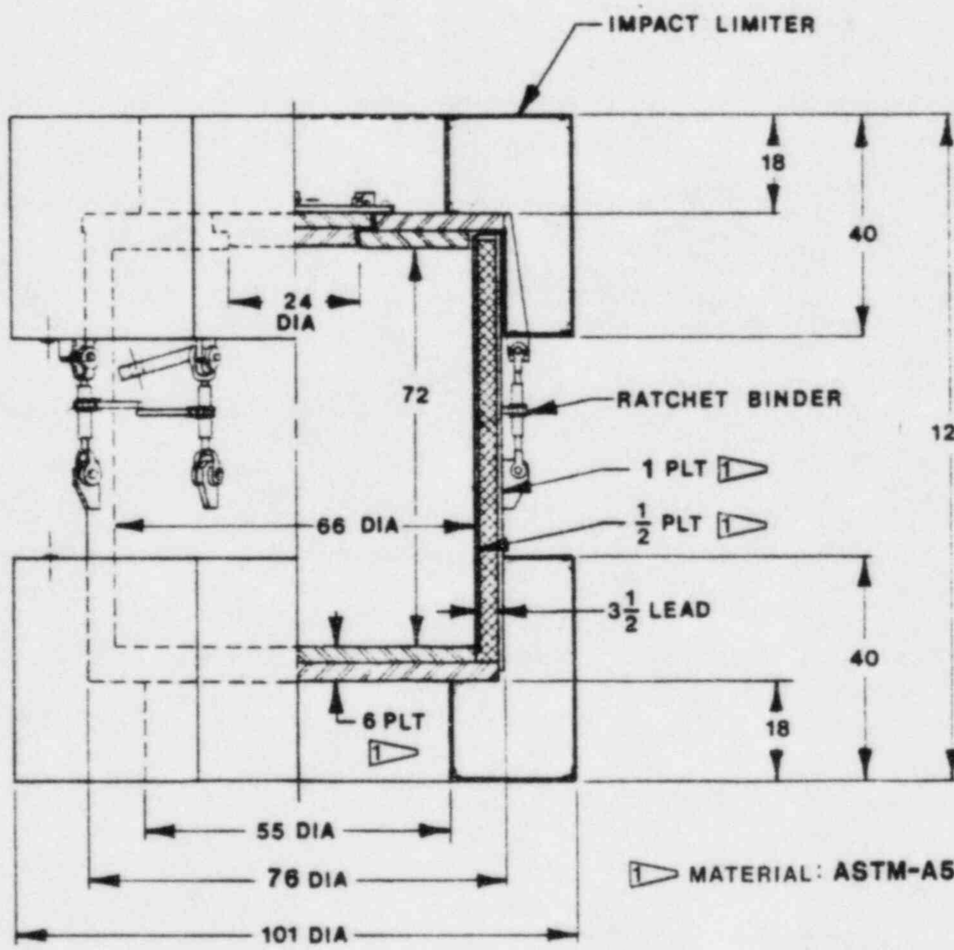
All Mk II cask welds are designed as full penetration and are made in accordance with weld procedures qualified to ASME, Section IX requirements. This is verified on all longitudinal welds via full radiographic inspection. All circumferential welds joining the inner and outer cask shells are made utilitizing groove configurations, that assure full penetration. Integrity of these welds is verified via magnetic particle inspection.

The various configurations are summarized in the figures given on the following three pages.

SHIELDED CASK MODEL OH142, BASELINE
Y-20-201D

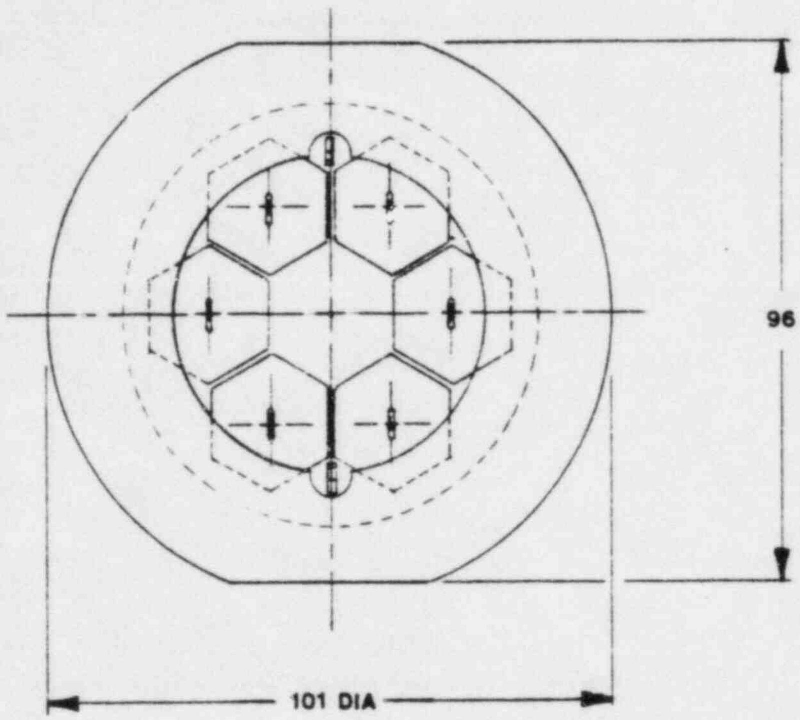
Revision 8, 4/85

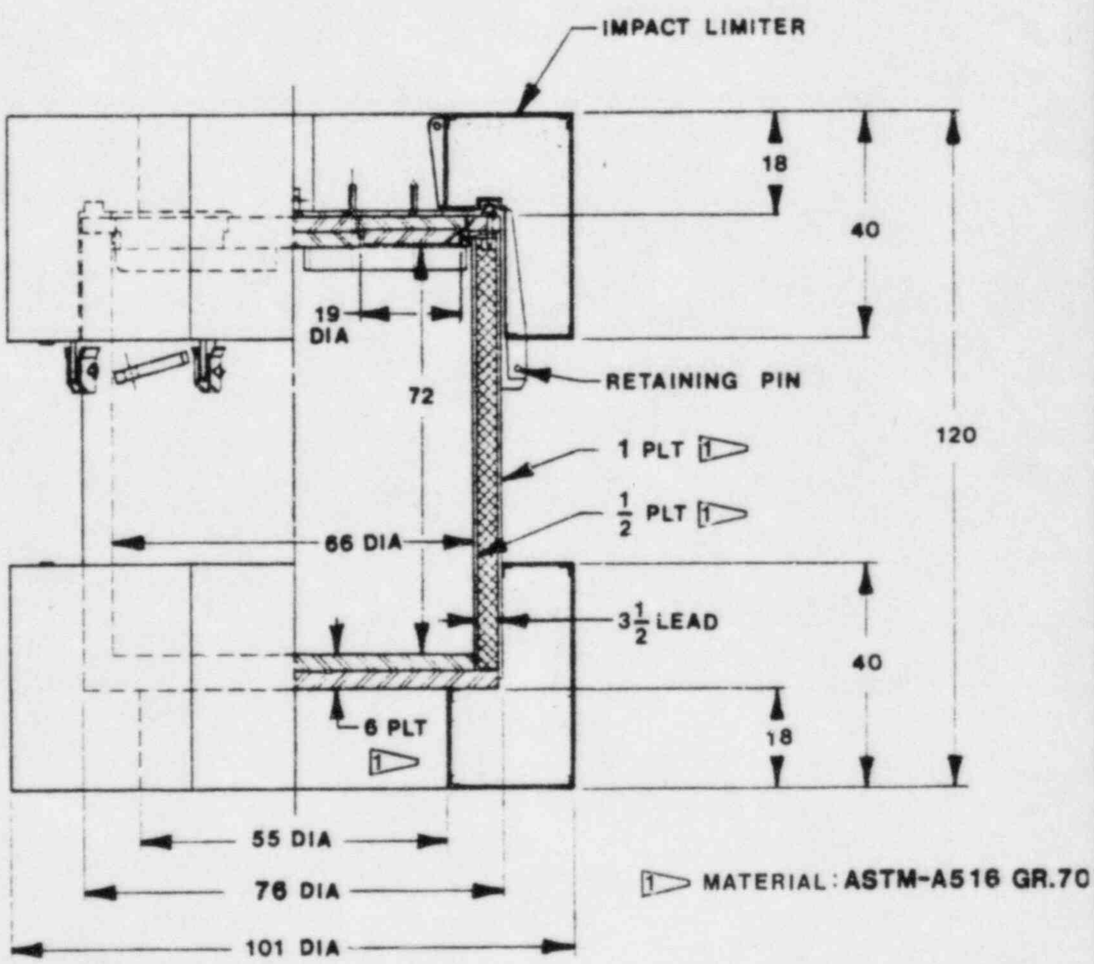




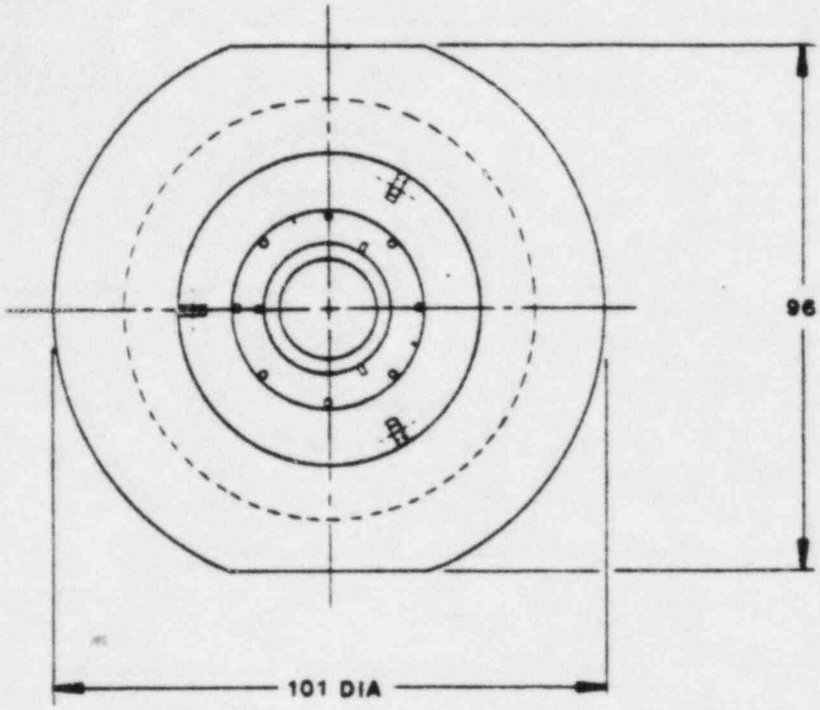
1 MATERIAL: ASTM-A516 GR.70

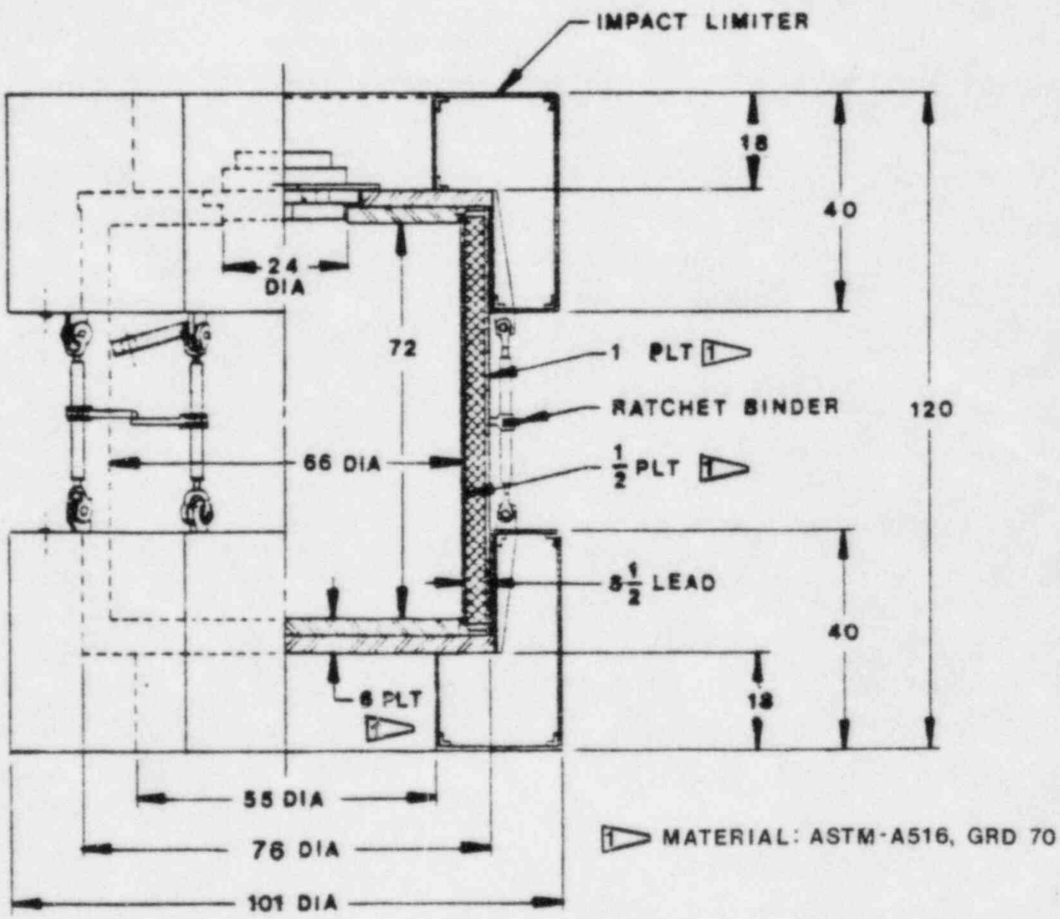
SHIELDED CASK MODEL OH142, MARK I
AL-20-202 and AL-20-203
(16" Dia. Optional Central Secondary Lid Not Shown)





SHIELDED CASK MODEL OH142, MARK II
Y-20-202D





0.2.1.3 Containment Vessel

The overpack itself is not intended to be the containment vessel. It's prime function is to reduce the severity of the hypothetical accident conditions such that the transportation cask can serve as the containment vessel.

As can be seen from the drawing in Appendix 1.10.1, the containment vessel uses two 3" thick steel plates joined together to provide a 6" thick steel lid assembly.

A high temperature silicone gasket is employed in the primary and secondary lid interfaces. The secondary lid also uses a redundant neoprene seal. To assure seal integrity, an operation and maintenance program is prescribed together with a leakage test on the containment vessel prior to its first use. (Refer to Section 6.0 and 7.0 below)

Waste products are contained within heavy gauge disposable steel liners. In the case of dewatered ion exchange resins, the liner is pressure tight to 7 psig, thereby providing redundant containment capability (22.5 psig for Mark II only).

0.2.1.4 Neutron Absorbers

There are no materials used as neutron absorbers or moderators in the Model OH-142 packaging.

0.2.1.5 Package Weight

Gross weight for the package is approximately 64,000 lbs. This includes an estimated payload weight of 10,000 lbs.

0.2.1.6 Receptacles

There are no internal or external structures supporting or protecting receptacles.

0.2.1.7 Drain Port

The cask is provided with a 3/4 inch NPT pipe plug and drain systems. It's use is for removal of entrapped liquids, i.e., rain, decontamination fluids, etc.

0.2.1.8 Tiedowns

Tiedowns are a structural part of the package. From the attached general arrangement drawing it can be seen that four reinforced tiedown locations are provided. Refer to Section 1.4.4 for a detailed analysis of their structural integrity.

0.2.1.9 Lifting Devices

Lifting devices are a structural part of the package. From the general arrangement drawing it can be seen that three reinforced lugs are provided in the Mark II configuration and two reinforced lugs are provided in the Mark I configuration.

0.2.1.10 Pressure Relief System

There are no pressure relief valves.

0.2.1.11 Heat Dissipation

There are no special devices used for the transfer or dissipation of heat. The package maximum design capacity is 400 watts. However, this value may be exceeded if it can be demonstrated that actual equilibrium temperatures with the higher heat load are still within allowable limits.

0.2.1.12 Coolants

There are no coolants involved.

0.2.1.13 Protrusions

There are no outer or inner protrusions except the external ratchet binders described in 0.2.1.2, above, and these are located within the envelope protected by the overpack.

0.2.1.14 Shielding

The contents will be limited such that the radiological shielding provided will assure compliance with DOT and IAEA regulatory requirements.

0.2.2 Operational Features

Refer to the General Arrangement drawing of the packaging, in Appendix 1.10.1. There are no complex operational requirements connected with the Model OH-142 packaging and none that have any transport significance.

0.2.3 Contents of Packaging

This application is for transporting the following radioactive materials as defined in U.S.A. and I.A.E.A. regulations:

a) Type "A" quantities in normal or special form;

b) Type "B" quantities, in normal or special form, as defined in 10 CFR 71.4 (q) and I.A.E.A. Safety Series No. 6, Section IV for Type B(U) packages;

c) "Large Quantity" radioactive materials, in normal or special form, as defined in 10CFR 71.4 (f);

d) Fissile quantities are those limited to the amounts as generally licensed under 10 CFR 71.9 and I.A.E.A. Safety Series No. 6, Section VI;

e) The chemical and physical form of the package contents will be in all forms, other than liquids. This will include ion exchange resins in a dewatered state and miscellaneous radioactive solid waste materials such as pipe, wood, metal scrap, etc.

The contents of the packaging shall not exceed 400 watts of internal decay heat, and shall be so limited to those quantities of radionuclides which result in acceptable radiation dose rates on the exterior surface of the package (200 mr/hr.) and at 2 meters from the cask surface (10 mr/hr.)

1.0 STRUCTURAL EVALUATION

This Section identifies and describes the principal structural engineering design of the packaging, components, and systems important to safety and to compliance with the performance requirements of 10 CFR 71 and I.A.E.A. Safety Series No. 6.

1.1 Structural Design

1.1.1 Discussion

The principal structural members and systems in the Model OH-142 packaging are: (1) the overpack; (2) the primary containment vessel or transport shield, as described in Section 0.2.1, above, and; (3) the disposable carbon steel liner. The above components are identified on the drawing as noted in Appendix 1.10.1. They work together to satisfy the standards set forth in subpart C of 10 CFR 71 and applicable sections in I.A.E.A. Safety Series No. 6. A detailed discussion of the structural design and performance of these components will be provided below.

1.1.2 Design Criteria

As noted above, the waste products such as dewatered ion exchange resins are contained within a welded heavy gauge disposable steel tank or liner. Resins are pumped into the liner where the carrier water is drawn off leaving only the dewatered resins behind. Liners used for dewatered resins have been pressure tested to 7 psig to

substantiate their integrity. Liners are placed within the combined transportation shield and overpack.

The shield top and bottom are constructed to two-three inch thick steel plates laminated together to provide a full 6 inches of solid steel. Cylindrical side walls have an external skin of 1 1/8 inch steel plate and an internal skin of 1/2 inch thick plate. These two plates encase 3 1/2 inches of lead resulting in a total side wall thickness of 5 1/8 inches.

An overpack or impact limiter provides localized protection to those critical areas of the assembly, one of which is the primary lid to body interface or seal. This area must receive minimum deformation during impact, as well as not exceed a maximum temperature of 500° F. Due to the design of the seal area, direct compression, or crushing of the seal is not possible. From the drawing it can be seen that the seal is recessed below the 1 1/8 inch thick plate. Use of a thick silicone seal will allow the joint to open more than 1/2 inch before sealing is lost.

1.2 Weights and Center of Gravity

The weight of the overpack, cask and liner (or payload) will not exceed 64,000 pounds. The overpack and cask weight is approximately 54,000 pounds. The center of gravity for the assembled

package is located at the approximate geometric center of gravity. A reference point for locating the center of gravity is shown on Drawing Y-20-200D. (See Appendix 1.10.1).

1.3 Mechanical Properties of Materials

The Model OH-142 packaging uses an outer and inner shell fabricated of various thicknesses of low carbon hot rolled steel. Material properties of the steel are as follows:

Per		A-36 MIL-HDBK-V	A-516 (Grade 60) ASME	A-516 (Grade 70) ASME
F_{tu}	=	55,000 psi	60,000 psi	70,000 psi
F_{ty}	=	36,000 psi	32,000 psi	38,000 psi
F_{su}	=	35,000 psi	36,000 psi	42,000 psi
F_{brg}	=	90,000 psi	90,000 psi	90,000 psi

Rigid polyurethane foam fills the cavity between the steel shells of the overpack. This material will have a density of approximately 20 pcf and be of a self-extinguishing variety.

Figure 1 represents the stress-strain curve for the NuPac NPI.F6 foam used for this package. The curve provides both minimum and maximum compressive properties and was derived from twenty samples of varying density and grain direction. A 95% probability factor was applied to the standard deviation to establish the spread shown.

Foam Specification NPI.F6 defines the detail foaming testing procedure. It specifies that foam samples will be taken during the actual foaming process and tested to verify that they are within ± 10% of the mean curve at 10%, 30%, and 60% strains.

PHYSICAL PROPERTIES

	UAL-2	UAL-4	UAL-10	UAL-20
Nominal Density, lbs./cu. ft.	2.0	4.0	10.0	20.0
Compressive Strength Ult. psi 77°F ASTM D1621	36	128	350	1060
Compressive Modulus "E" psi x 10^{-3} ASTM D1621	3000	5000	10,500	36,000
Ult. Tensile Stress psi ASTM D1623	65	125	290	570
Tensile Modulus "E" psi x 10^{-3} ASTM D1623	0.5	0.8	4.0	16.0
Shear Strength psi ASTM C273	46	95	215	610
% Moisture Absorption (all cut surfaces 24 hrs. total immersion)	30	25	20	14
Dielectric Constant at 9.375 KMC	1.04	1.08	1.21	1.38
Loss Tangent x 10^{-3}	(0.50)	(0.50)	(0.80)	(2.4)
"K" Factor, Btu/Hr./Ft.^{2}/In./°F ASTM C177	.115	.140	.155	.175
Flame Resistance ASTM 1692-67T	S.E.	S.E.	S.E.	S.E.
Component Ratios Isocyanate Polyol	 100 100	 100 100	 100 100	 100 100

Lead shielding will possess those properties referenced in ORNL-NSIC-68, Table 2.6, Page 84.

SPEC-DATA

This Spec-Data Sheet conforms to editorial style prescribed by The Construction Specifications Institute. The manufacturer is responsible for technical accuracy.

1. PRODUCT NAME

ALBI-CLAD Intumescent Fireproofing Mastics

2. MANUFACTURER

Albi Manufacturing Corporation
Cities Service Company
98 E. Main Street
Rockville, Conn. 06066
Phone: (203) 875-3385

3. PRODUCT DESCRIPTION

Basic Use: ALBI-CLAD mastics are intumescent coatings applied to provide fire protection for structural steel and to extend the inherent fire protection of concrete or masonry.

ALBI-CLAD is used wherever a long-lasting, durable, abrasion resistant fireproofing is required.

Unlike other conventional forms of fireproofing which depend upon water of crystallization or entrapped air, the intumescent coating generates a chemical reaction when exposed to flame or heat in excess of 300°F (148.9°C). This heat activated reaction generates a multi-cellular, carbonaceous foam many times the thickness of the coating. This cellular carbonaceous foam serves as an excellent high temperature insulator protecting the substrate. Simultaneously, this reaction liberates inert gases in the form of nitrogen and carbon dioxide which starves the flame of oxygen driving it further away from the protected surface. The carbonized surface acts as an excellent radiation shield reflecting much of the radiant energy input. Further, this reaction is endothermic providing additional cooling properties to the substrate to which it is applied.

Limitations: Before applying ALBI-CLAD over previously painted or primed surfaces, test for compatibility. If removal of incompatible primers by sand blasting is not practical, apply a suitable barrier coat and build-up to required thickness of ALBI-CLAD in multiple layers. Allow drying of previous coat before applying the succeeding build-up.

When using ALBI-CLAD 89 products, observe Red Label precautions. ALBI-CLAD 89 products contain aromatic solvent mixtures and should be protected from open flame. Fire extinguishing equipment should be available during installation.

Vapors of ALBI-CLAD 89 products may be strong and irritating. Fresh air hoods, masks and blowers should be provided when application is in confined area with inadequate ventilation.

Composition and Materials: ALBI-CLAD mastics are proprietary formulations of resins, binders, pigments and reinforcing inorganic fibers. Contains no asbestos.

ALBI-CLAD is offered in three formulations to effectively suit the end use desired.

ALBI-CLAD 89S (standard): A modified vinyl rich heavy-bodied mastic containing pigments, resins, and aromatic solvents. ALBI-CLAD 89S is a standard all purpose formulation for interior use on surfaces where heavy service abuse is anticipated.

ALBI-CLAD 89X (exterior): A modified vinyl rich heavy-bodied mastic containing pigments, resins and a blend of inorganic fibers using an aromatic solvent system. ALBI-CLAD 89X is recommended for exterior or corrosive exposures and for installations subject to abnormal structural movement.

Where ALBI-CLAD 89X is used for exterior application to steel members, a suitable and compatible rust inhibitive primer is required, such as Albi 487S primer (see below). Further, wherever ALBI-CLAD 89X is used for exterior application, a compatible, fire-inert weather resistant coating such as Albi 144 (see below) must be applied to the exterior surface for maximum durability.

ALBI-CLAD 101 (interior use only): A latex base, water-emulsion system, for interior applications only in areas not subject to high-humidity conditions.

Albi 487S Primer: A recommended phenolic primer for steel exposed to exterior or highly corrosive conditions. To be applied in accordance with manufacturer's directions to steel substrate.

Albi 144: A fire-inert weather-resistant coating, providing long-term protection of the ALBI-CLAD fireproofing, and supplied in a choice of decorative color finishes.

Sizes: ALBI-CLAD is packaged in 55 gal. (208.2 liters) and 30 gal. (113.6 liters) drums or 5 gal. (18.9 liters) pails.

Albi 487S Primer and Albi 144 are packaged in 5 or 1 gallon (3.79 liters) pails.

Textures and Finishes: Spray application of ALBI-CLAD results in a stucco-textured surface. Use a short nap paint roller to smooth down the finish or correct unsightly drippings and surface irregularities.

Colors: ALBI-CLAD comes in a standard light grey finish. On large size orders, special color pigmentation is available at a nominal up-charge.

4. TECHNICAL DATA

Fire Ratings: All ALBI-CLAD formulations provide comparable maximum protection at minimum thickness. ALBI-CLAD has been tested and listed by UL Inc. under Guide #40 U 18.12E. These tests on columns and beams were conducted in accordance with standard ASTM E119 test methods and such reports are available upon request.

ALBI-CLAD has been tested by Factory Mutual as well as other independent laboratories and has demonstrated excellent fire protection performance when subjected to instantaneous flame temperatures of 1800°F (982.2°C).

Research papers, published by the Portland Cement Association, indicates that a 3/16" (5 mm) application of ALBI-CLAD to the undersurface of concrete slabs can extend the composite fire rating by approximately 1 hour. A 7/16" (11 mm) application of ALBI-CLAD can extend the composite fire rating up to 2 hours. These independent tests confirm added fire protection value which could influence critical design of reinforced concrete as well as prestressed concrete construction.

Physical Characteristics: ALBI-CLAD resists impact, abrasion, vibration, flexure and similar physical abuse. It cures to a hard, dense film which will not dust, spall or flake; is resilient enough to permit expansion and contraction of substrate without cracking or delamination.

Withstands weathering (with weather resistant coating) and thermal shock without deleterious effect.

Chemical Resistance: Characteristics typical of other vinyl films. Accelerated weathering and aging tests conducted at UL Inc. indicate that: "after exposure to high-intensity ultra violet light, hydrogen sulphide atmosphere, sulphur dioxide—carbon dioxide, and 9 months exposure to 90% humidity, at temperatures in excess of 160°F (71.1°C), no significant adverse affect was observed."

Specific Gravity: 1.2.

Weight Per Gallon: 10.5 lbs. per gallon (1.25kg/L).

July, 1971
(Supersedes July 1970)

Drying/Curing Time: ALBI-CLAD dries to the touch within 10 to 15 minutes. Curing time to completely disperse occluded solvents—6 to 14 days as determined by thickness of application.

Cleaning and Thinning Solvents: For ALBI-CLAD 89 products use Toluol, Xylol or Albi's 89 solvent mixture. For ALBI-CLAD 101 use water.

5. INSTALLATION

Certified applications may be made by contractors qualified by Albi. Quality control is maintained by requiring factory or on-site training of applicators in proper application techniques as well as fundamentals of fire protection requirements.

Due to simplicity of equipment and application techniques, company personnel can be properly trained to apply it themselves under the supervision of company safety or fire prevention engineering staff.

Preparatory Work: On new work, masking need not be extensive because ALBI-CLAD overspray does not drift or dust beyond the immediate vicinity of the application. On existing work, where ALBI-CLAD will be applied and have possible contact with interior finish, equipment, etc. protection must be provided due to potential attack by aromatic solvents.

Surfaces to receive ALBI-CLAD should be dry and free of mill scale, loose rust, dirt, grease and oil. Priming is required where the substrate may be exposed to high humidity, corrosive fumes or exterior environments. When primer is required for Albi 89 use Albi 487S or other compatible primers possessing equal protective properties. Where primer is required for interior application of Albi 101, use a suitable PVA primer.

On new or existing work, where substrate is already primed, check the compatibility of ALBI-CLAD by installing a sample area to determine bonding adhesive characteristics.

Method: ALBI-CLAD is applied directly from the shipping container utilizing standard, heavy duty, pneumatic spray equipment. On small or hard to reach areas, ALBI-CLAD can be trowelled or palmed to the thickness specified.

The thickness of the application will depend upon the fire endurance rating specified. Measurement of the application is based upon wet film thickness taken at random with a probe to assure adequate coverage.

Architects or owners approval of an applied sample, large enough to provide a guide to the acceptability of the finished work, should be part of the specifications and contract documents. The completed project must match the thickness and texture of the approved sample.

In exterior or humid locations, a final weather resistant coating is required, such as Albi 144. The coating should not supress the intumescent action of ALBI-CLAD when the composite construction is exposed to fire.

Certification: Where required, certification of installation in accordance with specifications can be obtained. Upon completion of the work, the applicator will submit a certificate attesting to the proper rate of coverage to meet the specified fire endurance rating. To be acceptable, the certification should be signed by the applicator and countersigned by the Albi Manufacturing Corporation.

The responsibility of inspection and verification of correct thickness application lies with the representative of the owner or architect who initiates the request for certification.

Building Codes: Approval has been granted by authorities in areas governed by building codes and acceptance has been obtained by all major insurance rating organizations.

6. AVAILABILITY AND COST

Availability: ALBI-CLAD is a patented proprietary product, manufactured by Cities Service Company and its authorized licensees. ALBI-CLAD is manufactured in the United States, Canada and Europe. Shipment is made from the nearest manufacturing facility to the job-site or through authorized warehouse distribution centers.

Cost: Wherever fire protection, coupled with long-term durability, abrasion resistance and weatherability is required, ALBI-CLAD offers the maximum benefits for the money expended. While more expensive than the low cost spray asbestos and lightweight plaster fireproofing applications, it offers excellent economy when compared with concrete, masonry, gunite and lath and plaster.

Since prices will vary depending upon job conditions, location and fire protection requirements, refer to nearest Albi representative for accurate budget figures.

Due to its excellent wear resistant properties, ALBI-CLAD could provide a feasible solution for in-plant production of prefabricated modular homes or fabricated steel construction.

7. GUARANTEES

Cities Service Albi Products are guaranteed against manufacturing defects in material and workmanship.

Our responsibility under this guarantee shall be entirely fulfilled by furnishing, FOB factory, freight allowed to destination, a quantity of product equal to the quantity of product shown to our satisfaction within one year from date of installation to be so defective; or, at our sole option, this guarantee shall be entirely fulfilled by refund of the invoice value of the quantity of product shown to our satisfaction to be so defective within such guarantee period. *This guarantee is in lieu of all express warranties and, except as stated in this guarantee, the products are sold as is.*

Applicator shall guarantee that its installation of material conforms to manufacturer's recommendations, and shall further guarantee its workmanship connected with the installation for a period of one year from the date of installation.

8. MAINTENANCE

Cracks, nicks or dents caused by human or machine abuse may be repaired easily by hand using a putty knife.

When used in up-grading of existing fire rating requirements, or in plant additions, ALBI-CLAD can be applied directly to existing ALBI-CLAD surfaces, or to new additional structure. Removal of fireproofing to accomodate additional clips, supports, etc. can be achieved by scraping or chipping material away providing for cleaner and less costly alterations than would be experienced with other types of fireproofing such as concrete, lath and plaster, etc.

9. TECHNICAL SERVICES

Albi qualified applicators or factory representatives are available throughout the country. Write or phone collect to the nearest office for prompt assistance. Inquiries will be channeled to our nearest representative or qualified applicator for personal contact.

Albi Branch Offices:

P.O. Box 6148
San Mateo, Calif. 94403
(415) 574-3560

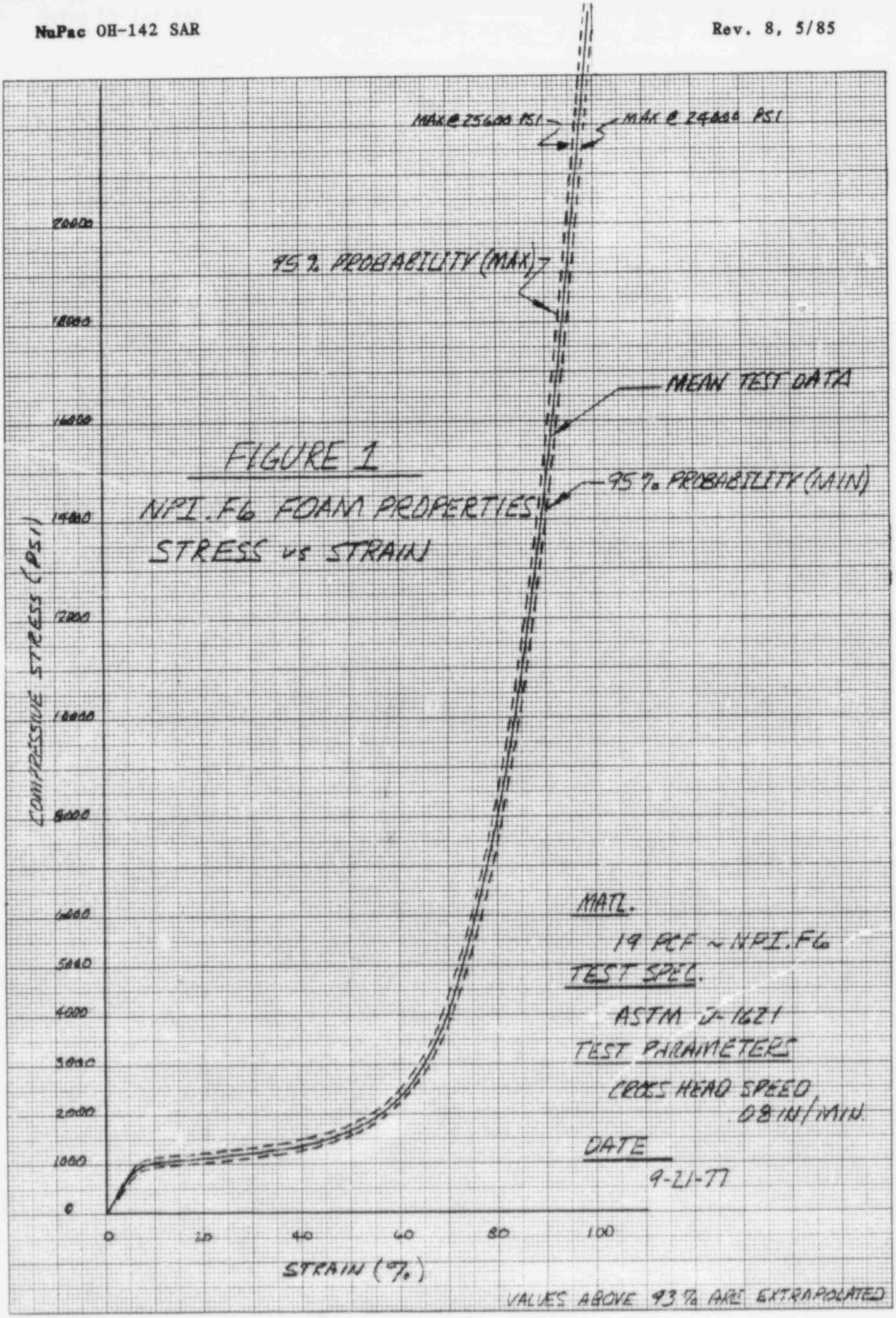
Cities Service Company
60 Wall St.
New York, N.Y. 10005
(212) 943-4023

In Canada:

Cities Service Chemicals Ltd.
118 Production Drive
Scarborough, Ontario
(416) 291-5519

10. THERMAL CONDUCTIVITY

Natural form: K = 2.9
Intumesed form: K = 57


MAX @ 25600 PSI
MAX @ 24000 PSI
95% PROBABILITY (MAX)
MEAN TEST DATA
FIGURE 1
NPI.F6 FOAM PROPERTIES
STRESS vs STRAIN
95% PROBABILITY (MIN)
COMPRESSIVE STRESS (PSI)
20000
18000
16000
14000
12000
10000
8000
6000
5000
4000
3000
2000
1000
0
0
20
40
60
80
100
STRAIN (%)
MATL.
19 PCF ~ NPI.F6
TEST SPEC.
ASTM D-1621
TEST PARAMETERS
CROSS HEAD SPEED
.08 IN/MIN.
DATE
9-21-77
VALUES ABOVE 93% ARE EXTRAPOLATED

1.4 General Standards for all Packages

This section demonstrates that the general standards for all packages are met.

1.4.1 Chemical and Galvanic Reactions

The materials from which the packaging is fabricated (steel, lead, and polyurethane foam) along with the contents of the package (disposable steel containers) will not cause significant chemical, galvanic, or other reaction in air, nitrogen or water atmosphere.

1.4.2 Positive Closure

The positive closure system has been previously described in Section 0.2.1. In addition, each package will be sealed with an approved tamper indicating seal and suitable locks to prevent inadvertent and undetected opening.

1.4.3 Lifting Devices

Two lifting locations are provided for the Mark I and three for the Mark II. Both have identical lugs. Total load for two lugs is:

P = (Pkg Wt) (3g's)/No. of Lugs

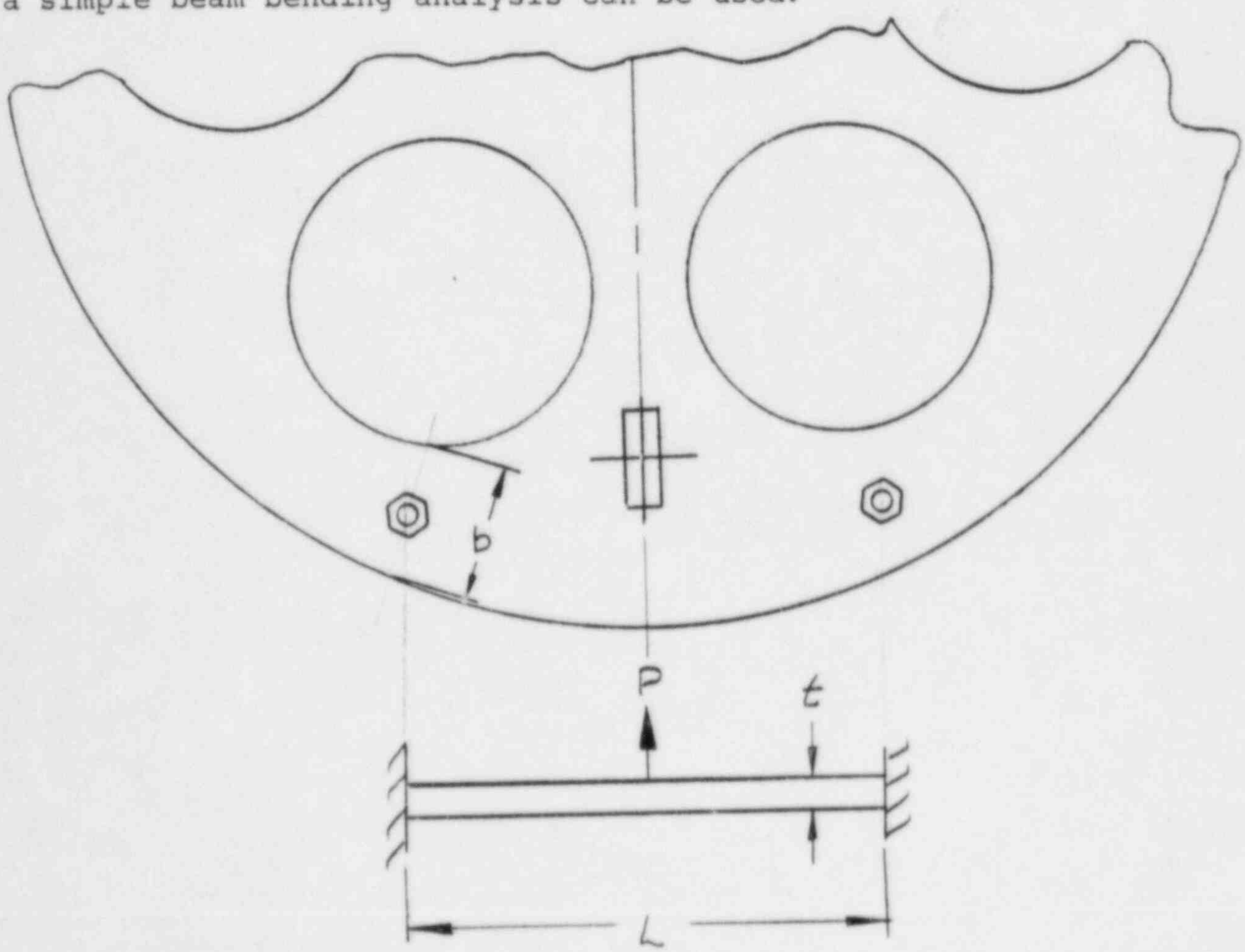
P = (64000 lbs) (3g's)/(2) = 96,000 lb/lug

From drawing No. A1-20-203 Rev. A and the following sketch, it can be seen that loads from the lugs are distributed into the six inch thick steel lid. The bulk of the load will be beamed through the lid to the two adjacent lid bolts. These bolts have a capacity of 120,750 lbs. each (per page 1-22d-3). The associated Margin of Safety is calculated as:

M.S. = (2) (120,750 lbs)/96,000 lb-1

M.S. = + Large

If, for simplicity, we conservatively assume that only one of the three inch thick lid plates will beam the load to the bolts a simple beam bending analysis can be used.



$f_b = 6M/bt^2 = 6\ PL/8bt^2$

Where:

$P = 96{,}000$ lbs.

$L = 27.5$ in.

$b = 7.0$ in.

$t = 3.0$ in.

$f_b = (6)(96{,}000)(27.5)/(8)(7)(3)^2$

$f_b = 31428$ psi

Margin of Safety is:

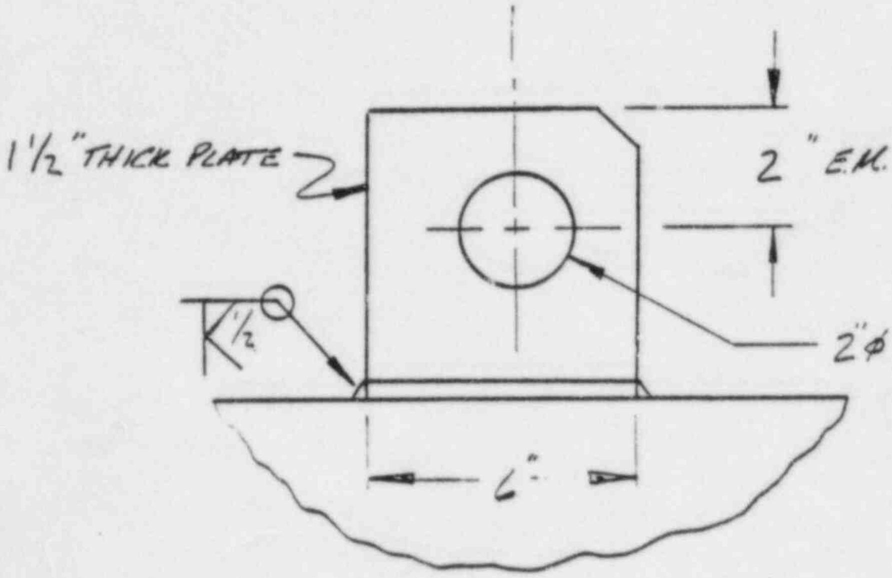
M.S. = 36000 psi/31428 psi-1

M.S. = +.15

This is conservative since the bending stress varies as the square of the plate thickness and only three inches of the six inch total thickness were used. Additional conservatism lies in the use of a uniform beam of minimum width. Therefore, from the above it can be concluded that the lug, bolts and lid can react the lifting load.

Lifting devices on the secondary lids are covered by sheet metal assemblies during transit. This prevents inadvertant lifting of the cask assemblies by lugs not designed to withstand the load.

The capacity of each lug can be determined from the following:



Using the standard 40° shearout equation:

$$P = F_{su}\ 2\ t \quad \left[E.M. - d/2 \cos 40^\circ\right]$$

$$= (35{,}000 \text{ psi})(2)(1\tfrac{1}{2}) \quad \left[\ 2 - (.766)\right]$$

$$= 129{,}570 \text{ lbs.}$$

Margin of Safety is:

MS = 129,570/96,000-1

MS = + .35

The capacity of the lug to cask interface can be calculated as follows:

Lug Weld Area

Weld Area $A = (6)(2)(1 \text{ in})(\sin 45^\circ)$

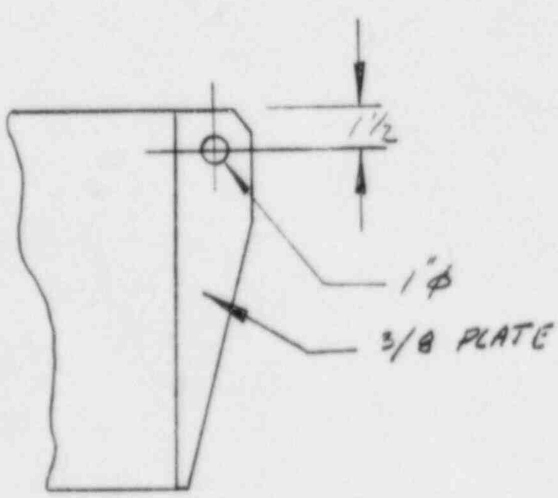
$A = 8.48 \text{ in}^2$

$$P = F_{ty}A$$
$$= (36,000)(8.48)$$
$$= 305,280 \text{ lbs/lug}$$
$$M.S. = 305,280/96,000-1$$
$$= + \text{Large}$$

Therefore, it can be concluded that the lifting points are more than capable of reacting a load equal to three times the package weight. Should the lugs experience a load greater than 129,570 pounds, they will shear out locally. This will have no detrimental effects on the package's ability to meet other requirements of the subpart. The lugs will be covered during transport.

Mark I Overpack Lifting Lug

Since the Mark I configuration has a removable overpack separate lifting lugs are provided. These will be covered during transit.



Using standard 40° shear out equation:

$$P = F_s\ 2t\ \left[E.M. - d/2 \cos 40^{\circ}\right]$$
$$= (35{,}000\ psi)(2)(3/8)\ \left[1.5 - 1/2 \cos 40^{\circ}\right]$$
$$= 29{,}320\ lbs.$$

Margin of Safety:

M.S. = 29,320 lbs./(3000 lbs.)(3 g's)/3 lugs -1

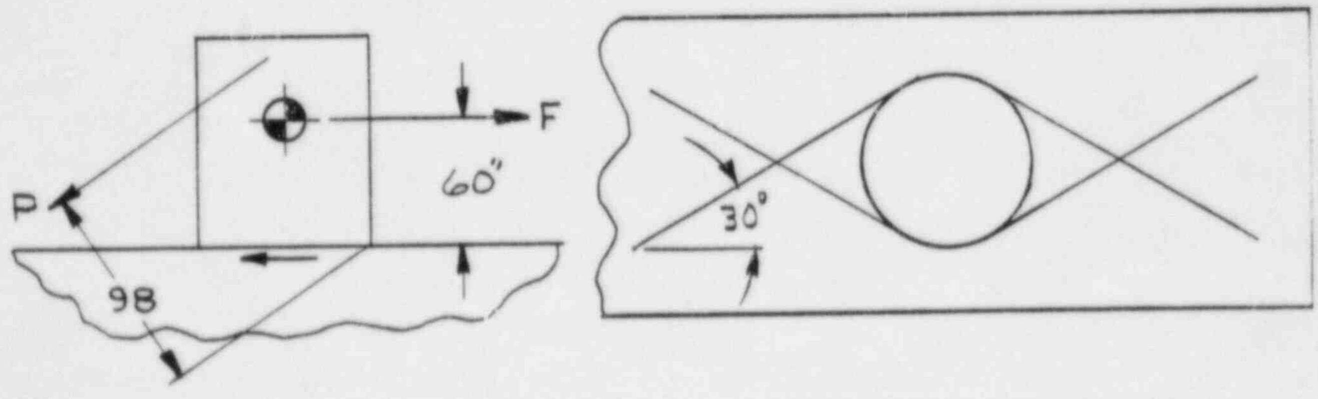
M.S. = <u>+ Large</u>

The 3/8 thick lugs will easily buckle under end drop impact condition producing no significant effect on the overpack or package. These lugs will be covered during transit.

1.4.4 Tiedowns

Four tiedowns are provided. The total load carried by each can be calculated as follows:

10g Longitudinal



$M_{corner} = 0$

$(64{,}000 \text{ lbs})(10 \text{ g's})(60)/2 \text{ lugs} = 98P$

$P = 195918 \text{ lbs}$

$P_R = P/\cos 30^\circ$

$P_R = 226{,}226 \text{ lbs}$

Therefore, the 10 g longitudinal load will produce a maximum load on the lug of

$P_R = 226{,}226 \text{ lbs (Longitudinal)}$

5 g's Lateral

$P = 195918 \text{ lbs } (5 \text{ g's}/10 \text{ g's})$

$P = 97959 \text{ lbs/lug}$

$P_R = P/(\sin 30^\circ)$

$P_R = 195918 \text{ lbs (Lateral)}$

2 g's Vertical

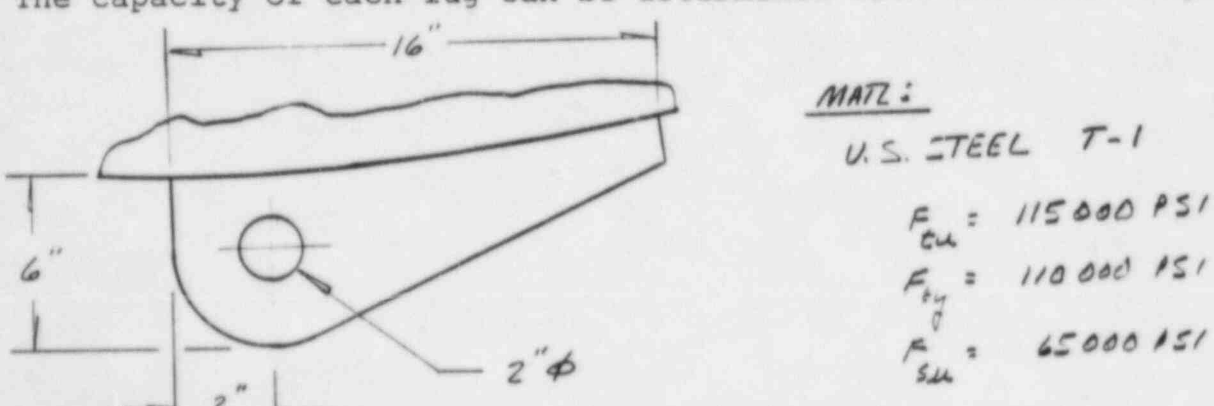
$P_V = (2 \text{ g's})(64{,}000 \text{ lbs})/4 \text{ lug}$

$P_V = 32000 \text{ lbs/lug}$

$P_R = 32000 \text{ lbs}/\sin 30^\circ$

$P_R = 64{,}000 \text{ lbs (Vertical)}$

The capacity of each lug can be determined from the following:



Using 40° shear out:

$$P = F_s 2t \left[E.M. - d/2 \cos 40^\circ \right]$$

Where

F_s = 65,000 psi

t = 2.0

EM = 3.0

d = 2

$$P = (65,000)(2)(2) \left[3.0 - .766 \right]$$

$$P = 580840 \text{ lbs (shear out capacity)}$$

Weld Area

$$P_W = (16 \text{ in})(2)(1.0 \text{ in})(35,000 \text{ psi})(\sin 45^\circ)$$

$$P_W = 791,960 \text{ lbs.}$$

Since the lugs are oriented in the direction of the load, there will be no bending stress.

From the above it can be seen that the maximum combined loads produced from the 10 g, 5g and 2 g's accelerations are:

$$P_R = (226226 \text{ lbs} + 195918 \text{ lbs} + 69000 \text{ lbs})/\text{lug}$$

$$P_R = 486144 \text{ lbs/lug}$$

The critical load path will be shear out of the lug or:

$$P = 580,840 \text{ lbs/lug}$$

Margin of Safety:

M.S. = 580840/486144 - 1

M.S. = +.20

Therefore, it can be concluded that the tiedowns are able to react a load greater than the <u>combined</u> 10, 5 and 2 *g* tiedown loads. Should the tiedowns experience loads greater than 580,840 lbs., the lug will locally shear out. This will not impair the overpacks ability to meet other requirements of the subsection.

1.5 Standards for Type "B" and Large Quantity Packaging

This section demonstrates that the standards for Type "B" and large quantity packaging are met.

1.5.1 Load Resistance

The requirement for load resistance is that, when simply supported at its ends, the cask must be able to withstand a uniformly distributed load equal to five times the cask weight. Conservatively, the outer shell alone is assumed to support

this load. Accordingly, the stress is

$$S_f = \frac{MC}{I}$$

where

$$M = \frac{1}{8}WL = (5)\left(\frac{1}{8}\right)(64,000)(112) = (4.48)(10^6) \text{ in-lb}$$

$$c = \frac{D}{2} = \frac{76}{2} = 38 \text{ in.}$$

$$I = \pi \frac{d_o4 - d_i4}{64} = \frac{\pi}{64}(76^4 - 74^4) = (16.5)(10^4) \text{in.}^4$$

and the corresponding stress is:

$$S_f = \frac{MC}{I} = \frac{(4.48)(10^6)(38)}{(16.5)(10^4)} = 1031 \text{ psi}$$

which results in a margin of safety of:

$$MS = \frac{F_{ty} - 1}{S_f} = \frac{36,000}{1031} - 1 = + \text{large}$$

Therefore, the package can safely react the "Load Resistance" condition.

1.5.2 External Pressure

An external pressure of 25 psig is reacted by the external shell in hoop compression. The stress can be calculated as follows:

$$f = Pr/t$$

Where

P = 25 psig

r = 38 in.

$t = 1.125$ in (Outside shell only)

$f = (25)(38)/1.125$

$f = 844$ psi

Margin of Safety:

$MS = F_{ty}/f-1$

$= 36,000/844 - 1$

$=$ + Large

The analysis is conservative due to the presence of 3 1/2 inches of lead. The lead assures buckling stability of the shell.

Pressure across the end is carried in plate bending by the 2-3 inch thick steel plates top and bottom. Assuming a circular plate uniformity load and with edges simply supported, the stress can be calculated as follows:

$f_r = 3W(3M+1)/8 \ Mt^2$ (per "Formulas for Stress and Strain" by Roark)

Where

$W = (25)(\pi)(78)^2/4 = 119,460$ lbs.

$t = 3"$

$M = 1/.33 = 3$

$f_r = (3)(119,460)(10)/8 \pi (3)(9)$

$f_r = 5282$ psi

Margin of Safety:

$MS = 36,000/5282-1$

$MS =$ + Large

It is therefore safe to conclude that the containment vessel can react a 25 psig pressure without loss of contents.

1.6 Normal Conditions of Transport

The Model OH-142 packaging has been designed and constructed, and the contents are so limited (as described in Section 0.2.3 above) that the performance requirements specified in 10 CFR 71.35 will be met when the package is subjected to the normal conditions of transport specified in Appendix A of 10 CFR 71. The ability of the Model OH-142 packaging to satisfactorily withstand the normal conditions of transport has been assessed as described below:

1.6.1 Heat

A detailed thermal analysis can be found in Section 1.7.3 wherein the package was exposed to direct sunlight and 130°F still air. The steady state analysis conservatively assumed a 24 hour day at maximum solar heat load. The maximum steady state temperature was found to be 168°F. These temperatures will have no detrimental effects on the package.

A second thermal analysis was run using the normal thermal conditions specified in 10 CFR 71 as revised August 1983. These conditions include 100°F ambient air, a significantly higher solar loading, and 400 watts of internal decay heat. The maximum steady state temperature under such conditions was found to be 139.1°F.

1.6.2 Cold

The materials of construction in this package are identical to those approved and used in numerous existing Type "B" licensed packages. All of the following utilize the same materials.

1. DOT 6400 Super Tiger
2. DOT 6272 Poly Panther
3. DOT 6679 Half Super Tiger
4. DOT 6553 Paducah Tiger
5. DOT 6744 Poly Tiger
6. SN-1 Shipping Container N.U.S.
7. Hittman - HN-300 Cask
8. NRC No. 9069 Westinghouse MO-1
9. Ontario Hydro Overpack - CDN U33 U33

Specifically, the Ontario Hydro package has operated continuously at these cold temperatures with no evidence of problems.

Therefore, on the basis of years of actual operating experience it is safe to conclude that cold will not substantially reduce the effectiveness of the package.

To improve the cold weather capability of the OH-142, MK II, the A-36 material on the shell and lid will be replaced by A-516. This material provides improved notch sensitivity and strength.

Foam material has been tested to $-40^{\circ}F$ and found to exhibit a small increase in compressive strength. Samples failed in the

same manner at -40°F as they did at room temperature, indicating that brittle fracture is not apparent at this temperature range.

	Compressure Strength (psi)		
% Strain	Room Temp.	-40°F	Variation
10	960	960	-0-
20	1050	1218	1.16
40	1300	1495	1.15
50	1600	1792	1.12
60	2260	2305	1.02
70	4310	4310	1.00
80	7640	8098	1.06

From the impact analysis shown on Page 1-20j, it can be seen that impact accelerations decrease as compressive strength increases. Therefore, cold conditions will not produce detrimental loading and testing indicates that brittle fracture characteristics are not present

1.6.3 Pressure

A differential pressure of .5 atmosphere will be reacted by the lid and its associated ratchet binder tie downs. From Section 1.5.2, it can be seen that the containment vessel can safely react a 25 psig external pressure. It is, therefore, safe to conclude that a positive margin of safety will exist for shells when subjected to the .5 atmospheric pressure.

Loads on the binders are calculated as follows:

$$P_b = (A\ in^2) Ip\ psi)/(\text{No. of Binders})$$

$$= (66)^2\ \pi\ (14.7/2)/(8)(4)$$

$$= 3143\ \text{lbs/binder}$$

Minimum breaking strength of each binder is 160,000 lbs.

Margin of Safety:

M.S. = 160,000/3036-1

M.S. = + Large

It can therefore be concluded that the packaging can safely react an atmospheric pressure of .5 times standard atmospheric pressure.

1.6.4 Vibration

Shock and vibration normally incident to transport are considered to have negligible effects on the Model OH-142 packaging. Ratchet binders and ball lock pins have been used successfully for years on similar Type "B" packages. The Paducah Tiger, an overpack for 10 ton UF_6 cylinders, uses both binders and ball lock pins to secure the lid. (Ref. D.O.T. 6553) More than 30 of these packages are in service and have traveled millions of miles without incident. They are also being used on shielded transportation casks and recently on an NRC licensed Mixed Oxide Fuel shipping container. (Ref. NRC No. 9069 W MO-1) Binders have been used for years as the standard means of securing cargo on both ships and rail applications.

Therefore, the OH-142 binders and ball lock pins are adequate to secure the lid when the packaging is subjected to the shock and vibration environment associated with normal transport.

1.6.5 Water Spray

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

1.6.6 Free Drop

Dropping a 64,000 pound package a distance of one foot is not a normal condition of transport. The package is permanently affixed or tied to a special tri-axle trailer. As such, it will not be handled like general freight at a truck terminal.

For conservatism we have combined the one foot handling drop with the 30 foot hypothetical accident drop condition and analized the package for a single 31 foot drop. The subsequent analysis, shown in Section 1.7.1, demonstrates the packages ability to withstand the combined 31 foot drop height.

1.6.7 Corner Drop

This requirement is not applicable since the Model OH-142 packaging is fabricated of steel.

1.6.8 Penetration

From previous container tests, as well as engineering judgment,

it can be concluded that the 13 pound rod would have a negligible effect on the heavy gauge steel shell overpack or cask.

1.6.9 Compression

N/A since package exceeds 10,000 lbs.

1.6.10 Conclusion

As the result of the above assessment, it is concluded that under normal conditions of transport:

1) There will be no release of radioactive material from the containment vessel;
2) The effectiveness of the packaging will not be substantially reduced;
3) There will be no mixture of gases or vapors in the package which could, through any credible increase in pressure or an explosion, significantly reduce the effectiveness of the package;
4) N/A (No coolants involved)
5) N/A (No coolants involved)

1.7 Hypothetical Accident Conditions

The Model OH-142 package has been designed and its contents are so limited that the performance requirements specified in 10 CFR 71.36 will be met if the package is subjected to the hypothetical accident conditions specified in Appendix B of 10 CFR 71.

To demonstrate the structural integrity of the package and its ability to withstand the hypothetical accident conditions, a detailed computerized analysis was conducted. It is important to note that the techniques, analysis methods, assumptions, and routines employed follow closely those used for other petitions such as:

1) DOT 6400 Super Tiger
2) DOT 6553 Paducah Tiger
3) DOT 6272 Poly Panther
4) DOT 6679 Half Super Tiger
5) DOT 6744 Poly Tiger
6) AECB - Resin Flask
7) Model MO-1 packaging - Docket No. 71-9069

These are proven techniques that agree closely with full scale tests as well as other publicized standars such as ORNL-NSIC-68. In all cases the analysis has been proven to be conservative when compared with full scale testing.

1.7.1 Free Drop

It was suggested that, for conservatism the 1 foot drop condition associated with normal handling be combined with the 30 foot accident condition to provide total drop height of 31 feet. Therefore, the following analysis have been conducted on the package using the full gross weight and a 31 foot drop.

The high density foam contained within the impact limiters is designed to crush on impact thus absorbing and distributing the load.

The mechanical properties for the foam used in this package can be found on Figure 1. These properties are applicable for loading conditions in the direction parallel and perpendicular to the rise direction. High density foams, greater than 18 pcf, exhibit these isotropic properties for two reasons. First, because of their high density, the amount of rise during the formation of the foam is small thus producing a cell structure that is very uniform and not elongated. Secondly, the size of the overpack allows the foam to expand laterally as well as vertically. Again, resulting in uniform grain structure and its associated isotropic properties. The two curves shown in Figure 1 represent the maximum and minimum statistical compressive properties based on a 95% probability for loading in either direction.

Three drop conditions for the package have been evaluated, i.e. end, corner, and side. For each we have reviewed the failure mechanism that would produce maximum load as well as maximum deformation. In these evaluations maximum and minimum mechanical properties were used to produce the most conservative results.

1.7.1.1 Free Drop Impact Analysis - End Impact

Energy to be absorbed by the impact limiter can be calculated as follows:

K.E. = Wh

Where

W = 64,000 lbs.

h = 31 ft.

K.E. = (64,000 lbs)(31 ft)

$= 1.98 \times 10^6$ ft-lbs

Assume:

1. Full area of overpack reacts load
2. Drop Height = 31 ft.

Energy absorption is calculated by:

Energy = (Foam Volume Crushed)(Crush Strength)

$K.E. = VF_c$

Where:

V = (AREA)(Depth)

$$= \frac{\pi}{4}\left[(D_o^2 - D_1^2)\right] h$$

$$= \frac{\pi}{4}\left[(101)^2 - (55)^2\right] h$$

$= 5636$ h in^3

$F_c = 1000$ psi (Nominal) @ 10% Strain

$(1.98 \times 10^6)(12) = (5636)h\ (1000)$

h = 4.22 in. (or 23% strain)

Assuming the 4.22 in deflection produces a 23% strain it is conservative to use the stress at 23% to calculate the acceleration. Therefore, at 23% strain the maximum compression stess is 1300 psi.

$$\text{Acceleration} = \frac{(1300\ \text{psi})(5636\ \text{in}^2)}{(64000\ \text{lb})}$$

$$= 114\ \text{g's}$$

Repeating the same analysis but with the following assumption:

Assume 1. Only projected area of cask reacts load

2. Drop height = 31 ft.

$$KE = A\ F_c\ h$$

$$(64000)(31)(12) = \frac{\pi}{4}\ (76.25^2 - 55^2)(1000)\ h$$

$$h = 10.86\ \text{in}$$

Strain = 10.86 in/18 in = .60 or 60% strain

Stress @ 60% strain = 2500 psi (Max.)

$$\text{Acceleration} = (2500\ \text{psi})(2190\ \text{in}^2)/(64000\ \text{lbs})$$

$$= 85.5\ \text{g's}$$

Therefore, the maximum acceleration experienced will be 114 g's.

Since the primary lid will be reacting these loads in direct compression, the binder will not be loaded. The secondary lid attachments must react these loads. Therefore, bolt stress can be found from the following:

The 24" secondary lid weight is:

$$W_L = 1776 \text{ lbs.}$$

Assume the lid must also react the projected area portion of the payload.

$$W_Y = (10000 \text{ lbs})(24)^2/(66)^2$$

$$W_Y = 1322 \text{ lbs}$$

Total equivalent wt.

$$WT = 1776 \text{ lbs} + 1322 \text{ lbs}$$

$$WT = 3098 \text{ lbs}$$

Bolt Loads:

$$P = (3098 \text{ lbs})(114 \text{ g})/8 \text{ bolts}$$

$$P = 44146 \text{ lbs/bolt}$$

Using 115 ksi 7/8 inch diameter bolts (SAE Grade 5) their strength is 56,000 lbs. (Area = .487 in^2 per Mil Hdbk V)
Margin of Safety:

$$M.S. = 56000/44146 - 1$$

$$M.S. = +.27$$ 24" Secondary Lid Closure Bolts

The optional 16" diameter lid design would have a larger margin of safety since it employs the same number and size bolts as the 24" design, but its weight and the weight of the payload projected on it is much less.

The optional 29 inch secondary lid weight is:

$$W_L = 2255 \text{ lbs}$$

Again, assume the lid must react the projected area portion of the payload:

$$W_Y = (10,000)\ (29)^2/(66)^2$$

Total equivalent weight is:

$$WT = 2255 + 1931 = 4186 \text{ lbs}$$

Bolt loads:

$$P = (4186)\ (114\ g)/8 \text{ Bolts}$$

$$= 59651 \text{ lbs/bolts}$$

Using ASTM A-320 Grade L7, 1 inch diameter bolts, the strength is 75,750 lbs. (Area = .606 in^2 per Mil Hdbk V).

Margin of Safety:

$$M.S. = (75,750/59,651)-1$$

$M.S. = +.27$ <u>Optional 29" Secondary Lid Closure Bolts</u>

Conclusion: It is therefore safe to conclude that the package can safely react the maximum loads for a 31 foot end drop without detrimental effects.

1.7.1.2 Free Drop Impact Analysis - Corner Drop

For the case of corner drop or edge impact the deformations experienced by the overpack are more difficult to approximate with a simple analysis. In order to account for the strain hardening which takes place in the foam a detailed computer program (CYDROP) was generated.

CYDROP treats the corner impact of a cylindrical package upon an unyielding surface. The package itself consists of a cylindrical payload portion surrounded by a larger cylindrical volume composed of a crushable media. So long as the deformations of the crushable media are modest - the problem may be approximately solved by assuming a uniform crush stress exists over the elliptical surface of the crush plane (contact surface). CYDROP was developed by NuPac specifically to address problems of large deformations of this crushable media and to treat geometries where the cylindrical overpack envelope possesses axisymmetric cylindrical voids (e.g. does not completely cover the cylindrical ends of the payload package).

The large deformation behavior of the crushable media is accommodated by determining the actual strain of the crushable media at a point. This strain is used to determine the corresponding stress from an implicit tabular definition of media stress-strain characteristics. The total crush force is found by a double integration over the contact area of the crush plane.

Stain energy absorbed by the crushable media is determined by integrating the crush force and its associated deformation. The package is assumed to be at "rest" when the computed strain energy value equals the applied kinetic (drop) energy.

The geometric calculations for the contact surface and the associated strains are carried out using a moving (x, y, z) coordinate system in which the x-y plane corresponds to the crush plane, see Figure A. The crush plane itself represents a segment of an ellipse. The contact area is this ellipse segment, provided no cylindrical end void exists. When a cylindrical end void exists, the contact area of the crush plane is reduced by the removal of a second elliptical region associated with the projection of this void into the contact plane.

Calculation of strain is somewhat more complex. In principal, the distance from point (x, y) in the crush plane to the payload is found and denoted, δ_{top}. Similarly the distance to the undeformed external overpack envelope is found and denoted, δ_{bot}. The strain represents deformation divided by original thickness, or:

$$\epsilon = \frac{\delta_{bot}}{\delta_{bot} + \delta_{top}}$$

At any point (x, y), the calculation of top may follow three branches, according to location. The three possible branches relate to the payload surface intercepted. They are:

<u>The Circular Bottom of the Payload</u>

The bottom of the payload cylinder describes an ellipse in the crush plane. If (x, y) is inside this ellipse, the point is considered "backed" by the bottom of the payload. An exception to this general statement is noted in the discussion of the "Unbacked Region", see below.

The Cylindrical Surface of the Payload

The cylindrical surface of the payload describes a rectangular region tangent to the payload bottom ellipse at its major axes. If (x, y) is outside the bottom ellipse yet possesses an x coordinate less than the radius of the payload bottom, the point is considered "backed" by the payload cylinder.

Unbacked Regions

Unbacked regions are of two forms - those associated with the cylindrical end void and those near the external surface of the overpack. The unbacked region associated with the end void is a point in the crush plane which lies within the ellipse defined by the void circle lying in the plane of the payload bottom. The unbacked region associated with points near the overpack extremeties is defined by those points (x, y) where the x coordinate exceeds the radius of the payload volume. Points which are "unbacked" employ a nominal crush stress for force integration purposes. (For current analysis, this stress was set to zero)

The calculation of δ_{bot}, the distance to the undeformed overpack envelope, may follow two branches. These branches correspond to intercepts with either the cylindrical surface of the overpack or the circular end of the overpack.

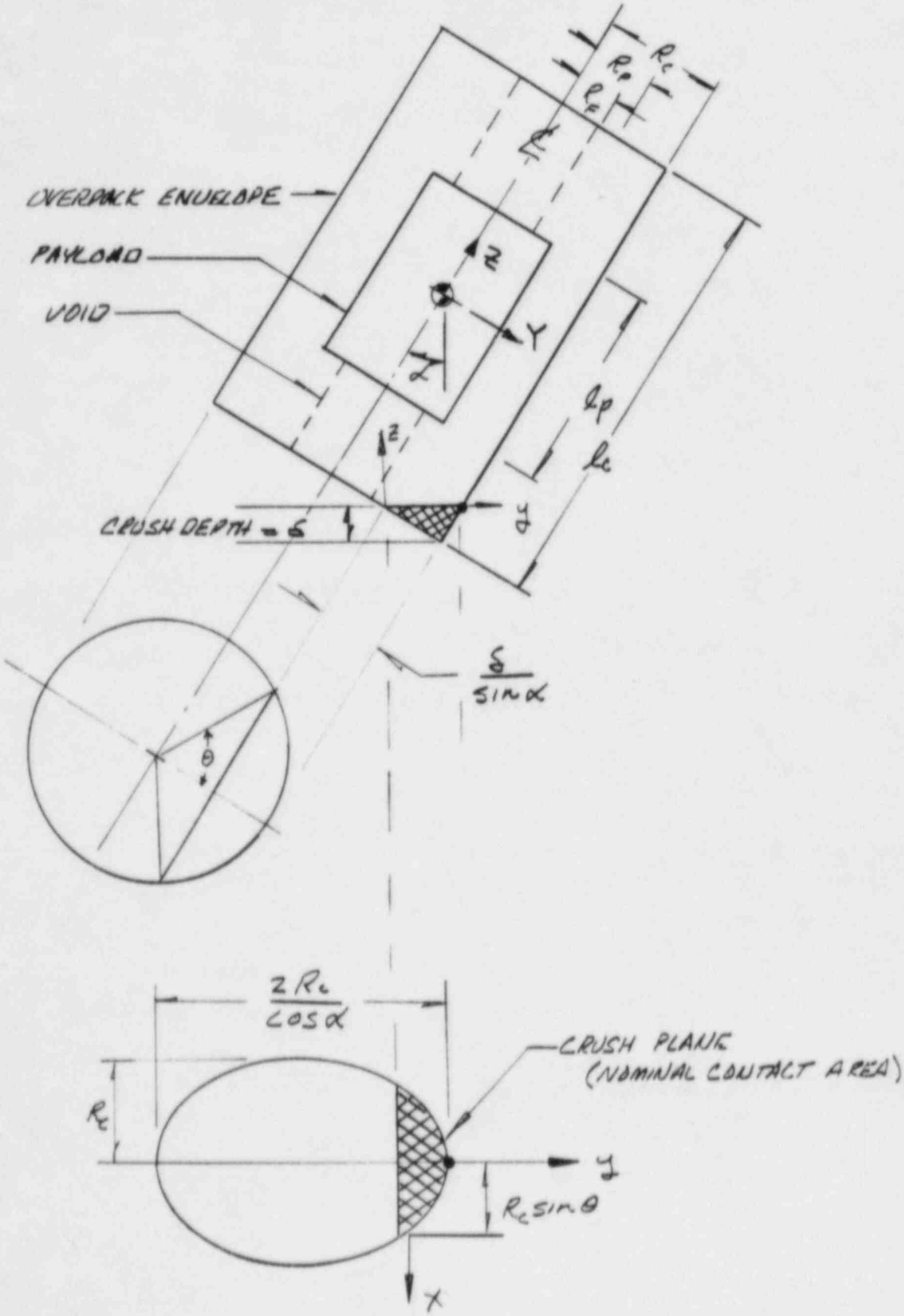
The analytics describing the geometry discussed above, consists of the sequential application of a series of geometric transformations of surfaces described in the coordinates of the cylindrical package (X, Y, Z) to the coordinates of the contact plane (x, y, z). The surfaces in package coordinates are:

Overpack Cylinder

$$X^2 + Y^2 = R_c^{\ 2}$$

FIGURE A

CORNER CYLINDER IMPACT GEOMETRY



Overpack Bottom Circle

$$X^2 + Y^2 = R_c^2$$

$$Z = -l_c/2$$

Payload Cylinder

$$X^2 + Y^2 = R_p^2$$

Payload Bottom Circle

$$X^2 + Y^2 = R_p^2$$

$$Z = -l_p/2$$

Void Circle at Payload

$$X^2 + Y^2 = R_f^2$$

$$Z = -l_p/2$$

Void Circle at Overpack Exterior

$$X^2 + Y^2 = R_f^2$$

$$Z = -l_c/2$$

In order to determine the maximum accelerations experienced, a total of 4 cases were run. Full range stress strain curves were used representing both minimum and maximum compressive stresses. These curves can be found on Page 1-4c and represent 95% probability numbers based to twenty samples. These samples included both perpendicular as well as parallel properties.

In addition to the variation in mechanical properties, the effects of the central hole in the overpack were evaluated. Since the program was written to ignore any energy contribution to unbacked foam a portion of the central overpack area was analytically eliminated because of the 55 in. diameter hole. By decreasing the central hole (Package External Hole Diam) the program would assume that that area was backed and able to absorb energy. Therefore, the backed and unbacked cases were also evaluated at the minimum and maximum material properties.

Case No. 1

Minimum mechanical properties
Full 55 inch central hole

Case No. 2

Minimum mechanical properties
Central hole filled

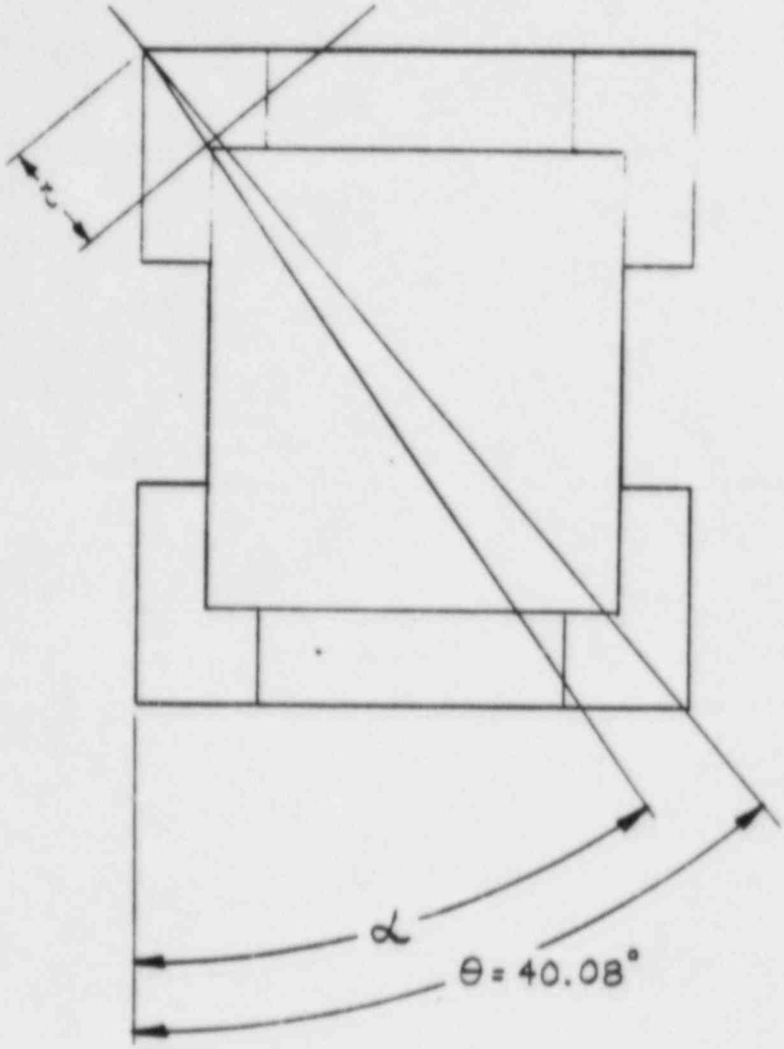
Case No. 3

Maximum mechanical properties
Full 55 inch central hole

Case No. 4

Maximum mechanical properties
Central hole filled

From the printouts it can be seen that columns 6 and 7 provide the total kinetic energy and absorbed strain energy for incremental crush depths. When these values become identical the package is in equilibrium. Column 8 provides this ratio for rapid evaluation. It is important to note that a large amount of additional energy absorbing capability remains in the package. From Case No. 1 it can be seen that the package comes to rest after reaching a crush depth of 20.50 inches.

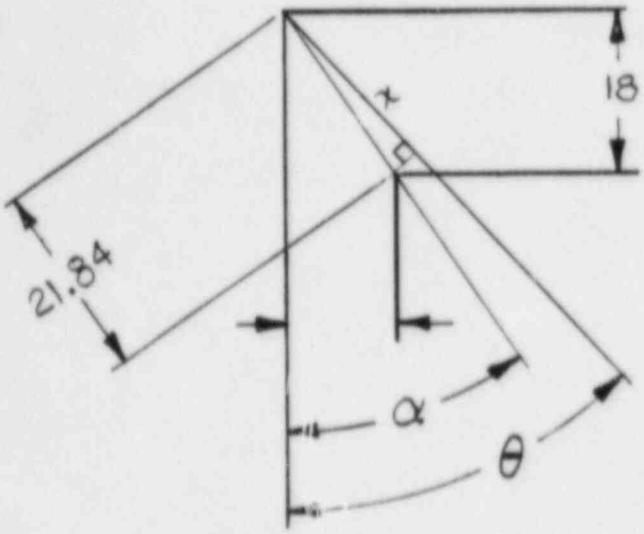


The available foam thickness can be calculated as follows:

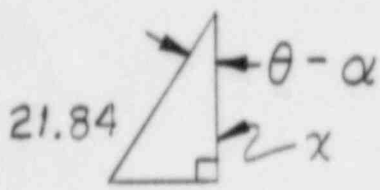
$$\theta = \tan^{-1}(101/120) = 40.08^{\circ}$$

The actual available thickness varies slightly from the diagonal thickness by the following amount:

$\alpha = \tan^{-1} \; (101-76.25)/(2)/18 \; = 34.51^{\circ}$



$\left[18^2+12.375^2\right]^{½} = 21.84$ (Diagonal Thickness)



$x = 21.84 \cos\,(40.08-34.51)$

$x = 21.74$ in. (Actual Available Thickness)

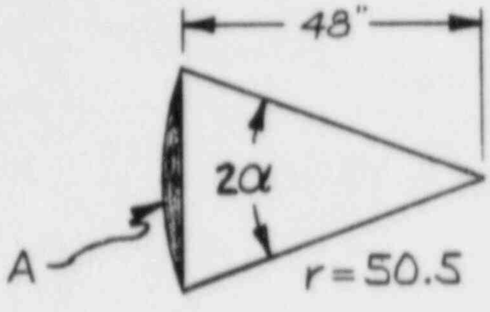
From Page 1-21a, the maximum strain energy is 32,360,741 in-lbs. at 21.74 in deflection.

Margin of Safety

M.S. = 32,360,741/25,200,000 -1

M.S. = +.28

If the corner drop was to occur in the flattened area of the overpack, some additional deformation would take place. The deformation would be directly related to the loss of available foam volume. This volume can be calculated as follows:



$A = r^2(\alpha - \sin 2\alpha/2)$

Where:

$r = 50.5$ in.

$\alpha = \cos^{-1}\alpha = 48/50.5 = 18.1^\circ$

$A = 50.5^2(18.10^\circ - \sin (2)(18.1)/2)$

$A = 52.4\ in^2$

or

$Vol = 52.4\ in^2/in$ of affected length

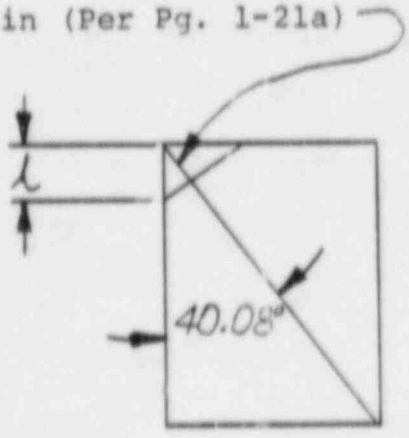
The effected zone will extend down the package by the following:

$\delta = 20.5$ in (Per Pg. 1-21a)

$\ell = \delta/\cos 40.08^\circ$

$\ell = 20.5/\cos 40.08^\circ$

$\ell = 26.7$ in.



Lost Volume is:

$V = (26.7\ in)(52.4\ in^3/in)$

$V = 1402\ in^3$

The total volume of foam used during the compression is given on Page 1-21a, Column 3.

$V_T = 22684\ in^3$

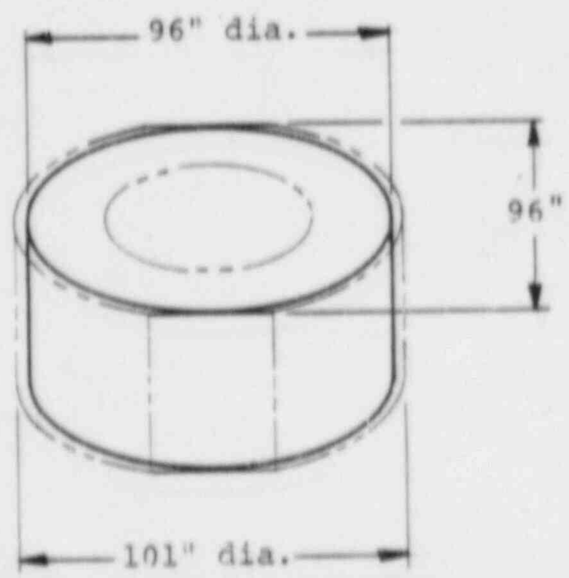
or

Loss = 1402/22684 = .06

Loss ≐ 6% due to flattened sides

Therefore, the absence of foam in the local flat area of the overpack results in only a 6% reduction in the available foam as calculated. This small reduction is more than offset by the availability of the additional crush depth and associated additional foam as calculated above. A positive Margin of Safety exists.

An alternate method of evaluating the effect of the overpack flats is to conservatively assume that the complete overpack is reduced to a diameter equal to the width across the flats. This approach analytically reduces the amount of foam available for energy absorption and is therefore conservative.



In order to establish the maximum deformation for this case, the following CYDROP (corner) case was run. From the attached output the maximum deformation was found to be 20.16 in. for a 31 foot drop. The available foam is:

$$t_a = \left[(96-76.25/2)^2 + 18^2\right]^{1/2} \cos\left[\tan^{-1}96/120-\tan^{-1}(96-76.25)/2/18\right]$$

t_a = 20.22 in (Available)

t_r = 20.16 in (Required)

After impact a small amount of foam remains.

This analysis conservatively neglects the presence of energy absorbing foam in the region from 96 inch diameter out to 101 inch diameter. Therefore, it can be again concluded that a positive Margin of Safety will exist for impact on to the flat portion of the overpack.

Loads or accelerations experienced by the package are also plotted as a function of crush depth. Accelerations were found to vary from a low of 72.2 g's to a high of 76.4 for the full range of conditions. The small spread in these accelerations is explained by the following. As the compressive strength is reduced the crush depth and contact area increase. Therefore, the small stress times a large area produces numbers equivalent to the product of high stresses times smaller impact area. Thus, normal variations in crush strengths do not significantly affect package loading.

ONTARIO HYDRO--SOFT FOAM--CASE NR. 2

```
PACKAGE WEIGHT            =  64000. (LBS)
PACKAGE EXTERNAL LENGTH   =  120.00 (IN)
PACKAGE EXTERNAL DIAMETER=    96.00 (IN)
PACKAGE EXTERNAL HOLE DIA=    55.00 (IN)
PAYLOAD ENVELOPE LENGTH   =   84.00 (IN)
PAYLOAD ENVELOPE DIAMETER=    76.00 (IN)

DROP HEIGHT               =   31.00 (FT)
ORIENTATION ANGLE         =   .6747 (RADIANS)

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

ONTARIO HYDRO--SOFT FOAM--CASE NR. 2

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
.50	11.9	3.	1316.	.0	23840000.	329.	.000	100.00	0.00	0.00	0.00	0.00
1.00	33.6	14.	7658.	.1	23872000.	2573.	.000	100.00	0.00	0.00	0.00	0.00
1.50	61.5	38.	21158.	.3	23904000.	9777.	.000	100.00	0.00	0.00	0.00	0.00
2.00	94.2	77.	42382.	.7	23936000.	25662.	.001	100.00	0.00	0.00	0.00	0.00
2.50	131.1	133.	70224.	1.1	23968000.	53813.	.002	100.00	0.00	0.00	0.00	0.00
3.00	171.6	209.	103557.	1.6	24000000.	97258.	.004	100.00	0.00	0.00	0.00	0.00
3.50	215.3	306.	141672.	2.2	24032000.	158566.	.007	100.00	0.00	0.00	0.00	0.00
4.00	261.9	425.	183806.	2.9	24064000.	239935.	.010	100.00	0.00	0.00	0.00	0.00
4.50	311.1	568.	228129.	3.6	24096000.	342919.	.014	100.00	0.00	0.00	0.00	0.00
5.00	362.7	737.	272777.	4.3	24128000.	468145.	.019	100.00	0.00	0.00	0.00	0.00
5.50	416.5	932.	317627.	5.0	24160000.	615746.	.025	100.00	0.00	0.00	0.00	0.00
6.00	472.4	1154.	363875.	5.7	24192000.	786122.	.032	100.00	0.00	0.00	0.00	0.00
6.50	530.2	1404.	407788.	6.4	24224000.	979038.	.040	100.00	0.00	0.00	0.00	0.00
7.00	589.8	1684.	454530.	7.1	24256000.	1194617.	.049	100.00	0.00	0.00	0.00	0.00
7.50	651.0	1995.	502768.	7.9	24288000.	1433941.	.059	100.00	0.00	0.00	0.00	0.00
8.00	713.7	2336.	554496.	8.7	24320000.	1698257.	.070	100.00	0.00	0.00	0.00	0.00
8.50	777.9	2709.	603525.	9.4	24352000.	1987763.	.082	100.00	0.00	0.00	0.00	0.00
9.00	843.4	3114.	659547.	10.3	24384000.	2303531.	.094	100.00	0.00	0.00	0.00	0.00
9.50	910.2	3552.	717595.	11.2	24416000.	2647816.	.108	100.00	0.00	0.00	0.00	0.00
10.00	978.1	4025.	776332.	12.1	24448000.	3021298.	.124	100.00	0.00	0.00	0.00	0.00
10.50	1047.1	4531.	832616.	13.0	24480000.	3423535.	.140	100.00	0.00	0.00	0.00	0.00
11.00	1117.1	5072.	900835.	14.1	24512000.	3856898.	.157	100.00	0.00	0.00	0.00	0.00
11.50	1188.0	5648.	973294.	15.2	24544000.	4325430.	.176	100.00	0.00	0.00	0.00	0.00
12.00	1259.7	6260.	1054924.	16.5	24576000.	4832485.	.197	100.00	0.00	0.00	0.00	0.00
12.50	1332.3	6908.	1139482.	17.8	24608000.	5381086.	.219	100.00	0.00	0.00	0.00	0.00
13.00	1405.6	7593.	1222977.	19.1	24640000.	5971701.	.242	100.00	0.00	0.00	0.00	0.00
13.50	1479.5	8314.	1315391.	20.6	24672000.	6606293.	.268	100.00	0.00	0.00	0.00	0.00
14.00	1554.0	9072.	1427121.	22.3	24704000.	7291921.	.295	100.00	0.00	0.00	0.00	0.00
14.50	1629.1	9868.	1552290.	24.3	24736000.	8036774.	.325	100.00	0.00	0.00	0.00	0.00
15.00	1704.6	10701.	1699129.	26.5	24768000.	8849629.	.357	100.00	0.00	0.00	0.00	0.00
15.50	1780.6	11573.	1855846.	29.0	24800000.	9738373.	.393	100.00	0.00	0.00	0.00	0.00
16.00	1856.9	12482.	2050383.	32.0	24832000.	10714930.	.431	97.76	2.24	0.00	0.00	0.00
16.50	1933.5	13430.	2270540.	35.5	24864000.	11795161.	.474	93.66	6.34	0.00	0.00	0.00
17.00	2010.4	14416.	2540788.	39.7	24896000.	12997993.	.522	91.68	8.32	0.00	0.00	0.00
17.50	2087.5	15440.	2836023.	44.3	24928000.	14342195.	.575	87.99	12.01	0.00	0.00	0.00
18.00	2164.7	16503.	3173465.	49.6	24960000.	15844567.	.635	85.94	11.94	2.11	0.00	0.00
18.50	2242.1	17605.	3606530.	56.4	24992000.	17539566.	.702	84.16	10.14	5.70	0.00	0.00

19.00	2319.5	18745.	4105660.	64.2	2502[illegible].	19467614.	.778	81.27	10.73	8.00	0[illegible]	0.00
19.50	2396.9	19924.	4683926.	73.2	25056000.	21665010.	.865	78.08	12.12	8.28	1.[illegible]	0.00
20.00	2474.2	21142.	5385546.	84.1	25088000.	24182379.	.964	75.21	11.61	10.59	2.59	0.00
20.50	2551.5	22399.	6232986.	97.4	25120000.	27087012.	1.078	73.49	11.52	10.26	2.78	1.95
21.00	2628.6	23694.	7134589.	111.5	25152000.	30428905.	1.210	71.45	11.46	8.84	5.00	2.84
21.50	2705.5	25027.	8073221.	126.1	25184000.	34230858.	1.359	69.81	11.37	9.25	5.29	4.37
22.00	2782.2	26399.	9126656.	142.6	25216000.	38530828.	1.528	66.33	10.40	10.47	3.[illegible]	7.41
22.50	2858.5	27809.	10241591.	160.0	25248000.	43372689.	1.718	66.40	9.39	10.38	4.49	9.34
23.00	2934.6	29257.	10691524.	167.1	25280000.	48606168.	1.923	66.43	8.60	10.66	5.15	9.16
23.50	3010.2	30744.	11121935.	173.8	25312000.	54059533.	2.136	65.95	7.39	11.61	3.63	10.84

CASE NO 1

PACKAGE WEIGHT = 64000. (LBS)
PACKAGE EXTERNAL LENGTH = 120.00 (IN)
PACKAGE EXTERNAL DIAMETER= 101.00 (IN)
PACKAGE LATERAL HOLE DIA= 55.00 (IN)
PAYLOAD ENVELOPE LENGTH = 84.00 (IN)
PAYLOAD ENVELOPE DIAMETER= 75.00 (IN)

DROP HEIGHT = 31.00 (FT)
ORIENTATION ANGLE = .5997 (RADIANS)

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

CASE NO 1

CYDROP NUCLEAR PACKAGING PROPRIETARY 14.45.38 77/09/25 PAGE 2

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	33.5	8.	7511.	.1	23872000.	1878.	.000	100.00	0.00	0.00	0.00	0.00
1.50	61.5	32.	23768.	.3	23904000.	8953.	.000	100.00	0.00	0.00	0.00	0.00
2.00	94.4	71.	41761.	.7	23936000.	24590.	.001	100.00	0.00	0.00	0.00	0.00
2.50	131.4	128.	69438.	1.1	23968000.	52389.	.002	100.00	0.00	0.00	0.00	0.00
3.00	172.3	203.	102638.	1.6	24000000.	95408.	.004	100.00	0.00	0.00	0.00	0.00
3.50	[illegible]	300.	140552.	2.2	24032000.	155206.	.006	100.00	0.00	0.00	0.00	0.00
4.00	262.7	420.	182312.	2.8	24064000.	236922.	.010	100.00	0.00	0.00	0.00	0.00
4.50	[illegible]	564.	227408.	3.6	24096000.	339352.	.014	100.00	0.00	0.00	0.00	0.00
5.00	354.1	733.	275454.	4.3	24128000.	465068.	.019	100.00	0.00	0.00	0.00	0.00
5.50	415.3	928.	325933.	5.1	24160000.	615414.	.025	100.00	0.00	0.00	0.00	0.00
6.00	474.6	1152.	377426.	5.9	24192000.	791254.	.033	100.00	0.00	0.00	0.00	0.00
6.50	532.4	1403.	429861.	6.7	24224000.	993076.	.041	100.00	0.00	0.00	0.00	0.00
7.00	[illegible]	1685.	[illegible]	7.6	24256000.	1221555.	.050	100.00	0.00	0.00	0.00	0.00
7.50	654.6	1997.	535687.	8.4	24288000.	1476490.	.061	100.00	0.00	0.00	0.00	0.00
8.00	716.2	2340.	593708.	9.3	24320000.	1758839.	.072	100.00	0.00	0.00	0.00	0.00
8.50	783.1	2715.	646936.	10.1	24352000.	2069000.	.085	100.00	0.00	0.00	0.00	0.00
9.00	849.4	3124.	705899.	11.0	24384000.	2407209.	.099	100.00	0.00	0.00	0.00	0.00
9.50	917.1	3565.	767761.	12.0	24416000.	2775624.	.114	100.00	0.00	0.00	0.00	0.00
10.00	985.9	4041.	824105.	12.9	24448000.	3173590.	.130	100.00	0.00	0.00	0.00	0.00
10.50	1055.0	4551.	890594.	13.9	24480000.	3602265.	.147	100.00	0.00	0.00	0.00	0.00
11.00	1127.1	5097.	961483.	15.0	24512000.	4065284.	.166	100.00	0.00	0.00	0.00	0.00
11.50	1199.2	5679.	1030083.	16.1	24544000.	4563175.	.186	100.00	0.00	0.00	0.00	0.00
12.00	1272.3	6297.	1104672.	17.3	24576000.	5096864.	.207	100.00	0.00	0.00	0.00	0.00
12.50	1346.2	6951.	1182835.	18.5	24608000.	5668741.	.230	100.00	0.00	0.00	0.00	0.00
13.00	1421.0	7643.	1271717.	19.9	24640000.	6282379.	.255	100.00	0.00	0.00	0.00	0.00
13.50	1495.5	8372.	1364653.	21.3	24672000.	6941471.	.281	100.00	0.00	0.00	0.00	0.00
14.00	1572.6	9140.	1468632.	22.9	24704000.	7649792.	.310	100.00	0.00	0.00	0.00	0.00
14.50	1649.5	9945.	1568501.	24.5	24736000.	8409075.	.340	100.00	0.00	0.00	0.00	0.00
15.00	1727.1	10790.	1681230.	26.3	24768000.	9221508.	.372	100.00	0.00	0.00	0.00	0.00
15.50	[illegible]	11673.	1810680.	28.3	24800000.	10094466.	.407	100.00	0.00	0.00	0.00	0.00
16.00	1883.5	12595.	1967184.	30.7	24832000.	11033952.	.445	100.00	0.00	0.00	0.00	0.00
16.50	1962.4	13555.	2134168.	33.3	24864000.	12064290.	.485	98.45	1.55	0.00	0.00	0.00
17.00	2041.7	14557.	2341443.	36.5	24896000.	13183192.	.530	96.13	3.87	0.00	0.00	0.00
17.50	2121.3	15596.	2563596.	40.1	24928000.	14409452.	.578	93.75	6.25	0.00	0.00	0.00
18.00	2201.2	16679.	2844067.	44.4	24960000.	15761523.	.631	91.65	8.15	0.00	0.00	0.00
18.50	2281.3	17799.	3154357.	49.3	24992000.	17261284.	.691	89.70	8.72	1.59	0.00	0.00
19.00	2361.6	18966.	3472857.	54.3	25024000.	18918068.	.756	87.10	10.48	2.42	0.00	0.00
19.50	2442.1	20161.	3883307.	60.7	25056000.	20757129.	.828	85.69	9.65	4.66	0.00	0.00
20.00	2522.7	21402.	4363359.	68.2	25088000.	22818795.	.910	84.34	8.97	6.68	0.00	0.00
20.50	2603.3	22684.	4891325.	76.4	25120000.	25132466.	1.030	81.42	10.13	6.77	1.68	0.00
21.00	2683.9	24005.	5525357.	86.3	25152000.	27736635.	1.103	78.13	11.57	7.80	2.50	0.00
21.50	[illegible]	25367.	6274154.	98.0	25184000.	30680513.	1.218	75.83	11.43	9.84	1.23	1.68
22.00	2845.0	26770.	7119670.	111.2	25216000.	34034969.	1.350	74.41	11.24	9.14	2.69	2.51
22.50	2925.4	28212.	7960613.	124.4	25248000.	37805040.	1.497	73.08	11.38	8.47	4.16	2.92
23.00	3005.8	29695.	8831374.	138.0	25280000.	42003167.	1.662	71.37	11.42	6.53	4.21	4.47
23.50	[illegible]	31218.	9829162.	153.6	25312000.	46668431.	1.844	70.19	9.53	10.25	4.18	5.75

CYDFUP   NUCLEAR PACKAGING PROPRIETARY   19.14.38   77/09/27   PAGE 1

CASE NO. 2

PACKAGE WEIGHT = 64000. (LBS)
PACKAGE EXTERNAL LENGTH = 120.00 (IN)
PACKAGE EXTERNAL DIAMETER = 101.00 (IN)
PACKAGE EXTERNAL HOLE DIA = 1.00 (IN)
PAYLOAD ENVELOPE LENGTH = 84.00 (IN)
PAYLOAD ENVELOPE DIAMETER = 76.00 (IN)

DROP HEIGHT = 31.00 (FT)
ORIENTATION ANGLE = .6997 (RADIANS)

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

CASE NO2

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	33.6	8.	7511.	.1	23872000.	1878.	.000	100.00	0.00	0.00	0.00	0.00
1.50	61.5	32.	20788.	.3	23904000.	8953.	.000	100.00	0.00	0.00	0.00	0.00
2.00	94.4	71.	41761.	.7	23936000.	24590.	.001	100.00	0.00	0.00	0.00	0.00
2.50	131.4	128.	69438.	1.1	23968000.	52389.	.002	100.00	0.00	0.00	0.00	0.00
3.00	172.0	203.	102638.	1.6	24000000.	95408.	.004	100.00	0.00	0.00	0.00	0.00
3.50	215.9	300.	140552.	2.2	24032000.	156206.	.006	100.00	0.00	0.00	0.00	0.00
4.00	262.7	420.	182312.	2.8	24064000.	236922.	.010	100.00	0.00	0.00	0.00	0.00
4.50	312.1	564.	227408.	3.6	24096000.	339352.	.014	100.00	0.00	0.00	0.00	0.00
5.00	364.1	733.	275454.	4.3	24128000.	465068.	.019	100.00	0.00	0.00	0.00	0.00
5.50	418.3	928.	326552.	5.1	24160000.	615569.	.025	100.00	0.00	0.00	0.00	0.00
6.00	474.6	1152.	380759.	5.9	24192000.	792397.	.033	100.00	0.00	0.00	0.00	0.00
6.50	532.9	1403.	438357.	6.8	24224000.	997176.	.041	100.00	0.00	0.00	0.00	0.00
7.00	593.0	1685.	499808.	7.8	24256000.	1231717.	.051	100.00	0.00	0.00	0.90	0.00
7.50	654.9	1997.	565055.	8.8	24288000.	1497933.	.062	100.00	0.00	0.00	0.00	0.00
8.00	718.2	2340.	633725.	9.9	24320000.	1797628.	.074	100.00	0.00	0.00	0.00	0.00
8.50	783.1	2715.	705404.	11.0	24352000.	2132410.	.088	100.00	0.00	0.00	0.00	0.00
9.00	849.4	3124.	780135.	12.2	24384000.	2503795.	.103	100.00	0.00	0.00	0.00	0.00
9.50	917.1	3565.	857894.	13.4	24416000.	2913302.	.119	100.00	0.00	0.00	0.00	0.00
10.00	985.9	4041.	939325.	14.7	24448000.	3362607.	.138	100.00	0.00	0.00	0.00	0.00
10.50	1056.0	4551.	1024968.	16.0	24480000.	3853680.	.157	100.00	0.00	0.00	0.00	0.00
11.00	1127.1	5097.	1115365.	17.4	24512000.	4388763.	.179	100.00	0.00	0.00	0.00	0.00
11.50	1199.2	5679.	1210601.	18.9	24544000.	4970255.	.203	100.00	0.00	0.00	0.00	0.00
12.00	1272.3	6297.	1311190.	20.5	24576000.	5600703.	.228	100.00	0.00	0.00	0.00	0.00
12.50	1346.2	6951.	1418181.	22.2	24608000.	6283046.	.255	100.00	0.00	0.00	0.00	0.00
13.00	1421.0	7643.	1530829.	23.9	24640000.	7020298.	.285	100.00	0.00	0.00	0.00	0.00
13.50	1496.5	8372.	1649884.	25.8	24672000.	7815476.	.317	100.00	0.00	0.00	0.00	0.00
14.00	1572.8	9140.	1780597.	27.8	24704000.	8673097.	.351	100.00	0.00	0.00	0.00	0.00
14.50	1649.6	9945.	1917674.	30.0	24736000.	9597664.	.388	100.00	0.00	0.00	0.00	0.00
15.00	1727.1	10790.	2072378.	32.4	24768000.	10595177.	.428	100.00	0.00	0.00	0.00	0.00
15.50	1805.0	11673.	2235243.	34.9	24800000.	11672083.	.471	100.00	0.00	0.00	0.00	0.00
16.00	1883.5	12595.	2424983.	37.9	24832000.	12837139.	.517	100.00	0.00	0.00	0.00	0.00
16.50	1962.4	13556.	2626268.	41.0	24864000.	14092952.	.567	98.84	1.16	0.00	0.00	0.00
17.00	2041.7	14557.	2866743.	44.8	24896000.	15473204.	.622	97.12	2.88	0.00	0.00	0.00
17.50	2121.3	15598.	3124205.	48.8	24928000.	16970941.	.681	95.38	4.62	0.00	0.00	0.00
18.00	2201.2	16679.	3437190.	53.7	24960000.	18611290.	.746	93.98	6.02	0.00	0.00	0.00
18.50	2281.3	17799.	3795930.	59.3	24992000.	20419570.	.817	92.44	6.40	1.16	0.00	0.00
19.00	2361.6	18960.	4184583.	65.4	25024000.	22414698.	.896	90.68	7.57	1.75	0.00	0.00
19.50	2442.1	20161.	4655505.	72.7	25056000.	24624720.	.983	89.74	6.92	3.34	0.00	0.00
20.00	2522.7	21402.	5195005.	81.2	25088000.	27087348.	1.090	88.83	6.40	4.77	0.00	0.00
20.50	2603.3	22684.	5781457.	90.3	25120000.	29831463.	1.188	86.85	7.17	4.79	1.19	0.00
21.00	2683.9	24005.	6436851.	101.4	25152000.	32898540.	1.308	84.61	8.14	5.49	1.76	0.00
21.50	2764.5	25367.	7302667.	114.1	25184000.	36345920.	1.443	83.02	8.03	6.91	.86	1.18
22.00	2845.0	26770.	8228953.	128.6	25216000.	40228825.	1.595	82.08	7.87	6.40	1.89	1.76
22.50	2925.4	28212.	9156420.	143.1	25248000.	44575168.	1.765	81.22	7.94	5.91	2.90	2.04
23.00	3005.6	29695.	10108771.	157.9	25280000.	49391466.	1.954	79.10	8.96	5.91	2.92	3.10
23.50	3085.7	31219.	11214907.	175.2	25312000.	54722385.	2.162	77.63	8.43	7.08	2.89	3.97

CYDRUP   NUCLEAR PACKAGING PROPRIETARY   19.14.57   77/09/27   PAGE 1

CASE NO 3

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PACKAGE WEIGHT                 =  64000.  (LBS)
PACKAGE EXTERNAL LENGTH        =  120.00  (IN)
PACKAGE EXTERNAL DIAMETER=        101.00  (IN)
PACKAGE EXTERNAL HOLE DIA=         55.00  (IN)
PAYLOAD ENVELOPE LENGTH  =         84.00  (IN)
PAYLOAD ENVELOPE DIAMETER=         76.00  (IN)

DROP HEIGHT                    =   31.00  (FT)
ORIENTATION ANGLE              =   .6997  (RADIANS)

NOMINAL CRUSH STRESS           =    0.00  (PSI)
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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

CASE NO 3

CYDRUP NUCLEAR PACKAGING PROPRIETARY 19.14.57 77/09/27 PAGE 2

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	33.6	8.	12013.	.2	23872000.	3003.	.000	100.00	0.00	0.00	0.00	0.00
1.50	61.5	32.	30340.	.5	23904000.	13592.	.001	100.00	0.00	0.00	0.00	0.00
2.00	94.4	71.	56752.	.9	23936000.	35365.	.001	100.00	0.00	0.00	0.00	0.00
2.50	131.4	128.	89753.	1.4	23968000.	71991.	.003	100.00	0.00	0.00	0.00	0.00
3.00	172.0	203.	128131.	2.0	24000000.	126474.	.005	100.00	0.00	0.00	0.00	0.00
3.50	215.9	300.	171537.	2.7	24032000.	201404.	.008	100.00	0.00	0.00	0.00	0.00
4.00	262.7	420.	219409.	3.4	24064000.	299140.	.012	100.00	0.00	0.00	0.00	0.00
4.50	312.1	564.	271696.	4.2	24096000.	421914.	.018	100.00	0.00	0.00	0.00	0.00
5.00	364.1	733.	328314.	5.1	24128000.	571914.	.024	100.00	0.00	0.00	0.00	0.00
5.50	418.3	928.	388344.	6.1	24160000.	751078.	.031	100.00	0.00	0.00	0.00	0.00
6.00	474.6	1152.	449733.	7.0	24192000.	960598.	.040	100.00	0.00	0.00	0.00	0.00
6.50	532.9	1403.	512451.	8.0	24224000.	1201146.	.050	100.00	0.00	0.00	0.00	0.00
7.00	593.0	1685.	576906.	9.0	24256000.	1473488.	.061	100.00	0.00	0.00	0.00	0.00
7.50	654.9	1997.	638194.	10.0	24288000.	1777260.	.073	100.00	0.00	0.00	0.00	0.00
8.00	718.2	2340.	706812.	11.0	24320000.	2113509.	.087	100.00	0.00	0.00	0.00	0.00
8.50	783.1	2715.	770541.	12.0	24352000.	2482848.	.102	100.00	0.00	0.00	0.00	0.00
9.00	849.4	3124.	841234.	13.1	24384000.	2885791.	.118	100.00	0.00	0.00	0.00	0.00
9.50	917.1	3565.	915577.	14.3	24416000.	3324994.	.136	100.00	0.00	0.00	0.00	0.00
10.00	985.9	4041.	983033.	15.4	24448000.	3799647.	.155	100.00	0.00	0.00	0.00	0.00
10.50	1056.0	4551.	1061537.	16.6	24480000.	4310789.	.176	100.00	0.00	0.00	0.00	0.00
11.00	1127.1	5097.	1144121.	17.9	24512000.	4862204.	.198	100.00	0.00	0.00	0.00	0.00
11.50	1199.2	5679.	1222842.	19.1	24544000.	5453944.	.222	100.00	0.00	0.00	0.00	0.00
12.00	1272.3	6297.	1307835.	20.4	24576000.	6085614.	.248	100.00	0.00	0.00	0.00	0.00
12.50	1346.2	6951.	1396678.	21.8	24608000.	6762742.	.275	100.00	0.00	0.00	0.00	0.00
13.00	1421.0	7643.	1497254.	23.4	24640000.	7486225.	.304	100.00	0.00	0.00	0.00	0.00
13.50	1496.5	8372.	1602148.	25.0	24672000.	8261076.	.335	100.00	0.00	0.00	0.00	0.00
14.00	1572.8	9140.	1720645.	26.9	24704000.	9091774.	.358	100.00	0.00	0.00	0.00	0.00
14.50	1649.6	9945.	1832950.	28.6	24736000.	9980173.	.403	100.00	0.00	0.00	0.00	0.00
15.00	1727.1	10790.	1960605.	30.6	24768000.	10928562.	.441	100.00	0.00	0.00	0.00	0.00
15.50	1805.0	11673.	2107074.	32.9	24800000.	11945481.	.482	100.00	0.00	0.00	0.00	0.00
16.00	1883.5	12595.	2285795.	35.7	24832000.	13043699.	.525	100.00	0.00	0.00	0.00	0.00
16.50	1962.4	13556.	2476197.	38.7	24864000.	14234197.	.572	98.45	1.55	0.00	0.00	0.00
17.00	2041.7	14557.	2714529.	42.4	24896000.	15531878.	.624	96.13	3.87	0.00	0.00	0.00
17.50	2121.3	15598.	2969074.	46.4	24928000.	16952779.	.680	93.75	6.25	0.00	0.00	0.00
18.00	2201.2	16679.	3289842.	51.4	24960000.	18517508.	.742	91.85	8.15	0.00	0.00	0.00
18.50	2281.3	17799.	3640436.	56.9	24992000.	20250078.	.810	89.70	8.72	1.59	0.00	0.00
19.00	2361.6	18960.	3998210.	62.5	25024000.	22159739.	.886	87.10	10.48	2.42	0.00	0.00
19.50	2442.1	20161.	4457618.	69.7	25056000.	24273696.	.969	85.59	9.65	4.66	0.00	0.00
20.00	2522.7	21402.	4993453.	78.0	25088000.	26634465.	1.062	84.34	8.97	6.68	0.00	0.00
20.50	2603.3	22694.	5582031.	87.2	25120000.	29280351.	1.156	81.42	10.13	6.77	1.68	0.00
21.00	2683.9	24005.	6289609.	98.3	25152000.	32248273.	1.282	78.13	11.57	7.80	2.50	0.00
21.50	2764.5	25367.	7113058.	111.1	25184000.	35598940.	1.414	75.83	11.43	9.84	1.23	1.68
22.00	2845.0	26779.	8027222.	125.4	25216000.	39384010.	1.562	74.41	11.24	9.14	2.69	2.51
22.50	2925.4	28212.	8947618.	139.8	25248000.	43627720.	1.728	73.08	11.38	8.47	4.16	2.92
23.00	3005.6	29695.	9900354.	154.7	25280000.	48339713.	1.912	71.37	11.42	8.53	4.21	4.47
23.50	3085.7	31219.	10978198.	171.5	25312000.	53559351.	2.116	70.19	9.63	10.25	4.18	5.75

CYDROP NUCLEAR PACKAGING PROPRIETARY 14.46.18 77/09/25 PAGE 1

CASE NO. 4

```
PACKAGE WEIGHT             =  64000.  (LBS)
PACKAGE EXTERNAL LENGTH    =  120.00  (IN)
PACKAGE EXTERNAL DIAMETER=    101.00  (IN)
PACKAGE EXTERNAL HOLE DIA=      1.00  (IN)
PAYLOAD ENVELOPE LENGTH    =   84.00  (IN)
PAYLOAD ENVELOPE DIAMETER=     76.00  (IN)

DROP HEIGHT                =   31.00  (FT)
ORIENTATION ANGLE          =   .6997  (RADIANS)

NOMINAL CRUSH STRESS       =    0.00  (PSI)
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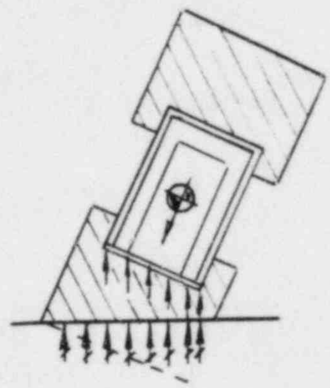
STRAIN VS STRESS TABLE

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 PLANE ++			++++ IMPACT ++++		++++++ ENERGY ++++++			DISTRIBUTION OF STRAIN RATIOS BY PERCENT OF CONTACT AREA				
CRUSH DEPTH (IN)	AREA (IN2)	VOLUME (IN3)	FORCE (LBS)	ACCEL. (G)	KINETIC (IN-LB)	STRAIN (IN-LB)	RATIO (SE/KE)	LE.70	GT.70 LE.80	GT.80 LE.90	GT.90 LE.95	GT.95
1.00	33.6	8.	12013.	.2	23872000.	3003.	.000	100.00	0.00	0.00	0.00	0.00
1.50	61.5	32.	30340.	.5	23904000.	13592.	.001	100.00	0.00	0.00	0.00	0.00
2.00	94.4	71.	56752.	.9	23936000.	35365.	.001	100.00	0.00	0.00	0.00	0.00
2.50	131.4	128.	89753.	1.4	23968000.	71991.	.003	100.00	0.00	0.00	0.00	0.00
3.00	172.0	203.	128181.	2.0	24000000.	126474.	.005	100.00	0.00	0.00	0.00	0.00
3.50	215.9	300.	171537.	2.7	24032000.	201404.	.008	100.00	0.00	0.00	0.00	0.00
4.00	262.7	420.	219409.	3.4	24064000.	299140.	.012	100.00	0.00	0.00	0.00	0.00
4.50	312.1	564.	271680.	4.2	24096000.	421914.	.018	100.00	0.00	0.00	0.00	0.00
5.00	354.1	733.	328314.	5.1	24128000.	571914.	.024	100.00	0.00	0.00	0.00	0.00
5.50	418.3	928.	389474.	6.1	24160000.	751361.	.031	100.00	0.00	0.00	0.00	0.00
6.00	474.6	1152.	455076.	7.1	24192000.	962498.	.040	100.00	0.00	0.00	0.00	0.00
6.50	532.9	1403.	524925.	8.2	24224000.	1207499.	.050	100.00	0.00	0.00	0.00	0.00
7.00	593.6	1685.	598831.	9.4	24256000.	1488438.	.061	100.00	0.00	0.00	0.00	0.00
7.50	654.8	1997.	676367.	10.6	24288000.	1807237.	.074	100.00	0.00	0.00	0.00	0.00
8.00	718.2	2340.	757543.	11.8	24320000.	2165715.	.089	100.00	0.00	0.00	0.00	0.00
8.50	783.1	2715.	842528.	13.2	24352000.	2565732.	.105	100.00	0.00	0.00	0.00	0.00
9.00	849.4	3124.	931385.	14.6	24384000.	3009211.	.123	100.00	0.00	0.00	0.00	0.00
9.50	917.1	3565.	1024203.	16.0	24416000.	3498108.	.143	100.00	0.00	0.00	0.00	0.00
10.00	985.9	4041.	1121095.	17.5	24448000.	4034432.	.165	100.00	0.00	0.00	0.00	0.00
10.50	1056.0	4551.	1222327.	19.1	24480000.	4620288.	.189	100.00	0.00	0.00	0.00	0.00
11.00	1127.1	5097.	1328165.	20.8	24512000.	5257911.	.215	100.00	0.00	0.00	0.00	0.00
11.50	1199.2	5679.	1439102.	22.5	24544000.	5949728.	.242	100.00	0.00	0.00	0.00	0.00
12.00	1272.3	6297.	1555276.	24.3	24576000.	6698323.	.273	100.00	0.00	0.00	0.00	0.00
12.50	1346.2	6951.	1678460.	26.2	24608000.	7506757.	.305	100.00	0.00	0.00	0.00	0.00
13.00	1421.0	7643.	1807372.	28.2	24640000.	8378215.	.340	100.00	0.00	0.00	0.00	0.00
13.50	1496.5	8372.	1943268.	30.4	24672000.	9315875.	.378	100.00	0.00	0.00	0.00	0.00
14.00	1572.8	9140.	2093516.	32.7	24704000.	10325071.	.418	100.00	0.00	0.00	0.00	0.00
14.50	1649.6	9945.	2250061.	35.2	24736000.	11410965.	.461	100.00	0.00	0.00	0.00	0.00
15.00	1727.1	10790.	2427777.	37.9	24768000.	12580425.	.508	100.00	0.00	0.00	0.00	0.00
15.50	1805.0	11673.	2613737.	40.8	24800000.	13840803.	.558	100.00	0.00	0.00	0.00	0.00
16.00	1883.5	12595.	2831821.	44.2	24832000.	15202192.	.612	100.00	0.00	0.00	0.00	0.00
16.50	1962.4	13556.	3062549.	47.9	24864000.	16675785.	.671	98.84	1.16	0.00	0.00	0.00
17.00	2041.7	14557.	3339847.	52.2	24896000.	18276384.	.734	97.12	2.88	0.00	0.00	0.00
17.50	2121.3	15598.	3635439.	56.8	24928000.	20020206.	.803	95.38	4.62	0.00	0.00	0.00
18.00	2201.2	16679.	3993153.	62.4	24960000.	21927354.	.878	93.98	6.02	0.00	0.00	0.00
18.50	2281.3	17799.	4400049.	68.3	24992000.	24025654.	.961	92.44	6.40	1.16	0.00	0.00
19.00	2361.6	18960.	4837746.	75.6	25024000.	26335103.	1.052	90.68	7.57	1.75	0.00	0.00
19.50	2442.1	20161.	5366887.	83.9	25056000.	28886261.	1.153	89.74	6.92	3.34	0.00	0.00
20.00	2522.7	21402.	5971071.	93.3	25088000.	31720751.	1.264	88.83	6.40	4.77	0.00	0.00
20.50	2603.3	22684.	6626995.	103.5	25120000.	34870267.	1.388	86.85	7.17	4.79	1.19	0.00
21.00	2683.9	24005.	7416167.	115.9	25152000.	38381058.	1.526	84.61	8.14	5.49	1.76	0.00
21.50	2764.5	25367.	8316292.	129.9	25184000.	42314172.	1.680	83.02	8.03	6.91	.86	1.18
22.00	2845.0	26770.	9322867.	145.7	25216000.	46723962.	1.853	82.08	7.87	6.40	1.89	1.76
22.50	2925.4	28212.	10342615.	161.5	25248000.	51640332.	2.045	81.22	7.94	5.91	2.90	2.04
23.00	3005.6	29595.	11308100.	177.9	25280000.	57073011.	2.258	79.10	8.96	5.91	2.92	3.10
23.50	3085.7	31218.	12591105.	196.7	25312000.	63067813.	2.492	77.63	8.43	7.08	2.89	3.97

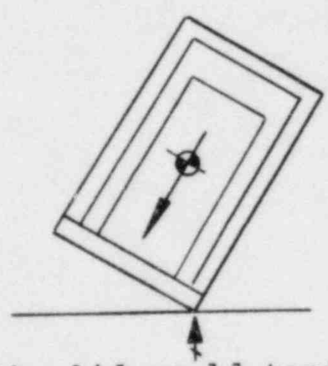
72.29

Impact accelerations produce internal loads on the lid of the package that must be reacted by the overpack and binders. The percent of respective load carried by the overpack or binder is dependent on the package configuration. For example, a package with an extremely thick overpack, the binders will experience no loads. Axial impact loads from the payload and lid are reacted in direct compression by the overpack to the impact surface. From the sketch below it can be seen that, for this case, the lid will be held in place relative to the cask body by the overpack. i.e. no binder loads.



(A)

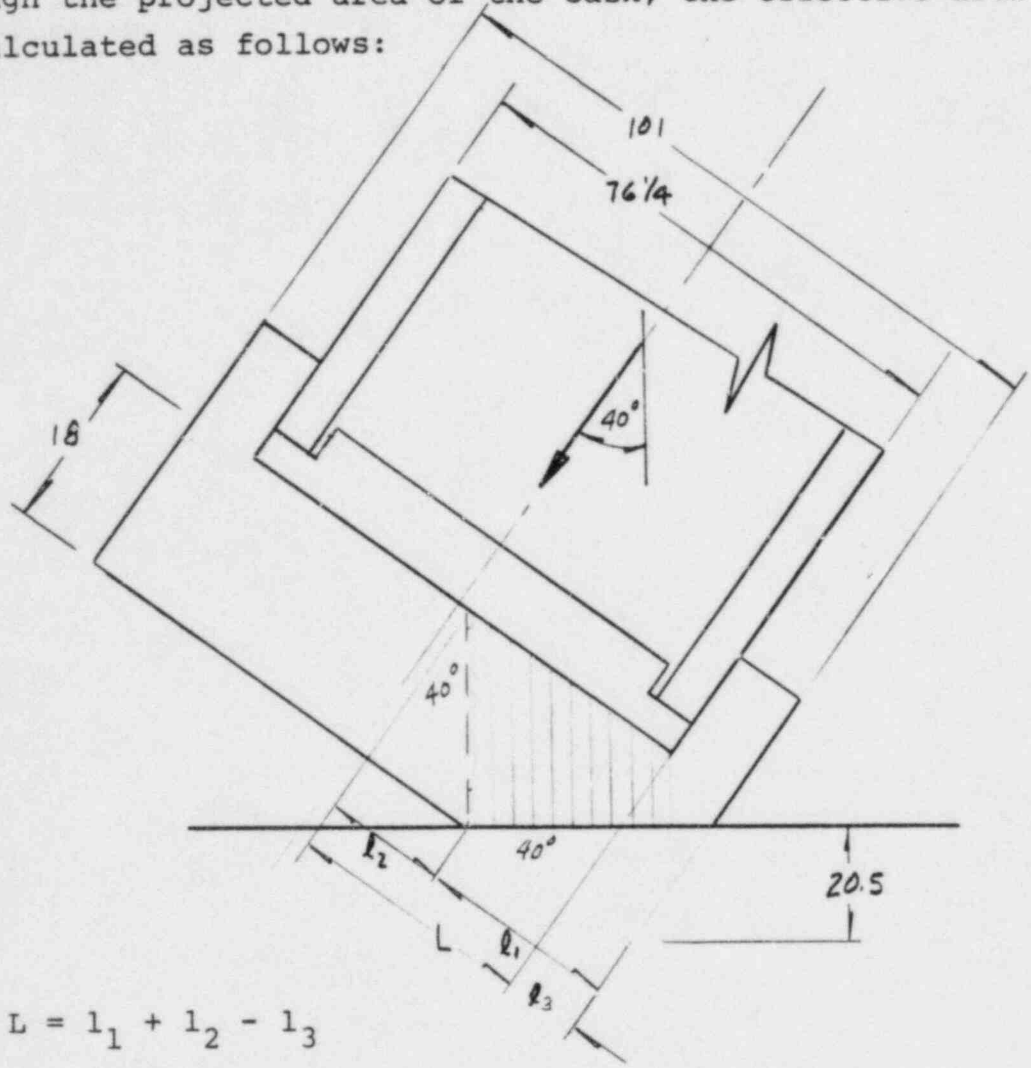
The opposite extreme would be that case in which the overpack was so thin as to provide no support to the lid.



(B)

Obviously in this case the lid would tend to pivot at the impact point under the effects of axial loading. The binders would be required to react this full load. i.e. no support from the overpack.

The OH-142 represents a configuration in between the two examples given above. In order to calculate the contribution that the overpack provides to the lid retention the projected area must be calculated. If we conservatively neglect the load distribution ability of the overpack and assume the loads are only transfered through the projected area of the cask, the effective area can be calculated as follows:

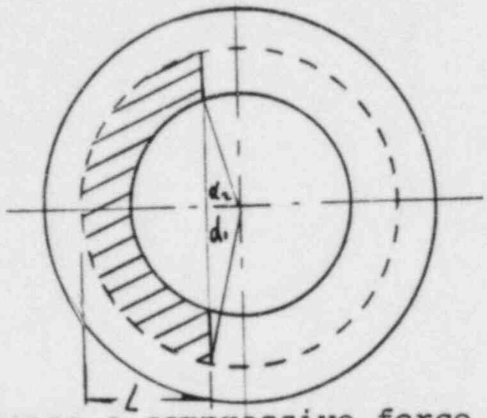


$$L = l_1 + l_2 - l_3$$

$$= 20.5/\text{Sin } 40^{\circ} + 18 \text{ Tan } 40^{\circ} - (101-76\ 1/4)/2$$

$$= 34.61 \text{ in}$$

The projected area is calculated as follows:



$\alpha_1 = 84.5° \ @ \ R = 38"$
$\alpha_2 = 82.4° \ @ \ R : 27.5"$

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:

$r_1 = 38$ in.

$r_2 = 27.5$ in.

$\alpha_1 = 84.5°$

$\alpha_2 = 82.4°$

$A = 1011.6 \text{ in}^2$

The overpack reaction will be:

$R = A\ F_{cr}$

$= (1011.6\ in^2)(1000\ psi)$

$= 1{,}011{,}600$ 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:

$\alpha = 84.5^o$

$R_o = 38.125$ in.

$R_1 = 27.5$ in.

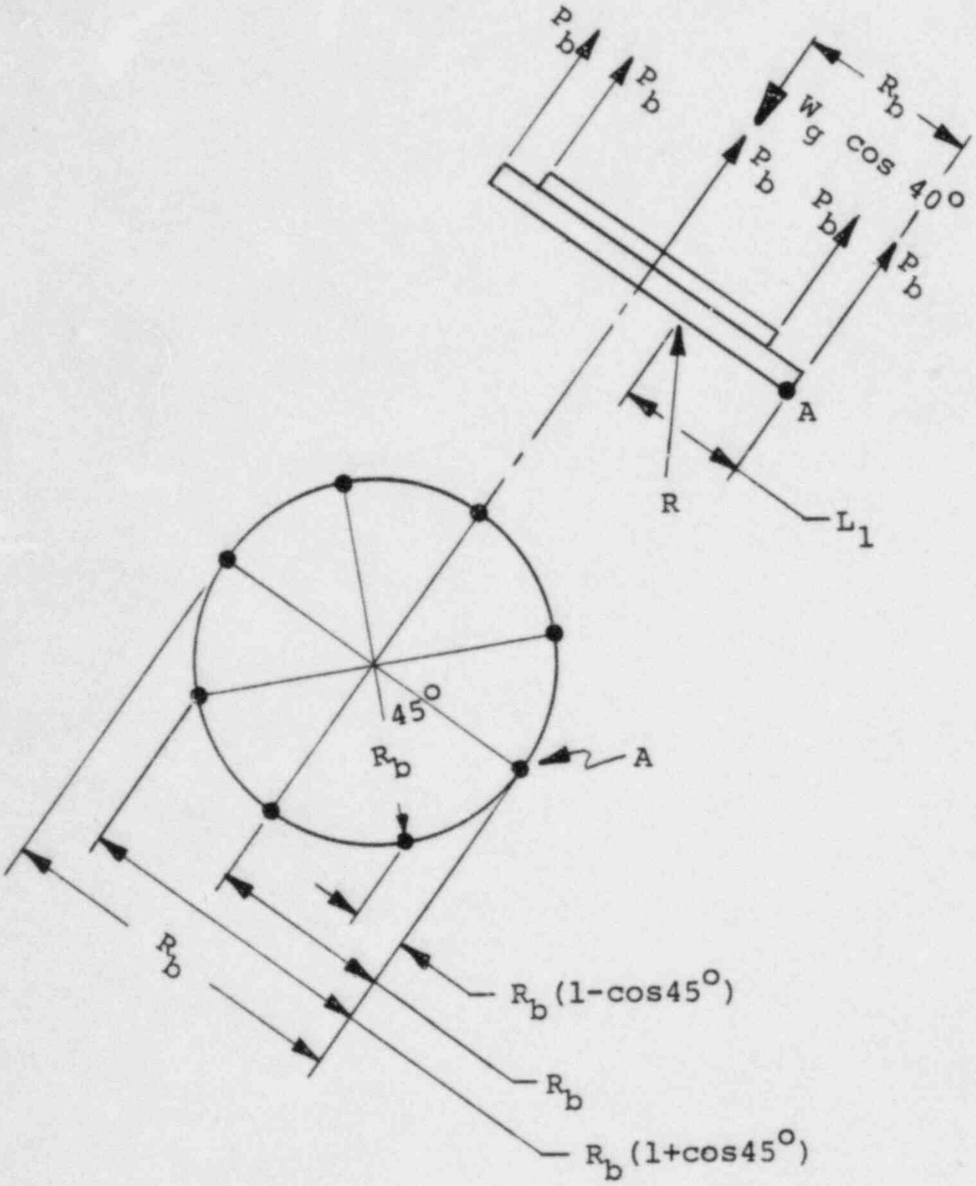
$$\bar{x} = 2(\text{Sin } 84.5^o)(38.125^3 - 27.5^3)/3(1.475)(38.125^2 - 27.5^2)$$

$\bar{x} = 22.3$ in.

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

$= 76.25/2 - 22.3$

$= 15.83$ in.



$$\sum M_A = 0$$

$$WgR_b \cos 40° = RL_1 \cos 40° + P_b\left[2R_b(1-\cos 45°)+2R_b+2R_b(1+\cos 45°)+R_b\right]$$

Where:

W = (Payload + Lid + Overpack)

= (10000 lbs. + 6900 lbs. + 3000 lbs.)

= 19900 lbs.

g = 76.4 g's (Max.)

R_b = 38.125 in.

R = 1,011,600 lbs.

L_1 = 15.83 in.

$$(19900)(76.4)(38.125)\cos 40^\circ = (1{,}011{,}660)(15.83)\cos 40^0 + (2)(38.125)P_b(1-\cos 45^\circ+1+1+\cos 45^\circ+.5)$$

$$44{,}402{,}789 = 12{,}267{,}878 + 266.785\ P_b$$

P_b = 120,454 lbs. per binder

Therefore, the maximum binder load will be 120,454 lbs. Capacity of the high strength 1 3/4 in. binder is 160,000 lbs. The Margin of Safety is:

M.S. = 160,000/120,454-1

M.S. = +.33 Closure System

As noted on Page 1-22b, the analysis was conservatively based, on the assumption that a uniform nominal 1000 psi crush force was reacted across the projected area. This is a simplifying but conservative assumption that does not take into consideration the strain hardening effect of the foam. In reality, the compression force will vary from zero of the central edge of the contact surface to over 14,000 psi at the cask corner.

The 1000 psi compression stress acting over the axial projected area was found to produce a maximum force of 1,011,600 lbs. (Ref. Page 1-22c) Any increase in this force will reduce the actual binder load.

The actual maximum impact force is calculated by the CYDROP program and is presented on Page 1-22a, Column 4 (i.e., 4,891,323 lbs.) or an axial component of F_a = 4,891,323 lbs. cos 40° = 3,262,000 lbs. Therefore, the actual value will be 3,262,000 lbs. vs. the 1,011,600 lb. force conservatively assumed.

If this load was applied directly to the lid as shown in the analysis, it would show that the lid was in full compression and, therefore, the binder would experience no load.

It should be noted that F_a will not be applied at the centroid but will be applied at the true center of pressure. Since the determination of the center of pressure involves integrating discrete pressures over unit area, the CYDROP program was modified to calculate the true center of pressure. The following output represents the rerun of the most critical corner drop case. The center of pressure location was found to be:

C of P = 23.155 in.

MODEL OH-142 OVERPACK - SOFT FOAM (CASE 1)

PACKAGE WEIGHT = 64000. (LBS)
PACKAGE EXTERNAL LENGTH = 120.00 (IN)
PACKAGE EXTERNAL DIAMETER= 101.00 (IN)
PACKAGE EXTERNAL HOLE DIA= 55.00 (IN)
PAYLOAD ENVELOPE LENGTH = 84.00 (IN)
PAYLOAD ENVELOPE DIAMETER= 76.00 (IN)

DROP HEIGHT = 31.00 (FT)
ORIENTATION ANGLE = .6997 (RADIANS)

NOMINAL CRUSH STRESS = 0.00 (PSI)

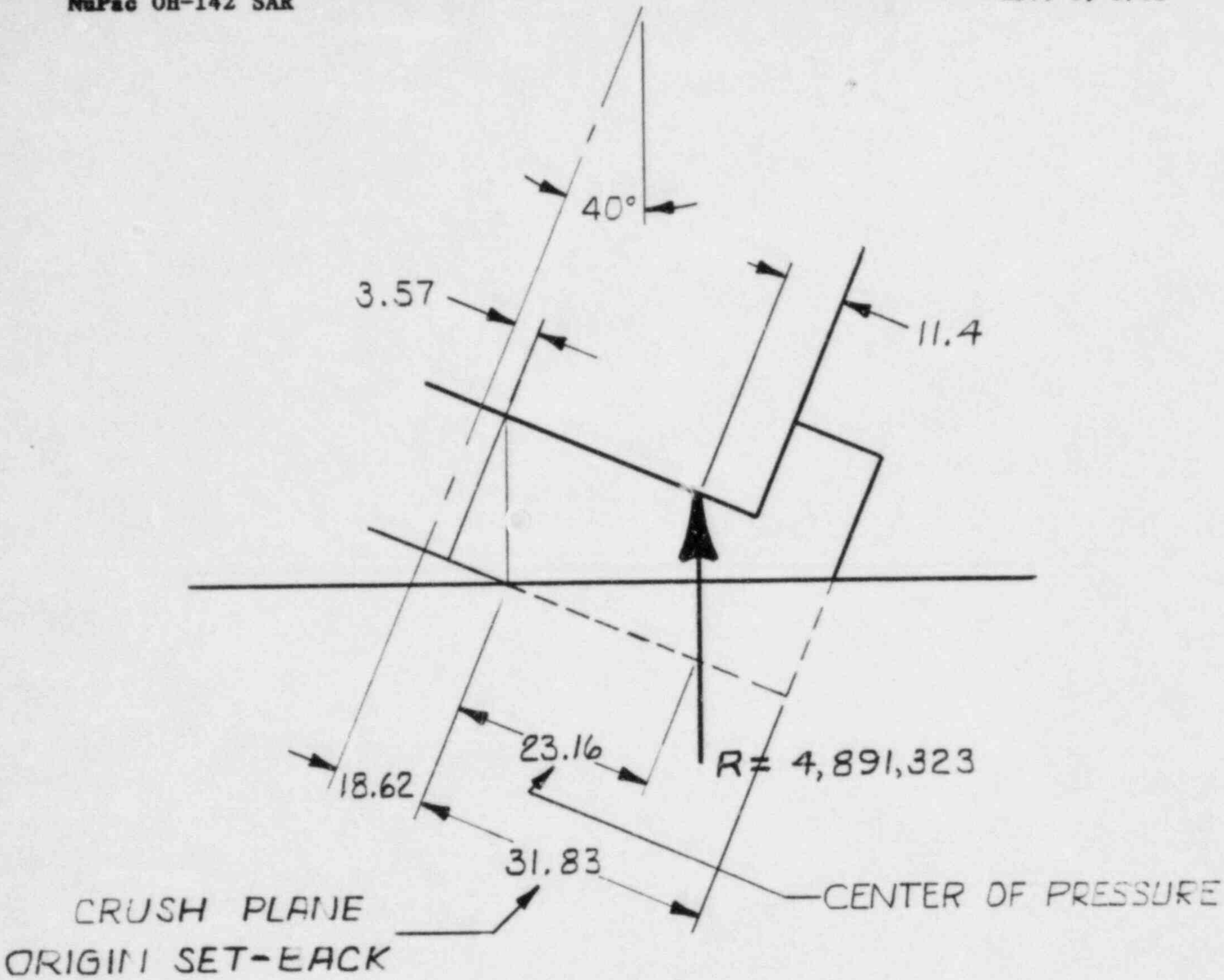
STRAIN VS STRESS TABLE

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

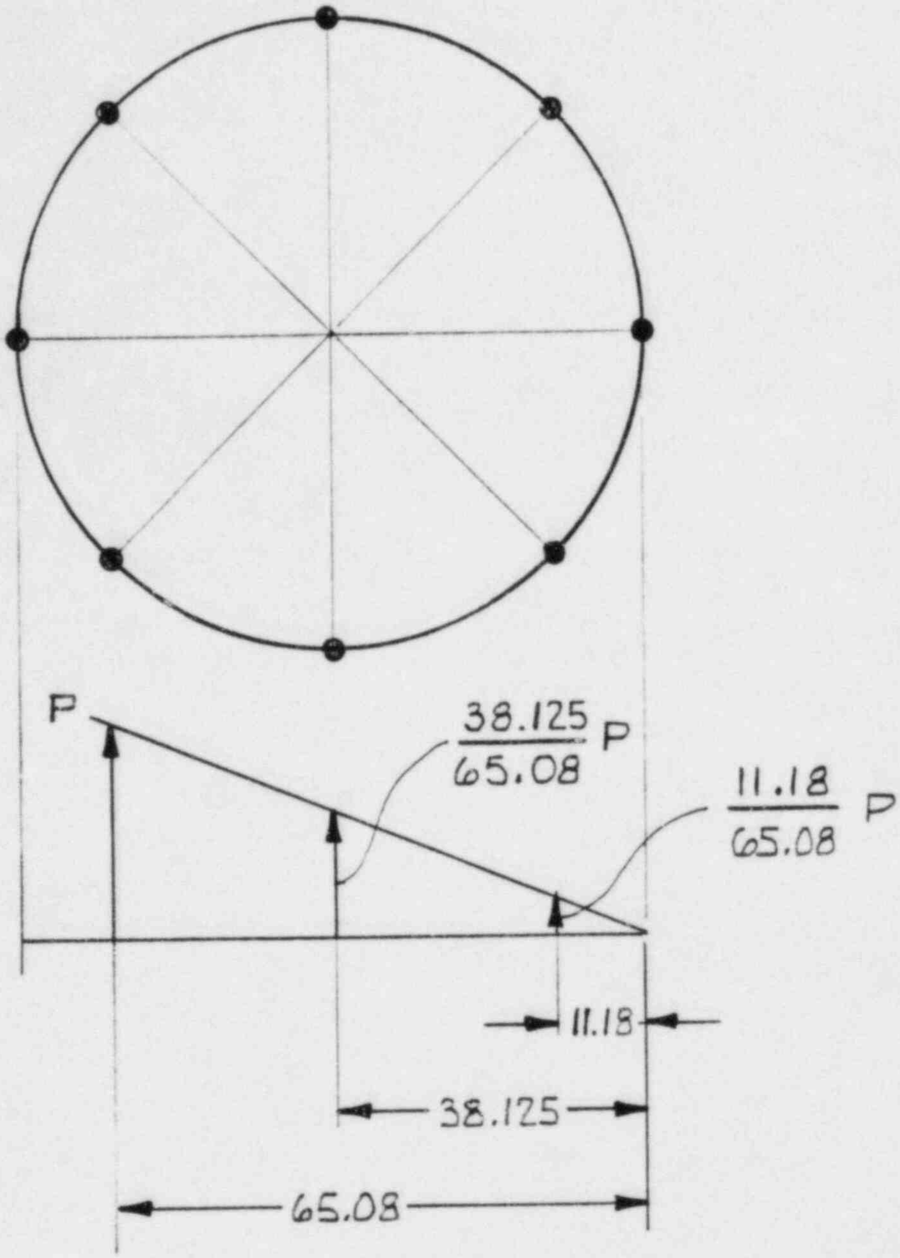
MODEL OH-142 OVERPACK - SOFT FOAM (CASE 1)

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	33.6	8.	7506.	.1	23872000.	1876.	.000	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			1.553,	CENTER OF PRESSURE (IN) =		.927					
1.50	61.5	32.	20773.	.3	23904000.	8946.	.000	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			2.329,	CENTER OF PRESSURE (IN) =		1.392					
2.00	94.4	71.	41730.	.7	23936000.	24572.	.001	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORISIN SETBACK (IN) =			3.106,	CENTER OF PRESSURE (IN) =		1.851					
2.50	131.4	128.	69382.	1.1	23968000.	52350.	.002	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			3.882,	CENTER OF PRESSURE (IN) =		2.301					
3.00	172.0	203.	102550.	1.6	24000000.	95333.	.004	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			4.658,	CENTER OF PRESSURE (IN) =		2.742					
3.50	215.9	300.	140413.	2.2	24032000.	156073.	.006	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			5.435,	CENTER OF PRESSURE (IN) =		3.177					
4.00	262.7	420.	182146.	2.8	24064000.	236713.	.010	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			6.211,	CENTER OF PRESSURE (IN) =		3.604					
4.50	312.1	564.	227167.	3.5	24096000.	339041.	.014	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			6.988,	CENTER OF PRESSURE (IN) =		4.026					
5.00	364.1	733.	275161.	4.3	24128000.	464623.	.019	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			7.764,	CENTER OF PRESSURE (IN) =		4.445					
5.50	418.3	928.	325761.	5.1	24160000.	614853.	.025	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			8.541,	CENTER OF PRESSURE (IN) =		4.870					
6.00	474.6	1152.	377288.	5.9	24192000.	790615.	.033	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			9.317,	CENTER OF PRESSURE (IN) =		5.322					
6.50	532.9	1403.	429702.	6.7	24224000.	992363.	.041	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			10.093,	CENTER OF PRESSURE (IN) =		5.799					
7.00	593.0	1685.	482641.	7.5	24256000.	1220448.	.050	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			10.870,	CENTER OF PRESSURE (IN) =		6.304					
7.50	654.8	1997.	536434.	8.4	24288000.	1475217.	.061	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			11.646,	CENTER OF PRESSURE (IN) =		6.830					
8.00	718.2	2340.	590769.	9.2	24320000.	1757018.	.072	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			12.423,	CENTER OF PRESSURE (IN) =		7.372					
8.50	783.1	2715.	647180.	10.1	24352000.	2066506.	.085	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			13.199,	CENTER OF PRESSURE (IN) =		7.911					
9.00	849.4	3124.	704837.	11.0	24384000.	2404510.	.099	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			13.975,	CENTER OF PRESSURE (IN) =		8.454					
9.50	917.1	3565.	763659.	11.9	24416000.	2771634.	.114	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			14.752,	CENTER OF PRESSURE (IN) =		9.004					
10.00	985.9	4041.	826029.	12.9	24448000.	3169056.	.130	100.00	0.00	0.00	0.00	0.00

	CRUSH PLANE ORIGIN SETBACK (IN) =			15.528,	CENTER OF PRESSURE (IN) =		9.554					
10.50	1056.0	4551.	889017.	13.9	24480000.	3597817.	.147	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			16.305,	CENTER OF PRESSURE (IN) =		10.120					
11.00	1127.1	5097.	956388.	14.9	24512000.	4059169.	.166	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			17.081,	CENTER OF PRESSURE (IN) =		10.685					
11.50	1199.2	5679.	1030321.	16.1	24544000.	4555846.	.186	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			17.857,	CENTER OF PRESSURE (IN) =		11.247					
12.00	1272.3	6297.	1104354.	17.3	24576000.	5089515.	.207	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			18.634,	CENTER OF PRESSURE (IN) =		11.829					
12.50	1346.2	6951.	1185292.	18.5	24608000.	5661926.	.230	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			19.410,	CENTER OF PRESSURE (IN) =		12.415					
13.00	1421.0	7643.	1267076.	19.8	24640000.	6275018.	.255	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			20.187,	CENTER OF PRESSURE (IN) =		13.022					
13.50	1496.5	8372.	1359802.	21.2	24672000.	6931738.	.281	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			20.963,	CENTER OF PRESSURE (IN) =		13.631					
14.00	1572.8	9140.	1459172.	22.8	24704000.	7636481.	.309	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			21.739,	CENTER OF PRESSURE (IN) =		14.234					
14.50	1649.6	9945.	1564080.	24.4	24736000.	8392294.	.339	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			22.516,	CENTER OF PRESSURE (IN) =		14.886					
15.00	1727.1	10790.	1690368.	26.4	24768000.	9205906.	.372	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			23.292,	CENTER OF PRESSURE (IN) =		15.493					
15.50	1805.0	11673.	[illegible]	28.4	24800000.	10082149.	.407	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			24.069,	CENTER OF PRESSURE (IN) =		16.186					
16.00	1883.5	12595.	1968499.	30.8	24832000.	11027925.	.444	100.00	0.00	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			24.845,	CENTER OF PRESSURE (IN) =		16.827					
16.50	1962.4	13556.	2134841.	33.4	24864000.	12053760.	.485	97.90	2.10	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			25.622,	CENTER OF PRESSURE (IN) =		17.538					
17.00	2041.7	14557.	2332840.	36.5	24896000.	13170681.	.529	96.12	3.88	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			26.398,	CENTER OF PRESSURE (IN) =		18.199					
17.50	2121.3	15598.	2547379.	39.8	24928000.	14390735.	.577	94.04	5.96	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			27.174,	CENTER OF PRESSURE (IN) =		18.943					
18.00	2201.2	16679.	2818199.	44.0	24960000.	15732130.	.630	92.03	7.97	0.00	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			27.951,	CENTER OF PRESSURE (IN) =		19.607					
18.50	2281.3	17799.	3128907.	48.9	24992000.	17218907.	.689	89.84	8.88	1.28	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			28.727,	CENTER OF PRESSURE (IN) =		20.280					
19.00	2361.6	18960.	3470520.	54.2	25024000.	18868763.	.754	87.80	9.12	3.07	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			29.504,	CENTER OF PRESSURE (IN) =		21.035					
19.50	2442.1	20161.	3873586.	60.5	25056000.	20704790.	.826	85.57	9.74	4.69	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			30.280,	CENTER OF PRESSURE (IN) =		21.727					
20.00	2522.7	21402.	4348516.	67.9	25088000.	22760315.	.907	83.12	10.50	6.39	0.00	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			31.056,	CENTER OF PRESSURE (IN) =		22.403					
20.50	2603.3	22684.	4863968.	76.0	25120000.	25063436.	.998	81.21	10.56	7.48	.75	0.00
	CRUSH PLANE ORIGIN SETBACK (IN) =			31.833,	CENTER OF PRESSURE (IN) =		23.155					
21.00	2683.9	24005.	5502860.	86.0	25152000.	27655143.	1.100	78.84	10.60	8.39	1.92	.25
	CRUSH PLANE ORIGIN SETBACK (IN) =			32.609,	CENTER OF PRESSURE (IN) =		23.801					
21.50	2764.5	25367.	6225497.	97.3	25184000.	30587233.	1.215	76.65	11.24	8.45	2.91	.75
	CRUSH PLANE ORIGIN SETBACK (IN) =			33.386,	CENTER OF PRESSURE (IN) =		24.465					



If we were to assume that one of the eight binders was destroyed prior to the 31 foot (9.45 m) drop and that the lid was infinitely rigid so that a triangular load distribution took place, the following maximum binder load can be calculated.



$\Sigma M_A = 0$

$2(65.08)P+2(38.125)^2P/(65.08)+2(11.18)^2P/65.08$

$+3,262,000(11.4) = (19,900 \text{ lbs})(76.4)(38.125) \cos 40^\circ$

$178.67 P + 37,186,800 = 44,402,789$

$P = 40,387$ lbs/binder

Therefore, if one of the eight binders are lost prior to the 31 foot drop, impact loads will be a maximum of 40,387 lbs. per binder.

The Margin of Safety, based on the new binder load, will be:

M.S. = 160,000 lbs/40,387 lbs -1

M.S. = +2.95

The analysis presented on Page 1-56 is conservative. Actual maximum binder or associated bolt loads will be 40,387 lbs.

The 1 5/8 inch diameter binder retain pins are loaded in double shear and have the following capacity:

$P = 2F_sA$

Where:

$F_s = .6F\mu$

$= (.6)(105{,}000 \text{ psi})$

$= 63{,}000 \text{ psi}$

$A = \pi(1.625)^2/4$

$= 2.07 \text{ in}^2$

$P = (2)(63{,}000 \text{ psi})(2.07 \text{ in}^2)$

$P = 261{,}316$ lbs.

Margin of Safety

M.S. = 261,316/120,454-1

M.S. = +1.17

Threfore, it can be concluded that the retaining pin has adequate capability of reacting the imposed loads.

Preloads are not an additive factor. Preloaded joints are relieved by the applied load and only cause an increase in fastener load when the applied load exceeds the preload.

Mark I Overpack Retainer Pins

For the Mark I configuration, the overpack is secured to the cask by means of 8 1/2" diameter ball lock pins acting in double shear. These pins pass through the ratchet binder lugs on the lid and the guide channels on the overpack. The reaction force required to retain the overpack is directly proportional to P_b.

Therefore

$$P_o = P_b \text{ (wt of overpack/w)}$$

$$= (120{,}454 \text{ lbs.})(3{,}000 \text{ lbs.})/(19{,}900 \text{ lbs.})$$

$$= 18{,}158 \text{ lbs. per pin}$$

The pins act in double shear through two thicknesses of 3/16 inch plate. Shear out capacity can be calculated as follows:

$$P_{su} = F_{su} 2t \quad E.M. - d/2 \text{ COS } 40^{\circ}$$

$$= (35{,}000(2)(.375)(1.5 - .25 \text{ COS } 40^{\circ})$$

$$= 34{,}350 \text{ lbs.} \quad \text{Shear Out}$$

The Carr Lane Model Number CL-8-BLP ball-lock pin has a rated double shear capacity of 32,800 lbs.

Margin of Safety

M.S. = 32,800 lbs/18,158 lbs. -1

M.S. = +.81

Therefore, it can be concluded that the overpack retainer pins are more than adequate for securing the overpack to the cask for the Mark I configuration.

Mark I Stud Substitution for Binders

As an option to ratchet binders, the Mark I configuration may use 8-1 3/8 NC Grade 5 studs. From above it was shown that the overpack for the Mark I is secured by means of retainer pins. Therefore, the remaining load that must be carried by the bolts can be calculated as follows:

$$(16900)(76.4)(38.125) \cos 40^{\circ} = 12267878+266.7P_b(71.25/76.25)$$

$$P_b = 95391\ (76.25/71.25)$$

$$P_b = 102{,}085 \text{ lbs/bolt}$$

The capacity of a 1 3/8" NC Grade 5 stud is:

$$P_s = F_{Tu}A_{net}$$

Where:

$$F_{Tu} = 105{,}000 \text{ psi (Min.)}$$

$$A_{net} = 1.15 \text{ in}^2$$

$$P_s = (105{,}000)(1.15)$$

$$P_s = 120{,}750 \text{ lbs./stud}$$

Margin of Safety

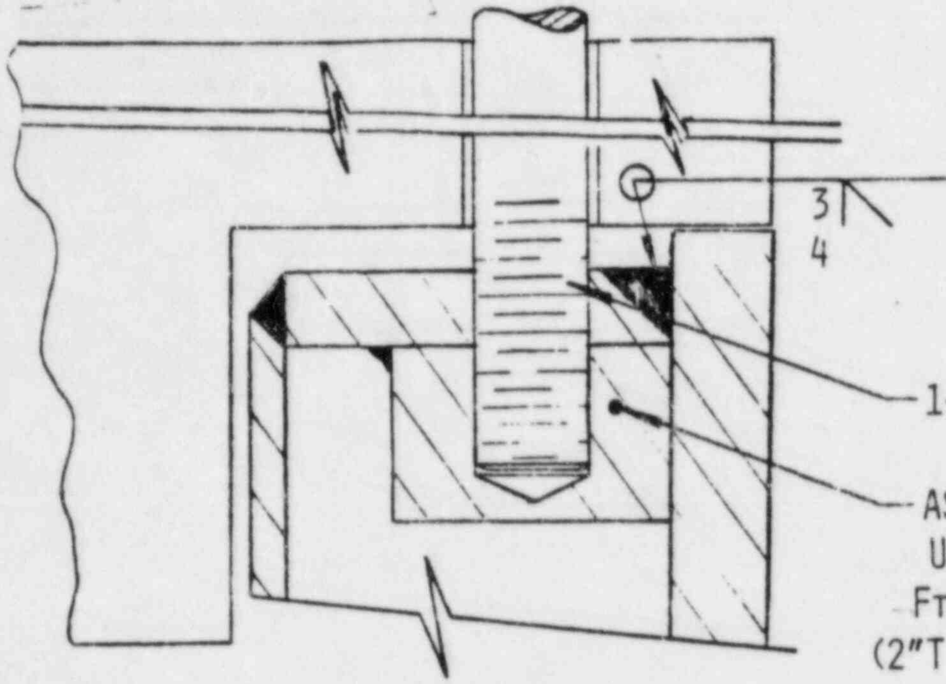
M.S. = 120,750/ 102,085-1

M.S. = + .18

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 3/8 NC Heavy Hex Nut is 1.378 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./1.398 in. -1

M.S. = +.27



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 centerline.

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

Where:

$F_{su} = 35,000$ psi

$A_{weld} = .75(8)$

$= 6.0 \text{ in}^2$

$P_w = (35,000 \text{ psi})(6.0 \text{ in}^2)$

$P_w = 210,000$ lbs.

Margin of Safety

M.S. = 210,000/102,085

M.S. = + 1.06

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

This number is conservative since the average compressive stress acting across the lid face will be substantially greater than the nominal 1000 psi assumed here. The higher foam compressive stress reduces the load that must be reacted by the binders. 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 binders.

From the above it can be seen that the binders can react the impact loads experienced in a 31 foot free drop.

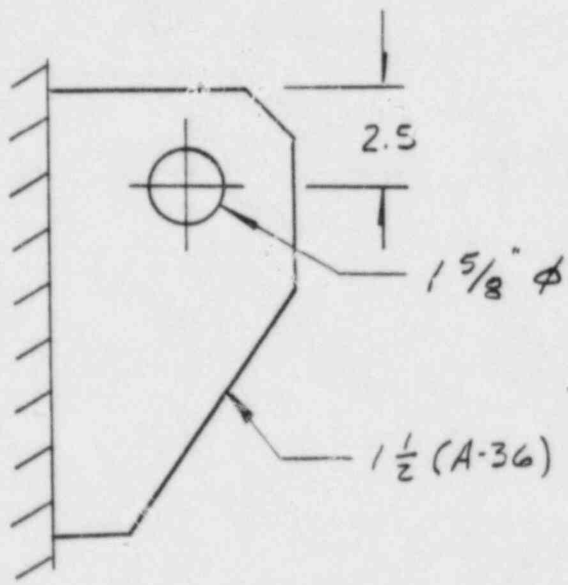
The capacities stated for the binders are established static allowables. They are manufactured from standard carbon steels and fail in the same manner as a bolt. Numerous studies have been conducted on the behavior of bolts under dynamic or impact loading. ORNL-TM-1312 Vol. 12 Structural Analysis of Shipping Casks states that carbon steel bolts "possess better physical properties under conditions of shock than indicated by static tests. Increase in the value of stress by a factor of 1.3 and a greater amount of strain before necking occurs were reported". This is substantiated by references 5, 8, 9, 10 and 11 of the same document.

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

Therefore, it can be concluded that the binders will react the impact load and retain the lid.

The lugs at each end of the binder will possess the following capability.

Body Lugs



Shear out:

Using the standard 40° shear out:

$$P_s = F_s 2t\ (E.M.-d/2 \cos 40^\circ)$$

Where:

F_s = 35000 psi

t = 1.50 in

EM = 2.50

d = 1.625 in.

$$P_s = (35000)(2)(1.50)(2.5 - .81 \cos 40^\circ)$$

$$= 197{,}350 \text{ lbs. shear out}$$

Weld area:

$$P_w = F_s A_w$$

Where:

$$F_s = 35000 \text{ psi}$$

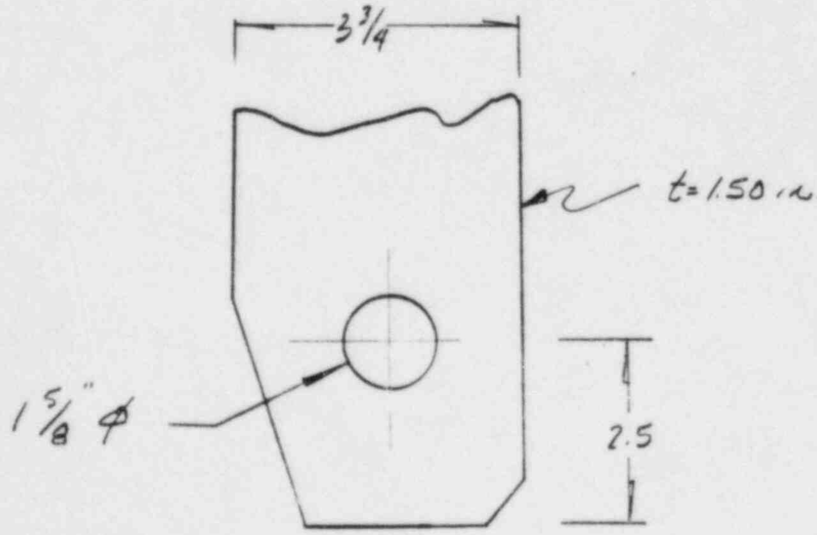
$$A_w = (18 \text{ in})(.50)(\sin 45^\circ)$$

$$= 6.36 \text{ in}^2$$

$$P_w = (35000)(6.36 \text{ in}^2)$$

$$P_w = 222{,}700 \text{ lbs. weld shear}$$

Lid Lugs



Bearing stresses in the lugs can be calculated as follows:

$f_{brg} = P/A$

Where:

P = 120,454 lbs. per lug

A = (1.50 in. thick)(1.625 in. dia.)

$f_{brg} = 120{,}454/(1.50)(1.625)$

$f_{brg} = 49417$ psi

Allowable bearing stress per Page 1-3

$f_{brg} = 90{,}000$ psi

Margin of Safety

M.S. = 90000/49417-1

M.S. = +.82

The lug capability in net area is:

$$P_t = F_{tu}A$$

Where:

$$F_{tu} = 110{,}000 \text{ psi (ASTM A-517)}$$

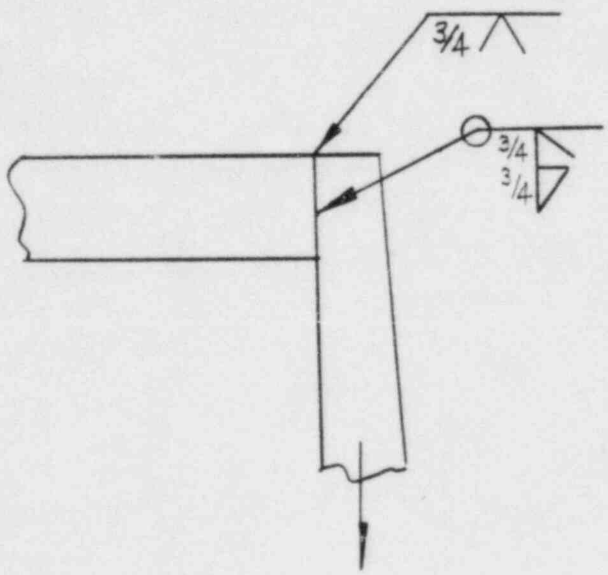
$$A = (3.75 - 1.625)(1.5)$$

$$= 3.19$$

$$P_t = (115{,}000 \text{ psi})(3.19 \text{ in}^2)$$

$$P_t = 366{,}850 \text{ lbs. (Net Area)}$$

Lug to lid attachment



Weld Shearing:

$$P_s = F_sA \text{ weld}$$

Where:

$$F_s = 35000 \text{ psi}$$

$$A = (1.50 \text{ in})(3.0 \text{ in}) = 4.5 \text{ in}^2$$

$$P = (35000 \text{ psi})(4.5 \text{ in}^2)$$

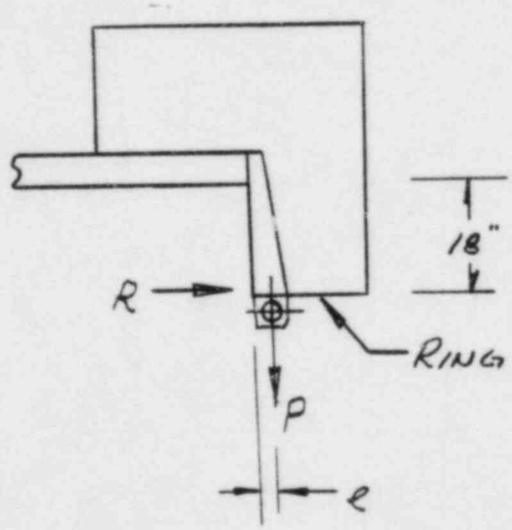
$$P = 157{,}500 \text{ lbs}$$

Margin of Safety

M.S. = 157,500/120,454-1

M.S. = +.31

Since the binder load is reacted eccentrically an inward radial load will be produced. This load is reacted by the lower circumferential skirt of the overpack. The load produces a compressive load on this skirt or ring. No additional load will be imposed on the upper lug weld due to this eccentricity condition.



$P e = RL$

$R = Pe/L$

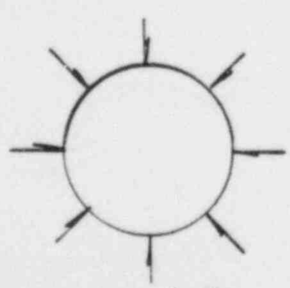
$= (160000 \text{ lbs})(2.5 \text{ in})/(18 \text{ in})$

$= 22222 \text{ lbs.}$

Where:

P = Maximum binder capacity

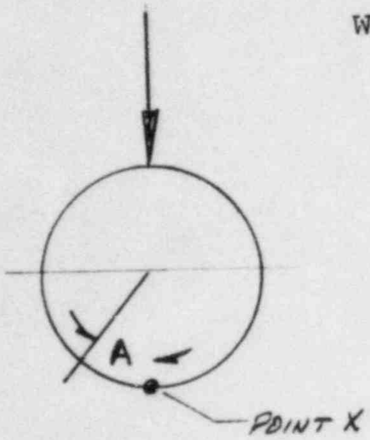
If these were totaled at each binder the ring would be loaded as follows:



Bending moment produced in a ring with two opposing loads is given by the following equation.

$$M = K_m P$$

(Ref. Rigid Ring Frames, Load Deflection, Summary Convair Report No. AZS-27-276)



Where:

$$K_m = \frac{\text{SinA}}{2} - \underline{1}$$

$P = 22222$ lbs

$r = ((101-76¼)/2 + 76¼)/2$

$r = 44.31$ in

By superposition

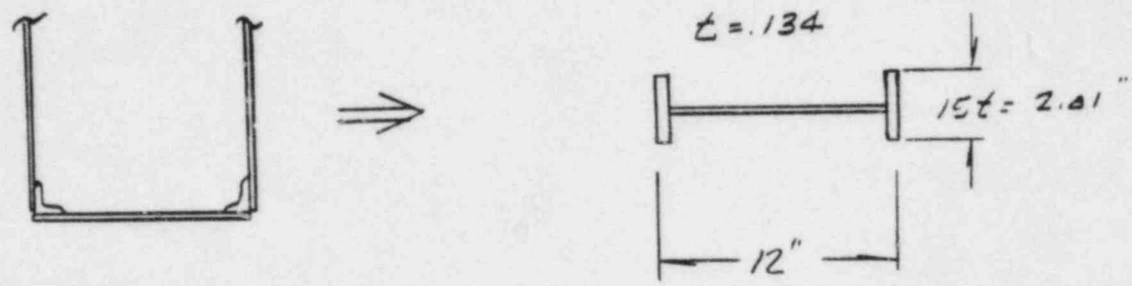
A	K_m			ΣK_m
0	-.31831	x 1	=	-.31831
45	+.03524	x 2	=	.07048
90°	+.18170	x 1	=	.18170
				-.06613

Therefore, the combined effect of the radial loads will produce a maximum K_m = .06613

M = (.06613)(22222 lbs)(44.31 in)

M = 65116 in-lbs (Max)

The ring has the following cross-section and associated modulus.



$$I_x = I_o + Ad^2$$

$$I_x = (.134)(1.2)^3/12 + (2)(.134)(2)(6)^2$$

$$I_x = 19.31 \text{ in}^4$$

Stress in the ring is given as:

$$f_r = MC/I_x$$

Where:

$M = 65116$ in-lbs

$C = 6$ in

$I_x = 19.31$

$$f_r = (65116)(6)/19.31$$

$$f_r = 20232 \text{ psi}$$

Margin of Safety:

M.S. = 35000/20232 -1

M.S. = +.73

Therefore, it can be concluded that the lower skirt of the overpack can safely react the eccentrically produced radial load. From the above, it can be seen that the critical load path for the binder attachment will be shear out at the lugs. The following positive margin of safety exists at those locations.

M.S. = 197350/120,454-1

M.S. = +.64

It can be concluded that the binders and their fitting can safely react the maximum loads produced during impact.

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.

Through hand integration it was found that an average compressive stress of 1700 psi was felt across the area producing contact angles of 67°.

Therefore, deflection at 67° is:

$$\delta = (1-\cos \theta/2)\ D/2$$

$$\delta = (1-\cos 33.5^{\circ})(101/2)$$

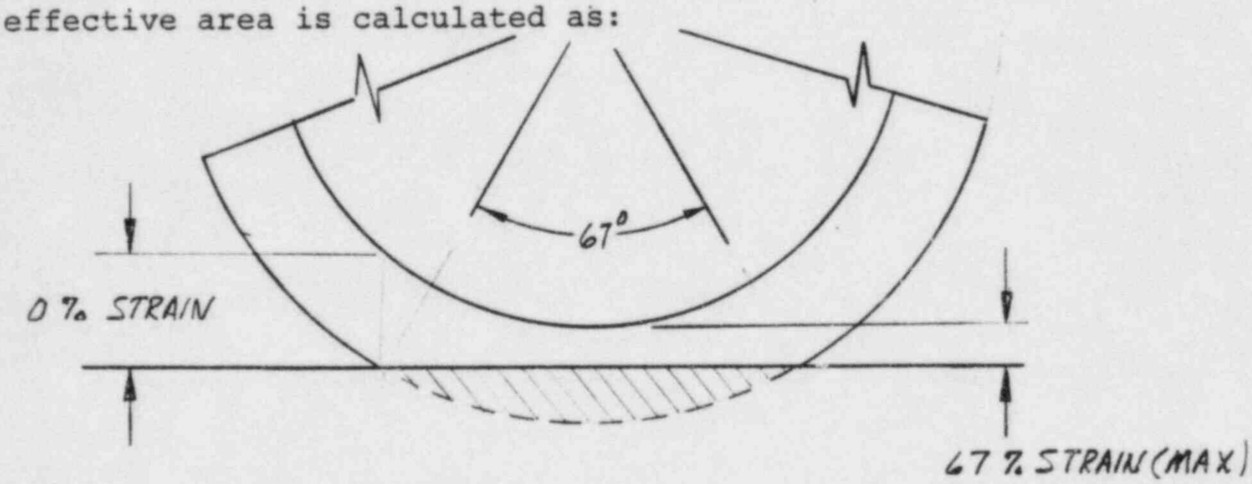
$$\delta = 8.39 \text{ in} \quad \text{Max}$$

Using the original thickness of 12.375 in. the maximum strain is:

Strain = 8.39 in/12.375 = 67%

This conservatively assures 4.00 in. of foam across the maximum damage area. Again it must be noted that this is extremely conservative since the overhanging portion of the overpack will absorb a large amount of energy thereby greatly reducing the total deformation.

Using the strain calculated above a very conservative acceleration can be calculated by assuming that the foam across the surface has all been stressed to a 67% strain. From the sketch below it can be seen that only that material directly beneath the cask experiences these strains and as you progress outward they rapidly decrease. Using this conservative assumption a strain of 67% will produce a maximum stress of 3600 psi (Ref. Figure 1). The effective area is calculated as:



$$A = 2RL \sin(\theta/2)$$

$$A = (2)(50.5)(44)(\sin 33.5^{\circ})$$

$$A = 2452 \text{ in}^2$$

If we apply the maximum stess of 3600 psi across the whole area the acceleration would be:

$$a = (2452\ in^2)(36000)/64000$$

$$a = 137.9\ g's$$

If the same integration analysis was repeated, using the full length of the overpack, an average compressive stress of 1300 psi would produce an impact angle of 58^o.

$$= (1-\cos 29^o)\ 101/2$$

$$= 6.33\ in$$

This would produce a maximum strain of:

$$Strain = 6.33\ in/12.375\ in$$

$$= 51\%$$

From Figure 1 the stress at a 51% strain is 1900 psi

The effective area is:

$$A = 2\ RL\ \sin \theta/2$$

$$A = (2)(50.5)(80)\ \sin 29^2$$

$$A = 3917\ in^2$$

$$a = (3917\ in^2)(1900\ psi)/64000\ lbs$$

$$a = 116\ g's$$

Therefore, maximum acceleration and deformations are experienced when only the projected area of the cask is reacted by the overpack.

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 exhibit if they were required to react these loads.
On the 24" lid design (which envelops the lighter weight 16" lid design):
Load per bolt is:

P = (1776 lbs Lid)(138 g's)/8 bolts

P = 30636 lbs (shear)

Bolt capacity is:

R = (115,000 psi)(.487 in^2)(60%)

R = 33603 lbs

Margin of Safety

M.S. = R/P -1

M.S. = 33603/30636 -1

M.S. = +.10

The optional secondary lid load is:

P = (2255 lb lid) (138 g's)/8 Bolts

= 38899 lbs/bolt (shear)

Bolt shear capacity is:

$$R = (75750 \text{ lbs}) (60\%)$$

$$= 45450 \text{ lbs}$$

PROPRIETARY DATA

Margin of Safety is:

$$M.S. = (45450/38899)-1$$

$$\underline{M.S. = +.17}$$

Conclusion:

From the above it can be concluded that under the most conservative conditions the package will maintain more than 4 in 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 31 feet will not produce detrimental effects to the package.

Foam material has been tested to -40°C and found to exhibit a small increase in compressive strength (< 16%). Samples failed in the same manner at -40°C as they did at room temperature, indicating that brittle fracture is not apparent at this temperature range.

From the SAR it can be seen that impact accelerations decrease as compressive strength increases. Therefore, cold conditions will not produce detrimental loading and testing indicates that brittle fracture characteristics are not present.

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 puncture energy can be calculated:

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

Where:

$S_1 = 55000$ psi (A-36)
$S_2 = 70000$ psi (A-516, Grade 70) Optional Matl.
$W = 64000$ lb.

$$t_1 = (64000/55000)^{.71}$$

$t_1 = 1.11$ (A-36)

$t_2 = .94$ (A-516, Grade 70)

Margin of Safety:

M.S. = 1.125/1.11-1

= +.02 (A-36) (1 1/8" PLT)

M.S. = 1.00/.94-1

M.S. = +.06 (A-516) (1" PLT)

The ends of the package are constructed from two thicknesses of 3 inch steel plates for a total of 6 inches. From the above, it was shown that the 1 1/8" (A-36) or 1" (A-516) steel sides backed by 3½" of lead were shown to be adequate. For the sake of completeness, the following analysis is presented to substantiate the adequacy of the end plates.

In order to demonstrate adequacy of the cylindrical flask overpack to withstand impact on a 6" diameter cylindrical pin, an "ANSYS" finite element analysis of the circular end plates has been performed. The analysis approach considered both large deflection behavior of the circular plate and bi-linear characteristics of the mild steel material.

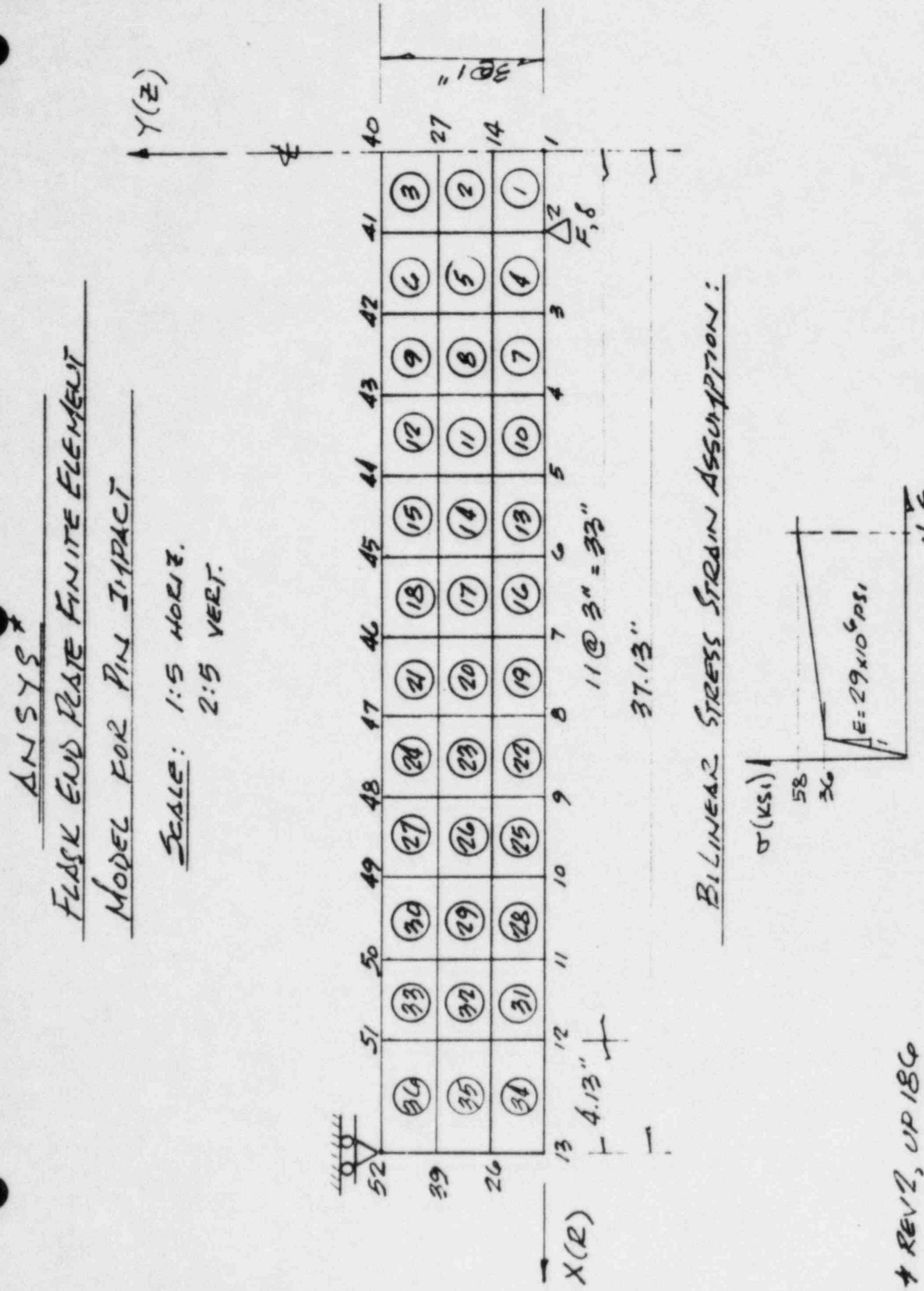
The mathematical model is shown in Figure 1. This model consists of 52 nodes and 36 iso-parametric quadrilaterals (STIF42) representing an axi-synemetric plate of three inches thickness and 74½" in diameter. The plate model was loaded by applying a series of prescribed displacements to node 2, corresponding to the contact perimeter of the 6" diameter puncture pin. At the outer diameter of the plates, node 52, 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.

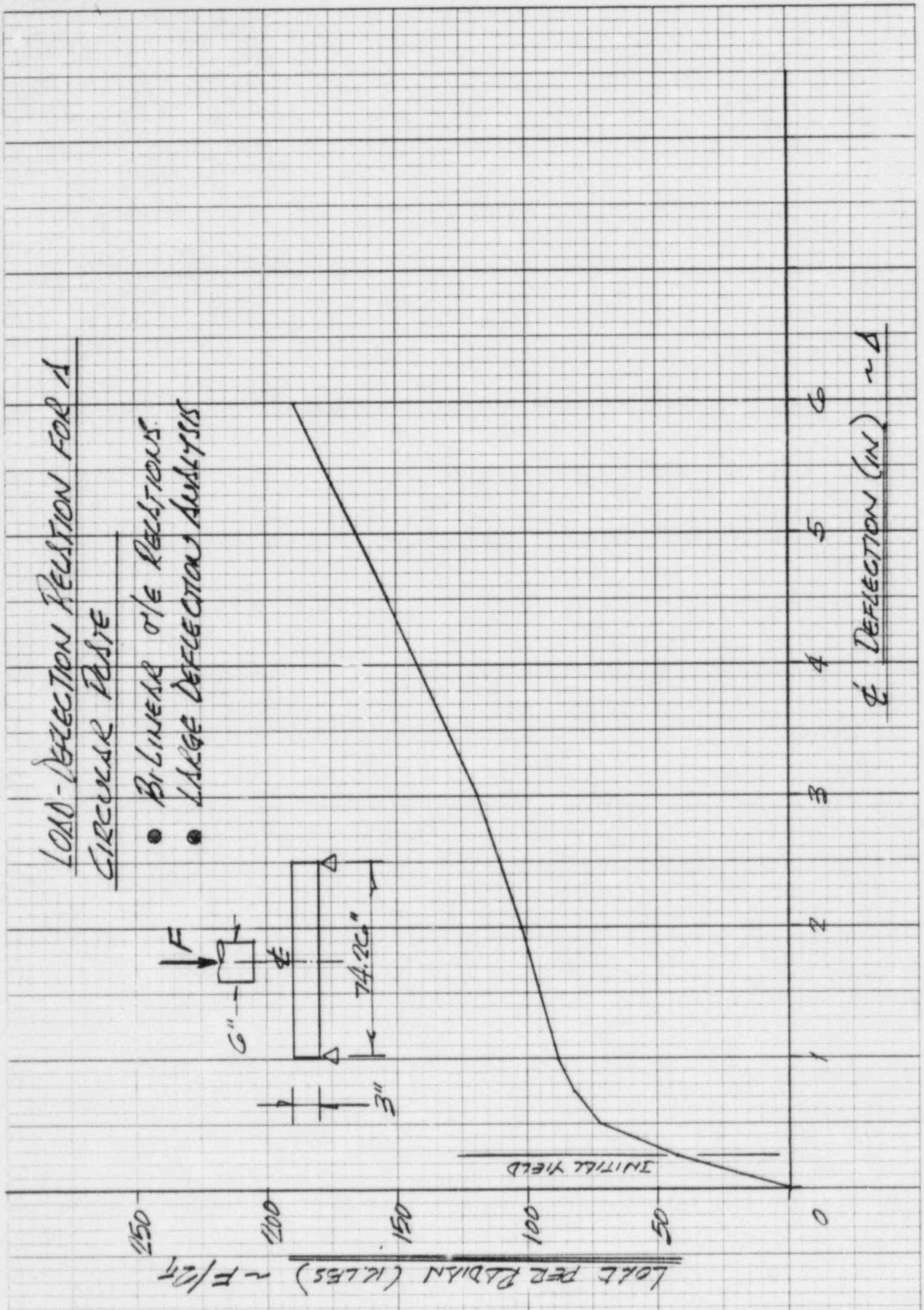
The conventional bilinear properties of mild steel used in this analysis are also shown in Figure 1. Importantly, this analysis assumed a conservative 10% value for strain at rupture.

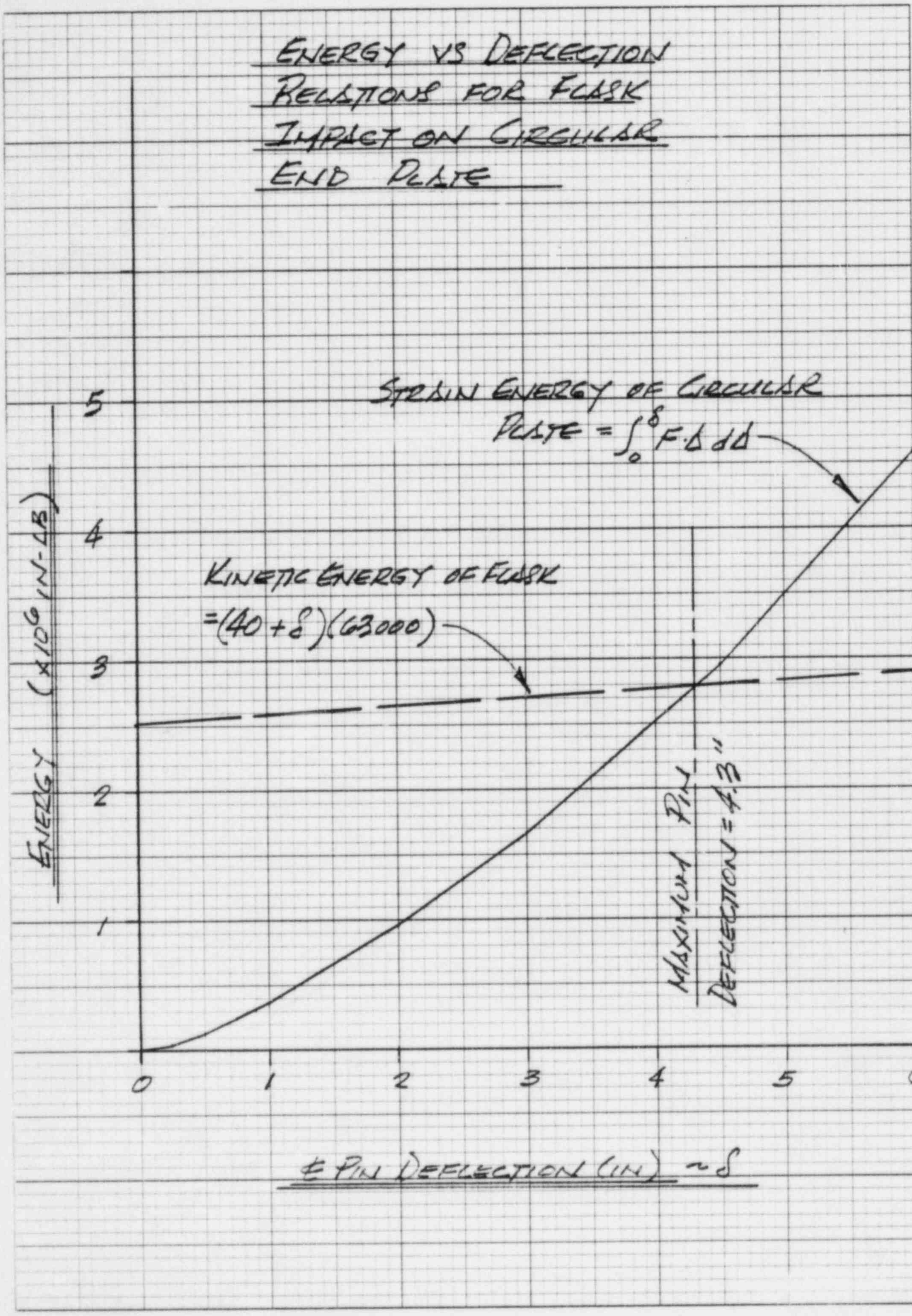
The structural behavior of the plate at maximum pin penetration is shown approximately in Figure 2. By approximately we mean Figure 2 illustrates strains and deformations at an "ANSYS" load step (imposed deformation) just beyond the maximum deformation actual experienced by the plate. Figure 2 illustrates 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 + 0.66; 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 3. Integrating this load-deformation relation, as shown in Figure 4, produces a description of plate strain energy versus deformation depth.

The kinetic energy relation of the dropped flask is also plotted on Figure 4. The intersection of these two energy relations defines the deformation depth at which the strain energy (or work done on the plate) equals the available kinetic energy. At this deformation depth, 4.3 inches, the deformation is arrested and can proceed no further.


ANSYS*
FLASK END PLATE FINITE ELEMENT
MODEL FOR PIN IMPACT
SCALE: 1:5 HORIZ.
2:5 VERT.
Y(Z)
X(R)
3.81"
11 @ 3" = 33"
37.13"
4.13"
F, δ
BILINEAR STRESS STRAIN ASSUMPTION:
σ (KSI)
58
36
E = 29x10^6 PSI
.16
MAX. STRAIN %
* REV 2, UP 186


LOAD-DEFLECTION RELATION FOR A CIRCULAR PLATE
• BI-LINEAR σ/ε RELATIONS
• LARGE DEFLECTION ANALYSIS
F
6"
74.26"
3"
INITIAL YIELD
LOAD PER RADIAN (KIPS) ~ F/2π
0
50
100
150
200
250
℄ DEFLECTION (IN) ~ Δ
1
2
3
4
5
6


ENERGY VS DEFLECTION RELATIONS FOR FLASK IMPACT ON CIRCULAR END PLATE
STRAIN ENERGY OF CIRCULAR PLATE = $\int_0^\delta F \cdot \Delta \, d\Delta$
KINETIC ENERGY OF FLASK =(40+δ)(63000)
MAXIMUM PIN DEFLECTION = 4.3"
ENERGY (x10^6 IN-LB)
℄ PIN DEFLECTION (IN) ~ δ
0
1
2
3
4
5
6

Puncture impact on a binder assembly could result in loss of effectiveness of that binder. Since the puncture test follows the 30 foot impact, no significant loads are reacted by the binders. The heavy 6 inch thick lid is stiffened by the overpack and can be safely retained by the remaining seven (7) binders.

The 7000 pound lid is more than adequate to compress the silicone gasket and seat the lid on its steel stops. Preload supplied by the binders only serves to secure the lid against the stop and retain it during impact. A torque rate will be applied adjacent to the binders. This will assure adequate preload. The prescribed torque of 80 ft-lbs will produce a preload of 3000 lbs. in each binder. This load will have no impact on the structural integrity of the package.

ANALYSIS OF 6 SECONDARY LID MARK I CONFIGURATION

The ends of the package are constructed of two thicknesses of three (3) inch steel plates for a total thickness of six (6) inches. The top pair of end plates contain six access holes spaced equally about a circumferential line with a 22" radius. The holes in the outer plate have a diameter of 20 1/2" whereas the holes in the corresponding inner plate have a diameter of 19". The lower plate is reinforced between holes with a vertical web comprised of a 2" x 4" rectangular steel bar.

Puncture resistance of this package end has been examined by a non-linear large deflection ANSYS finite element analysis. The six inch diameter puncture pin has been assumed to impact the cylinder at the center of the perforated circular end plates. The ANSYS solution employed a three dimensional model to represent the geometry and properties of the end plates. Bilinear stress-strain characteristics were used to represent the mild steel material.

The ANSYS finite element model is depicted in Figures 5 through 9. Two sets of symmetric boundary conditions were employed. One plane of symmetry passes through the center line of the access hole pattern whereas the second plane of symmetry passes mid-way between contiguous hole groups. Thus, the three dimentional ANSYS model represents a 30° "pie-slice" of the total lid assembly. The resultant 3-D model consists of 120 isoparametric 3-D cube elements (STIF45), representing the two plates, and 10 flat membrane sheel elements (STIF41), representing the vertical web stiffener attached to the inner plate.

Each of the two plates was separately modeled. Figures 5 and 7 present ANSYS generated planar plots of these two models and fully define the node point numbering scheme. Three dimensional plots of these two models are depicted in Figures 6, 8, and 9. The two plates were attached together as follows:

- Surrounding the holes, the filet weld was simulated by a series of wedge shaped finite elements (STIF45).

- At the outer circumference of the inner plate, the filet weld was again simulated by a series of wedge shape finite elements.

- Elsewhere, vertical deflection compatibility was achieved by use of the ANSYS coupled degree of freedom feature. No planar (X, Y) compatibility was imposed thus permitting realistic treatment of potential differential slip between plate surfaces.

The lid model was loaded by applying prescribed vertical displacements to nodes 2 and 3, corresponding to the contact perimeter of the 6" diameter puncture pin. These prescribed loads (deformations) were reacted by vertical displacement constraints imposed at the inner surface of the outer plate (nodes 142 to 147). Figure 10 depicts a planar illustration of these loads and reaction assumptions along a planar out through the model at a mid-plane between holes. Symmetric boundary conditions were imposed on the model along both radial cut surfaces.

Figure 11 illustrates approximate deformation and strain results at maximum penetration of the puncture pin. By approximate,we mean Figure 11 (imposed deformation) just <u>beyond</u> the maximum

deformation actual experienced by the plate. Figure 11 illustrates both deformed plate shape and effective strains for each of the finite elements at the mid plane between holes. On an effective strain basis, the most severely strained element possesses a rupture margin of greater than +0.06 thus, no puncture occurs.

Maximum pin penetration (deformation of plates) was determined by plotting the load-deformation characteristics of nodes 2 and 3 (the puncture pin diametrical location) as shown in Figure 12. Integrating this load-deformation relation, as shown in Figure 13, produces a description of plate strain energy versus deformation depth.

The kinetic energy relation of the dropped flask is also plotted on Figure 9. The intersection of these two energy relations defines the deformation depth at which the strain energy (or work done on the plates) equals the available kinetic energy. At this deformation depth, 5.05 inches, the deformation is arrested and can proceed no further.

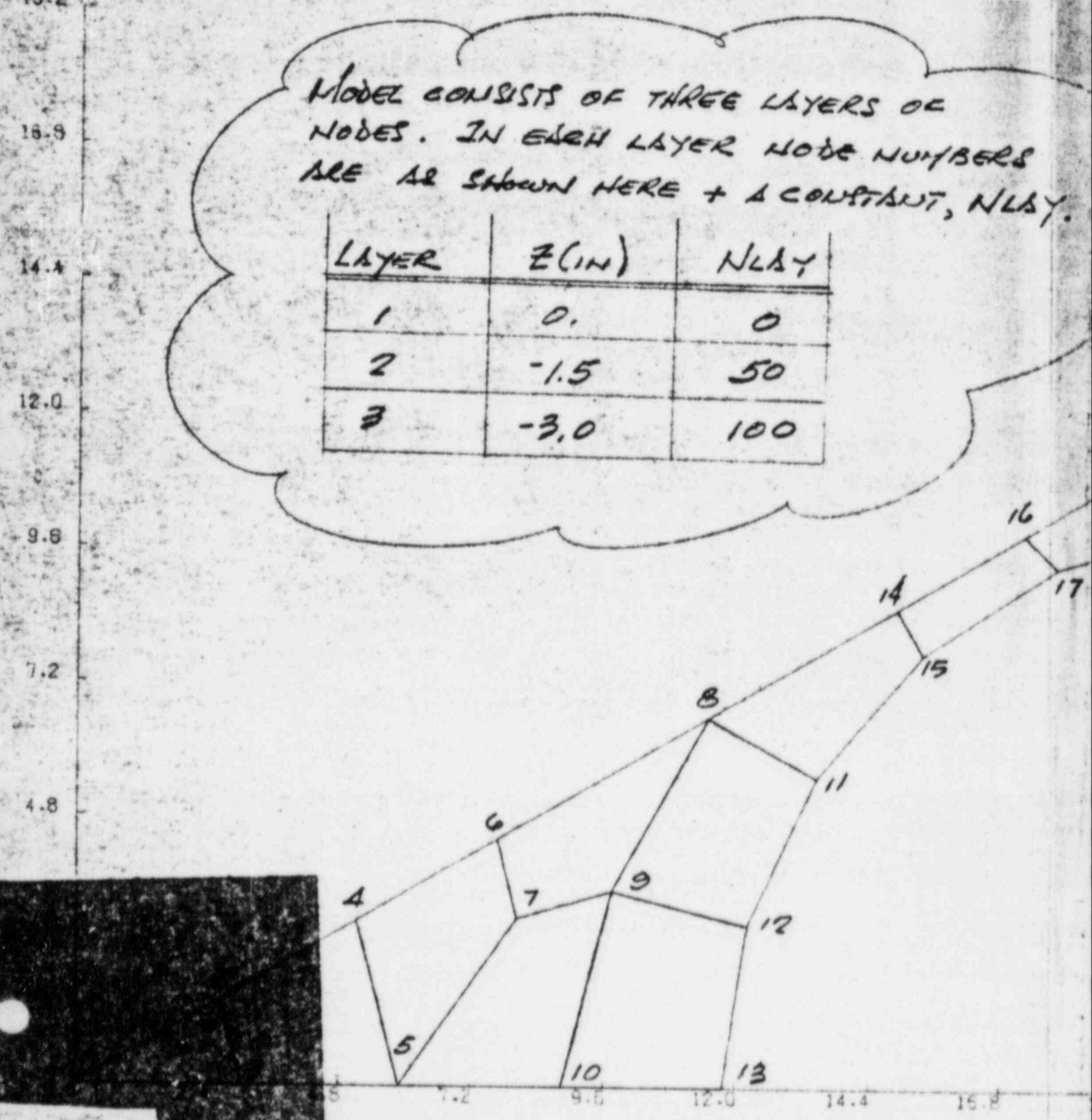
CONCLUSION: Therefore, the MARK I Lid is more than adequate in reacting 40 inch puncture drop condition.

~ FIGURE 5

FINITE ELEMENT
OF OUTER PLATE ~

MODEL CONSISTS OF THREE LAYERS OF NODES. IN EACH LAYER NODE NUMBERS ARE AS SHOWN HERE + A CONSTANT, NLAY.

LAYER	Z(IN)	NLAY
1	0.	0
2	-1.5	50
3	-3.0	100



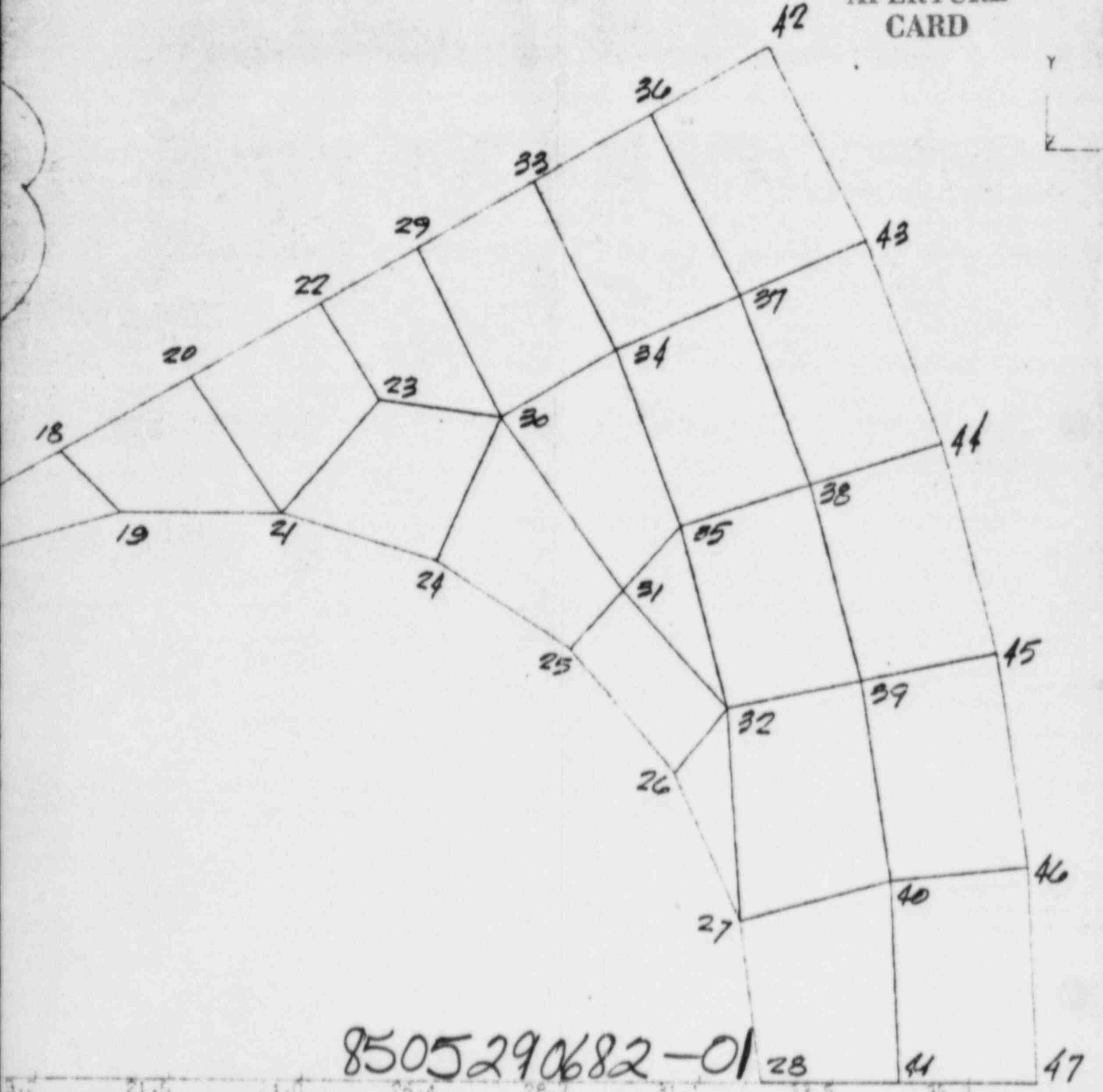
[redacted]PING FLASK LID - NUCLEAR PACKAGING INC.

MODEL

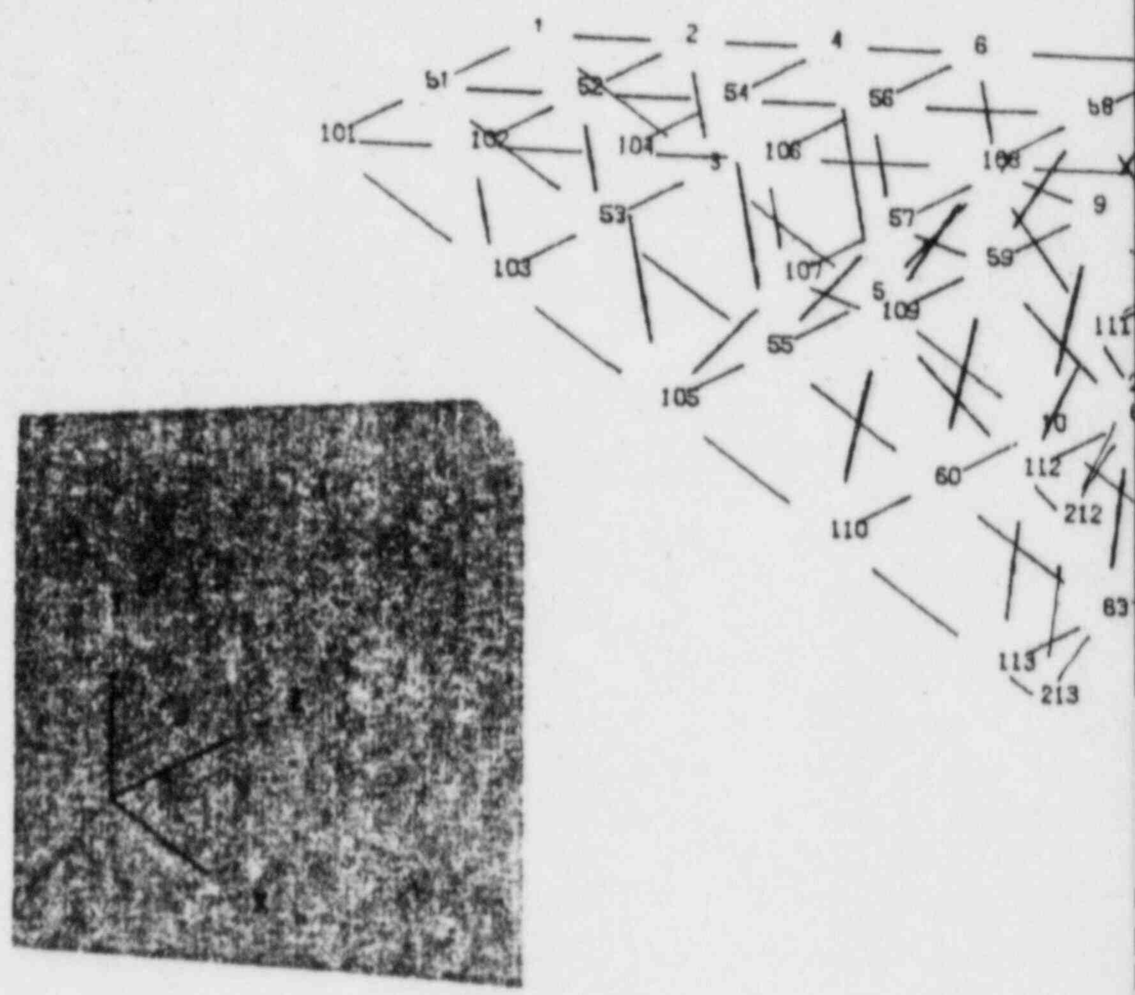
FLASK LID

Also Available On
Aperture Card

TI
APERTURE
CARD



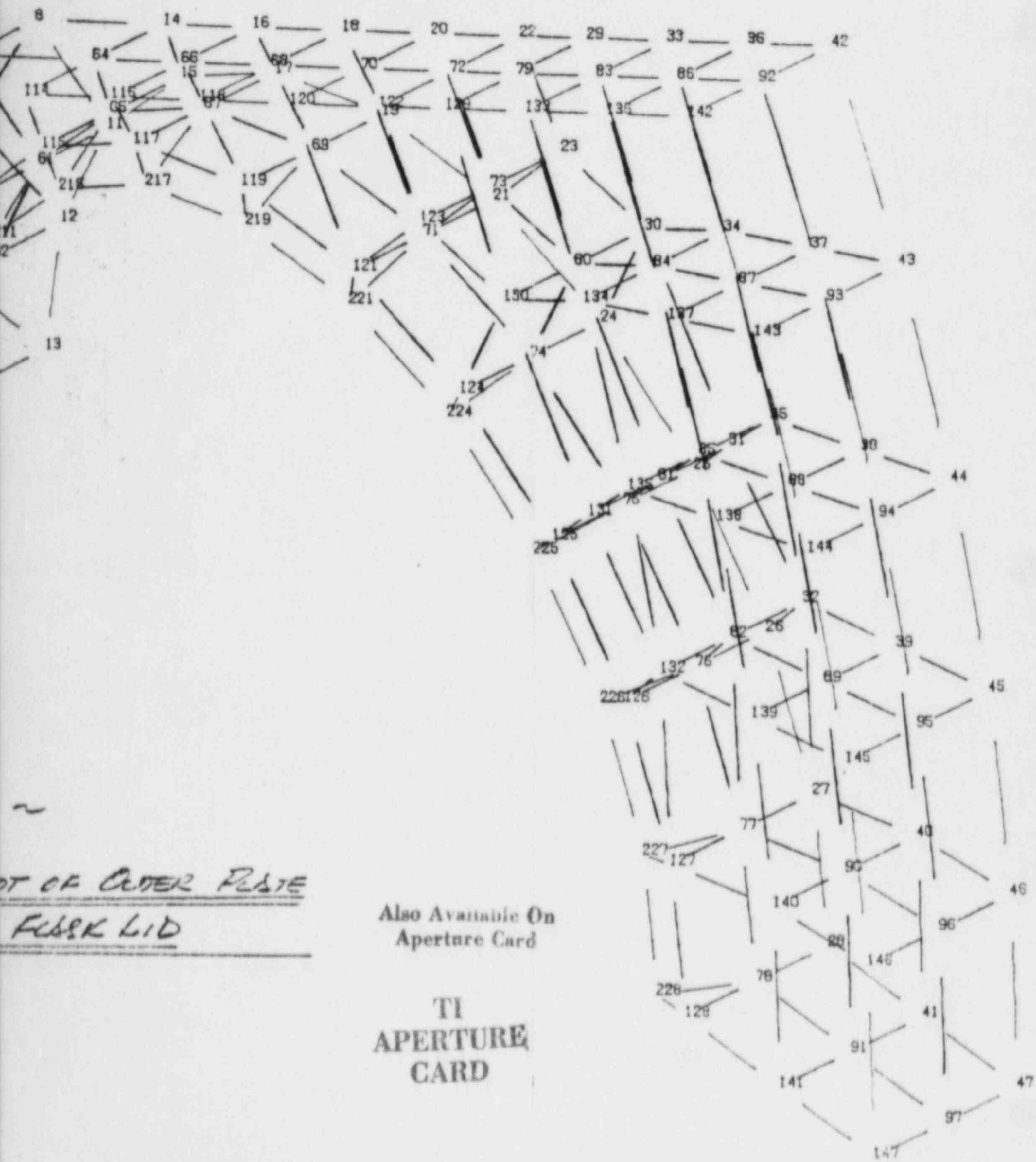
8505290682-01



~ FIGURE 6

THREE DIMENSIONAL PL
NUMBERED NODES ~

ANSYS 1 PUNCTURE ANALYSIS OF BULK RESIN SHIPPING FLASK LID - NUCLEAR PACKA



...OT OF OUTER PLATE
... FLASK LID

Also Available On
Aperture Card

TI
APERTURE
CARD

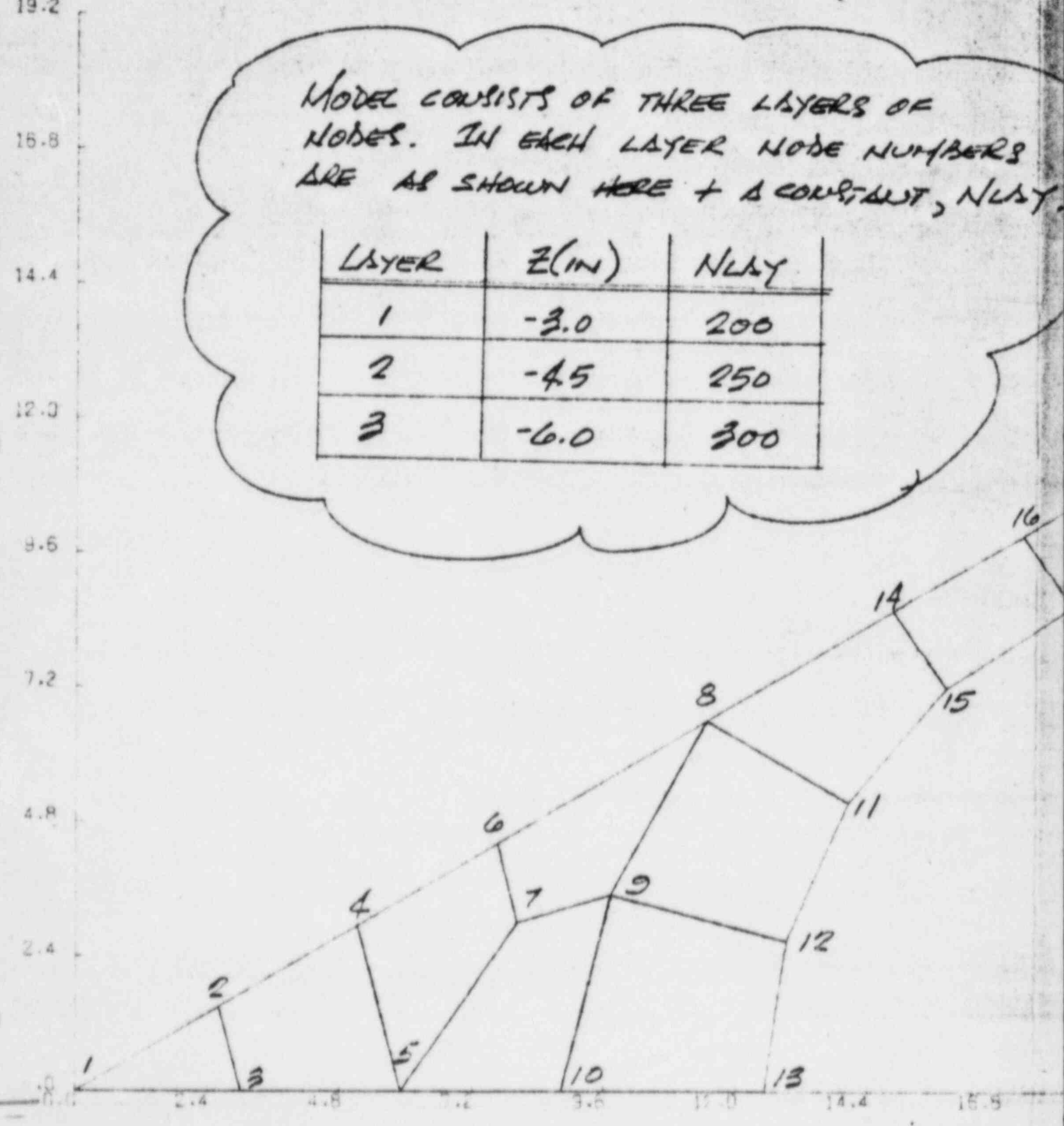
...GING INC.

8505290682-02

~ FIGURE

FINITE ELEMEN

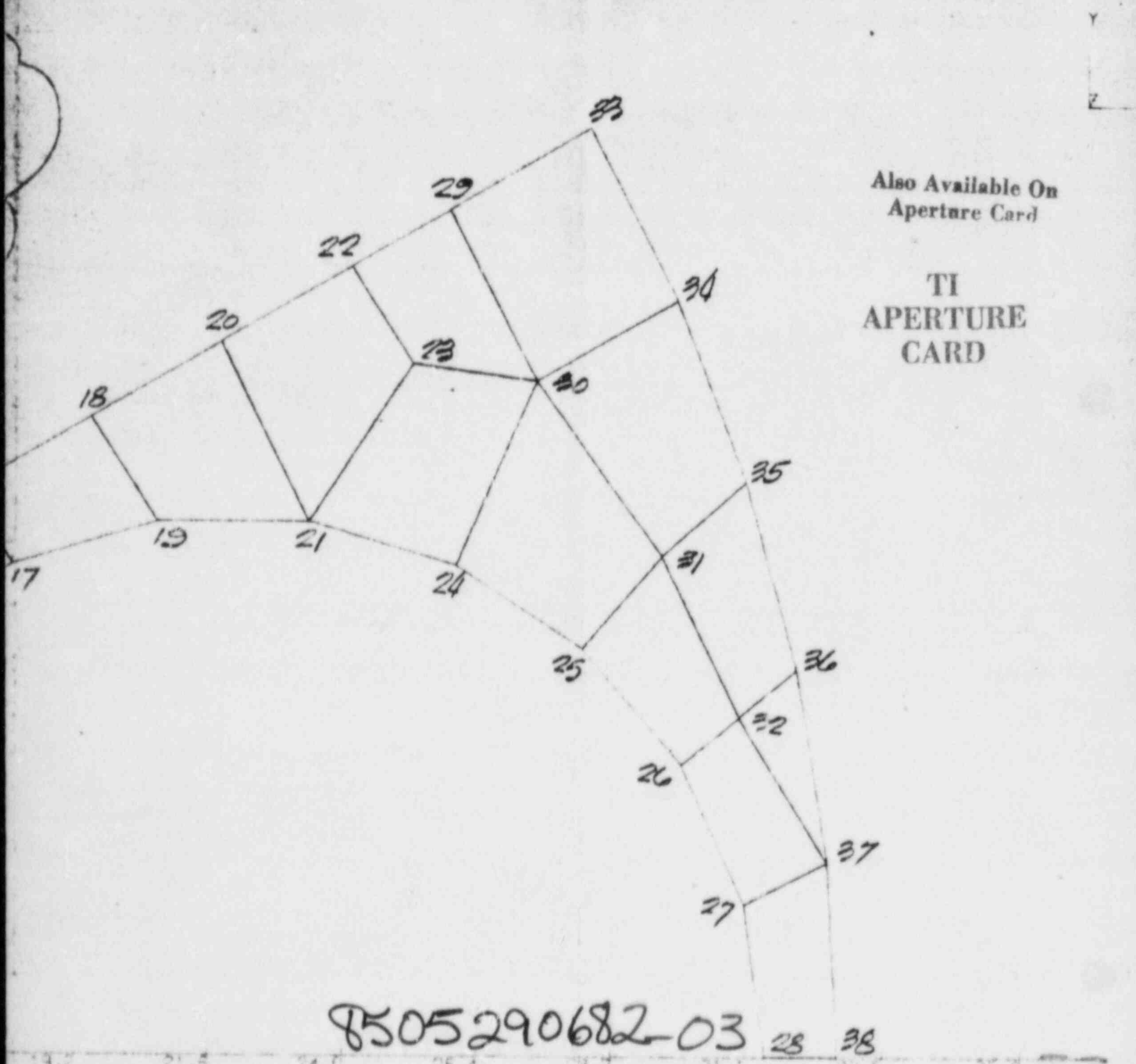
OF INNER PLATE ~



...7 ~

...T MODEL

...FLASK LID



Also Available On Aperture Card

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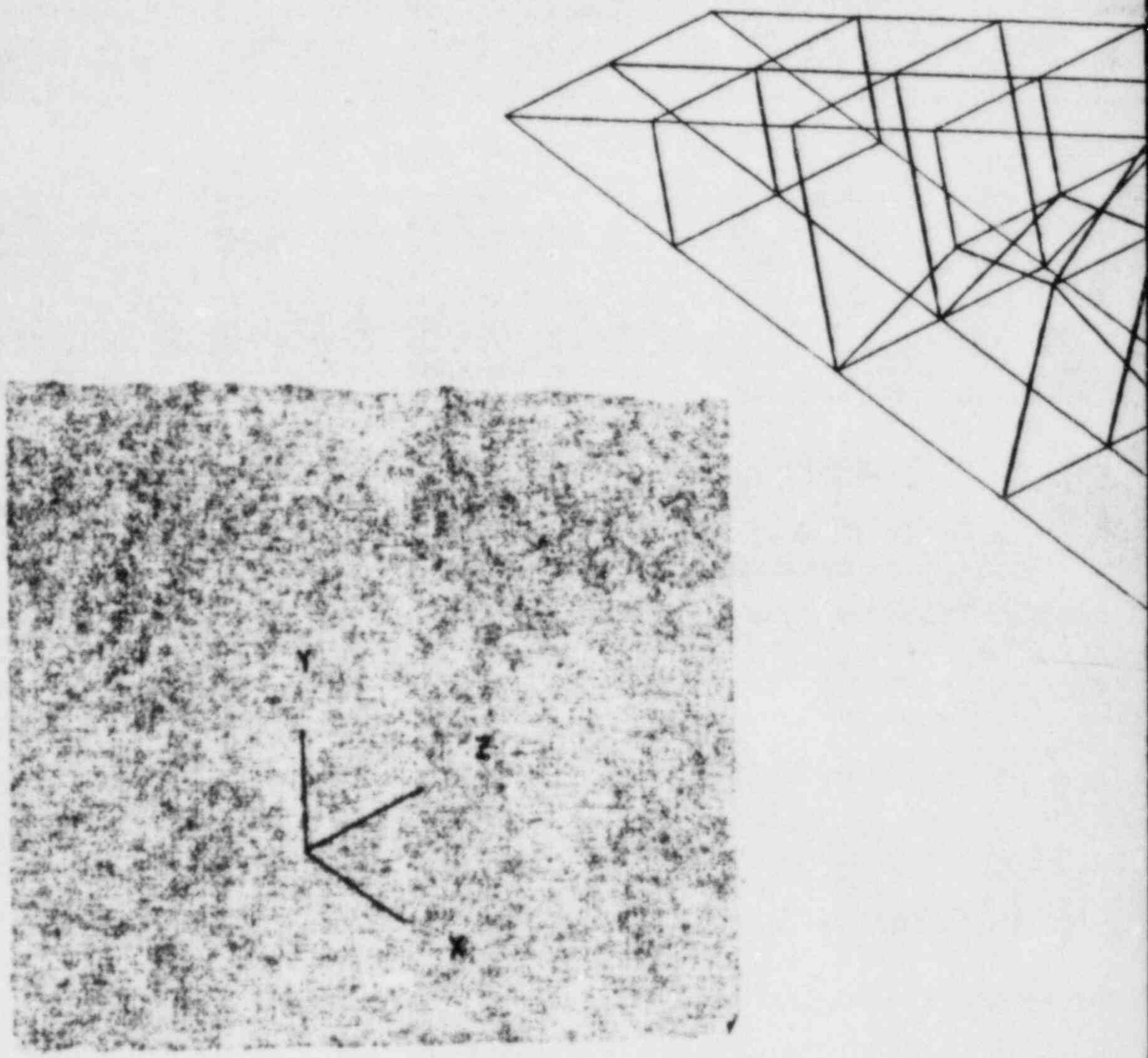
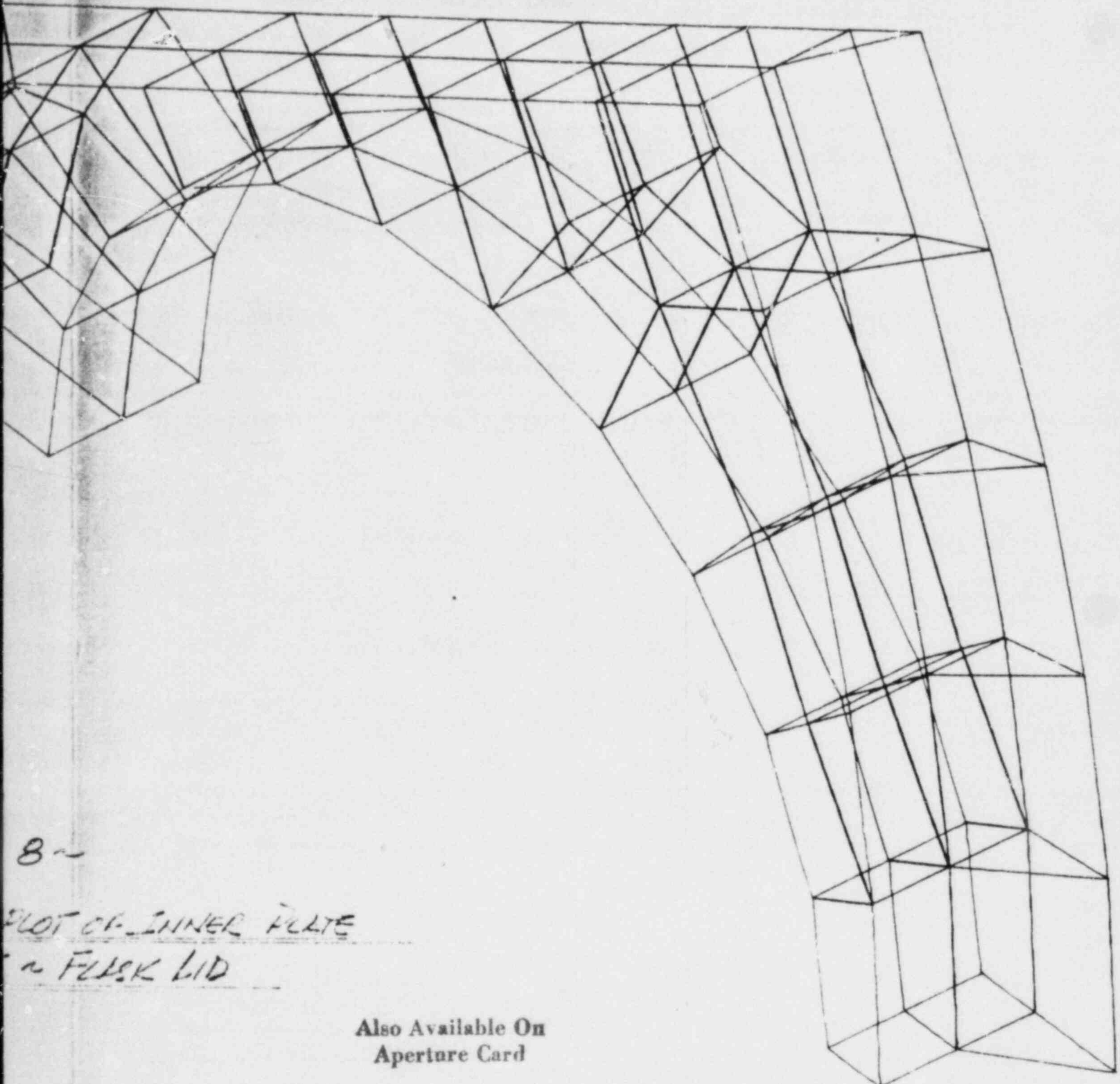
8505290682-03



— FIGURE

THREE DIMENSIONAL
UN-NUMBERED NODES

GEOMETRY ANSYS 2 PUNCTURE ANALYSIS OF BULK RESIN SHIPPING FLASK LID - NU



8 -

PLOT OF INNER PLATE

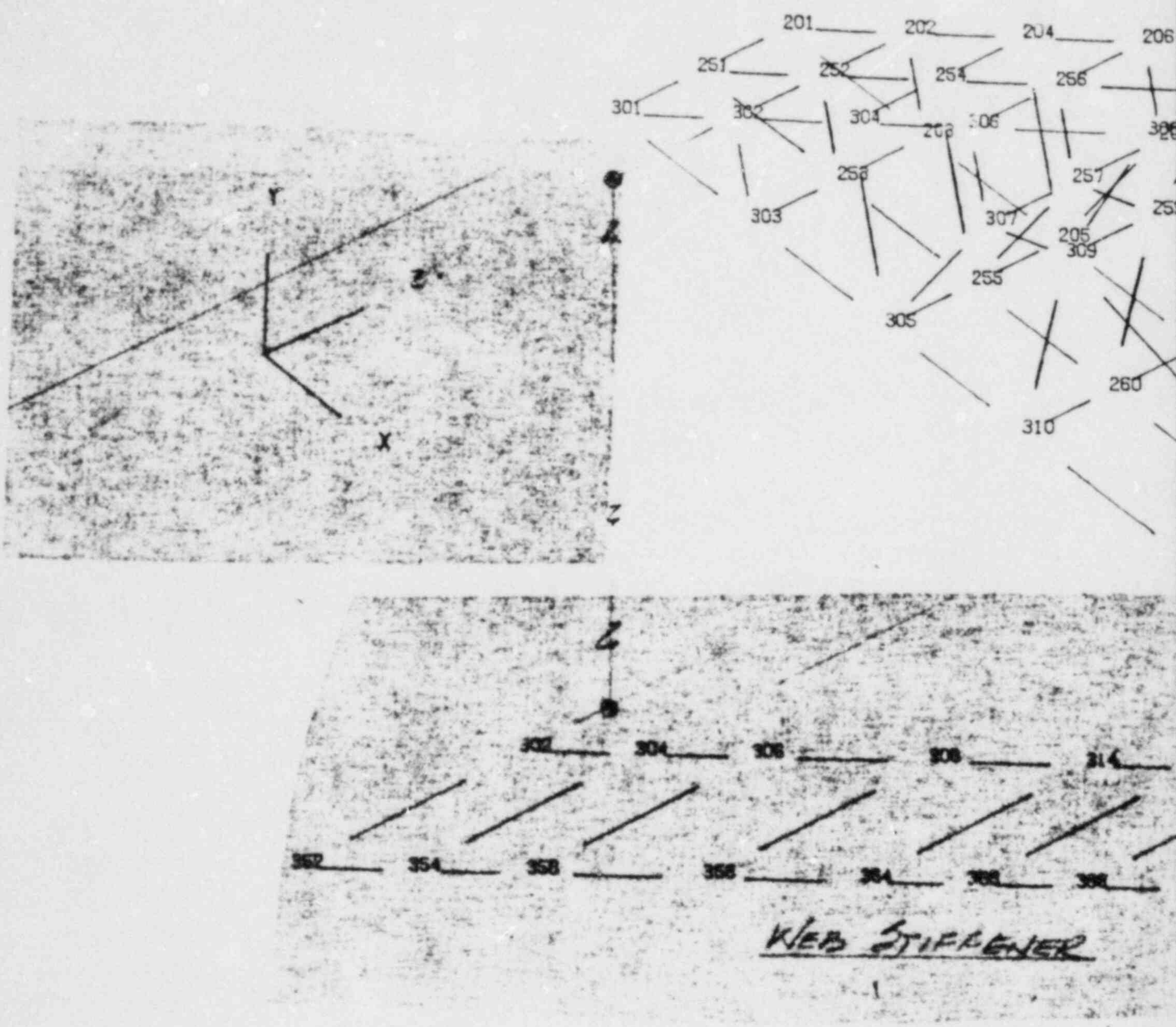
~ FLASK LID

Also Available On
Aperture Card

TI
APERTURE
CARD

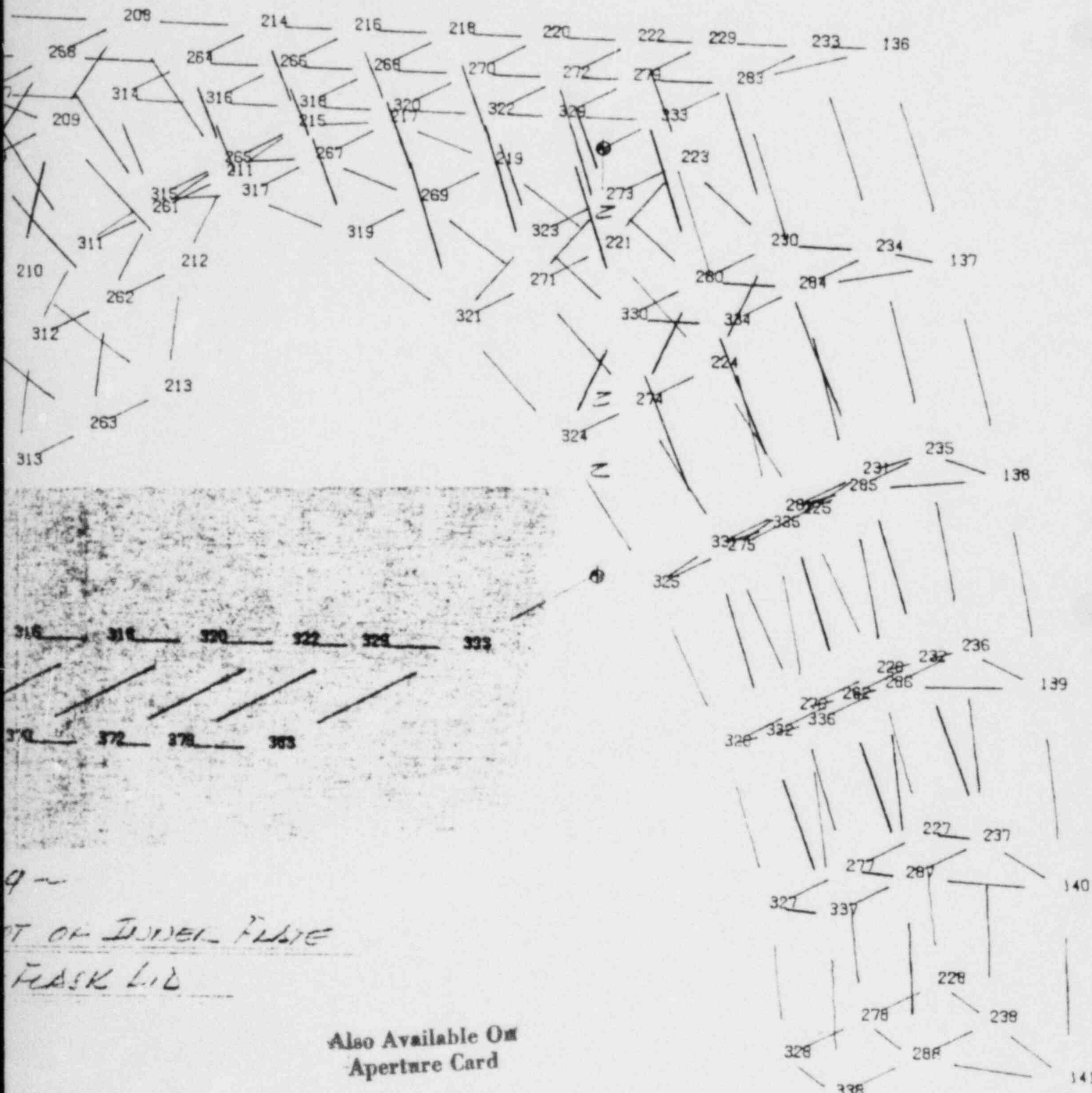
8605290682—04

CLEAR PACKAGING INC.



– FIGURE
THREE DIMENSIONAL PL
NUMBERED NODES –

GEOMETRY ANSYS 3 PUNCTURE ANALYSIS OF BULK RESIN SHIPPING FLASK LID - NUCLE



9 -

OF INNER PLATE

FLASK LID

Also Available On Aperture Card

TI APERTURE CARD

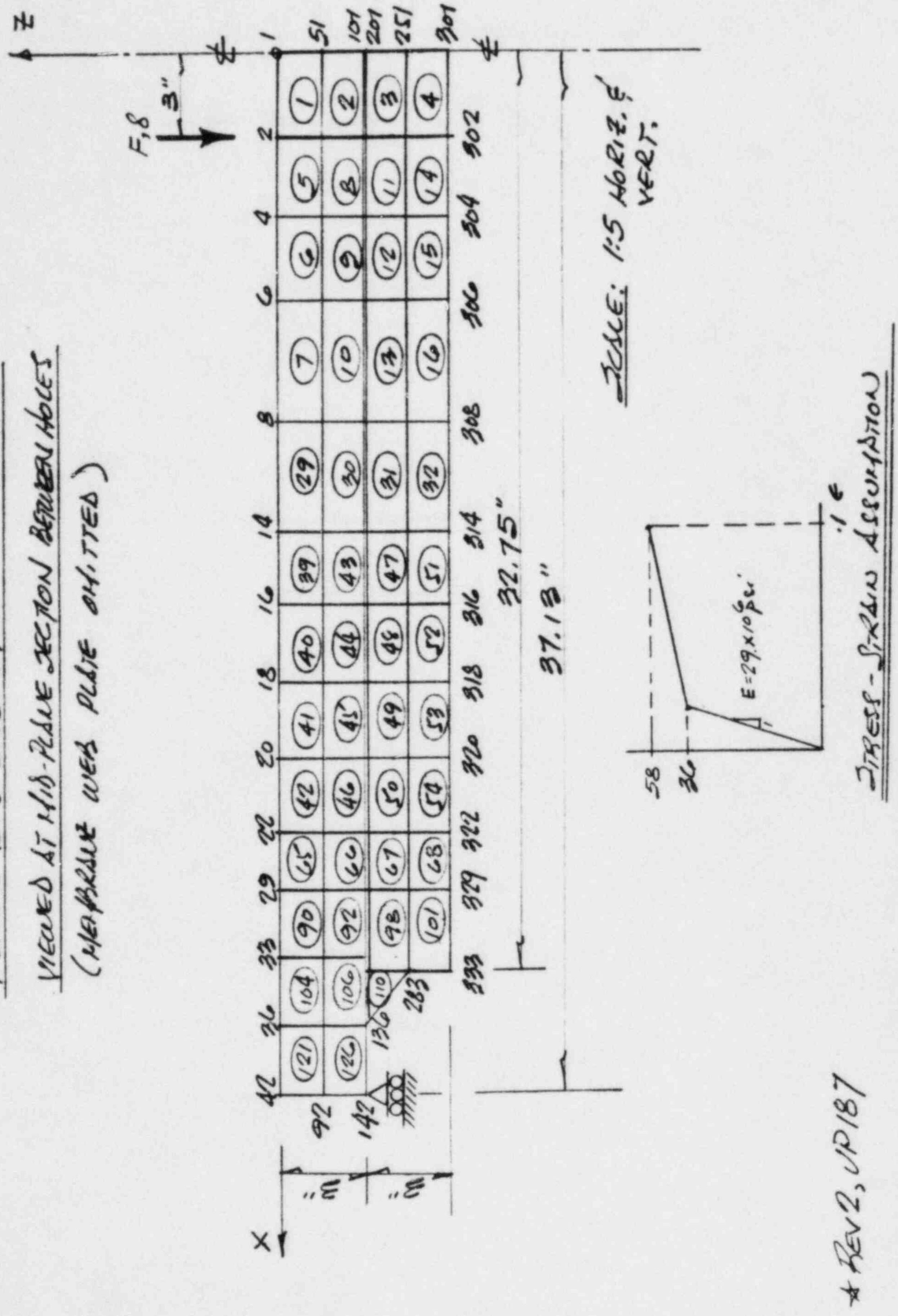
8505290682-05

AR PACKAGING INC.

~ FIGURE 10 ~

ANSYS* FINITE ELEMENT MODEL OF FLASK LID END CYLINDER PLATES

VIEWED AT MID-PLANE SECTION BETWEEN HOLES (MEMBRANE WEB PLATE OMITTED)



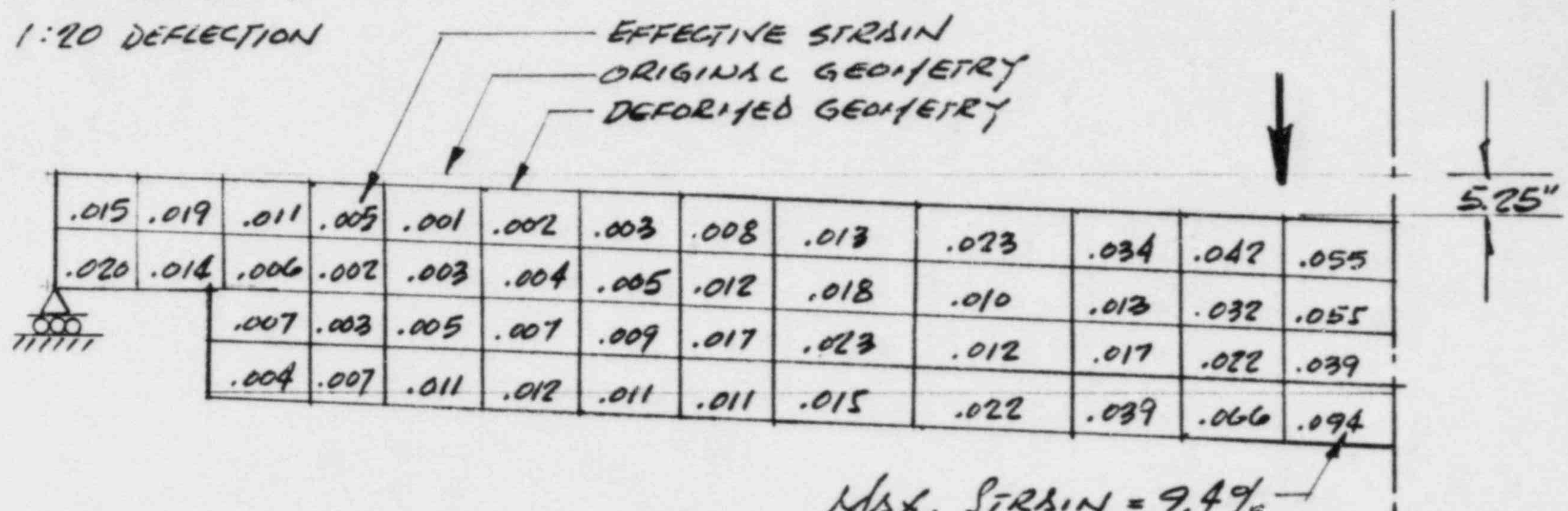
* REV 2, UP187

~ FIGURE 11 ~

ANSYS RESULTS AT A ℄ PIN DEFLECTION OF 5.25" (1)

(ACTUAL MAX. DEFLECTION = 5.05")(2)

SCALES: 1:5 GEOMETRY
1:20 DEFLECTION

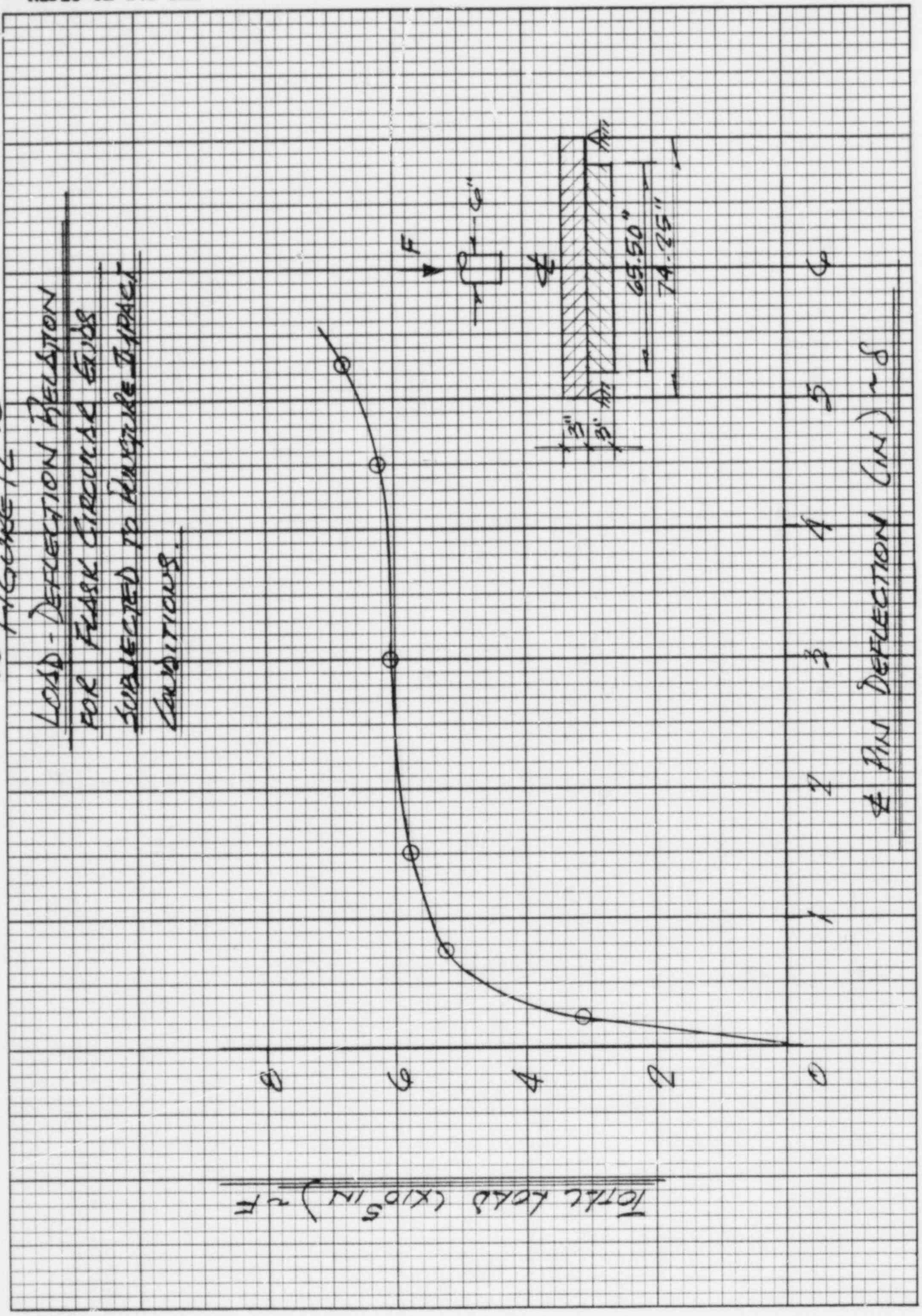


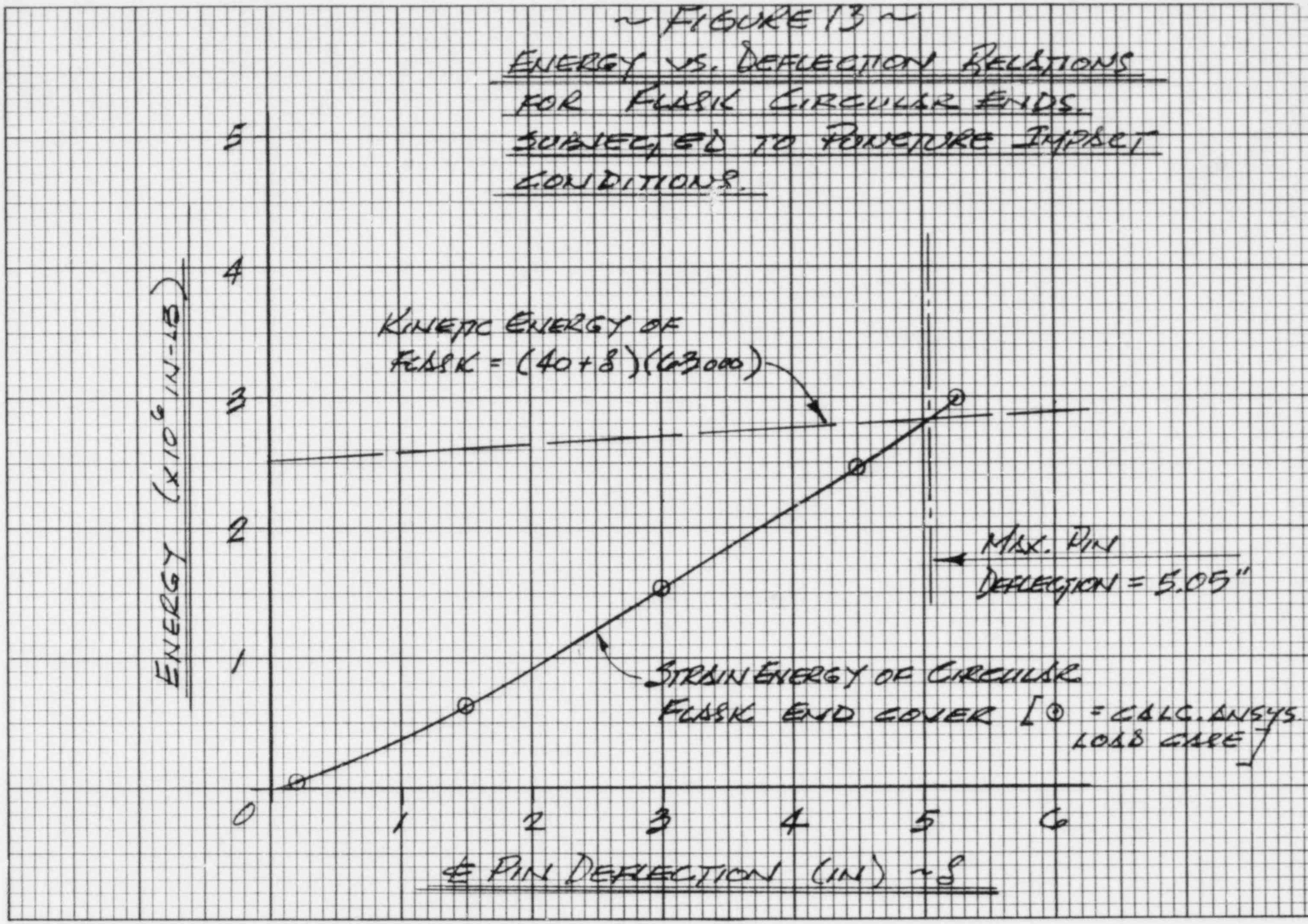
NOTES:

(1) ANSYS LOAD STEP 7 $\delta_{MAX} = 5.25"$
(2) $\delta = 5.05"$ ACHIEVES ENERGY BALANCE BETWEEN KINETIC AND STRAIN ENERGY.

RUPTURE MARGIN EVALUATION:

$$M.S._{RUPT} = \frac{10\%}{9.4\%} - 1 = +0.06$$


~ FIGURE 12 ~
LOAD - DEFLECTION RELATION
FOR FLASK CIRCULAR ENDS
SUBJECTED TO HYPOTHETICAL IMPACT
CONDITIONS.
F
6"
℄
65.50"
74.25"
3"
3"
0
1
2
3
4
5
6
℄ PIN DEFLECTION (IN) ~ δ
0
2
4
6
8
TOTAL LOAD (x10⁵ IN) ~ F


~ FIGURE 13 ~
ENERGY VS. DEFLECTION RELATIONS
FOR FLASK CIRCULAR ENDS
SUBJECTED TO PUNCTURE IMPACT
CONDITIONS.
KINETIC ENERGY OF
FLASK = (40+8)(63000)
MAX. PIN
DEFLECTION = 5.05"
STRAIN ENERGY OF CIRCULAR
FLASK END COVER [⊙ = CALC. ANSYS
LOAD CASE]
ENERGY (x10⁶ IN-LB)
0
1
2
3
4
5
6
℄ PIN DEFLECTION (IN) ~δ

1.7.3 Thermal

The following thermal evaluation of the package demonstrates it's ability to meet the normal transport and hypothetical accident conditions.

1.7.3.1 Summary of Pressures and Temperatures

Under steady state conditions, assuming a 24 hour day at maximum solar heat load, the maximum package temperature was found to be 168°F. The cask was reanalyzed with a thermal shield and the latest conditions required by 10 CFR 71. The maximum temperature under this analysis was 207°F with sun and 118.5° without solar loads.

When subjected to the hypothetical accident conditions, lead temperatures remained well below critical melting point. The primary and secondary seal temperature rose to 243°F and 458°F respectively. These are well below the 500°F allowable operating temperature for the silicone rubber seals. It has been shown that internal pressures are easily reacted by the containment vessel. Temperatures predicted for the thermal shield-equiped package were lower than these noted above for the Albi-Clad design. From the above, it can be safely concluded that thermal conditions will have little effect on the containment vessel integrity.

1.7.3.2 Thermal Analysis

This analysis treats both normal transport and hypothetical accident conditions. Specifically, conditions evaluated include:

Normal Transport

Exposed - Maximum Solar Flux

100°F Ambient Air (Design Criteria)

130°F Ambient Air

Hypothetical Accident Condition

Fire Exposure

30 Minute Fire @ 1475°F

Surface Emissivity = 0.8

Initial Conditions - 130°F Ambient Air

Cooling - Radiation Free Convection --70°F Ambient Air

The model employed for this analysis follows these introductory remarks. Briefly, the model consists of 68 node lumped parameter idealization. A single node was used to represent the source. For conservatism, the OH-142 shield has been assumed empty; that is, the fraction of heat absorbed by the payload during the hypothetical fire exposure has been neglected. The figure on the following page defines the model and graphically shows the placement of nodes. A detailed explanation is provided in the body of the analysis.

The overpack and cask outer shell is linked to the external environment (ambient air or fire source) by a pair of resistors, one represents radiation effects and one represents convection effects (free). During the 30 minute fire, the convection resistor is switched off. Solar flux is applied by a direct heat input to the outer shell.

Heat transfer through the foam insulation is represented by conduction resistors. To account for the possibility of foam char, the resistors are defined versus temperature such that

the foam is replaced by an equivalent air gap at 400°F. Gases generated from decomposition of the foam (temperature 600°F) are vented through six 1½ inch diameter holes in the external skin. These vents are closed with a standard ABS plastic pipe plug that melts well before off gasing starts.

The cylindrical sheet of the shield is thermally protected from fire by a 3/16 inch nominal thickness of Albi-Clad 89 Intumescent paint which exhibits a 4.1 expansion upon exposure to fire (@ 300°F). A comprehensive discussion of the experimental demonstration of this coating's thermal performance is summarized in Union Carbide Report No. K-1661, "Fissil Material Container and Packaging Development and Testing Program", April 1, 1966. The experimental thermal response of the container discussed in this reference compares closely with that predicted by the OH-142 shield thermal analysis.

Solution of the transient (fire) case is achieved by a conventional thermal analyzer program, THAN, based on the well known Lockheed Thermal Analyzer.

As an option, the OH-142 may be equiped with a 10 gauge stainless steel thermal shield in place of the Albi-Clad 89 Intumescent paint. Because the shield is installed slightly away from the surface of the biological shield, heat from the hypothetical fire event must employ the relatively inefficient heat transfer modes of radiation and air conduction to reach the biological shield. This produces similar insulating effects as the Albi-Clad coating.

The cask equiped with the thermal shield has been analyzed using the same thermal model as the Albi-Clad design except for those features specifically modeling the coating's response to the fire event. The latest revision of 10 CRF 71 (August 1983) was used to determine the loads to be applied to the thermal shield equiped cask. These loads are given below:

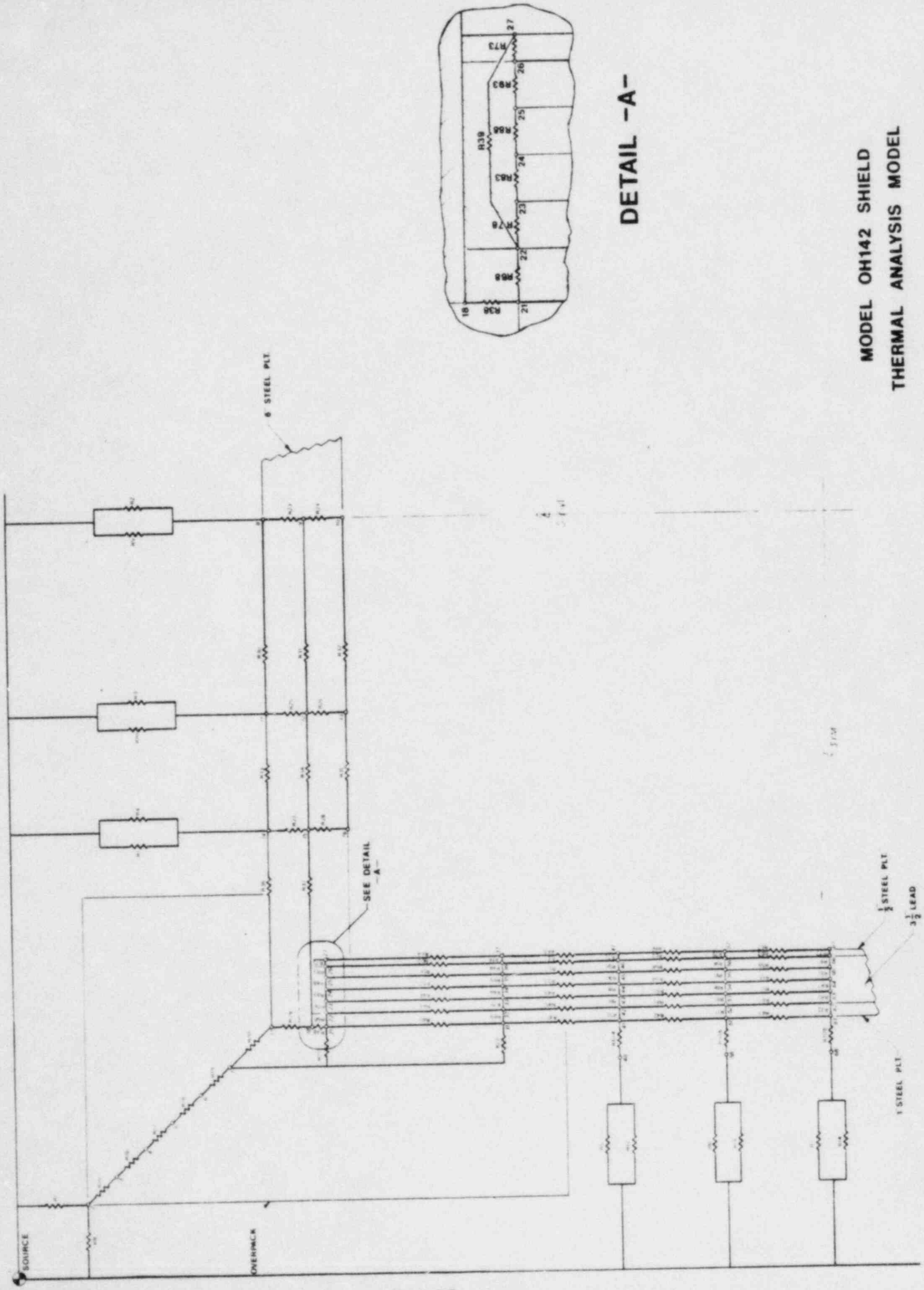
Normal Transport

400 watts internal decay heat
2950 BTU/12 hour day/ft^2 on upper horizontal flat surfaces
100°F ambient air temperature

Hypothetical Accident Condition

400 watts internal decay heat
No solar loads
100°F initial ambient air temperature
30 minute fire at 1475°F
100°F ambient air temperature after fire
Convection effective before, during, and after fire
Surface emissivity is .8

The analysis for a cask with the thermal shield is presented below, after the analysis for a cask protected with Albi-Clad.



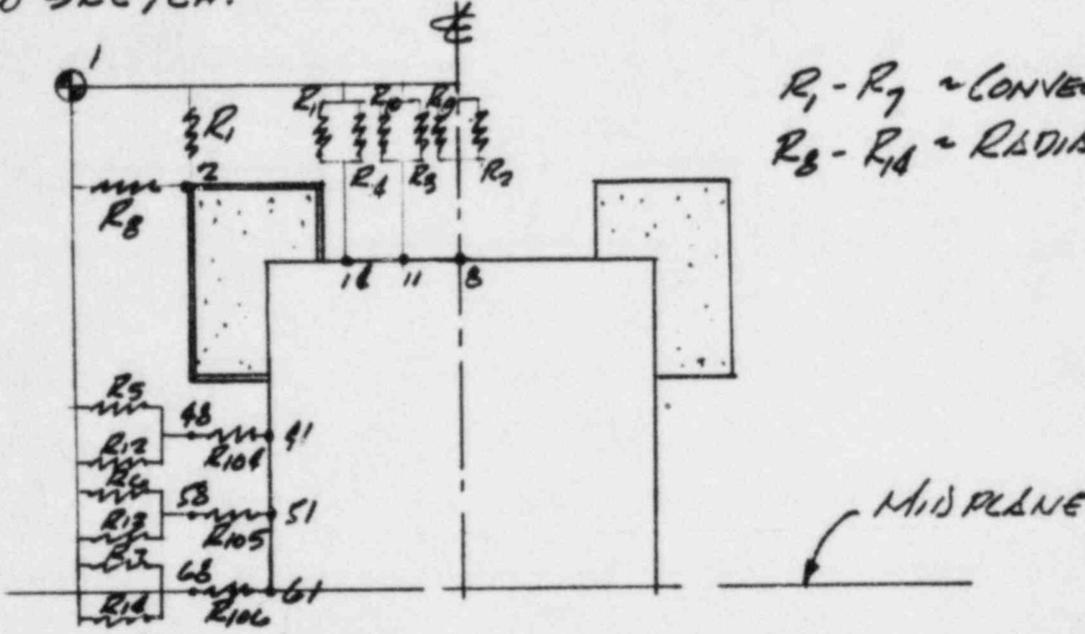
MODEL OH142 SHIELD
THERMAL ANALYSIS MODEL

1.7.3.2.1 THERMAL ANALYSIS MODEL

- REV 3/77 -

.1 EXTERNAL HEAT TRANSFER

EXTERNAL HEAT TRANSFER BETWEEN FLASK & THE PRESCRIBED EXTERNAL ENVIRONMENT INVOLVES BOTH RADIANT & CONVECTIVE MODES. THE EXTERNAL ENVIRONMENTAL NODE AND FLASK EXTERNAL NODES ARE ILLUSTRATED IN THE BELOW SKETCH.



$R_1 - R_7$ ~ CONVECTION
$R_8 - R_{14}$ ~ RADIATION

RELATED NODAL AREAS

NODE NR	AREA CALCULATION (IN²)		NODE AREA (FT²)
2	$\pi(50.5^2-27.5^2+50.5^2-38^2)+2\pi(50.5)(36)$ $+2\pi(27.5)(14)$	=	159.398
8	$\pi(10^2)$	=	2.182
11	$\pi(19^2-10^2)$	=	5.694
14	$\pi(27.5^2-19^2)$	=	8.623
41	$2\pi(38)(8)$	=	13.265
51	$2\pi(38)(8)$	=	13.265
61	$2\pi(38)(4)$	=	6.632

CONVECTIVE HEAT TRANSFER

THE BASIC CONVECTIVE MECHANISM IS:

$$q = h_i A_i (T_i - T_j)$$; i = NODAL SUBSCRIPT
h_i = FILM COEFFICIENT FOR i^{th} NODE
A_i = AREA OF i^{th} NODE
T_j = TEMPERATURE OF j^{th} NODE

THE "TRAN" THERMAL ANALYZER CODE ONLY ALLOWS SPECIFICATION OF A SINGLE FILM COEFFICIENT, $\bar{h}$. AS A CONSEQUENCE, NODAL EQUIVALENT AREAS WILL BE DERIVED AS FOLLOWS:

$$A_i^* = \frac{h_i A_i}{\bar{h}}$$; A_i^* = EQUIVALENT AREA FOR i^{th} NODE

McADAMS RECOMMENDS THE FOLLOWING FILM COEFFICIENT EXPRESSIONS: [L = LENGTH, IN FEET]

$$h = 0.29 \left(\frac{\Delta T}{L}\right)^{1/4}$$; VERTICAL CYLINDERS

$$= 0.27 \left(\frac{\Delta T}{L}\right)^{1/4}$$; HORIZONTAL PLATES - HEATED PLATE FACING UP

$$= 0.12 \left(\frac{\Delta T}{L}\right)^{1/4}$$; HORIZONTAL PLATES - HEATED PLATE FACING DOWN

$$= C \, (\Delta T/L)^{1/4}$$; GENERAL

FOR NODE 2:

LOCATION	AREA (FT²)	L (IN)	C	$A \cdot C \cdot (\frac{L}{12})^{-1/4}$
LWR. SURFACE $\pi(50.5^2 - 38^2)/144$	24.135	(50.5−38)	.12	2.867
EXT. VERT. SURF. $2\pi(50.5)(36)/144$	79.325	36	.29	17.479
TOP $\pi(50.5^2 - 27.5^2)/144$	39.139	(50.5−27.5)	.27	8.981
INT. VERT SURF. $2\pi(27.5)(14)/144$	16.799	14	.29	4.687
	Σ 159.398			Σ 34.015

$$h_2 = \frac{\Sigma A_i \cdot C_i (L_i/12)^{-1/4}}{\Sigma A_i} = .213397$$ ✓

- REV 3/77 -

FOR NODE 8, 11, 14:

$$h_{8,11,14} = \frac{A_8 \cdot C_8 \cdot (L_8/12)^{-1/4}}{A_8} = (.27)(27.5/12)^{-1/4} = .219445$$

FOR NODES 41, 51, 61:

$$h_{41,51,61} = C_{41} \cdot (L_{41}/12)^{-1/4} = (.29)(40/12)^{-1/4} = .214624$$

MEAN FILM COEFFICIENT & NODAL EFFECTIVE AREAS.

NODE NR. (i)	A_i	h_i	$A_i \cdot h_i$	A_i^*
2	159.398	.213397	34.015	158.900
8	2.182	.219445	0.479	2.238
11	5.694	✓	1.250	5.838
14	8.623	✓	1.892	8.838
48	13.265	.214624	2.847	13.300
58	13.265	✓	2.847	13.300
68	6.632	✓	1.423	6.647
Σ	209.060	1.516	44.753	

$$\bar{h} = \frac{\Sigma A_i h_i}{A_i} = .214066$$

- REV 3/77 -

RADIATION HEAT TRANSFER

FOR EXTERNAL RADIATION, THE APPLICABLE EXPRESSION IS:

$$K_{ij} = \sigma A_i \epsilon_i \quad ; \quad \sigma = .1714 \times 10^{-8} \; ; \; \epsilon = .8$$

$$K_{ij}/A_i = \sigma \epsilon_i = 1.371 \times 10^{-9}$$

RESIST. NR.	NODES i	j	A_i	K_{ij}
8	1	2	159.398	218.6×10^{-9}
9	|	8	2.182	2.992 ✓
10	|	11	5.694	7.808 ✓
11	|	14	8.623	11.82 ✓
12	|	48	13.265	18.19×10^{-9}
13	|	58	13.265	18.19 ✓
14	1	68	6.632	9.094 ✓

SIDE WALL CONDUCTIVE COATING (ALBI-CLAD 89)

RESISTORS 104, 105, 106 REPRESENT AN ALBI-CLAD COATING OF 3/16" THICKNESS WHICH EXPANDS AT A TEMPERATURE OF 300°F TO 4 TIMES THE PRE-FIRE THICKNESS. THIS INTUMESCENT MATERIAL EXHIBITS THERMAL CONDUCTIVITY OF:

BEFORE FIRE EXPOSURE : K = 2.9 Btu-in/hr-ft² °F
AFTER " " : K = 0.57

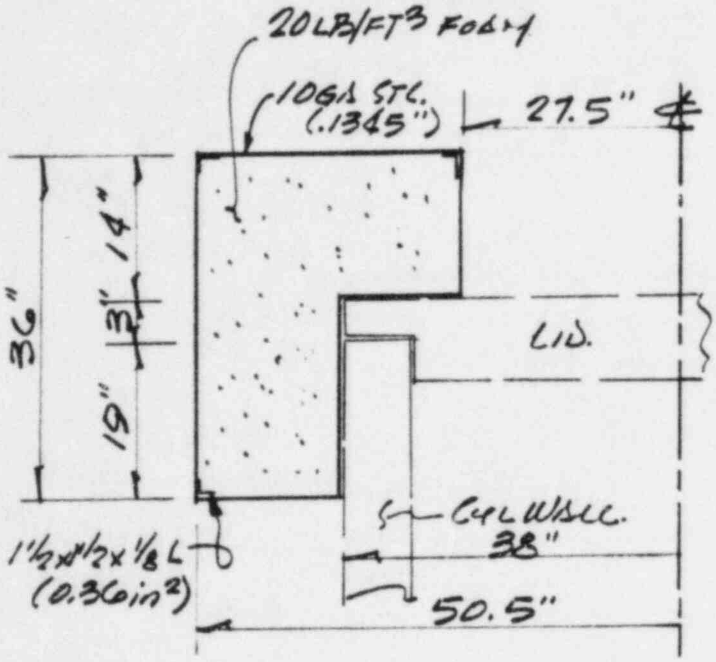
THE CONDUCTIVE RESISTOR IS THUS:

$$R_i = \left(\frac{t}{K}\right) \cdot \frac{1}{A_i} \quad ; \quad \frac{t}{K} = \frac{3/16}{2.9} = 6.46552 \times 10^{-2} \quad (T < 300°F)$$

$$= \frac{(3/16)(4)}{0.57} = 1.31579 \quad (T \geq 300°F)$$

RESIST NR.	NODES	(T < 300°F)	(T ≥ 300°F)	AREA
104	48 - 41	4.874×10^{-3}	99.19×10^{-3}	13.265
105	58 - 51	4.874×10^{-3}	99.19×10^{-3}	13.265
106	68 - 61	9.749×10^{-3}	198.4×10^{-3}	6.632

.2 CYLINDRICAL CORNER PROTECTING FOAM "DONUTS"



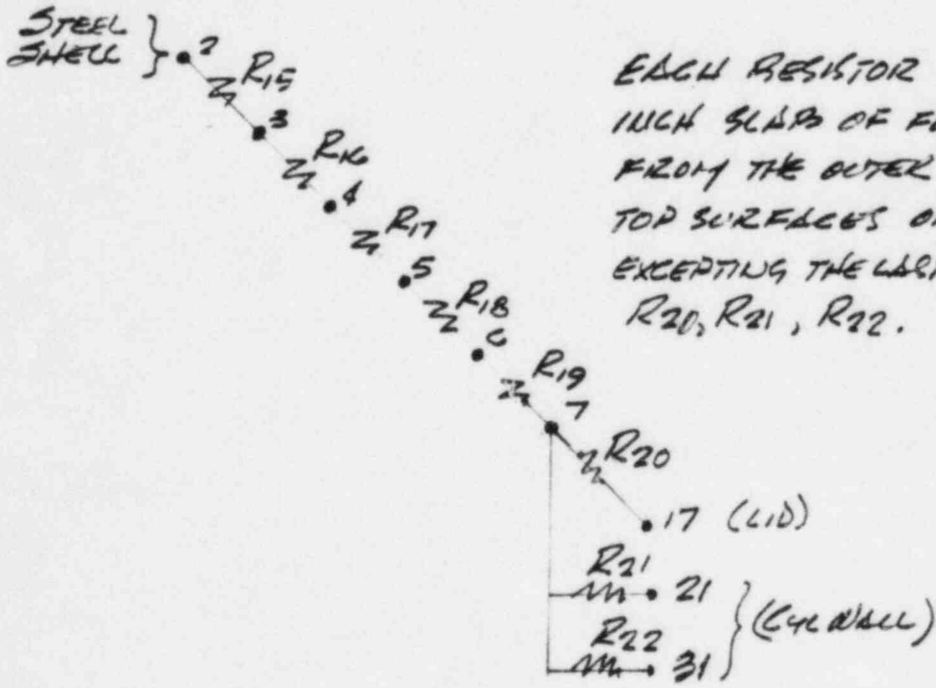
CARB. STEEL PROPS.

$k = 25$ Btu/hr-ft-°F
$C_p = .125$
$\rho = 487$ lb/ft³

FOAM PROPS.

$k = .2$ Btu-in/hr-ft²-°F
$C_p = .3$ Btu/lb
$\rho = 20$ lb/ft³

ANALYTIC MODEL.



EACH RESISTOR REPRESENTS A TWO INCH SLAB OF FOAM AS MEASURED FROM THE OUTER DIAMETER AND TOP SURFACES OF THE "DONUT"; EXCEPTING THE LAST (INNER MOST), IE R_{20}, R_{21}, R_{22}.

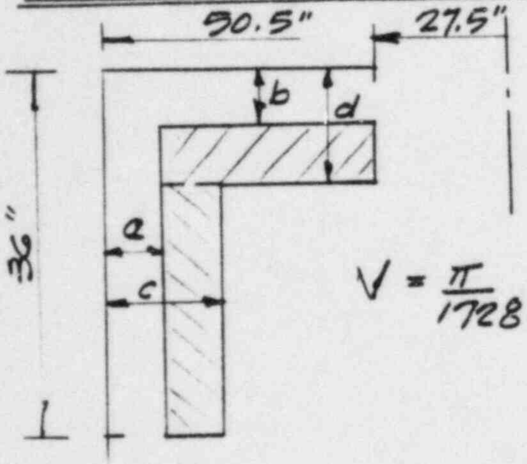
.3 CORNER PROTECTOR NODAL CAPACITANCES

NODE 2 - STEEL SHELL

$$V = 2\pi[(27.5)+(2)(50.5)](0.36) + (.1345)\{\pi(50.5^2-27.5^2)+\pi(50.5^2-38^2)+2\pi[(50.5)(36) + (27.5)(14)]\} = 3377.87 \text{ in}^3$$

$$C_2 = C_p \rho V = (.125)(487)\frac{(3377.87)}{(1728)} = \underline{119.00} \text{ Btu/°F}$$

NODES 3, 4, 5, 6, 7 ~ FOAM.



$$C_i = C_p \rho V_i = (.3)(20) V_i = 6 V_i$$

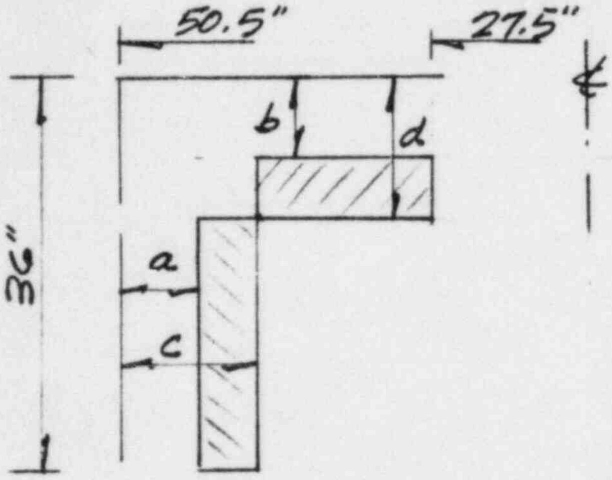
$$V = \frac{\pi}{1728}\left\{[(50.5-a)^2-27.5^2](d-b) + [(50.5-a)^2-(50.5-c)^2](36-d)\right\}$$

NODE NR	a (IN)	b (IN)	c (IN)	d (IN)	C_i (Btu/°F)
3	0	0	3	3	164.54
4	3	3	5	5	95.62
5	5	5	7	7	84.98
6	7	7	9	9	74.85
7	9	9	12.5	14	119.46
				Σ	539.45

CORNER PROTECTOR RESISTANCES

RESISTORS R_{15} TO R_{19} REPRESENT A SERIES HEAT PATH THROUGH THE EXTERNAL 10" OF THE FOAM PROTECTOR. RESISTORS R_{20} TO R_{22} REPRESENT PARALLEL HEAT PATHS BETWEEN THE METALLIC SHIPPING FLASK WALLS AND THIS 10" POINT (NODE 7) WITHIN THE FOAM PROTECTOR. TAKEN COLLECTIVELY, RESISTORS R_{20} TO R_{22}, ARE IN SERIES WITH RESISTORS R_{15} TO R_{19}.

THE CALCULATION SCHEME FOLLOWS THAT USED FOR CAPACITANCE.



$$R_i = \frac{1}{\frac{1}{R_{ac}} + \frac{1}{R_{bd}}}$$

$$R_{ac} = \frac{\ln(r_o/r_i)}{2\pi k L} = \frac{\ln\left[\frac{50.5-a}{50.5-c}\right]}{2\pi\left(\frac{.2}{12}\right)\left(\frac{36-d}{12}\right)}$$

$$= \frac{144}{2\pi(.2)} \cdot \frac{\ln[(50.5-a)/(50.5-c)]}{(36-d)}$$

$$R_{bd} = \frac{t}{kA} = \frac{(d-b)}{\frac{(.2)}{144}\cdot\pi\left[(50.5-c)^2 - 27.5^2\right]}$$

$$= \frac{144}{\pi(.2)} \cdot \frac{(d-b)}{[(50.5-c)^2 - 27.5^2]}$$

RESISTOR NR	a	b	c	d	RESISTANCE VALUE (°F-hr/Btu)
15	0	0	2	2	92.38×10^{-3}
16	2	2	4	4	103.1 ✓
17	4	4	6	6	115.9 ✓
18	6	6	8	8	131.5 ✓
19	8	8	10	10	150.7 ✓
* ‖Σ(20,21,22)	10	10	12.5	14	265.7 ✓

* ‖Σ = PARALLEL SUM ~ SEE NEXT SHEET FOR APPORTIONMENT

CORNER PROTECTOR RESISTANCES (CONT'D)

APPORTIONMENT OF RESISTANCES R_{20}-R_{22}

THE PARALLEL SUM OF THESE RESISTANCES IS:

$$R_{211} = 265.7 \times 10^{-3} \text{ °F-hr/Btu}$$

ASSUMING AN AREA BASED APPORTIONMENT RULE (CONTACT AREA WITH FLASK):

$$\frac{R_{PART}}{R_{TOTAL}} = \frac{1/A_{PART}}{1/A_{TOTAL}} ; \therefore R_i = R_T \cdot \frac{A_T}{A_i}$$

RESIST. NR. (i)	AREA CALCULATION	A_P (IN²)	R_i	NODES.
20	$\pi(38^2-27.5^2)+2\pi(38)(3)$ =	2876.91	684.7×10^{-3}	7-17
21	$2\pi(38)(9.5)$ =	2268.23	868.4×10^{-3}	7-21
22	Ditto	2268.23	868.4×10^{-3}	7-31

$$A_T = 7413.37$$

CHECK: $$R_{11\Sigma} = \frac{1}{\frac{1}{R_{20}}+\frac{1}{R_{21}}+\frac{1}{R_{22}}} = 265.7\times10^{-3} ✓$$

FOAM CHAR EFFECTS

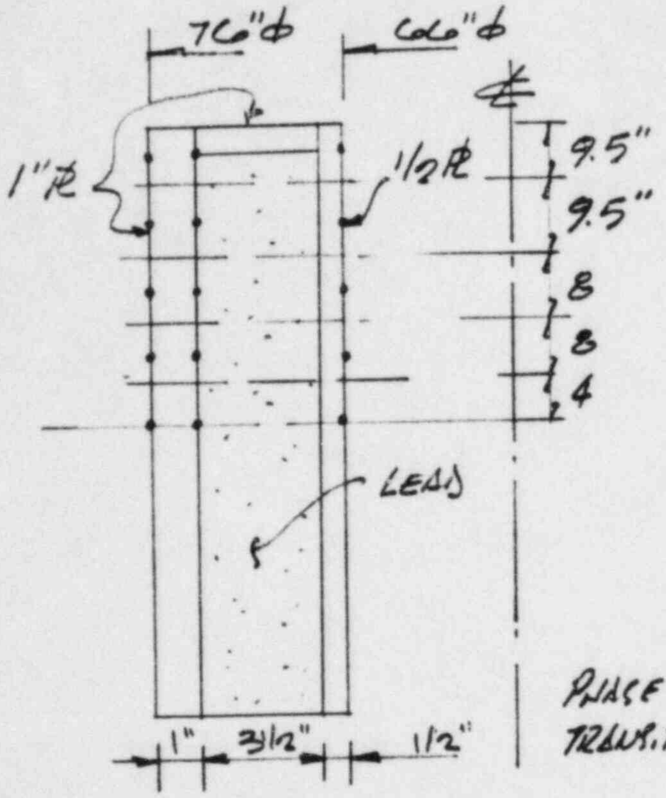
FOAM IS ASSUMED TO CHAR @ 400°F AND IS REPLACED BY AN AIR GAP. DEFINE:

$$R_F = \frac{R_{AIR}}{R_{FOAM}} = \frac{(k_{FOAM} = .2/12)}{k_{AIR}}$$

TEMP °F	TEMP °R	k_{AIR}	R_F
70	530.		1.
401.	860.	.0212	.7862
600	1060.	.0250	.6667
800	1260.	.0286	.5828
1000	1460.	.0319	.5225
1500	1960.	.0400	.4167
2000.	2460.	.0471	.3539

THIS TEMPERATURE VARIANCE IS ASSUMED FOR FOAM RESISTORS R_{15} TO R_{22}.

.4 CYLINDRICAL WALL THERMAL MODEL



CARB. STEEL (p166, SHAPPERT)

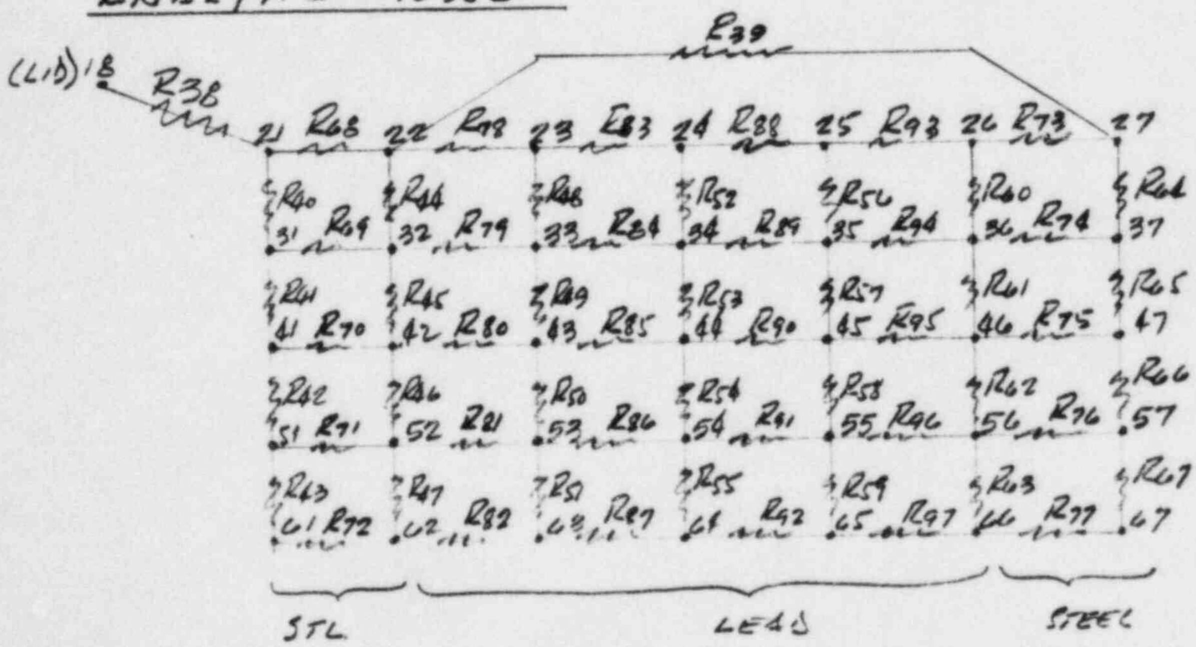
$k = 25$ BTU/HR-FT-°F
$C_p = .125$
$\rho = 487$ LB/FT3

LEAD

	SOLID	LIQUID
$k =$	18.6	9.3
$C_p =$	.0325	.038
$\rho =$	687	657

PHASE TRANSITION { $H_f =$ 10.95 BTU/LB; $T_{MP} =$ 621°F

ANALYTIC MODEL



$$R_{39} = \frac{\ln(r_o/r_i)}{2\pi K L} = \frac{\ln(37/33.5)}{2\pi(25)(1/12)} = 7.591\times10^{-3}$$

.5 CYLINDRICAL WALL RESISTORS

VERTICAL (LONGITUDINAL) RESISTORS:

$$R_{ij} = t_{ij}/kA_{ij}$$

LONGITUDINAL (RADIAL) RESISTORS:

$$R_{ij} = \ln(r_o/r_i)/2\pi k L_{ij}$$

VERTICAL RESISTORS

MAT'L	NR (i)	RADII (IN) r_o	r_i	AREA (IN^2)	t (IN^2)	R_i (°F-HR/BTU) SOLID	LIQUID
STEEL	40,41	38.-	37.5	118.60	9.5	38.45×10^{-3}	
"	42,43	38.	37.5		8	32.38 ✓	
"	44,45	37.5	37.	117.-	9.5	38.97. ✓	
"	46,47	37.5	37.-		8	32.81 ✓	
LEAD	48,49	37.	36.125	201. ✓	9.5	30.49 ✓	60.98×10^{-3}
	50, 51	37.	36.125		8	25.68 ✓	51.35 ✓
	52,53	36.125	35.25	196.2	9.5	31.24 ✓	62.48 ✓
	54,55	36.125	35.25		8.	26.31 ✓	52.61 ✓
	56,57	35.25	34.375	191.4	9.5	32.02 ✓	64.05 ✓
	58,59	35.25	34.375		8	26.97 ✓	53.93 ✓
	60,61	34.375	33.5	186.6	9.5	32.85 ✓	65.70 ✓
	62,63	34.375	33.5		8.	27.66 ✓	55.32
STEEL	64,65	33.5	33.	104.5	9.5	43.65 ✓	
"	66,67	33.5	33.		8.	36.76 ✓	

CYLINDRICAL RADIAL RESISTORS

MATL	i	RADII (IN) r_o	r_i	L (IN)	R_i SOLID	LIQUID
STL.	68, 69	38.	37.	9.5	214.5×10^{-6}	
	70, 71			8.-	254.7 ✓	
	72			4.	509.3 ✓	
"	73, 74	33.5	33.	9.5	120.9 ✓	
	75, 76			8.	143.6 ✓	
	77			4.	287.2 ✓	
LEAD	78, 79	37.	36.125	9.5	258.7 ✓	517.4×10^{-6}
	80, 81			8.	307.2 ✓	614.4 ✓
	82			4.	614.4 ✓	1.229×10^{-3}
"	83, 84	36.125	35.25	9.5	265.- ✓	$530.\times10^{-6}$
	85, 86			8.	314.7 ✓	629.4 ✓
	87			4.	629.4 ✓	1.259×10^{-3}
"	88, 89	35.25	34.375	9.5	271.7 ✓	543.4×10^{-6}
	90, 91			8.	322.6 ✓	645.2 ✓
	92			4.	645.2 ✓	1.290×10^{-3}
"	93, 94	34.375	33.5	9.5	278.7 ✓	557.4×10^{-6}
	95, 96			8.	330.9×10^{-6}	661.9 ✓
	97			4.	661.9 ✓	1.324×10^{-3}

NOTE: FOR LEAD $\frac{R_{i\,LIQ}}{R_{i\,SOL}} = 2.$

CYLINDRICAL WALL ~ NODAL CAPACITANCES & PHASE CHANGE

NODE	MAT'L.	AREA (IN)	THICK. (IN)	C_i (BTU/°F) SOLID	C_i (BTU/°F) LIQUID	(BTU) TOTAL HEAT AT PHASE CHANGE
21, 31	STEEL	118.6	9.5	39.69		
41, 51			8.	33.42		
61			4.	16.71		
22, 32	STEEL	117.	9.5	39.16		
42, 52			8.	32.97		
62			4.	16.49		
23, 33	LEAD	201.	9.5	24.67	27.59	8009.1
43, 53			8.	20.78	23.23	6744.5
63			4.	10.39	11.62	3372.3
24, 34	LEAD	196.2	9.5	24.08	26.93	7817.9
44, 54			8.	20.28	22.68	6583.5
64			4.	10.14	11.34	3291.7
25, 35	LEAD	191.4	9.5	23.49	26.27	7626.6
45, 55			8.	19.78	22.12	6422.4
65			4.	9.89	11.06	3211.2
26, 36	LEAD	186.6	9.5	22.91	25.61	7435.3
46, 56			8.	19.29	21.57	6261.3
66			4.	9.64	10.78	3130.7
27, 37	STEEL	104.5	9.5	34.97		
47, 57			8.	29.45		
67			4.	14.73		

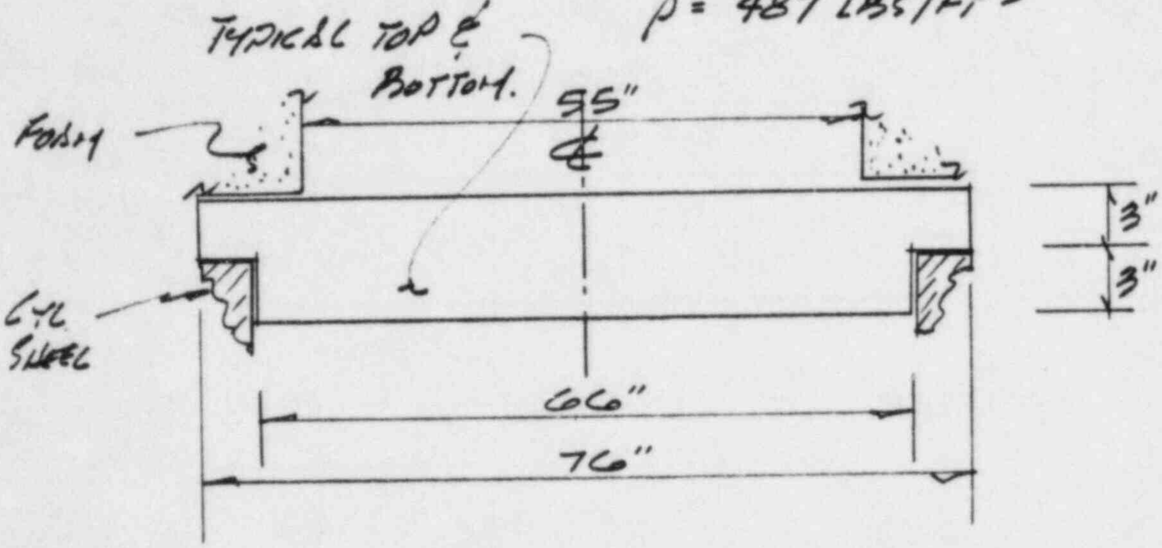
NOTE FOR LEAD $\frac{C_{i\,LIQ}}{C_{i\,SOL}} = \frac{(657)(.038)}{(687)(.0325)} = 1.1182$

6 LID THERMAL MODEL

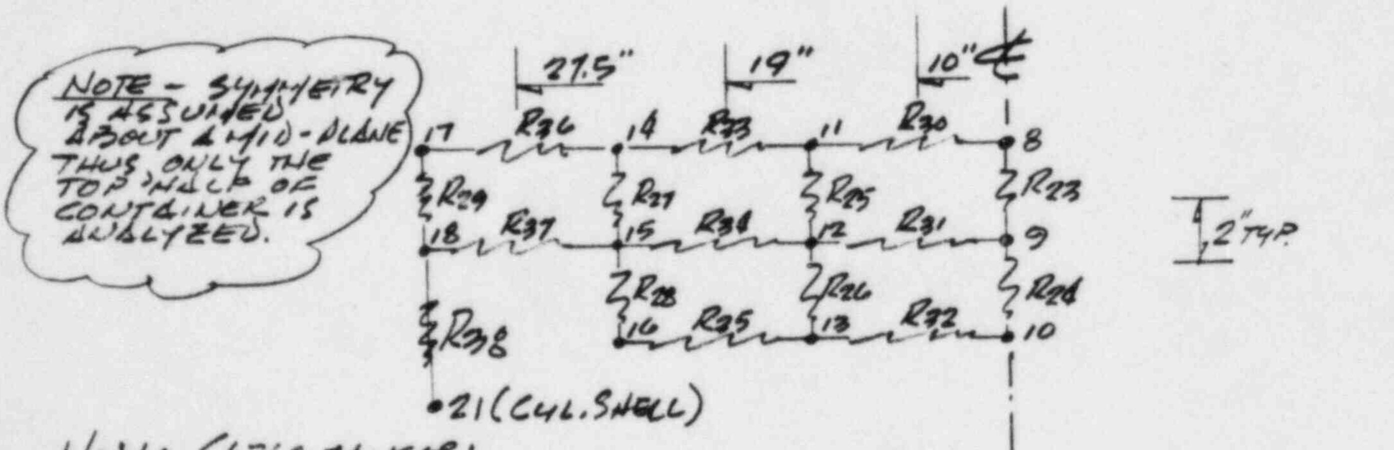
MAT'L: CARB. STEEL $k = 25$ BTU/HR-FT-°F

$C_p = 0.125$

$\rho = 487$ LBS/FT^3



ANALYTIC EQUIVALENT:



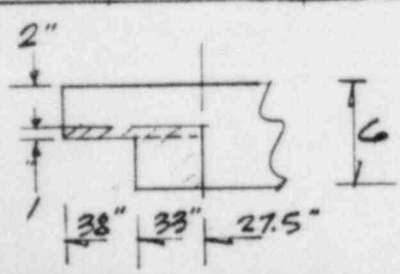
NODAL CAPACITANCES:

NODE	AREA (IN²)	VOLUME (FT3)	C_i (BTU/°F)
8, 9, 10	314.2	.36	22.13
11, 12, 13	820.–	.95	57.77
14, 15, 16	1241.7	1.44	87.49
17	2160.6	2.50	152.23
18	*	3.07	186.60

$A = \frac{\pi}{4}(D_o^2 - D_I^2) = \pi(R_o^2 - R_I^2)$

$V = A(2)/1728$

$C_i = \rho V C_p$



* NODE 18 SPECIAL GEOMETRY:

$V = \pi[(33^2 - 27.5^2)(3) + (38^2 - 27.5^2)(1)]/1728$

$= 3.07$ FT^3

LID MODEL (CONT'D)

CONDUCTIVE RESISTORS

TWO ANALYTIC EXPRESSIONS ARE PERTINENT —

- FOR VERTICAL RESISTORS:

$$R_{ij} = t_{ij}/kA_{ij} \quad ; t = FT, A = FT^2$$

- FOR HORIZONTAL RESISTORS:

$$R_{ij} = \frac{\ln(r_j/r_i)}{2\pi k L} \quad \begin{matrix} r_j = \text{outer radius} \\ r_i = \text{inner radius} \end{matrix}$$

VERTICAL RESISTORS:

NR. (i)	A (IN²)	t (IN)	R_i (°F-HR/BTU)
23,24	314.2	3	4.583×10^{-3} ✓
25,26	820.	↓	1.756 ✓
27,28	1241.7		1.160 ✓
29	2160.6		666.5×10^{-6}

HORIZONTAL RESISTORS:

NR.	r_j (IN) (OUTER)	r_i (IN) (INNER)	L (IN)	R_i
30,31,32	14.5	.5	2	128.6×10^{-3} ✓
33,34,35	23.25 ✓	14.5 ✓	|	18.04×10^{-3}
36,37	32.75 ✓	23.25	↓	13.09×10^{-3} ✓

RESISTOR 38 COUPLES THE LID NODE 18 TO EXTERNAL CYL SHELL NODE 21:

$$R_{38} = t/kA \quad ; \quad t = (19/4)/12 \; ; \; A = \frac{\pi}{4}(76^2 - 74^2)/144$$

$$= \frac{\left(\frac{19}{4}\cdot\frac{1}{12}\right)}{(25)\cdot\frac{\pi}{4}(76^2-74^2)\cdot\frac{1}{144}} = \frac{(19)(12)}{(4)(25)\cdot\frac{\pi}{4}(76^2-74^2)}$$

$$= 9.677\times10^{-3}$$

Changes to Thermal Model
to Account for Presence of Thermal Shield

For this analysis, resistors 104, 105 & 106 are changed to model air conduction and resistors 107, 108 & 109 are added to model in the effects of radiant heat transfer. Nodes 48, 58 & 68 are changed to model the capacitance of the 10 gauge Stainless Steel Thermal Shield.

A payload internal decay heat of 400 watts was assumed to be evenly distributed on the inside surface of the cask.

The thermal conductivity, k, of air varies with temperature as shown in the table below:

TEMPERATURE °F	k (BTU/hr. ft.°F)
0	.0133
32	.0140
100	.0154
200	.0174
300	.0193
400	.0212
500	.0231
600	.0250
700	.0268
800	.0286
1500	.0400
2500	.0471

For resistors 104-106, the conduction resistance afforded by the air in the air gap between the shield and the cask wall may be calculated as below:

$$R = \frac{L}{kA}$$ where L = Length in the direction of heat flow

A = Cross sectional area of flow path

RESISTOR	L (in)	A (ft^2) (p.1-113)	L/12A=kR (ft^{-1})	NODES
104	.25	13.265	.0016	48-41
105	.25	13.265	.0016	58-51
106	.25	6.632	.0031	68-61

<u>THAN</u> internally multiplies the L/A value with the appropriate value for k.

Radiation heat transfer is given by the following formula:

$$q = k\ (T_2^4 - T_1^4)$$

$$\text{where}\quad k = \frac{A_1 \sigma}{\left(\frac{1}{\varepsilon_1} - 1\right) + \frac{1}{F} + \frac{A_2}{A_1}\left(\frac{1}{\varepsilon_2} - 1\right)}$$

For simplicity, for this analysis the radiant areas A_1 and A_2 are taken as equal, and the form or shape factor, F, is assumed to equal unity. Under these assumptions, "k" may be rewritten as:

$$k = \frac{\sigma A}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right)}$$

where A = Represented area

σ = Stefan-Boltzman Constant, $.1714 \times 10^{-8}$

ε_1 = Emissivity of Surface 1

ε_2 = Emissivity of Surface 2

The outer surface of the carbon steel outer shell of the OH-142 can be conservatively taken to exhibit an emissivity of .9, while the inner surface of the thermal shield, being stainless steel, can be taken as .5.

Therefore, the following values of k may be calculated:

RESISTOR	A	k	NODES
107	13.265	1.077×10^{18}	48-41
108	13.265	1.077×10^{-8}	58-51
109	6.632	5.385×10^{-9}	68-61

The specific heat (ce) of stainless steel is .11 BTU/HR-lb-°F, Thus the heat capacity of nodes 48, 58 and 68 may be calculated: (density of stainless is taken as 488 lb/FT^3) $C = pVC_e$.

NODE	AREA (FT^2)	THICKNESS (IN)	C
48	13.265	.135	8.01 BTU/°F
58	13.265	.135	8.01 BTU/°F
68	6.632	.135	4.00 BTU/°F

1.7.3.3 Pressure Evaluation

If the package was assumed to contain water, it would experience an increase in internal pressure as a result of the hypothetical fire condition. From the above thermal analysis, it can be seen that the inside surface temperature of the package ranged from 187°F node 27 up to 457°F at node 10. Node 27 represents approximately 20% of the cask inside surface area and, as such, provides the condensation surface.

Assume that the package was initially loaded at 70°F. Therefore, from the steam tables:

$$P_1 = 14.7 \text{ psi (1 atm)} - .36 \text{ psi}$$

$$P_1 = 14.34 \text{ psi}$$

$$P_2 = 14.34 \text{ psi } (187^\circ+460^\circ)/(70^\circ+460^\circ)$$

$$P_2 = 17.50$$

From the tables @ 187°F:

$$P_3 = 8.79 \text{ psi}$$

$$P_4 = P_3 + P_2$$

$$P_4 = 26.29 \text{ psia}$$

or a differential internal pressure of:

$$P_L = 26.29 - 14.7$$

$$P_L = 11.59 \text{ psig}$$

This will produce a load on the lid of:

$$F = (\pi d^2/4)P_1$$

$$= (\pi (66)^2/4) \; 11.59 \text{ psig}$$

$$= 39651 \text{ lbs.}$$

OR

$$= 4956 \text{ lbs/binder}$$

Conservatively assuming that the binders follow the temperature profile of the uninsulated overpack external skin, their temperature at maximum internal pressure would be less than 450°F. From MIL-HDBK-5, Fig. 2.3.1.2.1(b), it can be seen that the binder would possess approximately 85% of its room temperature properties. Even if we were to evaluate it at 1000°F, it would still possess 39% of it's capability or:

$$P_t = (110{,}000 \text{ lbs})(.39)$$

$$P_t = 42{,}900 \text{ lbs.}$$

Margin of Safety:

$$\text{M.S.} = 42900/4956 - 1$$

$$\text{M.S.} = + \text{Large} \qquad \text{(Lid attachment)}$$

From Section 1.5.2 it was shown that a pressure of 25 psi generated a stress of only 5282 psi for one of the two 3 inch plates. Maximum temperature in this plate was 460°F. Again, from MIL-HDBK-V, properties would be reduced to 85% of room temperature, or:

$$\text{M.S.} = (.85)(36000 \text{ psi})/5282 \text{ psi} - 1$$

$$\text{M.S.} = + 4.79 \qquad \text{(Lid stress)}$$

From the above it can be concluded that the package can safely react the pressures generated from temperature effects.

.8 DETERMINATION OF STEADY STATE TEMPERATURES

STEADY STATE TEMPERATURE ESTIMATES ARE USED AS THE INITIAL VALUE ($t=0$) FOR THE HYPOTHETICAL FIRE ACCIDENT. FOR THIS STEADY STATE SYSTEM, HEAT IS INPUT TO THE FLASK BY SOLAR ILLUMINATION; HEAT IS REMOVED BY A COMBINATION OF RADIATION AND CONVECTION HEAT TRANSFER MODES. SOLAR ILLUMINATION DATA IS TAKEN FROM SCHAPPERT'S CASK DESIGNERS GUIDE, ORNL-NSIC-68, FEBRUARY 1970.

TWO COMPARATIVE APPROACHES ARE USED TO CALCULATE APPLICABLE INCIDENT SOLAR ILLUMINATION:

- PEAK EFFECTIVE ILLUMINATION ~ ACTUAL SOLAR CONSTANT VS TIME (ANGLE) IS ASSUMED TO ACT ON THE EXPOSED CROSS SECTION OF THE FLASK - ASSUMED AS A CYLINDER.
- MEAN ILLUMINATION ~ THE 24 HR SOLAR CONSTANT (10,600 BTU/FT²-DAY) IS USED AND ASSUMED TO ACT UPON THE MAXIMUM X-SECTION OF THE FLASK.

THE TOTAL HEAT IMPOSED UPON THE SYSTEM IS:

$$Q = A_s q_s \alpha$$

; A_s = CROSS SECTION EXPOSED TO SUN

q_s = SOLAR CONSTANT, (BTU/hr·ft²)

α = .8, ABSORPTIVITY OF SURFACE

THE HEAT IMPOSED ON A UNIT AREA IS:

$$q = \frac{Q}{A_T} = \frac{A_s}{A_T} q_s \alpha$$

; A_T = TOTAL SURFACE AREA

THE TOTAL (HALF) AREA OF THE FLASK SURFACE IS 180.042 FT² (SEE "EXT. HEAT TRANSFER")

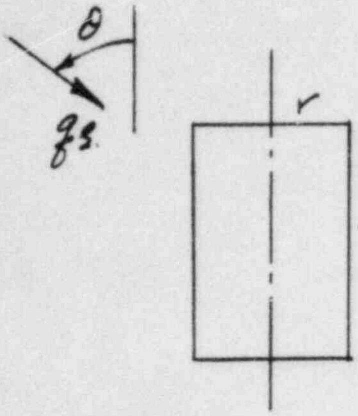
THE MAXIMUM X-SECTION OF THE FLASK IS:

VERT: $\frac{1}{144}\left[(38)(2)(20) + (50.5)(2)(21) + (2)(50.5-27.5)(14)\right] = 29.76 \text{ FT}^2$

HORIZ: $\frac{1}{144}\left[(50.5)^2 \pi\right] = 55.64 \text{ FT}^2$

PEAK ILLUMINATION APPROACH

[REF FIG 5.3 (LATITUDE 42°N), SHANPERT]



FOR A RIGHT CIRCULAR CYLINDER:

23.4 27.60

$$A_N = \pi r^2 \cos\theta + 2 r \ell \sin\theta$$ 53.06

$$Q = A_N q_s \alpha$$

$$q = \frac{Q}{A_T} = \frac{A_N}{A_T} \cdot q_s \cdot \alpha$$

WHERE: $r = 38/12$, FT. (R_1)

$\ell = (112 - 28)/12$, FT (R_2)

$\alpha = .8$

$A_T = 2\pi r^2 + 2\pi r \ell = 202.26 FT$ (R_3)

THE OBJECTIVE IS TO DETERMINE A MAXIMUM VALUE FOR THE UNIT SOLAR FLUX, q:

θ	q_s	q
90	0.	0.
84	100.	18.74
78	150.	29.61
72	180	36.95
66	210	44.28
60	225	48.18
54	238	51.19
48	250	53.42
42	260	54.58
36	270	55.04
30	275	53.70

→ $q_{MAX} = 55.1$ BTU/FT^{-2}-HR

(TOTAL SURF. AREA.)

MEAN ILLUMINATION APPROACH

THE 24 HR. SOLAR CONSTANT = 10600 BTU/FT²-DAY

$$q_s = \frac{10600}{24}(.35) = 154.58 \quad \text{BTU/FT}^2\text{-HR}$$

$$q = \frac{A_E}{A_T} q_s \alpha$$

$$= \frac{(55.64)}{(180.42)}(154.58)(.8) = 38.1 \quad \text{BTU/FT}^2\text{-HR.}$$

STEADY STATE TEMPERATURES (UNIT AREA)

LET: $f(T_s) = q_{in} - q_{out}$; FIND T_s SUCH THAT $f(T_s) \approx 0$

$$f(T_s) = q - k(T_s^4 - T_\infty^4) - \bar{h}(T_s - T_\infty)$$

$$F(T_s) = 1 - \frac{k}{q}(T_s^4 - T_\infty^4) - \frac{\bar{h}}{q}(T_s - T_\infty)$$

$$= \underbrace{\left(1 + \frac{k}{q}\cdot T_\infty^4 + \frac{\bar{h}}{q}\cdot T_\infty\right)}_{R_5} - \underbrace{\left(\frac{k}{q}\right)}_{R_6} T_s^4 - \underbrace{\left(\frac{\bar{h}}{q}\right)}_{R_7} T_s$$

WHERE: T_∞ = SINK TEMP (°R) = 100°F / 130°F
$k = 1.371 \times 10^{-9}$
$\bar{h} = .213979$
$q = 55.1 / 38.1$

FLASK STEADY STATE TEMPERATURES		SINK TEMP T_∞ = 100°F (559.69°R)	T_∞ = 130°F (589.69°R)
MEAN	q = 38.1 (BTU/FT²-HR)	130.3°F	156.9°F
PEAK	q = 55.1	142.7°F	168.0°F

The cask equiped with the thermal shield was analyzed per the latest revision of 10 CFR 71 using the same thermal model used in the transient analysis, except that solar loads are included. The solar loads for normal conditions to be applied to the top surface of the package are given in 10 CFR 71 to be

$$800\text{gcal/cm}^2\text{/12 hour day} = 2950\ \text{BTU/FT}^2\text{/12 hour day}$$
$$= 2950/12 = 245.8\ \text{BTU/hr/FT}^2$$

It is assumed that the package acheives a steady state condition with the sun perpetually directly overhead, note that the loads applied in this analysis are considerably higher (by a factor of 4.5) than those used in the previous analysis, and internal decay heat is included as well. Offsetting this extreme increase of severity is the required ambient temperature, which in the previous analysis was taken as 130°F. 10 CFR 71 now requires the analysis to assume the ambient temperature is 100°F.

Loads to be imposed on the model can be calculated by multiplying the unit solar load by the horizontal area represented by each node on the upper surface. Since only one half of the cask is modeled for this analysis, the effect of applying the solar loads this way is equivalent to applying the solar loads on both the upper and lower surfaces:

NODE	HORIZONTAL AREA (FT^2)	TOTAL LOAD (BTU/HR)
2	39.14	9620.6
8	2.18	536.3
11	5.69	1400.0
14	8.62	2119.5

The temperatures predicted by THAN for the loads and assumptions described above are presented in Table 1.7.3-1 below.

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	100.0000000	2	138.0797792	3	143.4375047	4	149.4169536
5	156.1387589	6	163.7653111	7	172.5053979	8	207.4315289
9	207.2402001	10	207.1871163	11	203.5959923	12	203.3610179
13	203.3030395	14	201.1097916	15	200.9985060	16	201.2854437
17	195.0757626	18	194.7904999	21	186.0593635	22	185.8991322
23	185.7520368	24	185.6452419	25	185.5786124	26	185.5524231
27	185.5587027	31	180.6898466	32	180.6943570	33	180.7030639
34	180.7165642	35	180.7352055	36	180.7592597	37	180.7717985
41	174.8742055	42	174.9974212	43	175.1269865	44	175.2360235
45	175.3250771	46	175.3943942	47	175.4153549	48	127.1937599
51	172.1150413	52	172.2354112	53	172.3638355	54	172.4733714
55	172.5635675	56	172.6339521	57	172.6551258	58	126.2172005
61	171.1362800	62	171.2630901	63	171.3978613	64	171.5122474
65	171.6059353	66	171.6785459	67	171.7001316	68	127.5764568

Table 1.7.3-1
Normal Conditions Steady-State Temperatures

A second steady-state analysis was performed on the model assuming no solar loads. This analysis predicts the initial temperatures used for the hypothetical accident thermal event as well as determining compliance with the package surface temperature limits for exclusive use shipments. The results of this analysis appears below as Table 1.7.3-2.

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	100.0000000	2	100.1174523	3	101.9975198	4	104.0957550
5	106.4544888	6	109.1307053	7	112.1976698	8	113.8490677
9	114.0090599	10	114.1318048	11	114.8842611	12	115.0542304
13	115.1815199	14	115.4727671	15	115.6393114	16	115.7593587
17	116.5304741	18	116.5885467	21	118.1334486	22	118.1674498
23	118.2017727	24	118.2347268	25	118.2664599	26	118.2970529
27	118.3095157	31	118.4398320	32	118.4450705	33	118.4554336
34	118.4709254	35	118.4913728	36	118.5166975	37	118.5294716
41	118.0835766	42	118.1133275	43	118.1480549	44	118.1823612
45	118.2164454	46	118.2504553	47	118.2648480	48	106.8862372
51	117.9275708	52	117.9574810	53	117.9927127	54	118.0276849
55	118.0624063	56	118.0968875	57	118.1113707	58	106.8289172
61	117.8600704	62	117.8917507	63	117.9287377	64	117.9650597
65	118.0007578	66	118.0358669	67	118.0504672	68	107.2718275

Table 1.7.3-1
Normal Conditions No Sun - Steady State

A transient analysis using initial temperatures from Table 1.7.3-2 was performed corresponding to the hypothetical fire event required by 10 CFR 71. Tables 1.7.3-3 through 1.7.3-6 give the termperature distributions for various times during the transient. Notably, the temperatures predicted by this analysis are lower than those predicted by the analysis used for the Albi-Clad package, in spite of the 400 watt internal decay heat load included in the thermal shield analysis and omitted from the analysis of the Albi-Clad package.

Figures 1.7.3-1 and 1.7.3-2 present plots of nodal termperature vs. time for the same points plotted on page 1-132 for the Albi-Clad design. Clearly, the thermal shield provides very good protection for the cask during the fire event.

TRANSIENT PROBLEM

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

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.0000000	2	168.0000000	3	168.0000000	4	168.0000000
5	168.0000000	6	168.0000000	7	168.0000000	8	168.0000000
9	168.0000000	10	168.0000000	11	168.0000000	12	168.0000000
13	168.0000000	14	168.0000000	15	168.0000000	16	168.0000000
17	168.0000000	18	168.0000000	21	168.0000000	22	168.0000000
23	168.0000000	24	168.0000000	25	168.0000000	26	168.0000000
27	168.0000000	31	168.0000000	32	168.0000000	33	168.0000000
34	168.0000000	35	168.0000000	36	168.0000000	37	168.0000000
41	168.0000000	42	168.0000000	43	168.0000000	44	168.0000000
45	168.0000000	46	168.0000000	47	168.0000000	48	168.0000000
51	168.0000000	52	168.0000000	53	168.0000000	54	168.0000000
55	168.0000000	56	168.0000000	57	168.0000000	58	168.0000000
61	168.0000000	62	168.0000000	63	168.0000000	64	168.0000000
65	168.0000000	66	168.0000000	67	168.0000000	68	168.0000000

TRANSIENT PROBLEM

TIME = 5.0000000E-01SEC.
MINIMUM RC PRODUCT = 1.9169394E-03SEC. ----- FOR NODE 66

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.0000000	2	1470.0640978	3	256.5909572	4	170.0400724
5	168.0316068	6	168.0023897	7	168.1644983	8	568.8364753
9	449.9769290	10	390.4083470	11	562.3161792	12	444.0652543
13	385.2934321	14	519.4732961	15	409.6554639	16	362.5795767
17	203.9544091	18	199.4220316	21	176.4347745	22	176.1120725
23	175.9501261	24	175.8015987	25	175.6597193	26	175.5197569
27	175.4602296	31	199.9077475	32	200.0239543	33	200.3234635
34	200.4537966	35	200.4437511	36	200.3137509	37	200.2133597
41	300.9049140	42	296.7816648	43	292.5750631	44	289.1937738
45	286.6430423	46	284.9363728	47	284.5802578	48	1437.9493350
51	307.6668432	52	305.2046903	53	302.8226291	54	300.8307092
55	299.2586296	56	298.1330277	57	297.8555833	58	1452.7005808
61	309.0078509	62	306.6025079	63	304.3367823	64	302.4498242
65	300.9565111	66	299.8720990	67	299.5929301	68	1452.7104636

TRANSIENT PROBLEM

TIME = 5.5000000E-01SEC.
MINIMUM RC PRODUCT = 1.9169394E-03SEC. ----- FOR NODE 66

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.0000000	2	855.8521555	3	262.1743557	4	170.4844404
5	168.0427203	6	168.0033715	7	168.2078895	8	523.5399357
9	465.4395743	10	417.6431575	11	515.5792843	12	458.0383151
13	411.0757675	14	469.0752615	15	419.0751732	16	384.3473828
17	208.9940814	18	204.8948086	21	178.3661934	22	177.9844479
23	177.7786021	24	177.5938963	25	177.4231943	26	177.2614687
27	177.1956576	31	202.9957477	32	203.1089902	33	203.3975771
34	203.5270620	35	203.5234075	36	203.4049873	37	203.3111281
41	300.4198199	42	296.7667694	43	293.0173823	44	290.0077381
45	287.7408457	46	286.2311819	47	285.9222500	48	552.0225079
51	306.6046977	52	305.5179672	53	304.0656418	54	302.6804755
55	301.4912389	56	300.6002928	57	300.3818037	58	615.3611569
61	309.4451744	62	308.0331349	63	306.4212790	64	304.9590007
65	303.7324125	66	302.8114166	67	302.5738390	68	838.1418269

TRANSIENT PROBLEM

TIME = 7.0000000E-01SEC.
MINIMUM RC PRODUCT = 1.9169394E-03SEC. ----- FOR NODE 66

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.0000000	2	415.4459931	3	266.1020080	4	171.8665544
5	168.0892276	6	168.0079627	7	168.3664442	8	467.2533093
9	462.7855426	10	454.0306415	11	454.5441635	12	450.3833918
13	442.3429455	14	403.8069498	15	403.8441413	16	406.1052619
17	220.5932790	18	218.3323483	21	184.7584473	22	184.2495925
23	183.9390298	24	183.6662601	25	183.4253506	26	183.2121387
27	183.1327684	31	210.7272292	32	210.8467427	33	211.1199245
34	211.2884347	35	211.3540601	36	211.3182189	37	211.2603737
41	281.6482199	42	282.3420630	43	282.5854524	44	282.7591994
45	282.9177008	46	283.1121853	47	283.2274739	48	258.0311187
51	301.9372870	52	301.9447697	53	301.8100800	54	301.6873611
55	301.5960619	56	301.5550315	57	301.5656480	58	245.1151036
61	307.3054696	62	307.0212058	63	306.6445707	64	306.3170969
65	306.0565069	66	305.8793255	67	305.8456443	68	398.0205612

TRANSIENT PROBLEM

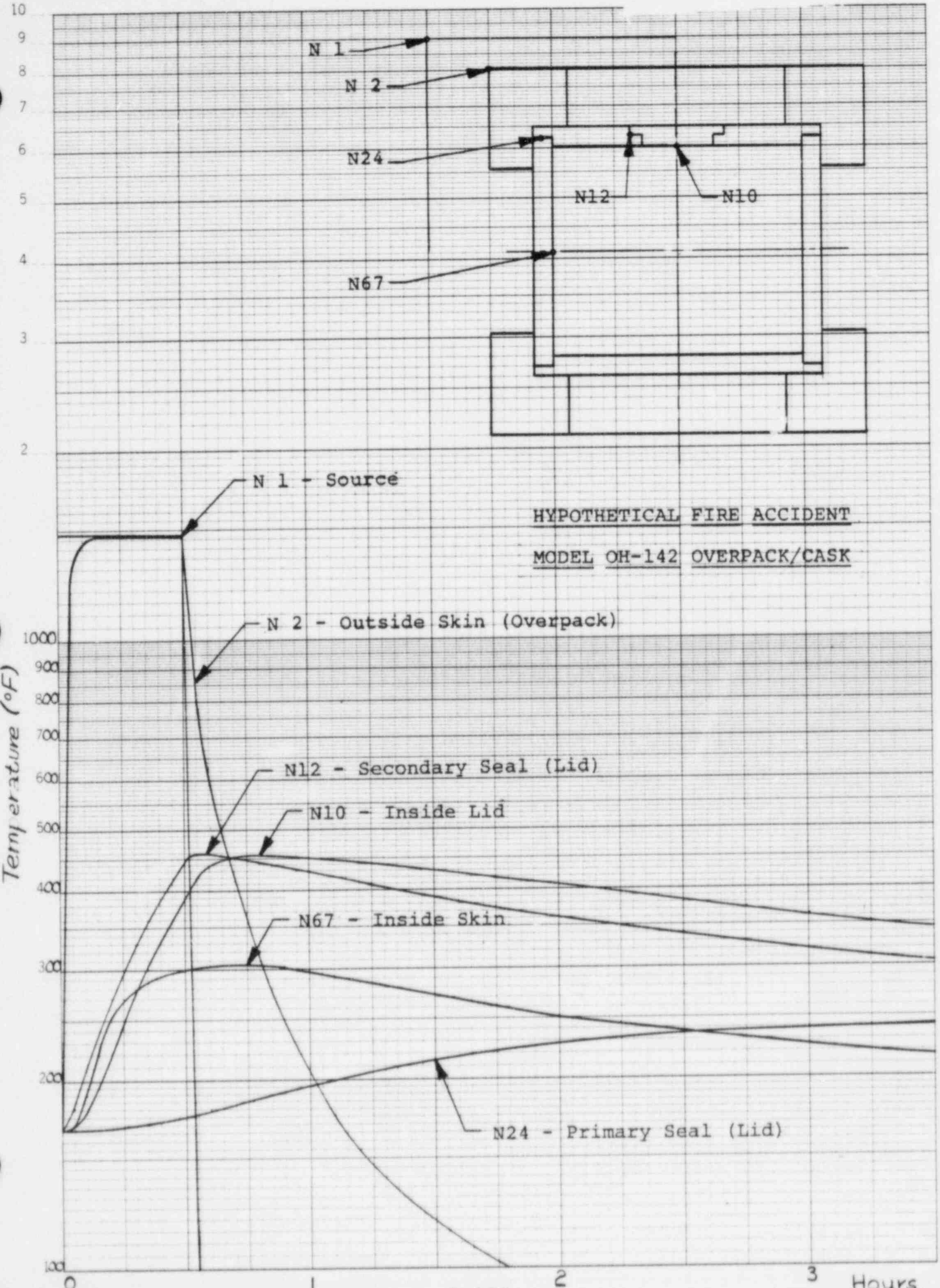
TIME = 8.0000000E-01SEC.
MINIMUM RC PRODUCT = 1.9169394E-03SEC. ----- FOR NODE 66

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.0000000	2	311.6252311	3	266.1900888	4	172.7809809
5	168.1311010	6	168.0126700	7	168.4924378	8	454.5682266
9	458.1192659	10	457.5325244	11	438.6005394	12	442.2503925
13	442.2141686	14	386.9314498	15	393.6026091	16	402.4455061
17	227.1150674	18	225.2646808	21	189.2001503	22	188.6430159
23	188.2874285	24	187.9779923	25	187.7095430	26	187.4785213
27	187.3959306	31	214.4683085	32	214.5708700	33	214.8005210
34	214.9537296	35	215.0277020	36	215.0194496	37	214.9799345
41	273.4789781	42	274.3303054	43	274.9338568	44	275.4691662
45	275.9430292	46	276.3625686	47	276.5194458	48	250.2778908
51	293.9690694	52	295.1962578	53	296.2507309	54	297.1230129
55	297.8195924	56	298.3542276	57	298.5178493	58	264.3232357
61	305.1939122	62	305.1543194	63	305.0351999	64	304.9720085
65	304.9543027	66	304.9772905	67	305.0039132	68	300.0537208

TRANSIENT PROBLEM

TIME = 3.6500000E+00SEC.
MINIMUM RC PRODUCT = 1.9169394E-03SEC. ----- FOR NODE 66

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.0000000	2	70.5988260	3	229.2160719	4	188.6303020
5	171.5050760	6	169.0866131	7	174.3657641	8	208.4461670
9	281.0838535	10	314.1330666	11	192.8350559	12	254.8755156
13	282.9915001	14	190.5263642	15	247.6547437	16	273.2325793
17	270.1186922	18	270.7709836	21	244.3726701	22	243.8801251
23	243.4189933	24	243.0615976	25	242.8081311	26	242.6595441
27	242.6417703	31	230.5401088	32	230.5658966	33	230.5865758
34	230.6472855	35	230.7258316	36	230.8059939	37	230.8360146
41	195.7599682	42	199.8464365	43	203.6611303	44	206.7546894
45	209.1443481	46	210.5404936	47	211.2652098	48	99.4189335
51	191.3866357	52	195.3502703	53	199.0510629	54	202.1129109
55	204.5214317	56	206.2645907	57	206.7150398	58	98.5710833
61	190.9510324	62	194.8818075	63	198.5343402	64	201.5603362
65	203.9459051	66	205.6798138	67	206.1323433	68	98.5994743


N 1
N 2
N24
N12
N10
N67
N 1 - Source
HYPOTHETICAL FIRE ACCIDENT
MODEL OH-142 OVERPACK/CASK
N 2 - Outside Skin (Overpack)
N12 - Secondary Seal (Lid)
N10 - Inside Lid
N67 - Inside Skin
N24 - Primary Seal (Lid)
Temperature (°F)
Hours
100
200
300
400
500
600
700
800
900
1000
2
3
4
5
6
7
8
9
10
0
1
2
3
46 4970
K+E SEMI-LOGARITHMIC • 2 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.0000000	2	1469.8569098	3	195.2162325	4	106.2448564
5	106.4864870	6	109.0921319	7	111.3676345	8	547.2553743
9	419.6289911	10	355.5894289	11	541.2297371	12	414.2553088
13	351.0761989	14	495.7614102	15	377.6664321	16	327.0726306
17	155.4470111	18	150.4889195	21	122.2957738	22	121.8378478
23	121.4932535	24	121.2293532	25	121.0385524	26	120.9159541
27	120.8919258	31	124.4831118	32	124.5033144	33	124.5718970
34	124.5796979	35	124.5481198	36	124.4926016	37	124.4632045
41	157.6094855	42	154.5963602	43	151.7706873	44	149.4878031
45	147.7356599	46	146.5094496	47	146.2142304	48	1447.0851526
51	163.4849911	52	160.4618608	53	157.6479446	54	155.3212223
55	153.4938432	56	152.1782718	57	151.8439854	58	1447.0306850
61	167.1648366	62	163.8012714	63	160.6723889	64	158.0992650
65	156.0871313	66	154.6438621	67	154.2788604	68	1443.7261758

Table 1.7.3-3
Fire Transient 0.5 hours

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	100.0000000	2	628.9221698	3	203.7875205	4	107.1957467
5	106.5118266	6	109.0863157	7	111.4402663	8	470.4582184
9	438.3803822	10	405.6021659	11	461.1553878	12	429.6524282
13	397.7814010	14	409.1186443	15	384.3926328	16	365.4050620
17	165.3696607	18	161.6723573	21	124.6078643	22	123.9911193
23	123.5141707	24	123.1434614	25	122.8713224	26	122.6929052
27	122.6561812	31	126.7131636	32	126.7495626	33	126.8455301
34	126.8826973	35	126.8756525	36	126.8358728	37	126.8085266
41	156.3373215	42	155.2302099	43	153.9364846	44	152.7981319
45	151.8721964	46	151.2104747	47	151.0607145	48	527.9228097
51	163.7702777	52	162.6798782	53	161.4239844	54	160.2771333
55	159.3112339	56	158.5901174	57	158.4106367	58	528.1091269
61	167.1581708	62	165.9613313	63	164.5789847	64	163.3225306
65	162.2679553	66	161.4829366	67	161.2884696	68	523.2832920

Table 1.7.3-4
Fire Transient 0.6 hours

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	100.0000000	2	321.2572101	3	206.6097900	4	109.1464439
5	106.5900840	6	109.0782138	7	111.6272482	8	429.2446388
9	431.2025983	10	429.7059325	11	412.8140747	12	414.9580081
13	414.1002150	14	356.8142018	15	362.4635903	16	371.4241146
17	180.2577503	18	177.9691577	21	130.0174147	22	129.1960783
23	128.5380216	24	128.0190669	25	127.6336209	26	127.3787105
27	127.3259181	31	130.8062998	32	130.8498053	33	130.9560335
34	131.0182186	35	131.0431243	36	131.0353860	37	131.0194196
41	153.4859279	42	153.2213246	43	152.9036070	44	152.6474986
45	152.4618418	46	152.3549[illegible]19	47	152.3461046	48	241.8462462
51	1[illegible]2.5744484	52	162.3319584	53	162.0453524	54	161.8051668
55	161.6234231	56	161.5107512	57	161.4960148	58	242.9682178
61	165.6817476	62	165.4304233	63	165.1325251	64	164.8820665
65	164.6916075	66	164.5722813	67	164.5558156	68	239.6474018

Table 1.7.3-5
Fire Transient 0.8 hours

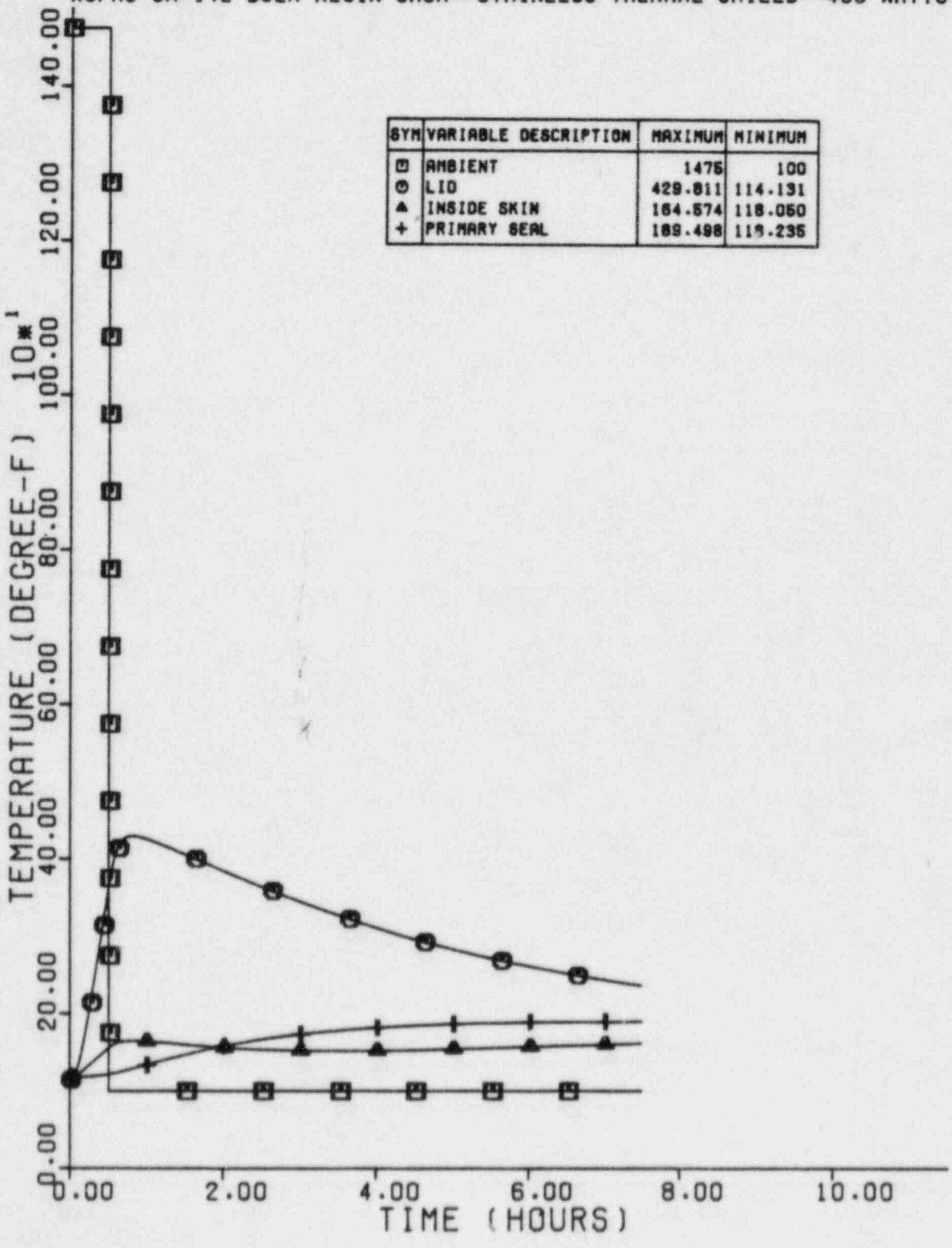
CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	100.0000000	2	103.1542295	3	158.5424807	4	135.2740667
5	116.6872012	6	113.5271166	7	123.7740815	8	236.0594669
9	238.0283778	10	239.0603285	11	221.0593006	12	222.7679622
13	223.6845184	14	217.1523338	15	218.8506233	16	220.0530252
17	213.3195498	18	212.7073391	21	190.5664977	22	190.1605707
23	189.7829637	24	189.4981124	25	189.3058140	26	189.2068217
27	189.2050538	31	177.9645934	32	177.9798688	33	178.0026504
34	178.0236041	35	178.0445948	36	178.0669296	37	178.0772637
41	167.4302377	42	167.5473153	43	167.6794454	44	167.7881326
45	167.8738046	46	167.9365975	47	167.9534369	48	124.3482388
51	162.1868217	52	162.2975526	53	162.4259723	54	162.5327275
55	162.6172983	56	162.6791357	57	162.6954271	58	122.4666109
61	160.3793327	62	160.4941007	63	160.6267543	64	160.7366234
65	160.8233046	66	160.8863276	67	160.9027308	68	123.2867579

Table 1.7.3-6
Fire Transient 7.3 hours

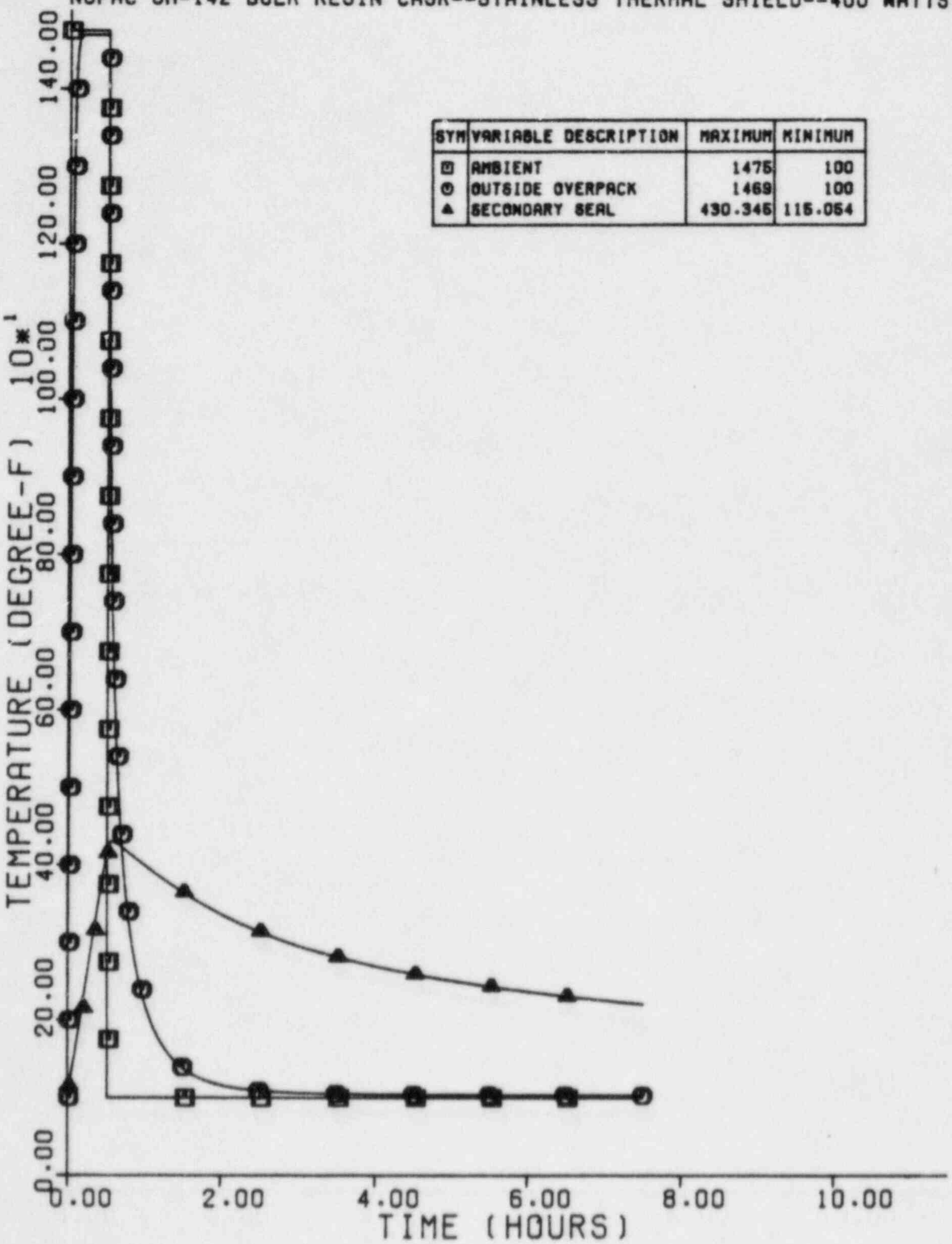
HYPOTHETICAL FIRE ACCIDENT

NUPAC OH-142 BULK RESIN CASK--STAINLESS THERMAL SHIELD--400 WATTS



HYPOTHETICAL FIRE ACCIDENT

NUPAC OH-142 BULK RESIN CASK--STAINLESS THERMAL SHIELD--400 WATTS



In order to evaluate the effect of the reduced insulation associated with a damaged or post-dropped overpack, the following analysis is presented:

Under corner impacts, Cases 1-4, the damage predictions are as follows:

Case	Ref. Page	Deformation (in)	Crush Volume (in^3)
1	1-21a	20.5	22684
2	1-21c	19.5	20161
3	1-21e	19.5	20161
4	1-21g	18.5	17799

The most severe of these damage predictions will be used to scale thermal effects.

Original Foam

1. Resistance (P. 1-36)

$$R_O = 859.28$$

2. Volume

$$V_O = \frac{\pi}{4}\left[(101^2-55^2)(18)+(101^2-76.25^2)(22)\right]$$

$$= 177249 \text{ in}^3$$

Damaged Foam Volume

$$V_D = 177249 - 22684 = 154565 \text{ in}^3$$

Scale Resistance Change as:

$$\frac{R_D}{R_O} = \frac{\frac{t_D}{KA}}{\frac{t_O}{KA}}$$

$$V_D = t_D A \; ; \; t_D = V_D/A$$

$$V_O = t_O A \; ; \; t_O = V_O/A$$

Thus:

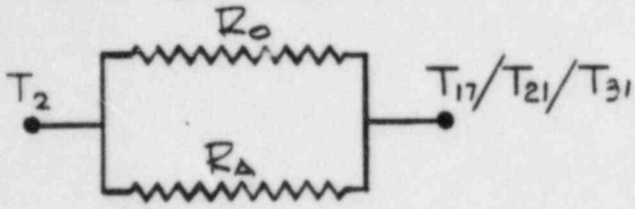
$$\frac{R_D}{R_O} = \frac{\frac{V_D}{KA^2}}{\frac{V_O}{KA^2}} = \frac{V_D}{V_O}$$

The damaged foam resistance is:

$$R_D = R_O \cdot \frac{V_D}{V_O} = (859.28\text{x}10^{-3}) \left(\frac{154565}{177249}\right)$$

$$= 749.31\text{x}10^{-3}$$

This is equivalent to:



$$R_D = \frac{1}{\frac{1}{R_O} + \frac{1}{R_A}}$$

Where R_A = an additional parallel resistance corresponding to the damage caused by the 30 ft. drop.

$$R_A = \frac{R_D R_O}{R_O - R_D}$$

$$= \frac{(749.31)(859.28)}{859.28-749.31} \text{ x } 10^{-3} = \underline{\underline{5.8549}}$$

The heat that flows across this damage resistor at t = 30 minutes is:

$$q_{2-24} = \frac{(T_2 - T_{24})}{R_A}$$

$$= \frac{(1470.1-175.8)}{5.8549} = 221.1 \text{ Btu/hr.}$$

In 30 minutes, the total heat flow is conservatively estimated at:

$$Q_{2-24} = 110.5 \text{ Btu.}$$

Assuming all this heat goes into the lid:

$$C_{LID} = \Sigma C_i, \ i = 8, 18$$

$$= 841 \text{ Btu}/^{o}\text{F (Ref. Page 1-42)}$$

The change in lid temperature is thus:

$$\Delta T_D = \frac{110.5}{841} = \underline{0.13^{o}F}$$

Thus, the predicted percent increase in seal temperature (Node 24) is:

$$\%\Delta T_{24} = \frac{.13}{175.8} \times 100 = \underline{\underline{0.074\%}}$$

Therefore, it can be concluded that the loss of insulation associated with damaged overpack will have no significant effect on seal or package temperature.

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 OH-142 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 OH-142 packaging.

8 | 7 | 6 | 5

15. PACKAGE SHALL BE MARKED & IDENTIFIED IN ACCORDANCE WITH THE REQUIREMENTS OF 10 CFR 71.85(c)

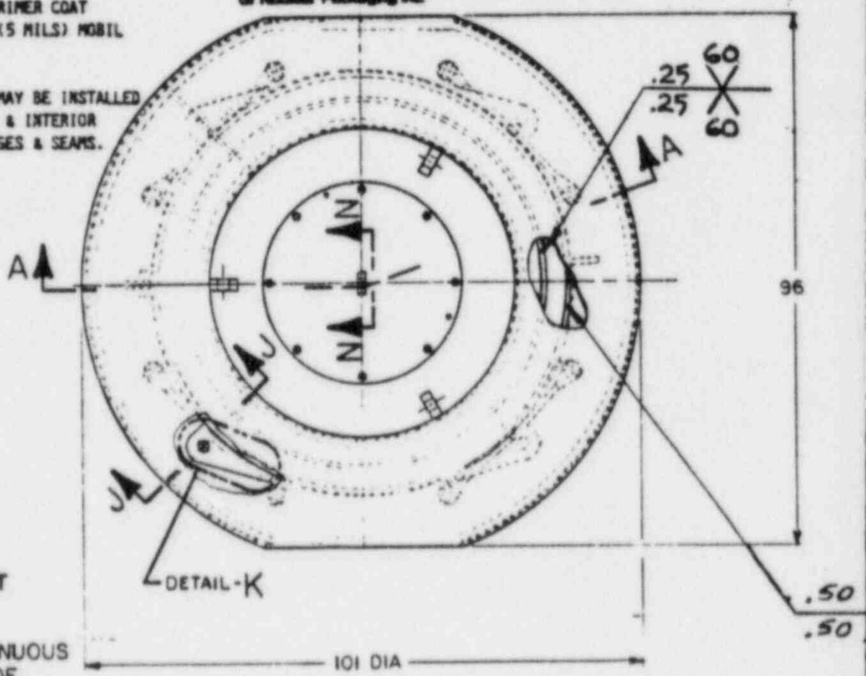
14. PRIMARY & SECONDARY LIDS & DRAIN SHALL BE EQUIPPED WITH TAMPER INDICATING DEVICES IN ACCORDANCE WITH 10 CFR 71.43(b)

12. COAT ALL EXPOSED EXTERIOR SURFACES OF FLASK BETWEEN UPPER AND LOWER OVERPACKS WITH ONE (1) COAT (MIN 3/16 THK) "ALBI-CLAD" NO. 89. AS AN OPTION, A 10 GA. NO. 304 STAINLESS STEEL THERMAL SHIELD MAY BE INSTALLED BETWEEN THE OVERPACKS.

11. PAINT ALL EXPOSED CARBON STEEL SURFACES WITH ONE COAT CARBOZINC 11 & ONE COAT PHENOLINE 305, COLOR 727 M. GRAY, OR ONE PRIMER COAT (5 MILS) MOBIL CHEM EPOXY NO. 89W9 & ONE FINISH COAT (5 MILS) MOBIL CHEM EPOXY NO. 89W9, COLOR: WHITE.

10. AS AN OPTION, 12 GA NO. 304 STAINLESS STEEL CLADDING MAY BE INSTALLED ON THE INTERIOR & EXTERIOR SURFACES OF THE FLASK BODY & INTERIOR SURFACES OF THE UPPER LID. & SEAL WELDED ALONG ALL EDGES & SEAMS.

D



C

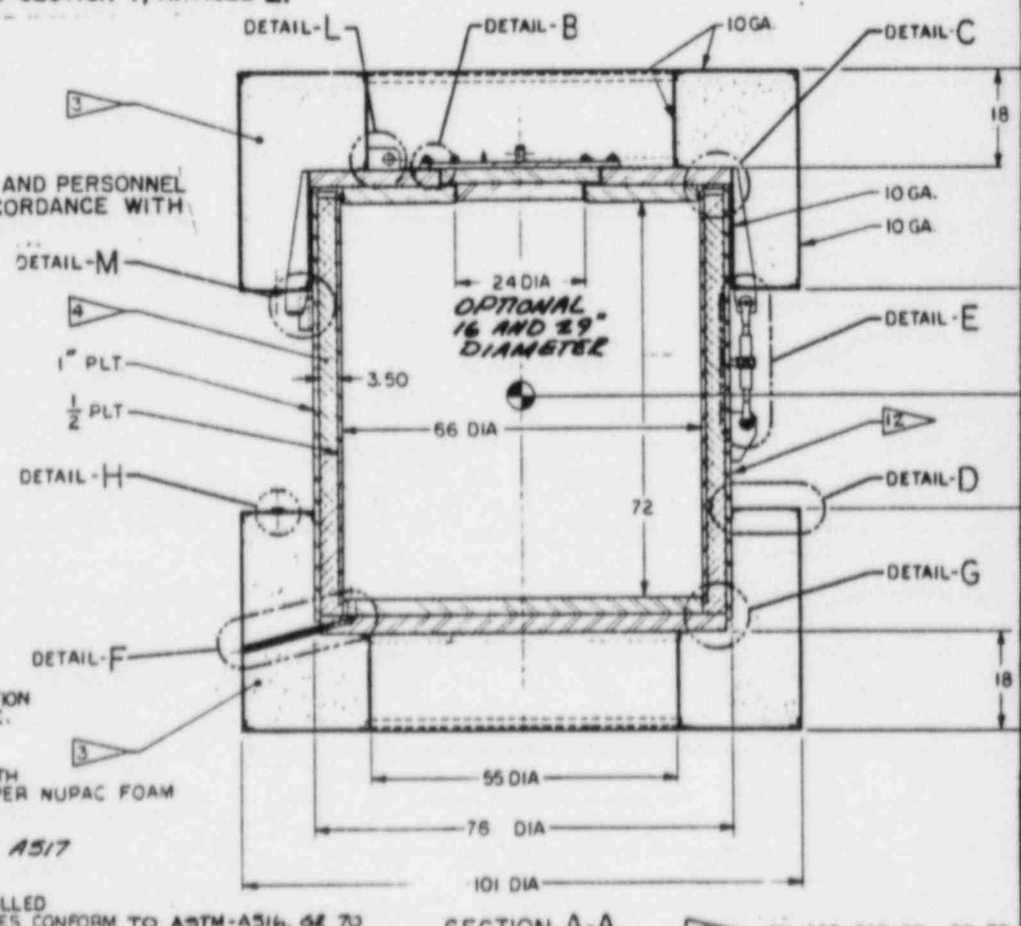
9. ALL WELDS SHALL BE INSPECTED VIA NDT METHODS AS FOLLOWS:

LIFTING LUG AND CIRCUMFERENTIAL CONTINUOUS WELDS: MAGNETIC PARTICLE PER ASME CODE SECTION III, DIVISION I, SUBSECTION NB, ARTICLE NB-5000 AND SECTION V, ARTICLE 7.

LONGITUDINAL SHELL WELDS: RADIOGRAPHIC PER ASME CODE SECTION III, DIVISION I, SUBSECTION NB, ARTICLE NB-5000 AND SECTION V, ARTICLE 2.

8. ALL WELDING PROCEDURES AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME CODE, SECTION IX.

B



7 REMOVED

6 REFERENCE DATA:
CASK WT: 54,000 LBS.
PAY LOAD: 10,000 LBS.
GROSS WT: 64,000 LBS.

5. REMOVED

4 LEAD: PER FEDERAL SPECIFICATION QQ-L-171e, GRADE A OR C.

A

3 FOAM: 1,000 PSI CRUSH STRENGTH RIGID POLYURETHANE, PER NUPAC FOAM SPECIFICATION NPI-F6.

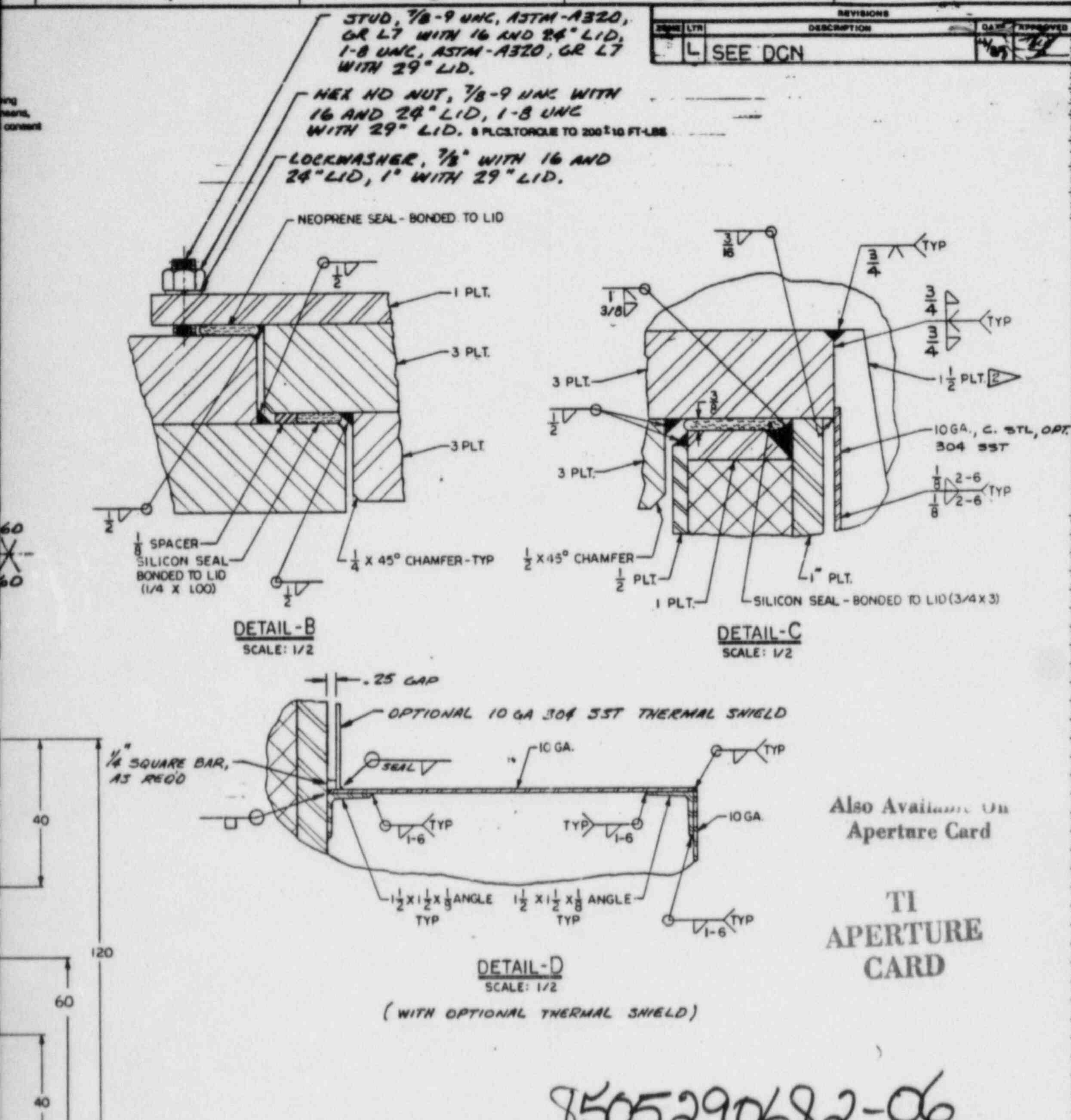
2 MATERIAL: ASTM-A514 OR A517

1. MATERIAL: LOW CARBON HOT ROLLED STEEL: PLATE & SHAPES CONFORM TO ASTM-A516, GR 70
: SHEETS CONFORM TO ASTM-A415, A36 OR 304 SST PER ASTM-A240 WHERE NOTED.

NOTES: UNLESS OTHERWISE SPECIFIED

SECTION A-A

13 AN AIR GAP OF .22 TO [...] BE VERIFIED DURING FA[...]



REVISIONS

LTR	DESCRIPTION
L	SEE DCN

Also Available On Aperture Card

TI APERTURE CARD

8505290682-06

ITEM	PART NO.	DESCRIPTION	MATERIAL

LIST OF MATERIAL

NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON

BULK RESIN SHIPPING FLASK
MODEL OH142

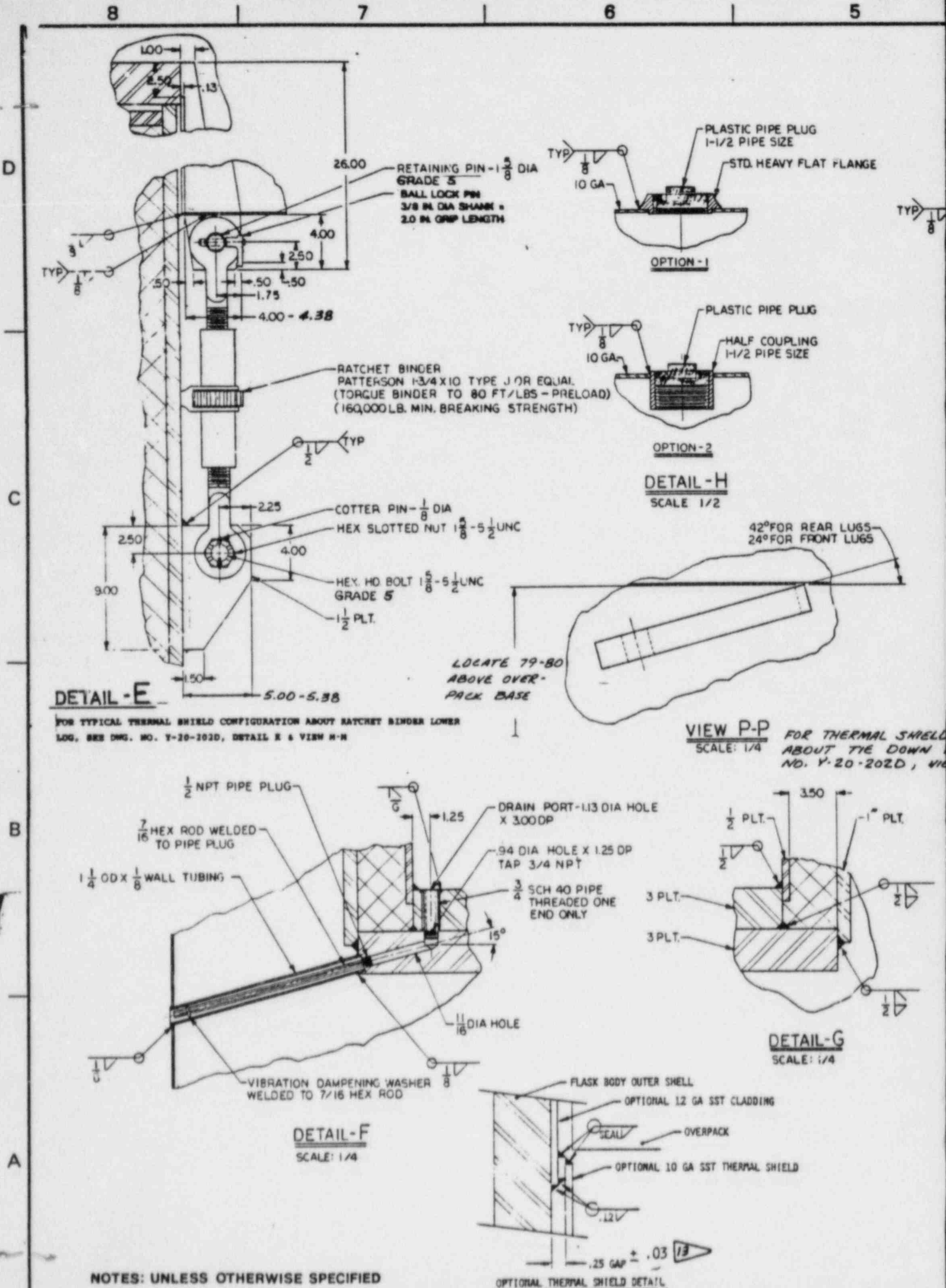
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: FRACTIONS ± ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ± 1 PLACE DECIMALS ±

DO NOT SCALE THIS DRAWING

DRAWN D.KENT 9-29-76
CHECK 9-29-76
ENGR 9/29/76

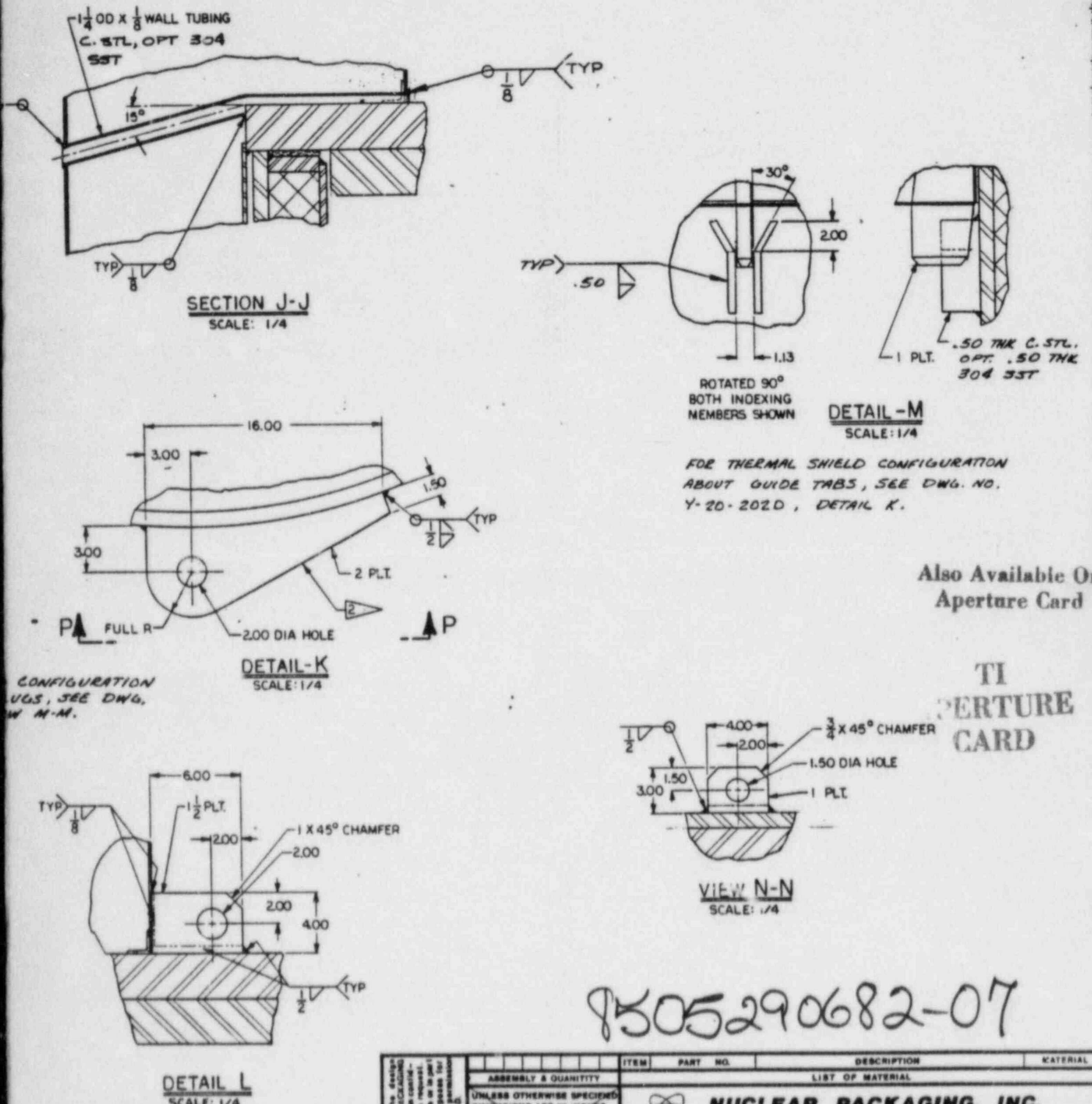
SCALE 1/2 | REV L | SHEET 1 OF 2
SIZE D | DWG NO. Y-20-201D

.28 INCHES SHALL BE MAINTAINED. THIS SHALL
BRICATION VIA INPROCESS INSPECTION.



NOTES: UNLESS OTHERWISE SPECIFIED

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	L	SEE DCN		



Also Available On Aperture Card

TI APERTURE CARD

8505290682-07

ITEM	PART NO.	DESCRIPTION	MATERIAL

LIST OF MATERIAL

PROPRIETARY DATA: This drawing and the design it covers are the property of NUCLEAR PACKAGING, INCORPORATED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: FRACTIONS ± ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ± 1 PLACE DECIMALS ±

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NEXT ASSY | USED ON — APPLICATION

NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON

BULK RESIN SHIPPING FLASK
MODEL OH142

DRAWN D. KENT 9-29-78 — SCALE: 1/16 — REV L — SHEET 2 OF 2 — SIZE D — DWG NO. Y-20-201D

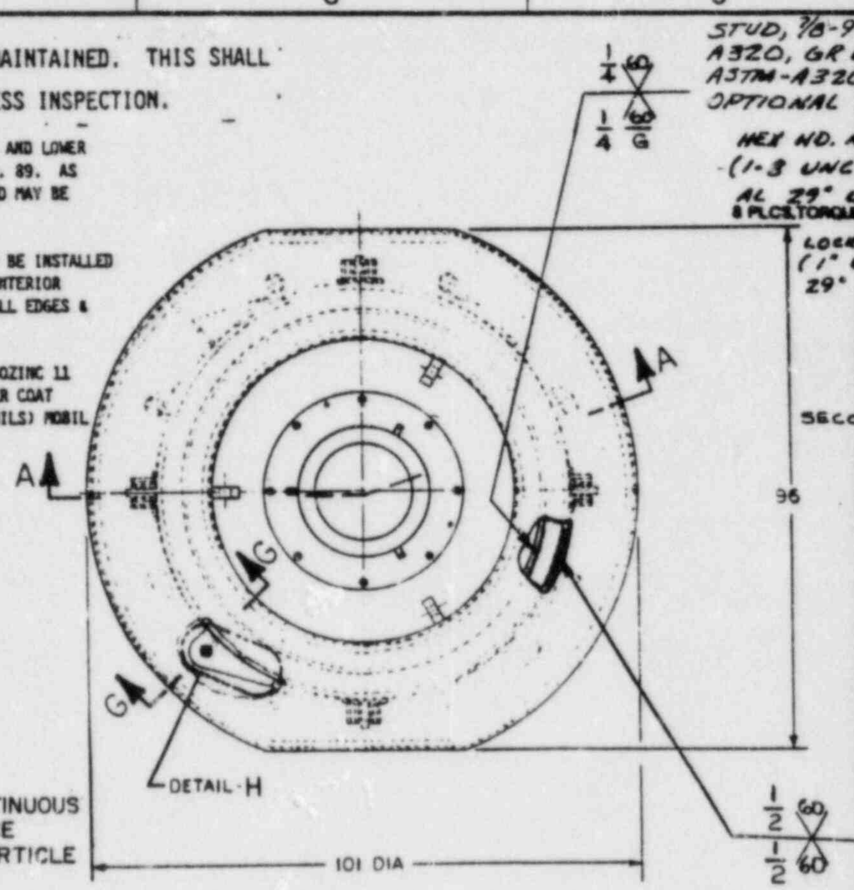
Y-20-201D L

14. AN AIR GAP OF .22 TO .28 INCHES SHALL BE MAINTAINED. THIS SHALL BE VERIFIED DURING FABRICATION VIA INPROCESS INSPECTION.

13. COAT ALL EXPOSED EXTERIOR SURFACES OF FLASK BETWEEN UPPER AND LOWER OVERPACKS WITH ONE (1) COAT (MIN 3/16 THK) "ALBI-CLAD" NO. 89. AS AN OPTION, A 10 GA. NO. 304 STAINLESS STEEL THERMAL SHIELD MAY BE INSTALLED BETWEEN THE OVERPACKS.

12. AS AN OPTION, 12 GA. NO. 304 STAINLESS STEEL CLADDING MAY BE INSTALLED ON THE INTERIOR & EXTERIOR SURFACES OF THE FLASK BODY & INTERIOR SURFACES OF THE UPPER & LOWER LIDS, & SEAL WELDED ALONG ALL EDGES & SEAMS.

11. PAINT ALL EXPOSED CARBON STEEL SURFACES WITH ONE COAT CARBOZINC 11 & ONE COAT PHENOLINE 305, COLOR 727 M. GRAY, OR ONE PRIMER COAT (5 MILS) MOBIL CHEM EPOXY NO. 89M9 & ONE FINISH COAT (5 MILS) MOBIL CHEM EPOXY NO. 89M5. COLOR: WHITE.



10. ALL WELD SHALL BE INSPECTED VIA NDT METHODS AS FOLLOWS:

LIFTING LUGS AND CIRCUMFERENTIAL CONTINUOUS WELDS: MAGNETIC PARTICLE PER ASME CODE SECTION III, DIVISION I, SUBSECTION NB, ARTICLE NB-5000 AND SECTION V, ARTICLE 7.

LONGITUDINAL SHELL WELDS: RADIOGRAPHIC PER ASME CODE SECTION III, DIVISION I, SUBSECTION NB, ARTICLE NB-5000 AND SECTION V, ARTICLE 2.

9. ALL WELDING PROCEDURE AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME CODE, SECTION IX.

8. MATERIAL: CONFORMS TO ASTM-A516 GRD. 70.

7. REMOVED

6. REFERENCE DATA:
CASK WT: 54,000 LBS.
PAY LOAD: 10,000 LBS.
GROSS WT: 64,000 LBS.

5. REMOVED

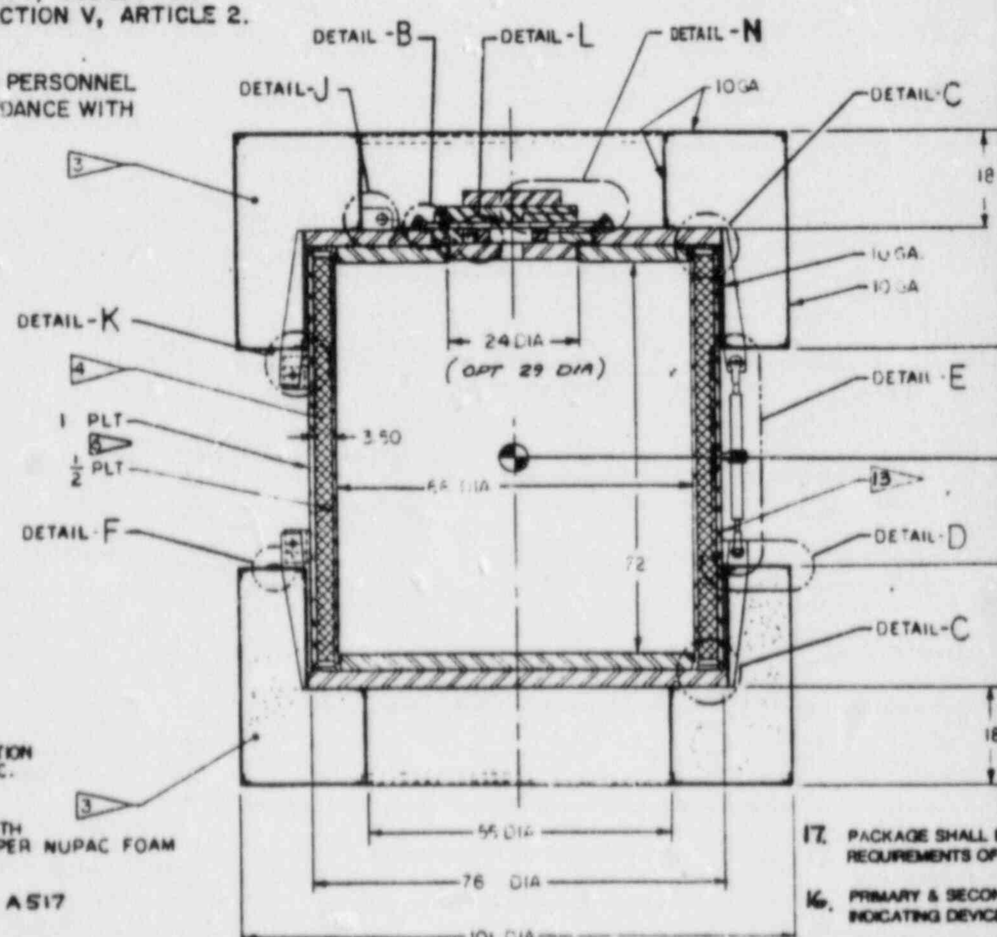
4. LEAD: PER FEDERAL SPECIFICATION QQ-L-171e, GRADE A OR C.

3. FOAM: 1,000 PSI CRUSH STRENGTH RIGID POLYURETHANE, PER NUPAC FOAM SPECIFICATION NPI-F6.

2. MATERIAL: ASTM-A514 OR A517

1. MATERIAL:
STEEL: PLATE & SHAPES CONFORM TO ASTM-A516 GRD 70
: SHEETS CONFORM TO ASTM-A415, A36 OR 304 SST PER ASTM-A240 AS NOTED

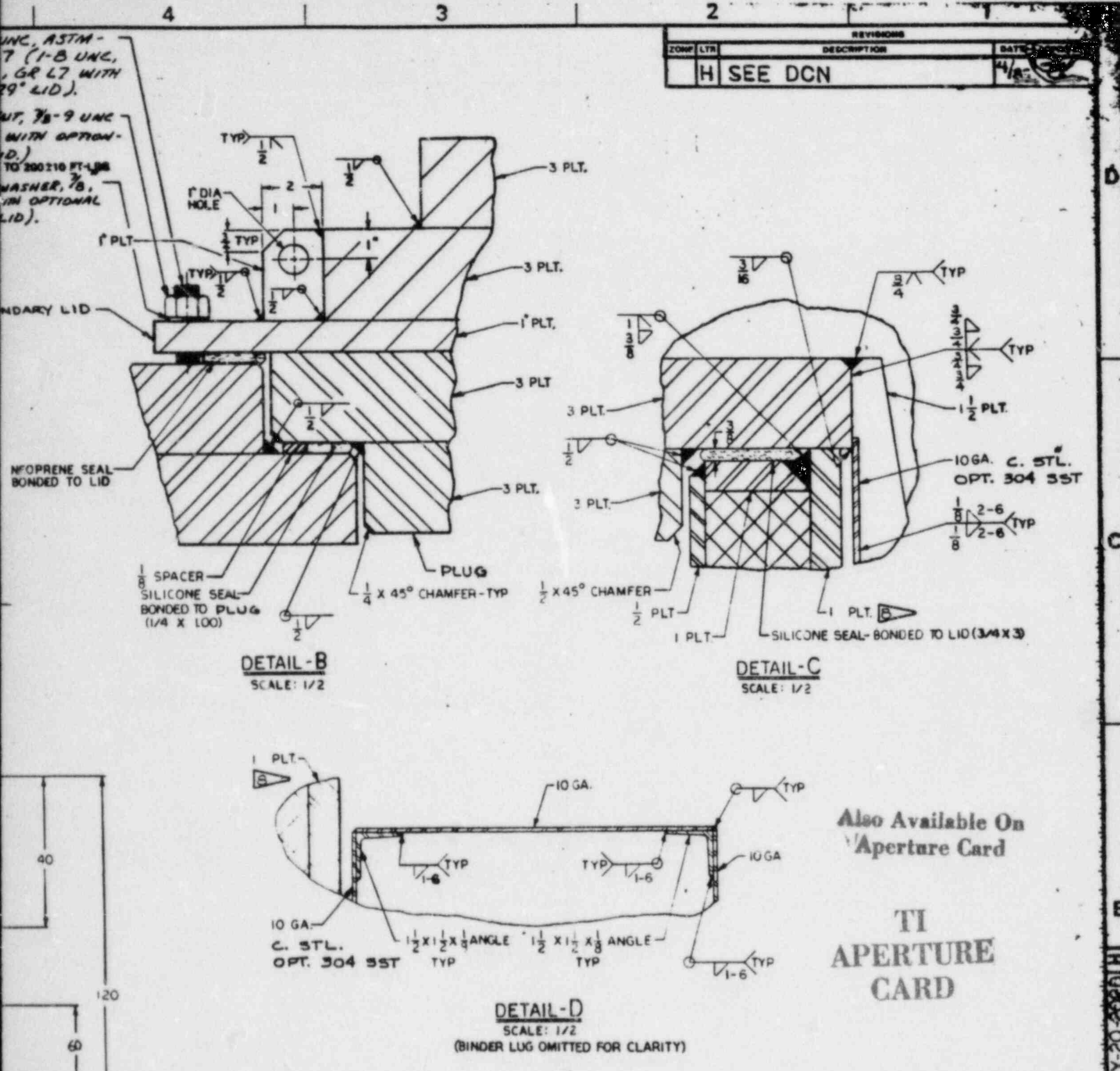
NOTES: UNLESS OTHERWISE SPECIFIED



SECTION A-A

17. PACKAGE SHALL B... REQUIREMENTS OF ...

16. PRIMARY & SECON... INDICATING DEVICE...



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TI APERTURE CARD

8505290682-08

MARKED & IDENTIFIED IN ACCORDANCE WITH THE 10 CFR 71.85(c)

ARY LIDS & DRAIN SHALL BE EQUIPPED WITH TAMPER IN ACCORDANCE WITH 10 CFR 71.43(b)

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ITEM	PART NO.	DESCRIPTION	MATERIAL
		LIST OF MATERIAL	

ASSEMBLY & QUANTITY

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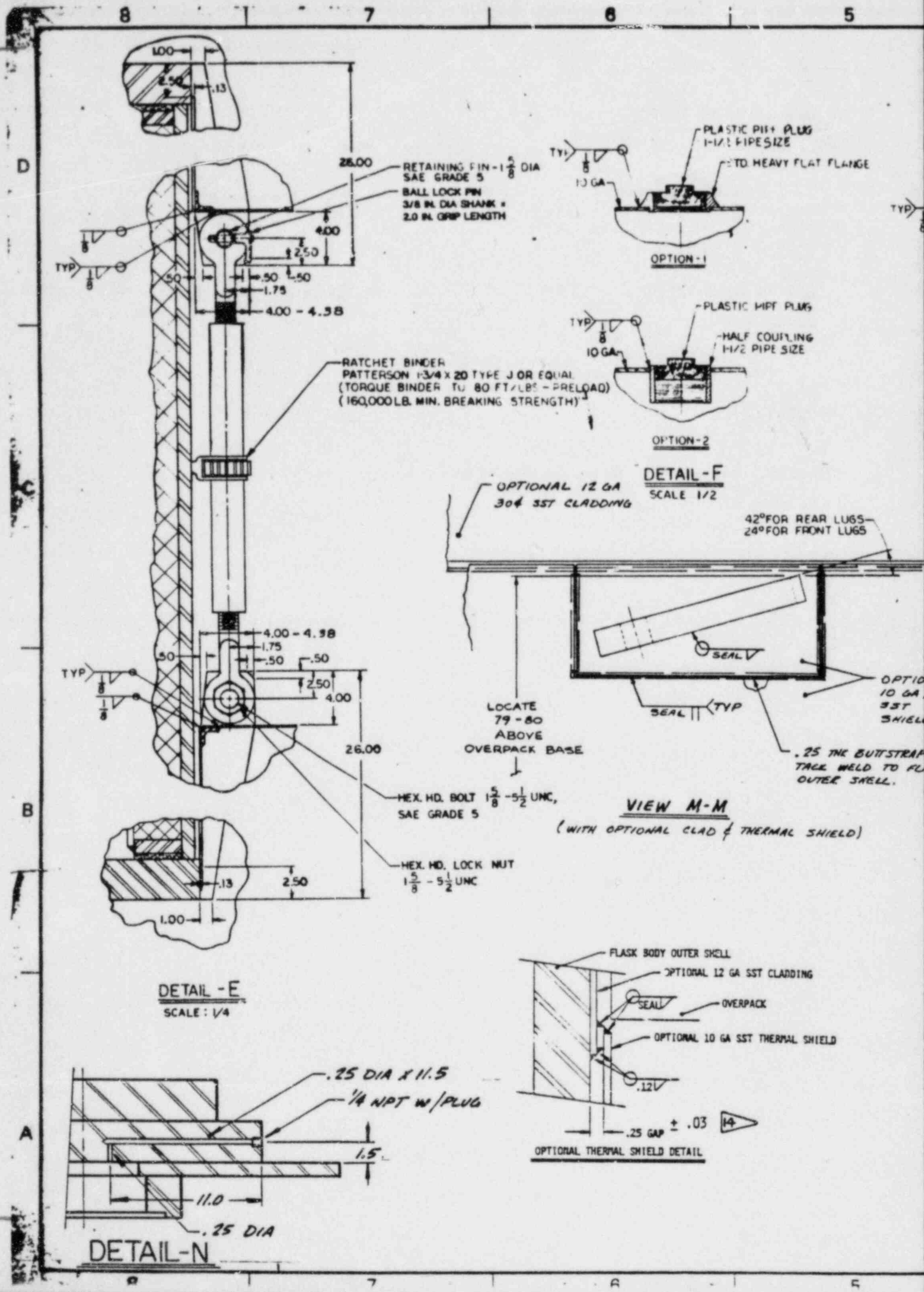
NEXT ASSY | USED ON

APPLICATION

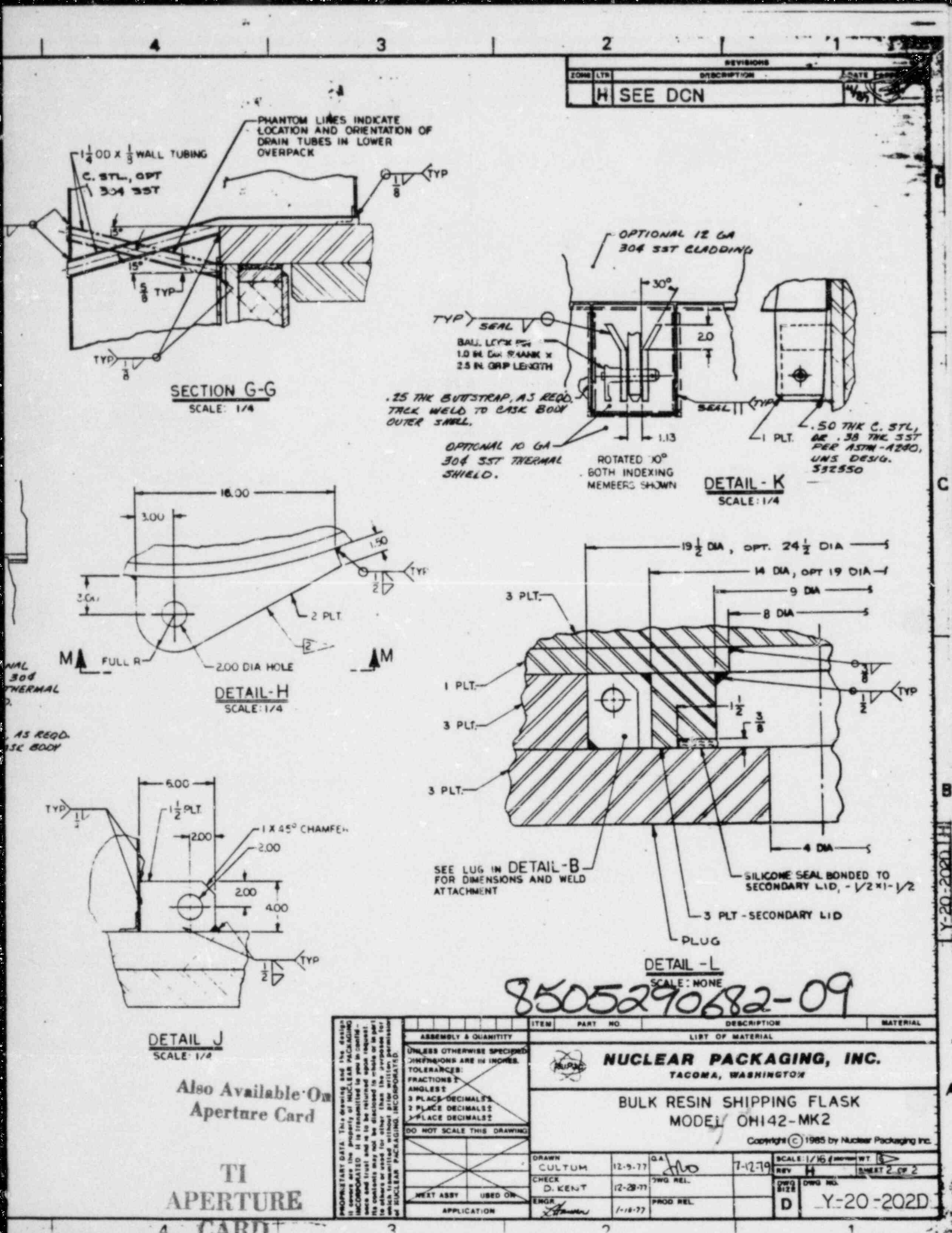
NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON

BULK RESIN SHIPPING FLASK
MODEL OH142 -MK2

DRAWN	CULTUM	12-9-77	Q.A.	7-12-78	SCALE 1/16
CHECK	D. KENT	12-28-78	DWG REL.	1-10-78	REV H
ENGR		1-10-77	PROD. REL.		DWG SIZE D · DWG NO. Y-20-2020



8
7
6
5
D
C
B
A
1.00
2.50
.13
26.00
RETAINING PIN - 1 5/8 DIA
SAE GRADE 5
BALL LOCK PIN
3/8 IN. DIA SHANK x
2.0 IN. GRIP LENGTH
4.00
2.50
TYP
1/8
.50
.50
.50
1.75
4.00 - 4.38
RATCHET BINDER
PATTERSON 1-3/4 X 20 TYPE J OR EQUAL
(TORQUE BINDER TO 80 FT/LBS - PRELOAD)
(160,000 LB. MIN. BREAKING STRENGTH)
4.00 - 4.38
1.75
.50
.50
.50
2.50
4.00
26.00
HEX. HD. BOLT 1 5/8 - 5 1/2 UNC,
SAE GRADE 5
HEX. HD. LOCK NUT
1 5/8 - 5 1/2 UNC
.13
2.50
1.00
DETAIL - E
SCALE : 1/4
PLASTIC PIPE PLUG
1-1/2 PIPESIZE
STD HEAVY FLAT FLANGE
10 GA
OPTION - 1
PLASTIC PIPE PLUG
HALF COUPLING
1-1/2 PIPE SIZE
10 GA
OPTION - 2
DETAIL - F
SCALE 1/2
OPTIONAL 12 GA
304 SST CLADDING
42° FOR REAR LUGS
24° FOR FRONT LUGS
SEAL
SEAL
TYP
LOCATE
79 - 80
ABOVE
OVERPACK BASE
OPTIO
10 GA
SST
SHIEL
.25 THK BUTTSTRAP
TACK WELD TO FL
OUTER SHELL.
VIEW M-M
(WITH OPTIONAL CLAD & THERMAL SHIELD)
.25 DIA X 11.5
1/4 NPT W/PLUG
1.5
11.0
.25 DIA
DETAIL-N
FLASK BODY OUTER SHELL
OPTIONAL 12 GA SST CLADDING
SEAL
OVERPACK
OPTIONAL 10 GA SST THERMAL SHIELD
.12
.25 GAP ± .03
14
OPTIONAL THERMAL SHIELD DETAIL


REVISIONS
ZONE LTR DESCRIPTION DATE
H SEE DCN
PHANTOM LINES INDICATE LOCATION AND ORIENTATION OF DRAIN TUBES IN LOWER OVERPACK
1 1/4 OD X 1/8 WALL TUBING
C. STL., OPT 304 SST
TYP
1/8
15°
5/8 TYP
SECTION G-G
SCALE: 1/4
OPTIONAL 12 GA 304 SST CLADDING
30°
TYP SEAL
BALL LOCK PIN 1.0 IN. DIA SHANK x 2.5 IN. GRIP LENGTH
2.0
.25 THK BUTTSTRAP, AS REQD. TACK WELD TO CASK BODY OUTER SHELL.
SEAL
1.13
OPTIONAL 10 GA 304 SST THERMAL SHIELD.
ROTATED 90° BOTH INDEXING MEMBERS SHOWN
1 PLT.
.50 THK C. STL, OR .38 THK SST PER ASTM-A240, UNS DESIG. S32550
DETAIL - K
SCALE: 1/4
16.00
3.00
1.50
3.00
2 PLT.
FULL R
2.00 DIA HOLE
M
DETAIL-H
SCALE: 1/4
19 1/2 DIA, OPT. 24 1/2 DIA
14 DIA, OPT 19 DIA
9 DIA
8 DIA
3 PLT.
1 PLT.
3 PLT.
3 PLT.
1 1/2
3/8
4 DIA
SEE LUG IN DETAIL-B FOR DIMENSIONS AND WELD ATTACHMENT
SILICONE SEAL BONDED TO SECONDARY LID, -1/2×1-1/2
3 PLT - SECONDARY LID
PLUG
DETAIL - L
SCALE: NONE
6.00
1 1/2 PLT.
1 X 45° CHAMFER
2.00
2.00
2.00
4.00
DETAIL J
SCALE: 1/4
8505290682-09
ITEM PART NO. DESCRIPTION MATERIAL
LIST OF MATERIAL
ASSEMBLY & QUANTITY
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: FRACTIONS ± ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ± 1 PLACE DECIMALS ±
DO NOT SCALE THIS DRAWING
NEXT ASSY USED ON
APPLICATION
NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON
BULK RESIN SHIPPING FLASK
MODEL OH142-MK2
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DRAWN CULTUM 12-9-77
CHECK D. KENT 12-28-77
ENGR 1-18-77
Q.A. 7-12-79
DWG REL.
PROD REL.
SCALE: 1/16
REV H
SHEET 2 OF 2
DWG SIZE D
DWG NO. Y-20-202D
Y-20-202D H

NOTES: UNLESS OTHERWISE SPECIFIED

1. MATERIAL: LOW CARBON HOT ROLLED STEEL:
   : PLATE & SHAPES CONFORM TO ASTM-A516, GR70
   : SHEETS CONFORM TO ASTM-A36 OR 304 SST PER ASTM-A240 WHERE NOTED.

2. MATERIAL : ASTM-A514 OR A517

3. FOAM: 1,000 PSI CRUSH STRENGTH RIGID POLYURETHANE. PER NUPAC FOAM SPECIFICATION NPI-F6.

4. LEAD: PER FEDERAL SPECIFICATION QQ-L-171E, GRADE A OR C.

5. REMOVED

6. REFERENCE DATA: CASK WT: 54,000LBS.
   PAY LOAD: 10,000LBS.
   GROSS WT: 64,000LBS.

7. REMOVED

8. ALL WELDING PROCEDURES AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME CODE, SECTION IX.

9. ALL WELDS SHALL BE INSPECTED VIA NDT METHODS AS FOLLOWS:
   LIFTING LUG AND CIRCUMFERENTIAL CONTINUOUS WELDS: MAGNETIC PARTICLE PER ASME CODE SECTION III, DIVISION I, SUBSECTION NB, ARTICLE NB-5000 AND SECTION V, ARTICLE 7.
   LONGITUDINAL SHELL WELD: RADIOGRAPHIC PER ASME CODE SECTION III, DIVISION I, SUBSECTION NB, ARTICLE NB-5000 AND SECTION V, ARTICLE 2.

10. AS AN OPTION, 12 GA. NO. 304 STAINLESS STEEL CLADDING MAY BE INSTALLED ON THE INTERIOR & EXTERIOR SURFACES OF THE FLASK BODY & INTERIOR SURFACES OF THE UPPER LID, & SEAL WELDED ALONG ALL EDGES & SEAMS.

11. PAINT ALL EXPOSED CARBON STEEL SURFACES WITH ONE COAT CARBROZINC II & ONE COAT PHENOLINE 305, OR ONE PRIMER COAT (5 MILS) MOBIL CHEM EPOXY NO. 89W9 & ONE FINISH COAT (5 MILS) MOBIL CHEM EPOXY NO. 89W9.

12. COAT ALL EXPOSED EXTERIOR SURFACES OF FLASK BETWEEN UPPER AND LOWER OVERPACKS WITH ONE (1) COAT (MIN 3/16 THK) "ALBI-CLAD" NO. 89. AS AN OPTION, A 10 GA. NO. 304 STAINLESS STEEL THERMAL SHIELD MAY BE INSTALLED BETWEEN THE OVERPACKS.

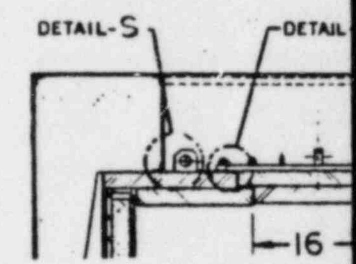
13. FLASKS FABRICATED PRIOR TO 3/84 MAY BE MADE USING ASTM-A36 MATERIAL. (FLASK BODY OUTER SHELL SHALL BE 1 1/8 IN. THICK, WITH FULL PENETRATION DOUBLE SIDED V GROOVE WELD FOR VERTICAL SEAM.)

14. AN AIR GAP OF .22 TO .28 INCHES SHALL BE MAINTAINED. THIS SHALL BE VERIFIED DURING FABRICATION VIA INPROCESS INSPECTION.

15. PACKAGE SHALL BE MARKED & IDENTIFIED IN ACCORDANCE WITH THE REQUIREMENTS OF 10 CFR 71.85(c)

16. PRIMARY & SECONDARY LIDS & DRAIN SHALL BE EQUIPPED WITH TAMPER INDICATING DEVICES IN ACCORDANCE WITH 10 CFR 71.43(b)

TOP VIEW SHOWING OPTIONA

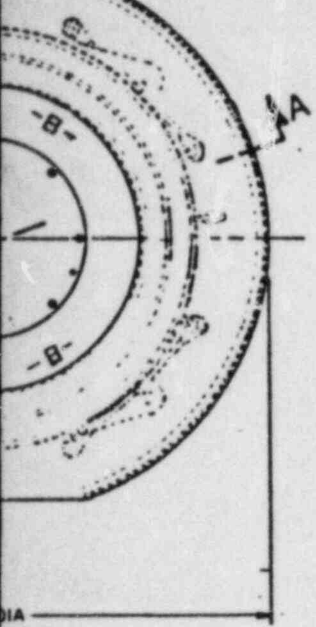


PARTIAL SECT A. A SHOWING OPTI

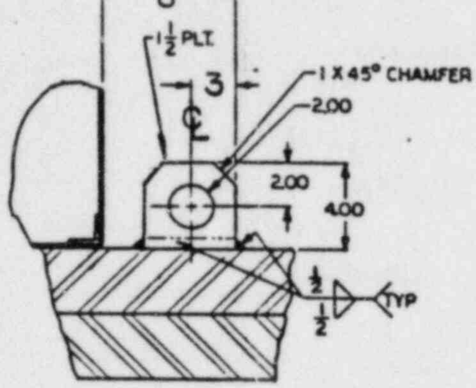
C B A

8 7 6 5

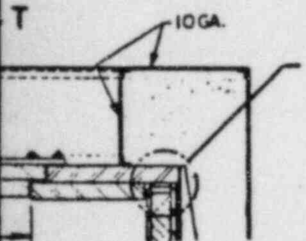
LTR	REVISIONS DESCRIPTION	DATE	APPROVED
E	SEE DCN	4-85	[illegible]



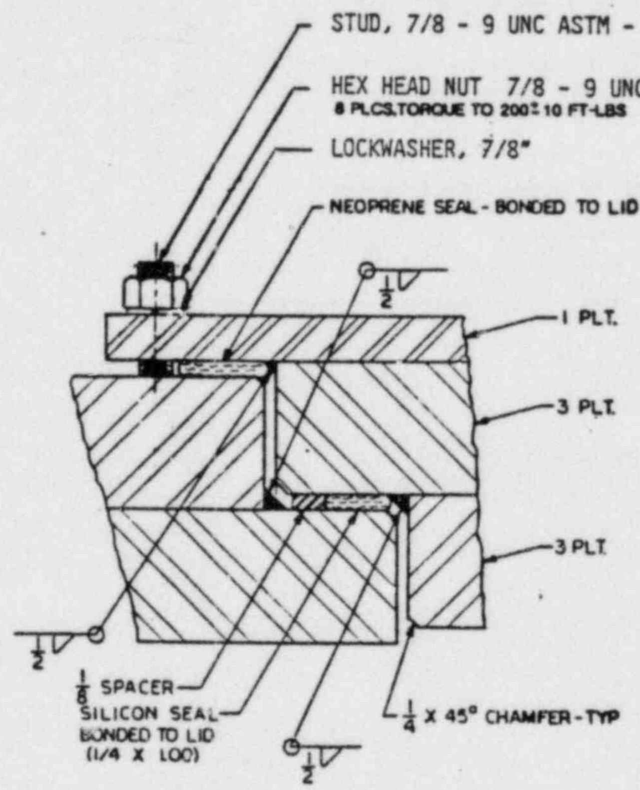
L 16" DIA SECONDARY LID



DETAIL - S



NAL 16" DIA SECONDARY LID



DETAIL - T

Also Available On Aperture Card

TI APERTURE CARD

8505290682-10

ITEM	PART NO	DESCRIPTION
	ASSEMBLY & QUANTITY	LIST OF MATERIAL

NUCLEAR PACKAGING
A Pacific Nuclear Company
FEDERAL WAY, WA

BULK RESIN SHIPPING FLASK
MODEL OH142 MK-I

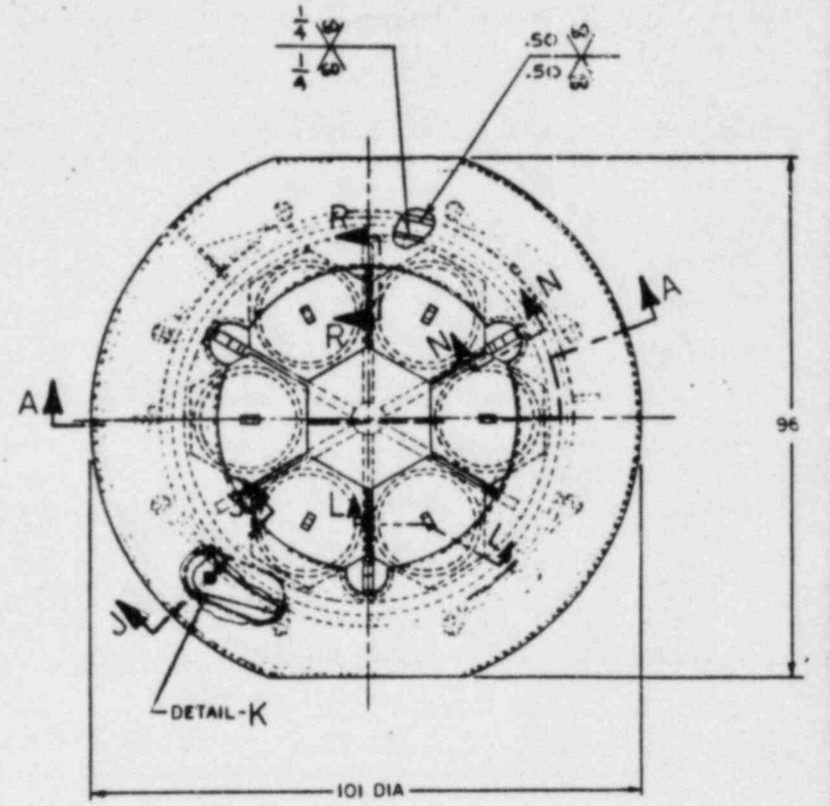
REL	[illegible]	4-31-85
APPD		
APPD		
APPD		
APPD		
QA	[illegible]	1/31/85
CHECK	[illegible]	
DRAWN	PEARSON	1-85

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: FRACTIONS ± ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ± 1 PLACE DECIMALS ±

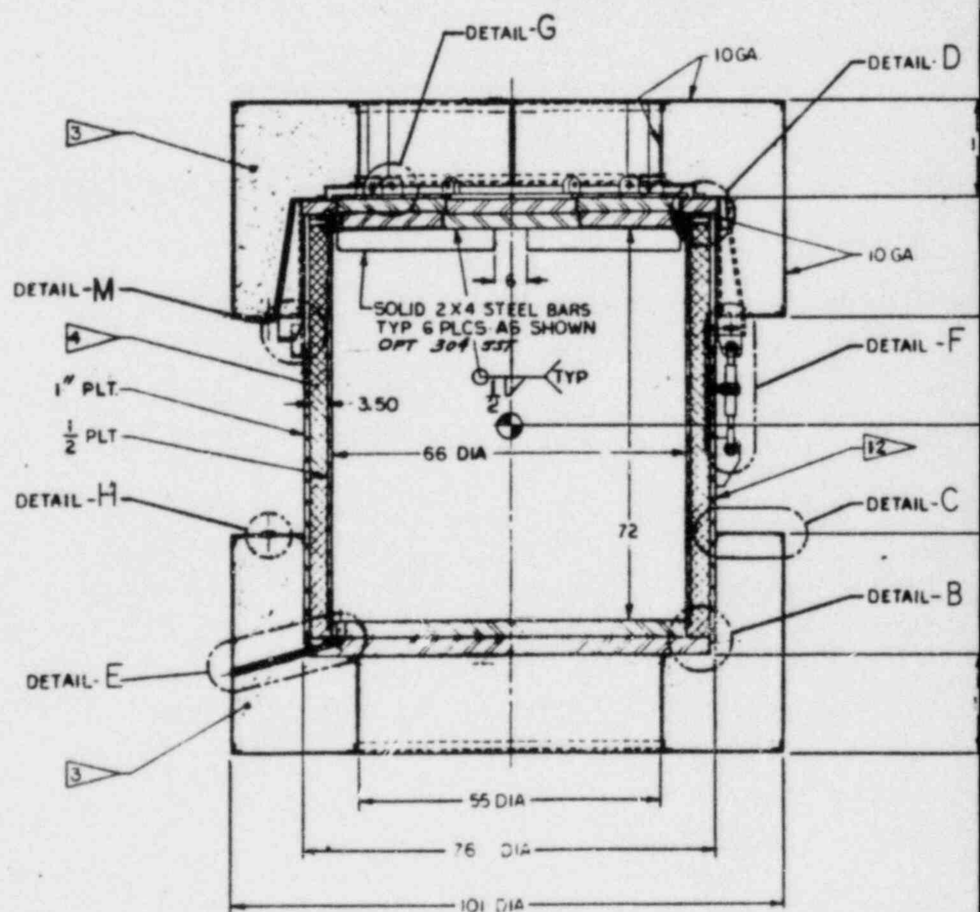
IT QTY | NEXT ASSY

SCALE	—	WT.	—
REV	F	SHEET	OF 3
DWG SIZE B	DWG NO. AL-20-202		

4 3 2 1

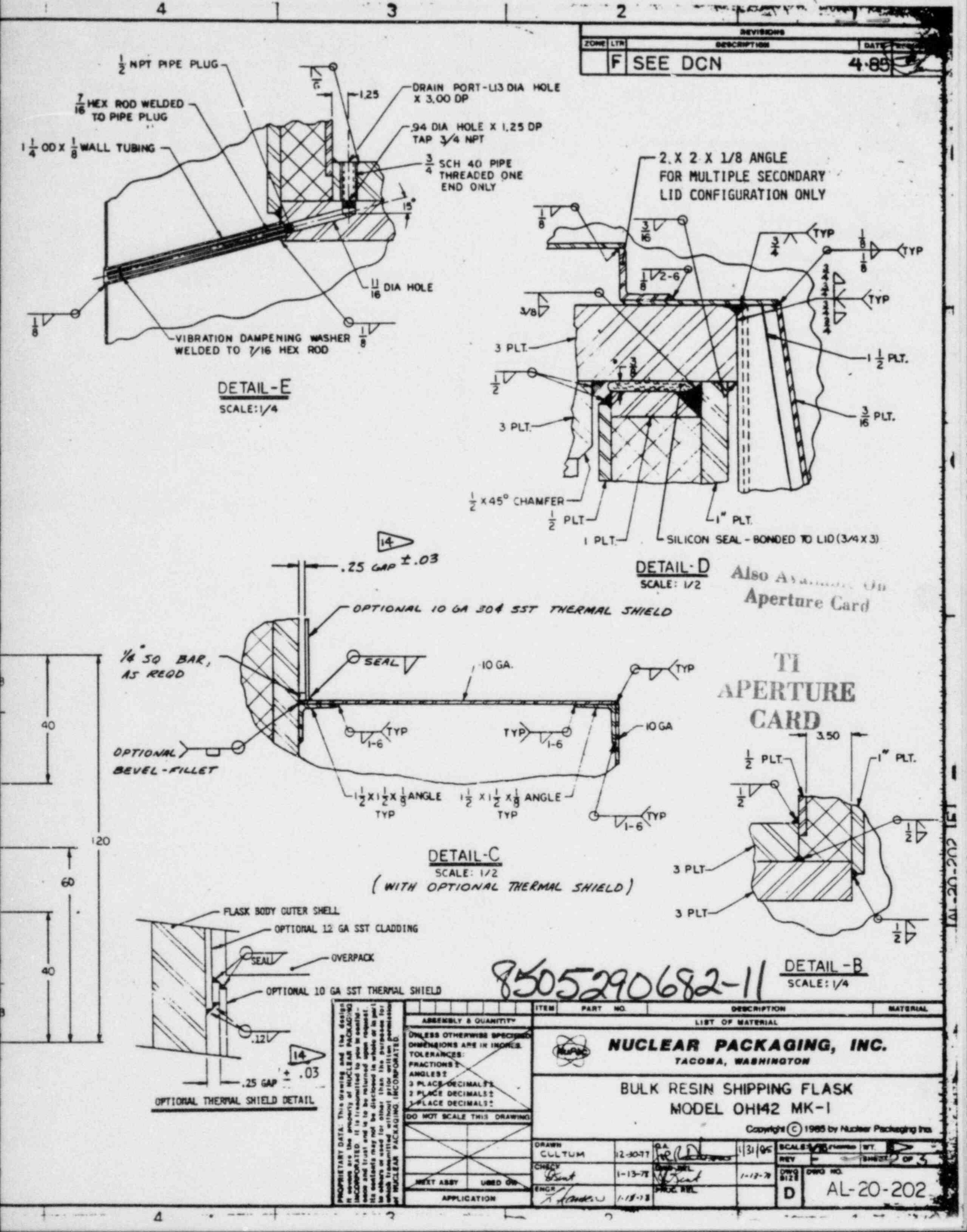


1/4
1/4
.50
.50
R
R
N
N
A
A
L
L
J
96
DETAIL-K
101 DIA



DETAIL-G
10GA
DETAIL-D
3
10 GA
DETAIL-M
SOLID 2 X 4 STEEL BARS
TYP 6 PLCS-AS SHOWN
OPT 304 SST
6
4
TYP
1" PLT
3.50
1/2 PLT
66 DIA
DETAIL-F
12
DETAIL-H
DETAIL-C
72
DETAIL-B
DETAIL-E
3
55 DIA
76 DIA
101 DIA

SECTION A-A



REVISIONS
ZONE LTR DESCRIPTION DATE
F SEE DCN 4-85
1/2 NPT PIPE PLUG
7/16 HEX ROD WELDED TO PIPE PLUG
1 1/4 OD X 1/8 WALL TUBING
DRAIN PORT-1.13 DIA HOLE X 3.00 DP
1.25
.94 DIA HOLE X 1.25 DP TAP 3/4 NPT
3/4 SCH 40 PIPE THREADED ONE END ONLY
15°
11/16 DIA HOLE
VIBRATION DAMPENING WASHER WELDED TO 7/16 HEX ROD
DETAIL-E
SCALE: 1/4
2 X 2 X 1/8 ANGLE FOR MULTIPLE SECONDARY LID CONFIGURATION ONLY
TYP
3 PLT.
1 1/2 PLT.
3/16 PLT.
1/2 X 45° CHAMFER
1/2 PLT
1" PLT.
1 PLT.
SILICON SEAL - BONDED TO LID (3/4 X 3)
DETAIL-D
SCALE: 1/2
Also Available On Aperture Card
TI APERTURE CARD
.25 GAP ±.03
OPTIONAL 10 GA 304 SST THERMAL SHIELD
1/4" SQ BAR, AS REQD
SEAL
10 GA.
OPTIONAL BEVEL-FILLET
1 1/2 X 1 1/2 X 1/8 ANGLE TYP
DETAIL-C
SCALE: 1/2
(WITH OPTIONAL THERMAL SHIELD)
3.50
1/2 PLT.
1" PLT.
3 PLT
DETAIL-B
SCALE: 1/4
40
120
60
40
FLASK BODY OUTER SHELL
OPTIONAL 12 GA SST CLADDING
OVERPACK
OPTIONAL 10 GA SST THERMAL SHIELD
.25 GAP ± .03
OPTIONAL THERMAL SHIELD DETAIL
8505290682-11
ITEM PART NO. DESCRIPTION MATERIAL
LIST OF MATERIAL
ASSEMBLY & QUANTITY
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NEXT ASSY USED ON
APPLICATION
NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON
BULK RESIN SHIPPING FLASK
MODEL OH142 MK-1
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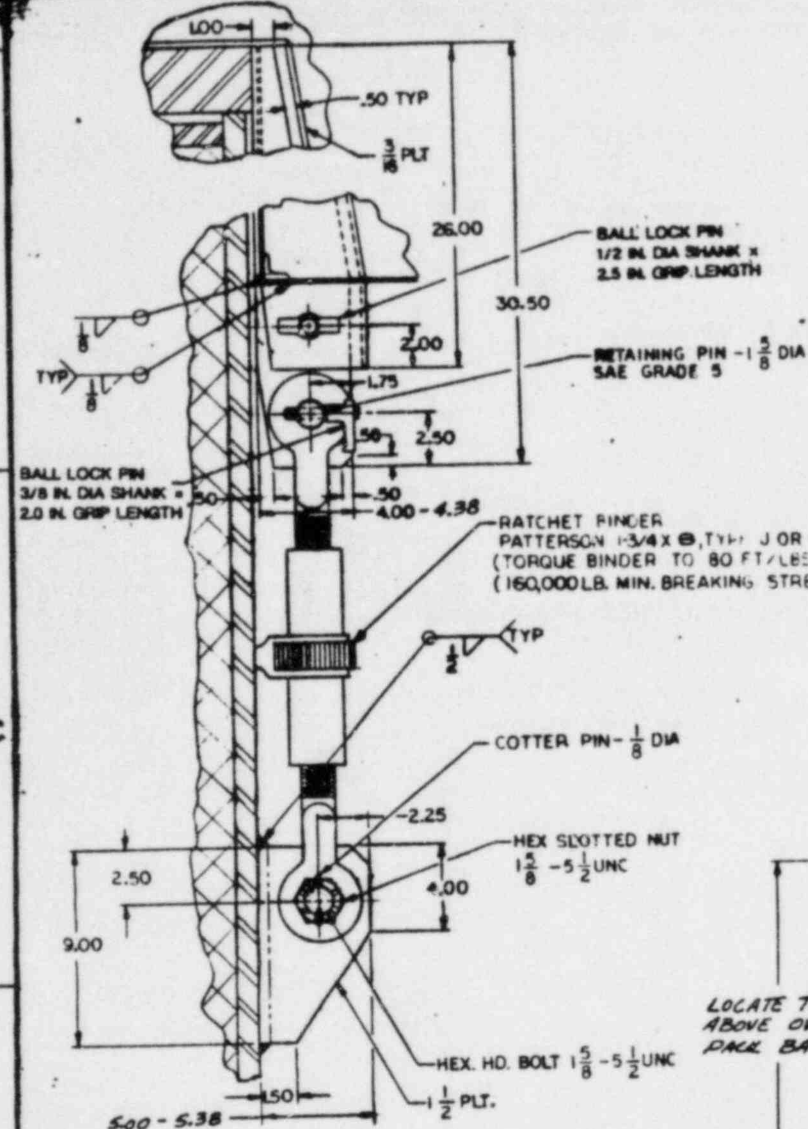
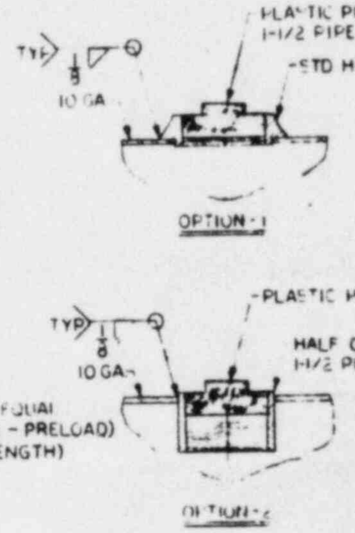
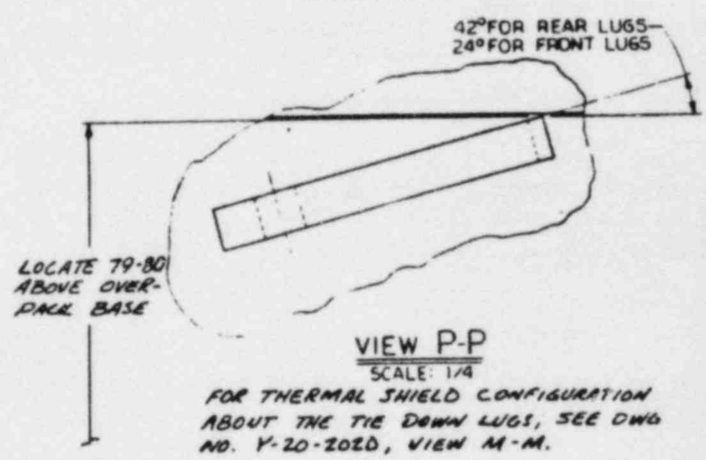
DRAWN CULTUM 12-30-77
CHECK 1-13-78
ENGR 1-18-78
1/31/85
1-13-78
SHEET 2 OF 3
DWG SIZE D
DWG NO. AL-20-202



DETAIL - F
SCALE: 1/4

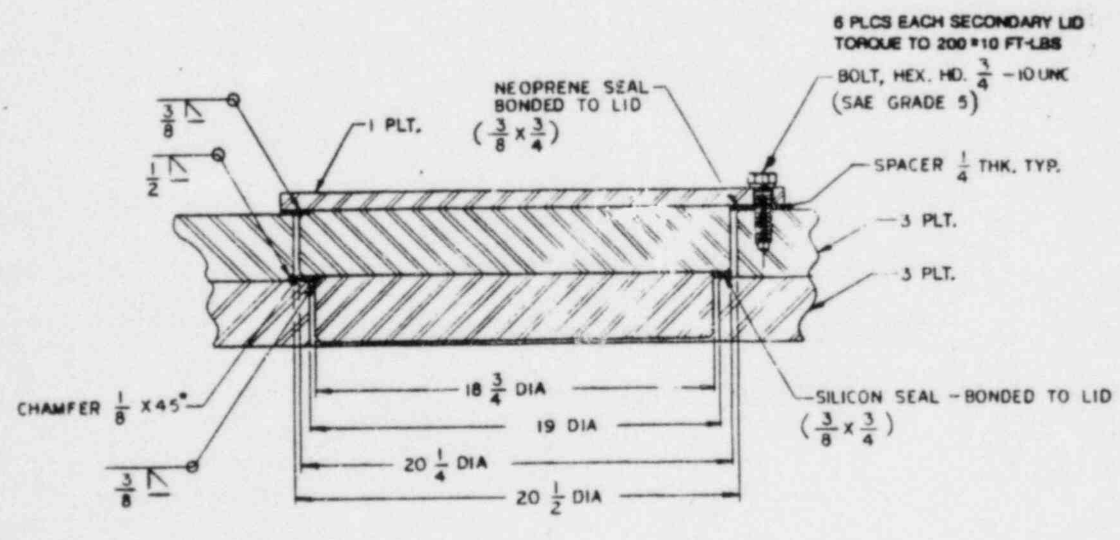


DETAIL - H
SCALE 1/2

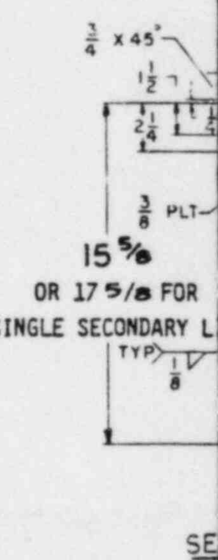


VIEW P-P
SCALE: 1/4

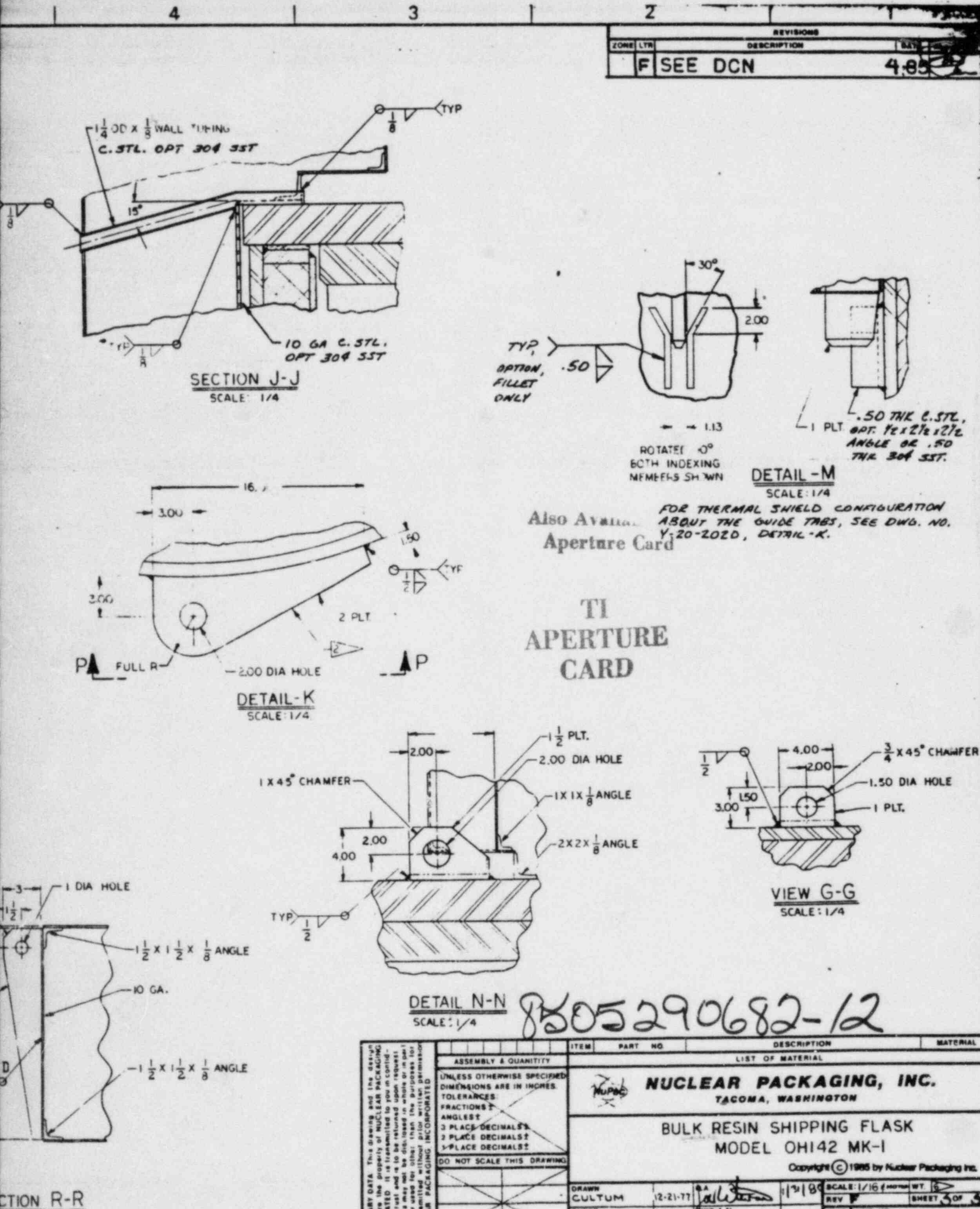
FOR THERMAL SHIELD CONFIGURATION ABOUT THE TIE DOWN LUGS, SEE DWG NO. Y-20-2020, VIEW M-M.



SECTION L-L
SCALE: 1/4



NOTES: UNLESS OTHERWISE SPECIFIED



Also Available On Aperture Card

TI APERTURE CARD

8505290682-12

ITEM	PART NO	DESCRIPTION	MATERIAL
		LIST OF MATERIAL	

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ASSEMBLY & QUANTITY

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DO NOT SCALE THIS DRAWING

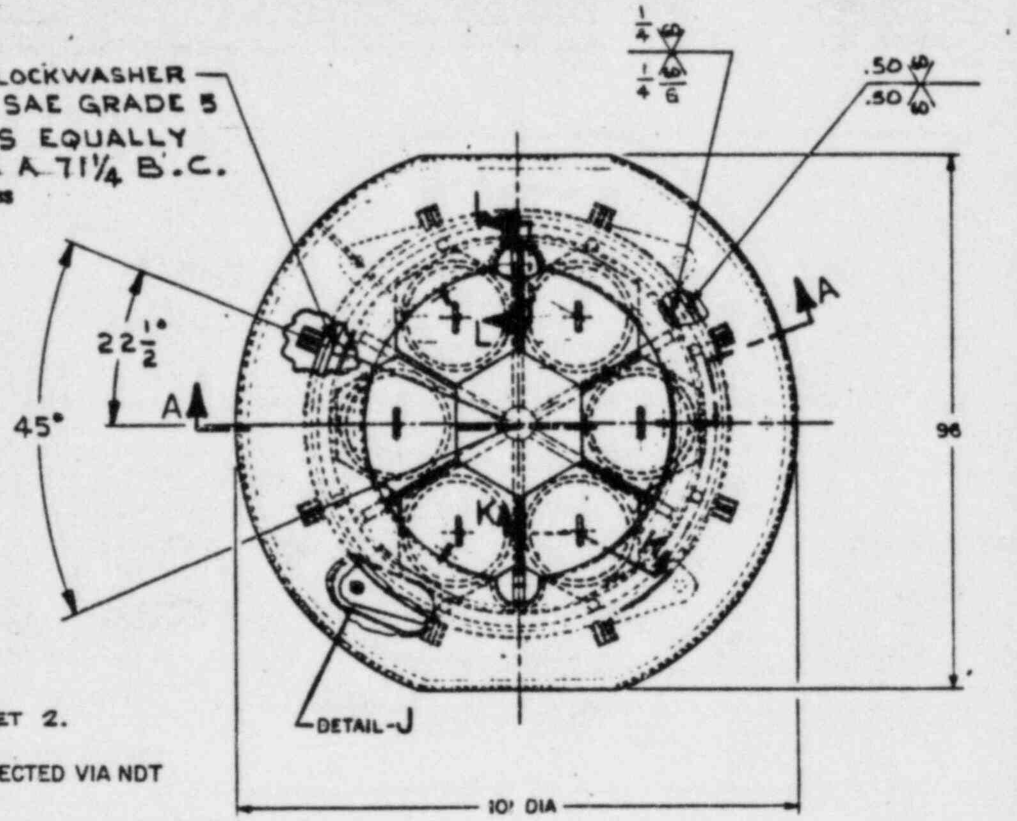
NEXT ASSY | USED ON — APPLICATION

NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON

BULK RESIN SHIPPING FLASK
MODEL OH142 MK-I

DRAWN CULTUM 12-21-77 | QA 1-13-78 | CHECK 1-13-78 | DWG REL 1-13-78 | ENGR 1-13-78 | PROD. REL

SCALE: 1/16 | WT | REV F | SHEET 3 OF 3 | SIZE D | DWG NO. AL-20-202

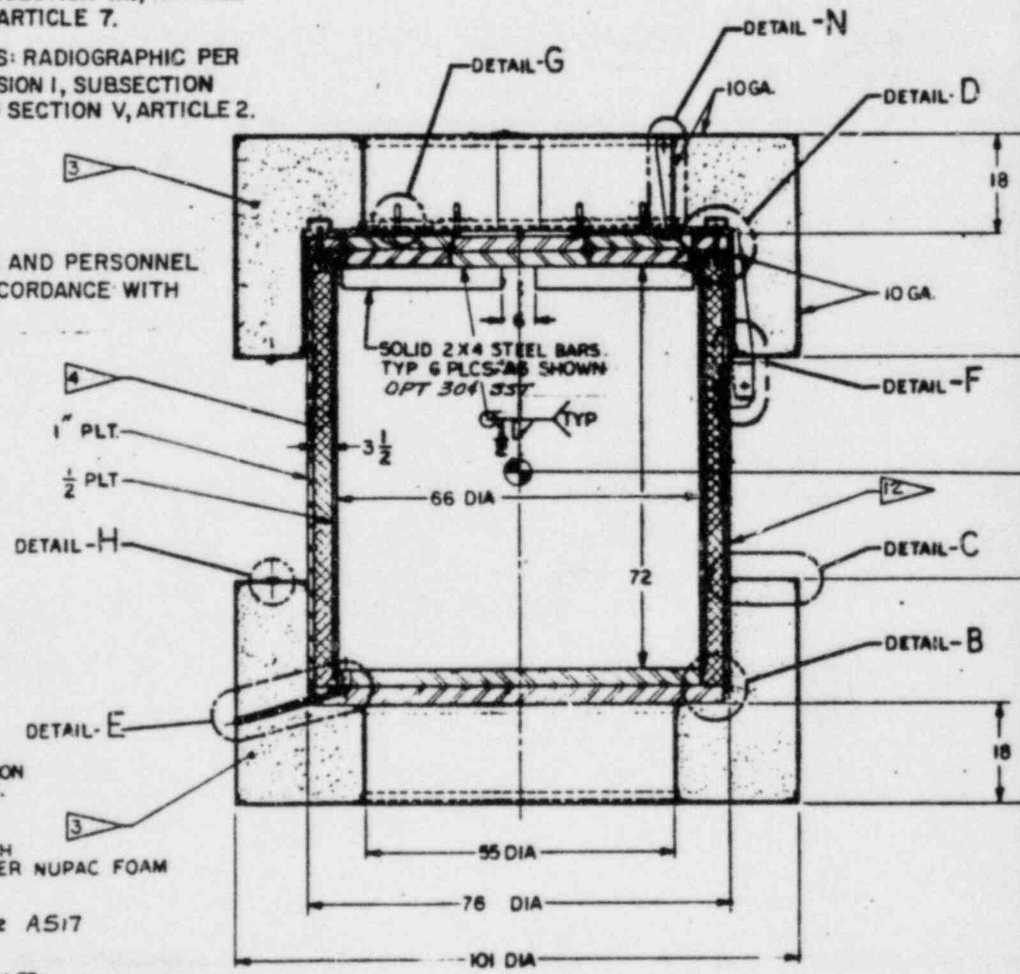


NOTES CONTINUE ON SHEET 2.

9. ALL WELDS SHALL BE INSPECTED VIA NDT METHODS AS FOLLOWS:

LIFTING LUGS AND CIRCUMFERENTIAL CONTINUOUS WELDS: MAGNETIC PARTICLE PER ASME CODE SECTION III, DIVISION I, SUBSECTION NB, ARTICLE NB-5000 AND SECTION V, ARTICLE 7.

LONGITUDINAL SHELL WELDS: RADIOGRAPHIC PER ASME CODE SECTION III, DIVISION I, SUBSECTION NB, ARTICLE NB-5000 AND SECTION V, ARTICLE 2.



8. ALL WELDING PROCEDURES AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME CODE, SECTION IX.

7 REMOVED

6 REFERENCE DATA:
CASK WT: 54,000LBS.
PAY LOAD: 10,000 LBS.
GROSS WT: 64,000LBS.

5. REMOVED

4 LEAD: PER FEDERAL SPECIFICATION QQ-L-171e, GRADE A OR C.

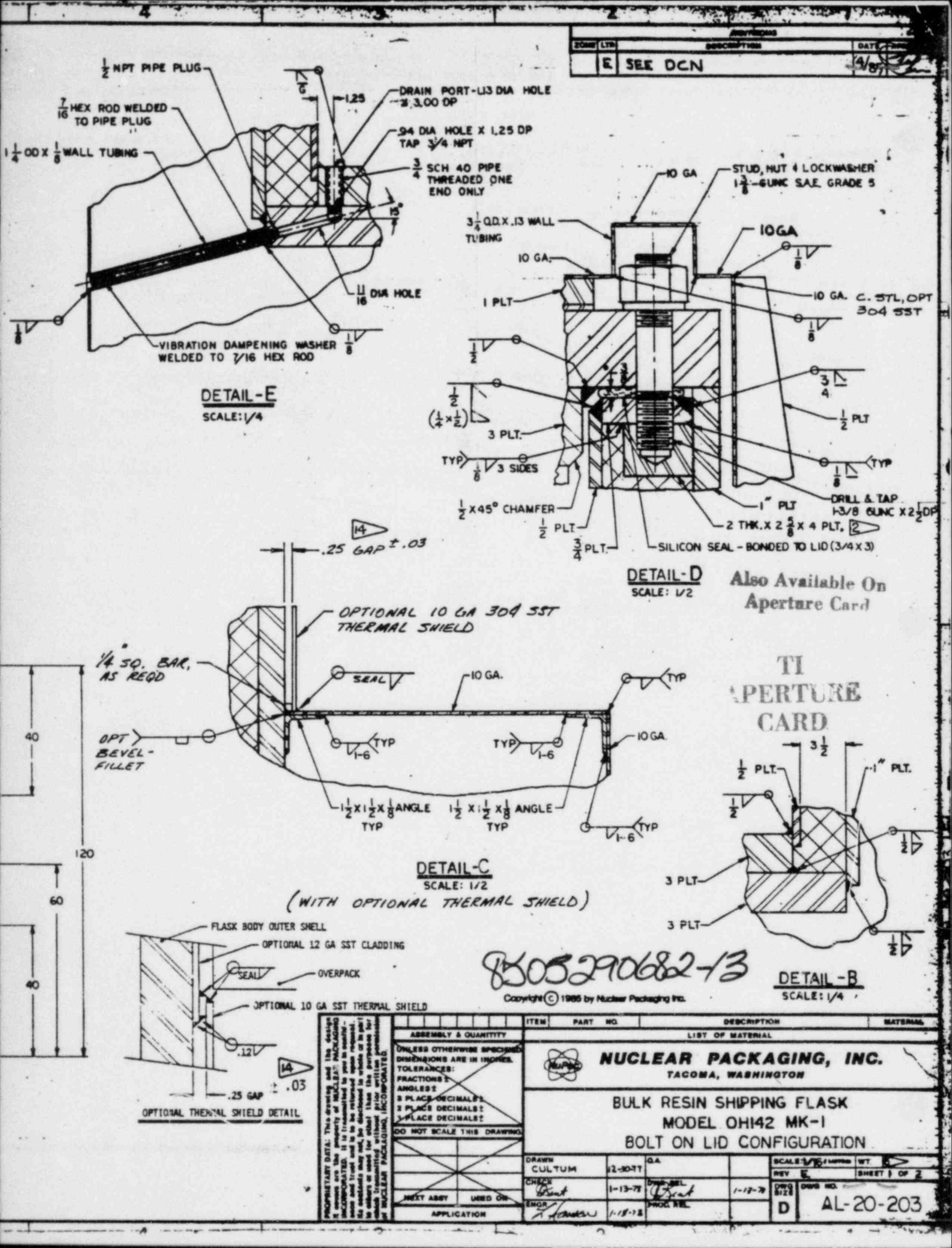
3 FOAM: 1,000 PSI CRUSH STRENGTH RIGID POLYURETHANE. PER NUPAC FOAM SPECIFICATION NPI-F6.

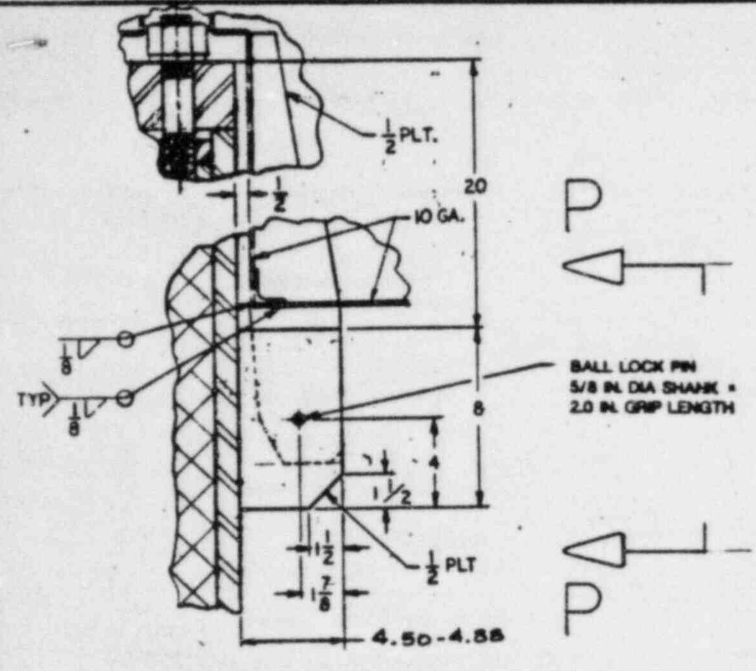
2 MATERIAL: ASTM-A514 or A517

1. MATERIAL: LOW CARBON HOT ROLLED
STEEL: PLATE & SHAPES CONFORM TO ASTM-A516, GR 70
: SHEETS CONFORM TO ASTM-A415, A36 or 304 SST PER ASTM-A240 WHERE NOTED.

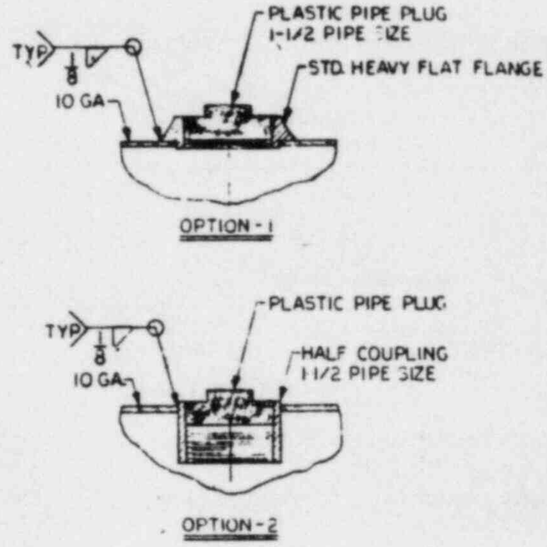
SECTION A-A

NOTES: UNLESS OTHERWISE SPECIFIED


REVISIONS
ZONE LTR DESCRIPTION DATE
E SEE DCN
1/2 NPT PIPE PLUG
7/16 HEX ROD WELDED TO PIPE PLUG
1 1/4 OD X 1/8 WALL TUBING
DRAIN PORT-1.13 DIA HOLE X 3.00 DP
1.25
.94 DIA HOLE X 1.25 DP TAP 3/4 NPT
3/4 SCH 40 PIPE THREADED ONE END ONLY
15°
11/16 DIA HOLE
VIBRATION DAMPENING WASHER WELDED TO 7/16 HEX ROD
DETAIL-E
SCALE: 1/4
10 GA
STUD, NUT & LOCKWASHER 1 3/8-6UNC S.A.E. GRADE 5
3 1/4 O.D. X .13 WALL TUBING
10 GA
10 GA.
1 PLT
10 GA. C. STL, OPT 304 SST
3/4
1/2 PLT
3 PLT.
TYP 1/8 3 SIDES
1/2 X 45° CHAMFER
1/2 PLT.
3/4 PLT.
1" PLT
2 THK. X 2 5/8 X 4 PLT.
SILICON SEAL - BONDED TO LID (3/4 X 3)
DRILL & TAP 1-3/8 6UNC X 2 1/2 DP
DETAIL-D
SCALE: 1/2
.25 GAP ±.03
OPTIONAL 10 GA 304 SST THERMAL SHIELD
1/4 SQ. BAR, AS REQD
SEAL
10 GA.
TYP
OPT BEVEL-FILLET
1-6
10 GA.
1 1/2 X 1 1/2 X 1/8 ANGLE TYP
1 1/2 X 1 1/2 X 1/8 ANGLE TYP
DETAIL-C
SCALE: 1/2
(WITH OPTIONAL THERMAL SHIELD)
40
120
60
40
FLASK BODY OUTER SHELL
OPTIONAL 12 GA SST CLADDING
SEAL
OVERPACK
OPTIONAL 10 GA SST THERMAL SHIELD
.12
.25 GAP ± .03
OPTIONAL THERMAL SHIELD DETAIL
3 1/2
1/2 PLT.
1" PLT.
3 PLT
3 PLT
DETAIL-B
SCALE: 1/4
8505290682-13
Copyright © 1985 by Nuclear Packaging Inc.
Also Available On Aperture Card
TI APERTURE CARD
ITEM PART NO. DESCRIPTION MATERIAL
LIST OF MATERIAL
ASSEMBLY & QUANTITY
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: FRACTIONS ± ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ± 1 PLACE DECIMALS ±
DO NOT SCALE THIS DRAWING
NEXT ASSY USED ON
APPLICATION
NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON
BULK RESIN SHIPPING FLASK
MODEL OH142 MK-I
BOLT ON LID CONFIGURATION
DRAWN CULTUM 12-30-77
CHECK 1-13-78
ENGR 1-18-78
REV E
SHEET 1 OF 2
SIZE D
DWG NO. AL-20-203



DETAIL - F
SCALE: 1/4

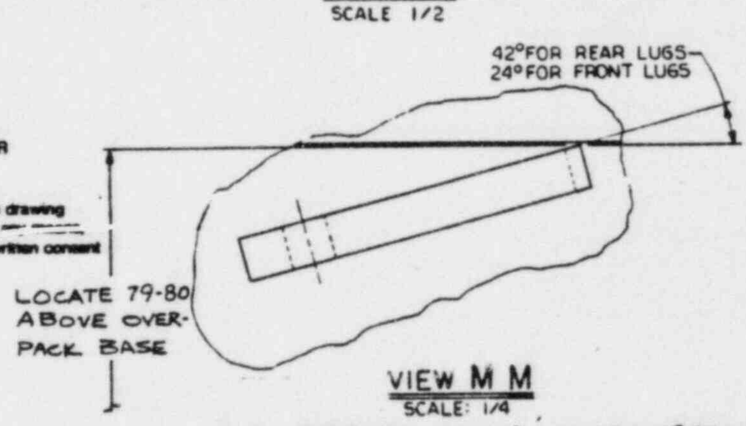


DETAIL - H
SCALE 1/2

17. PACKAGE SHALL BE MARKED & IDENTIFIED IN ACCORDANCE WITH THE REQUIREMENTS OF 10 CFR 71.85(c)

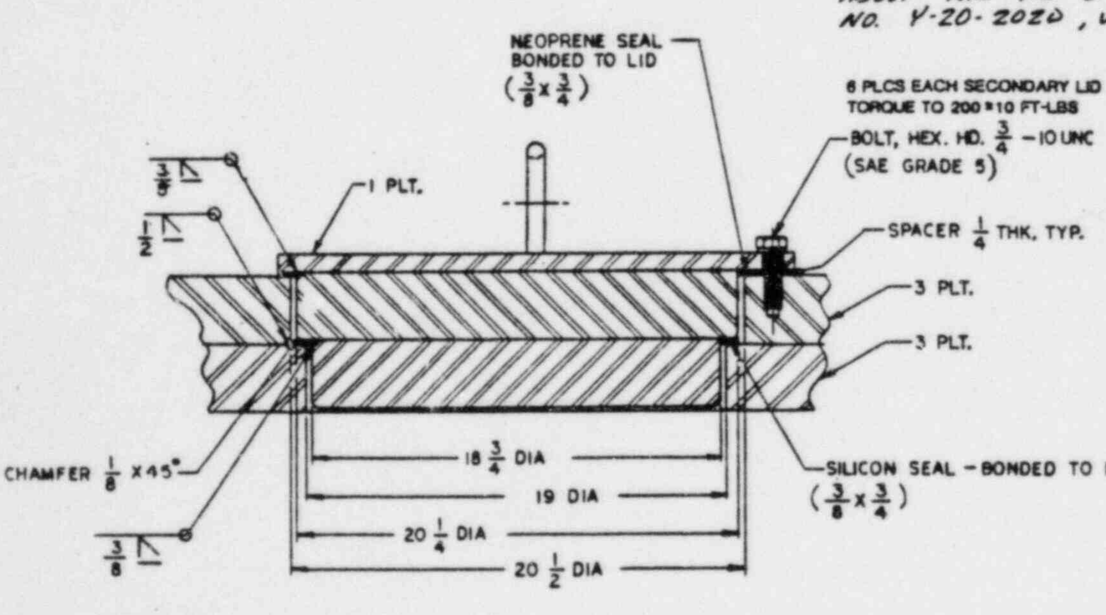
16. PRIMARY & SECONDARY LIDS & DRAIN SHALL BE EQUIPPED WITH TAMPER INDICATING DEVICES IN ACCORDANCE WITH 10 CFR 71.43(b)

NOTES: CONTINUED

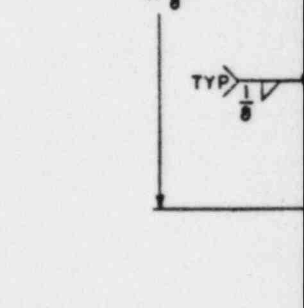


VIEW M M
SCALE: 1/4

FOR THERMAL SHIELD CONFIGURATION ABOUT THE TIE DOWN LUGS, SEE DWG. NO. Y-20-2020, VIEW M-M.



SECTION K-K
SCALE: 1/4



DETA
SCAL

14
13.
12.
11.
10.
NO

NOTES: UNLESS OTHERWISE SPECIFIED

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	E	SEE DCN		

AN AIR GAP OF .22 TO .28 INCHES SHALL BE MAINTAINED. THIS SHALL BE VERIFIED DURING FABRICATION VIA INPROCESS INSPECTION.

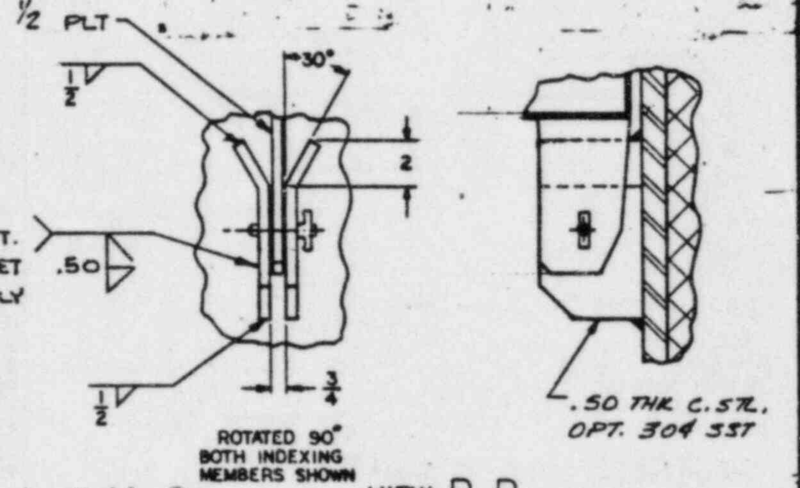
FLASKS FABRICATED PRIOR TO 8-84 MAY BE MADE USING ASTM-A36 MATERIAL. (FLASK BODY OUTER SHELL SHALL BE 1⅛ IN. THICK, WITH FULL PENETRATION DOUBLE SIDED V GROOVE WELD FOR VERTICAL SEAM.)

COAT ALL EXPOSED EXTERIOR SURFACES OF FLASK BETWEEN UPPER AND LOWER OVERPACKS WITH ONE (1) COAT (MIN 3/16 THK) "ALBI-CLAD" NO. 89. AS AN OPTION, A 10 GA. NO. 304 STAINLESS STEEL THERMAL SHIELD MAY BE INSTALLED BETWEEN THE OVERPACKS.

PAINT ALL EXPOSED CARBON STEEL SURFACES WITH ONE COAT CARBOZINC 11 & ONE COAT PHENOLINE 305, COLOR 727 M. GRAY, OR ONE PRIMER COAT (5 MILS) MOBIL CHEM EPOXY NO. 89W9 & ONE FINISH COAT (5 MILS) MOBIL CHEM EPOXY NO. 39W9, COLOR: WHITE.

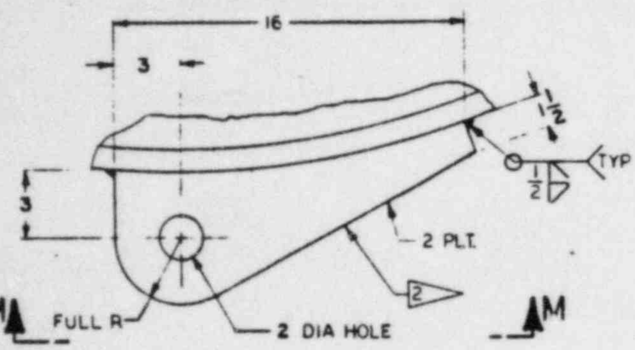
AS AN OPTION, 12 GA NO. 304 STAINLESS STEEL CLADDING MAY BE INSTALLED ON THE INTERIOR & EXTERIOR SURFACES OF THE FLASK BODY & INTERIOR SURFACES OF THE UPPER LID, & SEAL WELDED ALONG ALL EDGES & SEAMS.

TES: CONTINUED

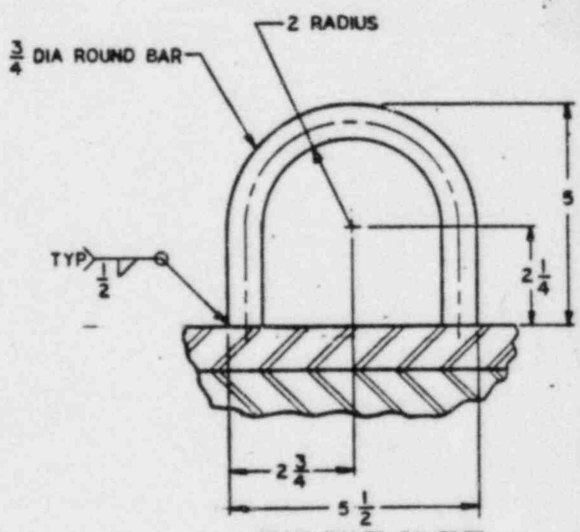


VIEW P-P
SCALE: 1/4

FOR THERMAL SHIELD CONFIGURATION ABOUT THE GUIDE TABS, SEE DWG NO. Y-20-2020, DETAIL K.

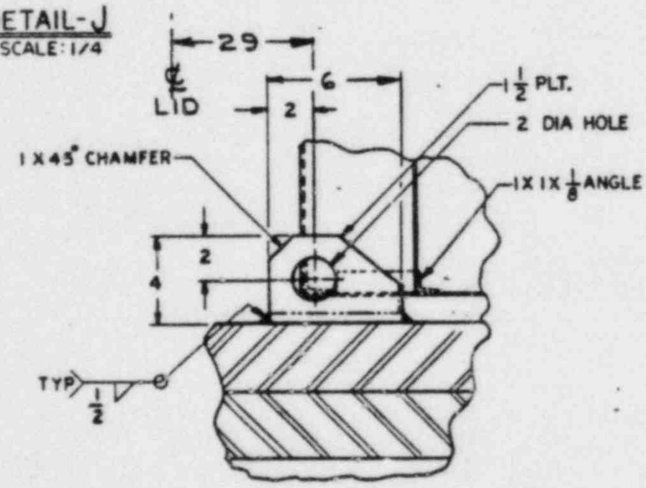


DETAIL-J
SCALE: 1/4

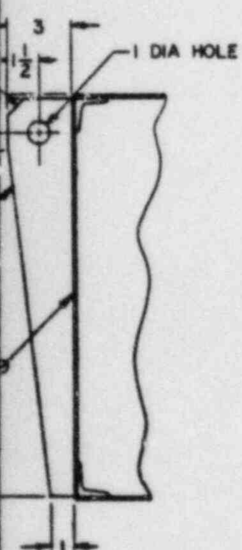


LIFTING BALES COVERED DURING TRANSPORT

DETAIL G-G
SCALE: 1/2



DETAIL L-L
SCALE: 1/4



IL-N
: 1/4

8505290682-14

ITEM	PART NO.	DESCRIPTION	MATERIAL

LIST OF MATERIAL

ASSEMBLY & QUANTITY

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: FRACTIONS ± ANGLES ± 3 PLACE DECIMALS ± 2 PLACE DECIMALS ± 1 PLACE DECIMALS ±

DO NOT SCALE THIS DRAWING

NEXT ASSY | USED ON
APPLICATION

NUCLEAR PACKAGING, INC.
TACOMA, WASHINGTON

BULK RESIN SHIPPING FLASK
MODEL OH142 MK-I
BOLT ON LID CONFIGURATION

DRAWN: CULTUM	12-21-77	Q.A.		SCALE: 1/16
CHECK: [signature]	1-13-78	DWG REL: [signature]	1-13-78	REV E — SHEET 2 OF 2
ENGR: [signature]	1-13-78	PROD. REL.		DWG SIZE D — DWG NO. AL-20-203

AL-20-203 E

2.0 THERMAL EVALUATION

A Thermal Analysis for the Model OH-142 packaging has been conducted and the results are described in Section 1.7.3, above.

3.0 CONTAINMENT

This chapter identifies the package containment for the normal conditions of transport and the hypothetical accident conditions.

3.1 Containment Boundary

3.1.1 Containment Vessel

The containment vessel claimed for the Model OH-142 package is the shielded transportation cask as described in Section 0.2 and the general arrangement drawing in Appendix 1.10.1.

The following is applicable exclusively to the OH-142, MK II.

The OH-142, MK II will be used to carry a heavy gauge steel liner with a capacity of approximately 120 cubic feet of ion exchange resin. The liner is a cylindrical container with .1340 inch thick walls and .1875 inch thick heads. Each liner is pressure tested to 22.5 psig.

During transport the liner will contain a maximum of 120 cubic feet of resin originating from the purification system. The size of the resin beads ranges from 0.4 - 0.6 mm in diameter. Type "B" overpacks are designed to provide containment of the radioactive material for normal and transportation accident conditions. The design of the OH-142 did not take credit for the liner inside the overpack. Thus, there is no containment credit for the liner.

The liner's structural integrity is such that it would most likely retain its contents in case of the hypothetical accident condition. The SAR considers only the cask as containment, which is a conservative position.

It has been demonstrated by calculations that the sealing arrangement is unaffected by accident conditions. For this reason, it is impossible that ion exchange resin, because of the size of the beads, could escape. Gaseous radioactivity could be present in the package and is considered to be the critical item in containment calculations.

Gaseous activity can arise from decay products of radionuclides carried in the ion exchange columns. The only radionuclide that decays to a gaseous radioactive material in the ion exchange resin is iodine which decays to the noble gas xenon. The iodine itself will be in the ionic form, therefore fixed on the ion exchange resin.

There are several isotopes of iodine. However, the only isotopes of relevance to this evaluation are I-131 and I-133. The other isotopes are either in very small quantities compared to I-131 and I-133 or they decay to products that are either stable or would not be in the vapour phase.

From the list of radionuclides shown it can be seen that the maximum anticipated I-131 content will be 1500 Ci. It was conservatively assumed that all other iodine is I-133. For the calculations, it is assumed that when the liner is shipped the above maximum will be jointly present. There would be no xenon present initially as a result of the dedeutoration process. The maximum possible xenon activities have been calculated using the following assumptions:

a) All gaseous fission products originally present in the spent IX resin are removed during the dedeuteration process which takes place on site prior to shipment.

b) Only the formation of xenon, from the decay of radioactive iodine. was considered.

c) Only two isotopes, viz I-131 and I-133, were felt to be of significance in this study. The others were ignored either because they decay to stable isotopes of xenon (eg., I-130, I-132 and I-134) or are expected to be present in negligible amounts (eg., I-135).

d) The xenon isotopes considered were Xe-131^{m}, Xe-133^{m} and Xe-133.

e) The processes of build-up and decay of each of these isotopes is such that their concentration in the resin

reaches a maximum value several days after dedeuteration. As is shown below, Xe-131^{m} achieves its maximum value after 13.98 days, Xe-133^{m} after 1.96 days and Xe-133 after 2.72 days. Although physically impossible, the maximum value of each isotope was assumed to exist concurrently in the resin and this was used in the safety assessment of the overpack.

The maximum activities are calculated to be:

2.7 Ci	of	Xe-131 (m)	after	13.98 days
48.3 Ci	of	Xe-133 (m)	after	1.96 days
177.0 Ci	of	Xe-133	after	2.72 days

The A_2 value, when considering several radionuclides, must reflect the mixture. The following equation is used to determine an A_2 value taking into account Xe-131(m), Xe-133 and Xe-133(m).

$$A_2 \text{ (mixture)} = \frac{\Sigma \text{ Ci}}{\Sigma \text{ (Ci}/A_2\text{i)}}$$

Where:

Ci - activity of each radionuclide

$(Ci/A_2)i$ - activity of each radionuclide divided by its A_2 value

The maximum activities calculated above for the radionuclides of concern are:

2.7 Ci of Xe-131 (m)
48.3 Ci of Xe-133 (m)
177.0 Ci of Xe-133

The individual A_2 values are 100 Ci for Xe-131 (m) and 1000 Ci for Xe-133. The A_2 value for Xe-133 (m) is based on a comparison with Xe-133. The effective gamma energy for Xe-133 (m) is 0.023 MeV while the effective gamma energy for Xe-133 is 0.0296 MeV.

Thus, A_2 for the mixture is:

$$A_2 = \frac{2.7 + 28.3 + 177}{\frac{2.7}{100} + \frac{48.3}{1000} + \frac{177}{1000}} = 904 \text{ Ci}$$

The permissible leak rate can be determined from ANSI-N14.5 "Leakage Tests on Packages for Shipment of Radioactive Materials".

a) For normal condition of transport:

$$R_N = A_2 \times 2.78 \times 10^{-10}$$
$$R_N = 904 \times 2.78 \times 10^{-10}$$
$$R_N = 2.51 \times 10^{-7} \text{ Ci/sec}$$

The free volume within the cask cavity is:

$V_T = 142 \text{ ft.}^3$

$V_R = 120 \text{ ft.}^3$ (Resin Volume)

V_V = 33% of resin volume is void

$= (.33)(120) = 40 \text{ ft.}^3$

$V_{Free} = V_T - V_R + V_V$

$= 62 \text{ ft.}^3 \text{ or } 1.75 \text{ m}^3$

The specific activity of the medium is:

$C_N(\text{Xe-131 m}) = 2.7 \text{ Ci}/1.75 \text{ m}^3 = 1.54 \text{ Ci/m}^3$

$C_N(\text{Xe-133 m}) = 48.3 \text{ Ci}/1.75 \text{ m}^3 = 27.60 \text{ Ci/m}^3$

$C_N(\text{Xe-133 }) = 177.0 \text{ Ci}/1.75 \text{ m}^3 = \underline{101.14 \text{ Ci/m}^3}$

TOTAL $C_N = 130.28 \text{ Ci/m}^3$

Permissible leak rate:

$L_N = R_N/C_N$

$= 2.51 \times 10^{-7} \text{ Ci/sec}/130.28 \text{ Ci/m}^3$

$= 1.92 \times 10^{-3} \text{ cm}^3\text{/sec}$

Test sensitivity is:

$\underline{S = L/2 \doteq 10^{-3} \text{ cm/sec}}$ (Normal)

b) For accident conditions:

$R_A = A_2 \times 1.65 \times 10^{-9} \text{ sec}$

$R_A = 904 \times 1.65 \times 10^{-9}$

$R_A = 1.47 \times 10^{-6} \text{ Ci/sec}$

Permissible leak rate is:

$L_A = 1.49 \times 10^{-6} \text{ Ci/sec}/130.28 \text{ Ci/m}^3$

$L_A = 1.14 \times 10^{-8} \text{ m}^3\text{/sec}$

$L_A = 1.14 \times 10^{-2} \text{ cm}^3\text{/sec}$

Test sensitivity is:

$$\underline{S \doteq L/2 = 5 \times 10^{-3}\ cm^3/sec}\ \text{(Accident)}$$

The OH-142 Cask has been designed to permit a leak test at any time necessary for the safe transport of radioactive material.

Radionuclides Carried Exclusively
in the OH-142 MK II

Based on analysis of resin samples, it is assumed that the following maximum activities could be present inside the OH-142 MK II.

Radionuclide	Activity (Curies)
Arsenic-76	15
Barium-140	30
Cobalt-60	300
Cobalt-58	30
Chromium-51	30
Copper-64	600
Cesium-134 and 137	3000
Iron-59	30
Iodine-131	1500
Iodine (not 131)	1650
Manganese-54	30
Manganese-56	180
Niobium-95	75
Sodium-24	15
Strontium-89	450
Strontium-90	15
Xenon	1200
Zinc-65	15
Zirconium-95	75

3.1.2 Containment Penetration

There are no penetrations into the containment vessel.

3.1.3 Seals and Welds

A silicone seal is placed between the primary lid to body interface. It is described in Section 0.2.1.3 above. All joints are arc welded with full penetration welds.

3.1.4 Closure

The closure devices for the lid consist of eight 1 3/4 inch diameter ratchet binders as described in Section 0.2 above.

3.2 Requirements for Normal Conditions of Transport

The following is an assessment of the package containment under normal conditions of transport as a result of the analysis performed in Chapters 1.0 and 2.0 above. In summary, the containment vessel was not affected by these tests. (Refer to Section 1.6 above).

3.2.1 Release of Radioactive Material

There was no release of radioactive material from the containment vessel.

3.2.2 Pressurization of Containment Vessel

Normal conditions of transport will have no affect on pressurizing the containment vessel.

3.2.3 Coolant Contamination

This section is not applicable since there are no coolants involved.

3.2.4 Coolant Loss

Not applicable.

3.3 Containment Requirements for the Hypothetical Accident Conditions

The following is an assessment of the packaging containment under the hypothetical accident conditions as a result of the analysis performed in Chapters 1.0 and 2.0 above. In summary, the containment vessel was not affected by these tests. (Refer to Section 1.7).

3.3.1 Fission Gas Products

Not applicable since there are no fissionable materials involved.

3.3.2 Release of Contents

The analysis performed in Chapters 1.0 and 2.0 above show that there is no release of radioactive material under the hypothetical accident conditions.

4.0 SHIELDING EVALUATION

4.1 Introduction

The Model OH-142 packaging consists of a lead and steel containment vessel which provides the necessary shielding for the various radioactive materials to be shipped within the package. (Refer to Section 0.2.3 for packaging contents). Tests and analysis performed under Chapters 1.0 and 2.0 above have demonstrated the ability of the containment vessel to maintain its shielding integrity under normal conditions of transport and hypothetical accident conditions. Prior to each shipment, radiation readings will be taken at the package surface and 2 meters from the package surface based on individual loadings to assure compliance with applicable regulations.

The OH-142 is intended for use with payloads of up to 400 watts (1365 BTU/HR) of internal decay heat. There are many forms of typical 400 watt payloads which will result in dose readings well below 200 mr/hr at the surface and 10 mr/hr at two meters from the cask surface. An example of such a payload is given below, and a simple point-kernal analysis is given to predict exterior dose rates.

4.2 Example Payload

Assume a payload of 400 watts of Cesium-137 concentrated at a point at the center of a concrete shell 6 inches thick at the center of the OH-142. The .662 MeV Gamma rays emitted from this

source would travel through 6 inches of concrete, 0.5 inches of steel, 3.5 inches of lead, and 1.125 inches of steel to get to the cask surface.

It is generally accepted that 207 curies of Cesium-137 is equivalent to 1 watt of internal decay heat. Therefore, 400 watts of Cs-137 is equivalent to:

(400 watts)(207 curies/watt) = 82800 curies

The number of .662 MeV Gamma rays emitted by this source can be found from the definition of a curie (3.7×10^{10} disintegration/second) and the fact that Cs-137 generates such a gamma ray in 85% of its disintegrations:

$$(82800 \text{ curies})(3.7 \times 10^{10} \text{ disint./sec/ci})(.85 \text{ gamma/disint}) = 2,604 \times 10^{15} \text{ gamma/sec}$$

From Blizard, Reactor Handbook, Volume III, Part B Second Edition, the photon (Gamma) flux through a multi-layered shield is

$$\emptyset_A = S\ B\ e^{(-\Sigma\mu t)}/4\pi R^2$$

where $\emptyset_A$ = Photon Flux at point in question

S = Photon Generation Rate

B = Dose Build-up Factor

μt = Number of mean free paths through material of mass attenuation coefficent μ and thickness t

R = Distance from source to point in question

The dose buildup factor, B, may be expressed in the Taylor form:

$$B = Ae^{\alpha(\Sigma\mu t)} + (1-A)e^{-\beta(\Sigma\mu t)}$$

where A, α, β = Experimentally derived factors dependant on material and Photon energy

Reactor Shielding for Nuclear Engineers, by N. M. Schaeffer, states that the outer most shield material greater than two mean free paths thick should be used for determining the coefficients A, α, and β.

For a .662 MeV Photon through concrete steel and lead, the following table applies (from Blizard):

SHIELD MATERIAL	μ (CM^{-1})	A	α	β
Concrete	.18060	11.598	.10202	.01305
Iron	.57343	9.452	.09252	.01851
Lead	1.16068	1.970	.03620	.24635

From this information, the following table may be built:

LAYER	MATERIAL	THICKNESS (IN./CM)	μt
1	Concrete	6.0/15.24	2.75
2	Steel	0.5/1.27	.73
3	Lead	3.5/8.89	10.32
4	Steel	1.125/2.86	1.65
		Σ 11.125/28.26	15.44

From the table above, it can be seen that the outer most shield material greater than two mean free paths thick is the lead. Therefore B may be determined as below:

$$B = 1.970\ e^{(.03620)(15.44)} + (1-1.970)e^{(-.24635)(15.44)}$$

$$= 3.4235$$

Then, the total flux at the surface of the outer shield is

$$R = 38.124(2.54) = 96.84\ \text{cm}$$

$$\emptyset_s = (2.604 \times 10^{15})(3.4235)e^{-15.44}/4\ (96.84)^2 = 14900\ \text{photons/cm}^2\text{-sec}$$

The flux at 2. meters (200 cm) from the surface is

$$\emptyset_{2m} = (2.604 \times 10^{15})(3.4235)e^{-15.44}/4\ (296.84)^2 = 1586\ \text{photons/cm}^2\text{-sec}$$

These photon fluxes may be converted to an equivalent radiation dose using a conversion factor, found in <u>A Handbook of Radiation Shielding Data</u>, ANS/SD-76/14, J. C. Courtney, Editor, for a phonton at .662 MeV, the conversion is 1.460×10^{-3} mrem/hr per phonton/sec-cm^2:

$$\text{DOSE} = (14900)(1.46 \times 10^{-13}) = 21.8\ \text{mrem/hr at the surface}$$

$$\text{DOSE} = (1586)(1.46 \times 10^{-3}) = 2.3\ \text{mrem/hr at 2 meters from the surface}$$

Dose margins of safety for this particular payload geometry are as below:

At the surface:

$$\text{M.S.} = \frac{200}{21.8} - 1 = +8.17$$

At 2 meters:

$$\text{M.S.} = \frac{10}{2.3} - 1 = +3.35$$

4.3 Discussion

The example payload geometry gives large positive margins of safety on shielding, demonstrating that internal heat loads of 400 watts or more may occur without violating cask external dose rate requirements. This particular geometry was chosen because of the relatively simple calculations required to analyze it. It is both conservative and unrealistic. Many very realistic geometries may occur which involve 400 watts of internal decay heat, but produce external dose rates well below regulatory requirements.

5.0 CRITICALITY EVALUATION

Not applicable for the Model OH-142 packaging.

6.0 OPERATING PROCEDURES

This section describes the general procedures to be used for loading and unloading the various configurations of the Model OH-142 packaging.

6.1 Procedures for Loading the Package

The following procedure assumes that the cask is in the loading area assembled in its over-the-road configuration. The cask may or may not be on the vehicle used to transport the cask over public roads.

6.1.1

Loosen and remove the ratchet binders which secure the primary lid. Inspect ratchet binders for thread wear. Inspect ratchet mechanism for proper operation. Replace any parts showing signs of wear, corrosion, or damage which could hamper proper operation or design strength. If the cask is to be loaded from the bottom (MK2), inspect ball-lock pins shown in Detail K of Y-20-202D for wear, corrosion and proper operation.

NOTE: The upper impact limiter is permanently affixed to the primary lid on the MK 0 (Baseline) and MK 2 configurations. On the MK 1 and MK 1 (Alternate) configurations, the primary lid and upper impact limiter can be removed separately.

6.1.2

Remove the lid by attaching suitable hooks to the primary lid lifting lugs. Care should be taken during the operation so as not to damage the lid to body interface seal while setting the lid down. For bottom loading operations (MK2), the entire cask body is removed from the bottom lid. The cask body should be set down only on flat, clean surfaces.

6.1.3

Inspect the inside of the shielded cask to assure there are no loose articles within the packaging. Inspect and clean seals attached to underside of lid. Brush off and clean thoroughly the seal to body interface. Replace seals upon signs of wear or deterioration.

6.1.4

Place the disposable steel liner into the cask. If the liner is significantly smaller than the internal cavity of the OH-142, sufficient shoring and/or bracing shall be provided to insure the payload will not shift significantly during shipment. For bottom loading operations, the secondary lid is removed per steps 6.1 through 6.1.8 below. The cask lid and body assembly is placed over the disposable liner and the liner held inside the cask body using appropriate hardware.

6.1.5

Replace lid and secure it to body by fastening the eight ratchet binders. Torque ratchet binders to 80-100 ft-lb torque. If the cask employs a bolt-on lid (MK I), primary lid closure bolts shall be torqued to 300 ± 25 ft-lbs. For bottom loading operations, the cask lid and body assembly with payload held inside the cask body is placed onto the bottom closure and the liner is released within the cask. The ratchet binders are secured as in all other configurations involving them.

6.1.6

If any loading of material is to be done through any of the secondary openings in the upper lid of the cask, the secondary lid nuts should be removed and Steps 6.1.7 through 6.1.9 shall be performed.

6.1.7

The lug in the center of the secondary lid may be used to remove the secondary lid from the cask. Care should be taken to avoid damage to the gasket in the lip of the secondary lid.

6.1.8

Inspect secondary lid studs, bolts and nuts for signs of wear. Damaged threads and excessive corrosion shall be cause for replacement of these items.

6.1.9

Load cask through secondary lid. Replace secondary lid and torque bolts to 200 ± 10 ft-lbs.

6.1.10

Survey the loaded cask to assure compliance with 10 CFR 71.47. Inspect for surface contamination per the requirements of 10 CFR 71.81(i).

6.1.11

If the shipment is not classified as Low Specific Activity material, a leak-test per 7.2.5.1 or 7.2.5.2 shall be performed if required by ANSI N14.5.

6.1.12

Inspect the package for proper labeling necessary to meet all applicable regulations.

6.1.13

Using suitable material handling equipment, transfer the package to the transport vehicle, if it is not already on the vehicle.

6.1.14

Check to see that the secondary lid lifting lugs are covered for transit.

6.1.15

Install an approved security seal.

6.1.16

Secure package to the transport vehicle using the appropriate tie down devices, if it is not already. If the cask had been previously secured to the vehicle, re-check all tie-down devices for proper security.

6.2 Procedures for Unloading the Package

6.2.1

The requirements of 10 CFR 20.205 shall be followed whenever greater than Type A quantities of RAM are received.

6.2.2

Move the unopened package to the appropriate unloading area. Place it in a suitable unloading attitude.

6.2.3

Perform an external inspection of the unopened package. Record any significant or potentially significant observations.

6.2.4

Remove the security seal.

6.2.5

Repeat steps 6.1.1 and 6.1.2 in Section 6.1, above, for removing the overpack lid.

6.2.6

Remove the disposable steel liner.

6.2.7

After unloading the entire package, the interior and exterior shall be visually inspected to assure that it has not been significantly damaged i.e., no cracks, punctures, holes or broken welds. The MK2 model may be unloaded from the bottom in a similar manner as described above, with appropriate modifications similar to those required for loading from the bottom.

6.2.8

The following configuration checks shall be performed after unloading and prior to any loading activity:

6.2.8.1 Exterior nameplates, stencils, placards and other required identification is in place and legible.

6.2.8.2 Latch pins, ratchet binders and gaskets are in place and in good operating condition and free of defects.

6.2.8.3 All required documentation is completed and retained/displayed as specified by the regulatory authority and the user.

7.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

7.1 Acceptance Tests

The Model OH-142 packaging shall be inspected and released for use by responsible operation personnel prior to loading. The following items will be included in such inspection:

7.1.1

Before first use, all OH-142 package configurations shall be subjected to the leak test appropriate to the configuration as described below in section 7.2.5.

7.1.2

All configuration checks described in section 6.2.8 above.

7.1.3

The cask shall be pressure tested to 1.5 times the normal operating pressure of the cask. This may be taken conservatively as the pressure given for the Hypothetical Accident Condition in Section 1.7.3.3. In that section, the pressure is given as 11.59 psig, so this test shall be carried out at 17.4 psig.

7.1.4

The integrity of the shield shall be demonstrated by means of a gamma scan performed on the lead-filled cylinder during the fabrication process. See Appendix 7.3 for a description of this procedure.

7.2 Maintenance Program

7.2.1

A good sound industrial maintenance program should be followed to assure the integrity of the Model OH-142 packaging. Components such as gaskets, latch pins, nuts, studs, bolts, and ratchet binders, shall be inspected prior to each use and repaired or replaced as necessary. A leak test will be performed when seals are replaced or when damaged seals are suspected. The test will be performed in accordance with Section 7.2.5 below.

7.2.2

As a minimum, sealing gaskets shall be replaced with new gaskets meeting the description in drawings shown in Section 1.10.1 Appendix every twelve (12) months (sooner if visible wear is detected).

7.2.3

Ratchet binders must work free and easy. Lubricate as required and replace if necessary.

7.2.4

Any damaged or lost fasteners will be replaced with the grade and strength fastener as shown on the drawings in Section 1.10.1 Appendix.

7.2.5

Before first use and whenever the gaskets are replaced, the leak test appropriate to the OH-142 configuration being used shall be conducted (see below). Regardless of condition, all gaskets shall be replaced every twelve (12) months.

7.2.5.1 In the case of the MK 1 and MK 1 (Alternate) configuration, the package should be tested to seven (7) psig and soap bubble tested in accordance with ANSI N14.5, Section A3.3. Gauge pressure shall be monitored through appropriate fittings in the drain port area. (See Dwg AL-20-202, Detail E or AL-20-203, Detail E).

7.2.5.2 In the case of the MK 0 (Baseline) and MK 2 configuration, the package should be leak tested utilizing a halogen detector type test in accordance with ANSI N14.5, Section A3.7. The halogen gases shall be introduced to the fully assembled package through appropriate fittings in the drain port area or a vent port, if so equipped. (See Dwg Y-20-201D, Detail F or Y-20-202D, Detail N).

7.2.5.3 The leak tests described in Sections 7.2.5.1 and 7.2.5.2 shall be performed at the Primary and Secondary seals and at all ports as appropriate for the particular OH-142 cask configuration. The acceptance criterion will be 10^{-3} std cm^3/s. Test sensitivity will be approximately 10^{-4} std cm^3/s.

7.3 APPENDIX

APPENDIX 7.3.1 DISCUSSION OF GAMMA SCAN PROCEDURE

Lead shielding integrity shall be confirmed via gamma scanning. There are two gamma scan techniques utilized. The main difference is in the method utilized to determine acceptance criteria.

Both Gamma Scan Techniques are exactly the same in all other respects and are conducted as follows.

An Eberline E120 probe or equivalent is used to scan the outer surface of the cask while an Iridium 192 or Cobalt 60 source of sufficient strength is present in the center of the cask. The source is first placed on the bottom of the cask while the surface is scanned around its circumference parallel to the source. The source is then moved up a pre-determined distance and the circumference scanned again. This sequence is repeated until the entire cask surface is scanned.

For these tests, the cask surface is gridded (in this case the grid consists of 4 inch squares) and a chart is made to reflect the gridded cask surface. Readings are taken from each grid square by scanning every point in the grid and recording the maximum reading in the corresponding grid on the chart. This data then serves as the raw gamma scan results. All readings are in Milliroentgens (MR).

The readings are evaluated by comparing them to predetermined MR values for nominal, or as designed, lead thickness and nominal -10% lead thickness.

The two different methods utilized to determine acceptance criteria are discussed below.

The Laboratory Calibration Method (NuPac Procedure GS-001) utilizes test blocks of the cask wall made up of lead and steel sheets. The test blocks simulate nominal or as designed and -10% lead thicknesses. The source is placed behind the test block at a distance equal to the inside radius of

the cask. The probe is then placed on the outside of the test block and readings are taken. This sequence is repeated on the nominal and -10% test blocks and the data is recorded.

The resultant values are then averaged. A ratio of the values is also developed. Then the average value is multiplied by the ratio. The value so derived is the maximum acceptable value for the shielding to be inspected.

The Field Calibration Method (NuPac Procedure GS-022) utilizes a specially fabricated test lid which incorporates a holder for various lead and steel sheet thicknesses. This fixture is installed onto the cask to be scanned. The test lid is then set up to simulate the nominal lead thickness, the source is placed below the test lid in the cask at a distance equal to the inside radius of the cask. Readings are then taken. The test lid is then set up to recreate the -10% lead thickness configuration, and readings are again taken. Other readings are then taken in 1/8 inch lead thickness increments between and beyond the two base readings until four to eight readings are obtained. The data is then plotted on a chart of readings versus lead thickness. The value for nominal lead -10% is then utilized as the maximum acceptable reading during the actual gamma scan.

8.0 QUALITY ASSURANCE

8.1 Organization

Full responsibility for the Quality Assurance (QA) Program adherence to 10CFR71, Appendix E criteria rests with NuPac. Some Quality Program activities are delegated to other organizations, i.e., calibration of measuring equipment, however, the responsibility of the control of quality in the other organizations continues to rest with NuPac.

The NuPac Quality Department has sufficient authority and organizational freedom to identify quality programs, implement corrective action and verify corrective action effectiveness.

Additionally, the Quality Department is independent from other organizations within NuPac and reports directly to the President of NuPac. The Quality Department is headed up by the Quality Manager who is responsible for the development, implementation and administration of the entire NuPac Quality Program. See Figure 2, "Organization Chart, Nuclear Packaging, Inc.".

The Quality Manager and all other quality personnel and/or organizations within, or utilized by NuPac, are fully qualified for their quality responsibilities. Qualification records are maintained in the NuPac Quality Record File.

8.2 Quality Assurance Program

NuPac has established and implemented the QA Program described herein. Training and/or evaluation of personnel qualifications are required for all QA functions in accordance with written procedure and are approved by the Quality Manager. The QA Program assures that all quality requirements, engineering specifications, and specific provisions of any package design approval are met. Those characteristics critical to safety are emphasized.

Nuclear Packaging, Inc. has developed a quality system to assure traceability and control the quality of all materials and processes utilized in the production of radioactive shielding, casks, containers, and other equipment pertaining to shipping packaging for irradiated fuel, high level waste and plutonium.

The Quality Manual delineates requirements and procedures necessary to exercise control over design, documentation, procurement, material, fabrication, inspection, inventory, shipment and quality data retention.

NuPac Quality System and implementing Quality Procedures are designed and administered to meet the 18 criteria of 10CFR71, Appendix E. Figure 1 is a matrix delineating the relationship between the 17 NuPac Quality Procedures and the 18 10CFR71, Appendix E criteria.

8.3 Design Control

NuPac Quality Procedures (QP's) have been developed, approved, and implemented to control design review in such a manner to assure that the following occur:

(a) Design activity is planned, controlled and documented.

(b) Regulatory and design requirements are correctly translated into specifications, drawings and procedures.

(c) Design documents contain quality requirements.

(d) Deviations from quality requirements are controlled.

(e) Designs are reviewed to assure adequate design verification activities, i.e.; stress, thermal, accident analysis, etc., are performed and that design characteristics can be controlled, inspected and tested, and that acceptance criteria are identified.

(f) Interface control is established and adequate.

(g) Design and specification changes are reviewed and approved by the same organization(s) as the original issue.

(h) Design errors and deficiencies are documented and corrective action to prevent recurrence is taken.

(i) Design organization(s) and their responsibilities and authorities are delineated and controlled via written procedure.

8.4 Procurement Document Control

The NuPac QA Program assures that all purchased material, components, equipment and services adhere to design specifications.

Supplier evaluation and selection, objective evidence of supplier quality, assignment of quality requirements to procurement documents and related design documents, and source, in-process and receiving inspection are all administered and controlled in accordance with approved NuPac QA procedures.

8.5 Instructions, Procedures and Drawings

Quality planning is developed for all activities requiring quality participation in accordance with approved NuPac QA procedures by qualified Quality Engineers (QE's) and are approved by the Quality Manager.

All design documentation, i.e., drawings, specifications, special processes, etc. affecting quality are reviewed by the Quality Department and referenced in quality planning as necessary to assure adherence to package design approvals and the applicable criteria of 10CFR71, Appendix E.

8.6 Document Control

Policy and procedure for review, approval, release and change control of all controlled, quality related documents are delineated in approved NuPac QA Procedures. Provisions are provided in the QA Procedures for identification of individuals/organizations responsible for review, approval and issuance of documents. Document control responsibilities, facilities and distribution requirements are also addressed.

Controlled documents include, but are not limited to:

(a) Design specifications;

(b) Design and manufacturing drawings;

(c) Special process specification and procedures;

(d) Procurement documents;

(e) QA Procedures and manuals;

(f) Quality Planning for receiving, in-process and source inspection;

(g) Source Surveillance and evaluation reports;

(h) Test procedures;

(i) Audit Reports.

8.7 Control of Purchased Materials, Parts and Components

Procurement documents are reviewed for acceptability of suggested suppliers based on the NuPac approved supplier lists. In addition, and as required, supplier surveys are conducted to further assure supplier acceptability.

Quality requirements and standard clauses are added to procurement documents to require suppliers to identify material, provide test reports, control special processes, certify equipment and personnel, etc.

Quality planning is prepared and approved by the Quality Department for performance of source and receiving inspections in accordance with package design approval requirements and applicable 10CFR71 criteria.

All described activity is delineated in approved NuPac QA Procedures.

8.8 Identification and Control of Materials, Parts and Components

The identification and control of materials, parts, components and completed and in-process assemblies is administered by the Quality Department in accordance with approved NuPac QA Procedures. These procedures address quality status tags, maintenance of material identification and traceability, part identification, and related documentation.

8.9 Control of Special Processes

NuPac approved QA Procedures delineate the policies and procedures established to control such special processes as: welding, heat treating, lead pouring, non-destructive examination, etc., in accordance with applicable codes, standards, specifications, 10CFR71

criteria and other requirements. Special processes developed by NuPac suppliers and by NuPac are documented. These documents are controlled as described in Section 8.6.

8.10 Inspection

All receiving, source and in-process inspection activities are performed in accordance with approved NuPac QA procedures. All inspection personnel and/or organization qualifications are reviewed and accepted by the Quality Manager prior to inspection activity. The inspection activity is performed in strict accordance with approved quality planning prepared by qualified QE personnel (see also Section 8.5.

Mandatory hold points, inspection equipment requirements, accept/reject criteria, personnel requirements, characteristics to inspect, variables/attributes recording instruction, reference documentation and other requirements are included in the inspection planning.

8.11 Test Control

A test control program as it applies to quality is addressed in approved NuPac QA Procedures and assures, via required planning, that all required testing, such as proof and acceptance tests are identified and performed in accordance with test procedures, design requirements and limitations. Prerequisites, accept/reject criteria, data recording criteria, instrumentation calibration, environmental

conditions, documentation and evaluation requirements, etc. are delineated in the test procedures and changes to the test procedures are required to be reviewed/approved by the same organization(s) as the original issue.

8.12 Control of Measuring and Test Equipment

Administration of the calibration of measuring equipment and instrumentation is performed by the Quality Department in accordance with approved NuPac QA Procedures. The calibration system assures that all standard measuring instruments (SMI) are calibrated and properly adjusted at specified intervals to maintain accuracy within predetermined limits. Calibration is performed using equipment traceable to national standards. All calibrated equipment is statused, identified and controlled in such a manner as to meet the requirements of 10CFR71, Appendix E, Section 8.12.

8.13 Handling, Shipping and Storage

NuPac approved QA Procedures require that handling, storage and shipping requirements adherence verification criteria be included in quality planning. These requirements are designed to prevent damage or deterioration of material and equipment. Information pertaining to shelf life, environment, packaging, temperature, cleaning, handling, presevation, etc., is included as required to meet design, NRC package approval and/or U. S. Department of Transportation shipping requirements.

Shipping documentation preparation, departure and arrival time and destination data recording is also addressed in the planning when applicable.

8.14 Inspection, Test and Operating Status

The use of inspection status tags, quality inspection stamps and other means to indicate inspection and test status at or for NuPac are delineated in approved NuPac QA Procedures.

The clarity of the status indication, prevention of inspection and/or test step by passing and prohibition of removal or modification of status indications, except with Quality Department approval/Material Review disposition is assured via these procedures. See also Section 8.15.

8.15 Non-conforming Material, Parts or Components

NuPac approved QA Procedures require that material, components and equipment that do not conform to requirements are controlled to prevent their inadvertent use. Identification, segregation, discrepancy reporting, dispostion of non-conformances by authorized individuals and reinspection activities are performed and controlled in strict accordance with these procedures.

8.16 Corrective Action

Failures, malfunctions and deficiencies in material, components, equipment and services are identified and reported to the Quality Manager and the President. The cause of the condition and corrective action necessary to prevent recurrence is identified, implemented and then followed up to verify corrective action effectiveness. Detail requirements for this activity is delineated in approved NuPac QA Procedure.

8.17 Quality Assurance Records

A quality records system is in effect at NuPac and is administered in accordance with approved NuPac QA Procedures. The purpose of the quality record system is to assure that documented evidence pertaining to quality related activities is maintained and available for use by NuPac, its customers, and/or regulatory agencies, as applicable. Quality Records include, but are not limited to, inspection and test records, audit reports, quality personnel qualifications, design reviews, quality related procurement data, supplier evaluation reports, etc. Retention times and record protection requirements are also delineated.

8.18 Audits

Quality program audits are performed on a periodic, scheduled basis. Written planning sheets and check lists are utilized.

Audit results and corrective action activity are reported to management, in writing, and are retained in the quality assurance record files. Current NuPac practice is to audit all quality functions on an annual basis. Details of the NuPac Audit System are delineated in approved NuPac QA Procedures.

QUALITY REQUIREMENTS MATRIX

10 CFR VS NuPac

10CFR50, Appendix B 10CFR71, Appendix E	NuPac Quality Manual
I. Organization	Quality Program & Organization Chart QP 1 - Quality Control Manual QP 14 - Quality Assurance Training
II. Quality Assurance Program	Same As Above
III. Design Control	QP 2 - Design Review QP 15 - Engineering Holds QP 17 - Design Control
IV. Procurement Document Control	QP 4 - Procurement Control QP 15 - Engineering Holds
V. Instructions, Procedures and Drawings	QP 3 - Document Control QP 5 - Quality Planning QP 15 - Engineering Holds
VI. Document Control	QP 3 - Document Control QP 15 - Engineering Holds
VII. Control of Purchased Material, Equipment and Services	QP 4 - Procurement Control QP 12 - Material Control
VIII. Identification and Control of Materials, Parts and Components	QP 3 - Document Control QP 12 - Material Control

IX.	Control of Special Process	QP 4 - Procurement Control QP 5 - Quality Planning QP 6 - Inspection and Verification QP 16 - Special Process Qualifications and Control
X.	Inspection	QP 6 - Inspection and Verification
XI.	Test Control	QP 5 - Quality Planning QP 6 - Inspection and Verification QP 15 - Engineering Holds
XII.	Control of Measuring and Test Equipment	QP 11 - Calibration Control
XIII.	Handling, Storage and Shipping	QP 12 - Material Control
XIV.	Inspection, Test and Operating Status	QP 6 - Inspection and Verification
XV.	Nonconforming Materials, Parts, or Components	QP 7 - Discrepancy Reporting and Control
XVI.	Correction Action	QP 8 - Corrective Action
XVII.	Quality Assurance Records	QP 1 - Quality Control Manual QP 9 - Quality Records QP 10 - Quality Forms Control
XVIII.	Audits	QP 13 - Audits

EXHIBIT A

ORGANIZATION CHART

NUCLEAR PACKAGING INCORPORATED