Westinghouse Electric Corporation
3 Gateway Center
Box 2278, Pittsburgh, Pa. 15230

January 30, 1968

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

Attention: Mr. Donald A. Nussbaumer, Chief
Source and Special Nuclear Materials Branch

Subject: Application for Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages

For Div of Compliance

Gentlemen:

The Westinghouse Electric Corporation hereby requests amendments to the subject license to authorize the delivery of special nuclear material to a carrier for transport in the packagings described in our application dated November 18, 1966, as revised by our transmittals of May 25, 1967, December 8, 1967, December 12, 1967 and the attachment to this letter.

Please send the amendments to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect, (412) 255-3907.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

Attachment: License

7 copies transmitted

ITEM # 58 From CO - Hdqrs.

(12)

321

SNM-338
Shipping - NFD
1/30/68

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder, "Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages," immediately in front of the last previous transmittal letter, dated December 15, 1967.

Revised pages 7, 9, 11, 13, 16, 17, 20, 28 and 29 should be inserted in the binder and the old pages removed. The revised tabular page of Appendix K should be inserted and the old page removed.

The removed pages may be filed in the back of the binder.

REVISION RECORD (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
5	9/11/67	3	Added Section 14 and Appendix J
5	9/11/67	35-40	Added BB 300-1 package
5	9/11/67	Appendix J	Added
6	9/26/67	25-26	Added Spc. Pkg. for Zorita Spc. Assy's
7	11/3/67	40	Added Spc. Pkg. for Selni Rod Shipments
7	11/3/67	41-42	New
8	12/8/67	42	Added RCC-1 package
8	12/8/67	43	New
8	12/8/67	Appendix K	Added
9	12/12/67	15	Inserted reference to Drawing SKA-219
9	12/12/67	Appendix B	Added Drawing SKA-219
10	12/15/67	34-40	Revised Section 14 to describe BB-250-1 packaging and testing
10	12/15/67	Appendix J	Drawing revised
11	1/30/68	9 and 16	Added requirement that computed k_{eff} values be adjusted
11	1/30/68	11,13,17 & 20	Changed to read "adjusted k_{eff}"
11	1/30/68	28	Added paragraph on nuclear safety referencing General Criticality Standards section
11	1/30/68	29	Revised Package Array Evaluation section. Added details on calculations.
11	1/30/68	Appendix K	Decreased Max. Enrichment. Eliminated need for Poison Pl.

4.1 (continued - RCC)

method of poison plates in the packaging, when the poison plates are required.

Coolants - Not applicable.

4.2 Contents Description

Radioactivity - Not applicable.

Identification and Enrichment of SNM - The SNM will be unirradiated uranium enriched $\leq$ 5 w/o in the isotope U-235.

Form of SNM - The SNM will be in the form of clad fuel assemblies. Specific data on maximum assembly parameters are included in Appendix A. The reactivity values listed in Appendix A equal the computed reactivity adjusted by a factor to provide for the probable error in the calculations. The contents will be loaded in such a fashion that if the package were to be flooded and subsequently drained, any water which may have penetrated the contents would drain simultaneously.

In the clad form, the assemblies will not disruptively react or decompose at the Accident Thermal condition. No chips, powders, or solutions will be offered for transport in this packaging.

4.2 (continued - RCC)

design of the lifting lugs will be such that, under an excessive load, the lug will fail across the hole before it would transmit disruptive stresses to the container. Similarly, the tie-down devices, which will accomodate 1" diameter steel cables, will have adequate strength to meet the static load requirement.

General Criticality Standards - The contents of each package will be so limited that, for a single container, with the contents maximumly moderated and fully reflected, the adjusted k_{eff} of the contents will be $\leq$ 0.90. No consideration of dispersable material is required because the contents will be limited to clad components. See specific data in Appendix A.

The calculations will be made by the Nuclear Engineering Department using LEOPARD/1 or PDQ-03/2 or similar experimentally verified procedures. The requirement that fuel be in assemblies in a fixed array will assure that these calculations will be accurate and directly applicable. The calculations will include the effects of the neutron absorbing plates, when used.

/1 Barry, R.F., "LEOPARD - A Spectrum Dependent Non-Spatial Depletion Code for the IBM 7094," WCAP-3269-26 (September 1963).

/2 Caldwell, W.R., "PDQ-03 - A Program for the Solution of the Neutron Diffusion Equations in Two Dimensions on the IBM 704," WAPD-TM-179 (May, 1960).

4.3 (continued - RCC)

Any number of undamaged but flooded packages will also be nuclearly safe, since a single package will have a k_{eff} of $\leq$ 0.90 and there will be a minimum of 12 inches of water between the contents of any two packages. If the water drains away, the contents will also drain, so that the array returns to an unmoderated condition.

For the low-enriched assemblies under consideration, studies using LEOPARD and PDQ-03 demonstrate that a rise of k_{eff} (above the single package value) for an unlimited array does not occur at any reduced water density, due to the parasitic neutron absorption by the container walls and internal structure. Consequently, no degree of interspersed partial moderation can produce an array k_{eff} in excess of the single package k_{eff} resulting from complete flooding.

The maximum credible accident condition is conceived to involve only two packages, crushed top-to-top so that the spacing between the pairs of assemblies will be 1.7 inches, and aligned parallel to each other. This array is then assumed to be flooded. The heavy structural members of the base and the internal component support structures of the packagings will provide sufficient spacing so that any other package in the shipment will be isolated from this combination by a minimum of 12 inches of water.

The Nuclear Engineering Department will use the calculational procedures specified under General Criticality Standards to assure that the adjusted k_{eff} does not exceed 0.98 for the four assemblies in the maximum credible accident (MCA) array.

5.2 Contents Description - CC

Radioactivity - Not applicable.

Identification and Enrichment of SNM - The SNM will be unirradiated uranium enriched $\leq$ 5 w/o in the isotope U-235.

Form of SNM - The SNM will be in the form of clad fuel assemblies. Specific data on maximum assembly parameters are included in Appendix B. The reactivity values listed in Appendix B equal the computed reactivity adjusted by a factor to provide for the probable error in the calculations. The contents will be loaded in such a fashion that if the package were to be flooded and subsequently drained, any water which may have penetrated the contents would drain simultaneously.

In the clad form, the assemblies will not disruptively react or decompose at the Accident Thermal condition. No chips, powders, or solutions will be offered for transport in this packaging.

Neutron Absorbers, etc. - Not specified. No decrease in reactivity resulting from this type of material is included in the nuclear safety analysis.

Maximum Weight of Fissile Content - Listed in Appendix B.

Maximum Net Weight of Contents - Listed in Appendix B.

Maximum Decay Heat - Not applicable.

5.3 Compliance with Subpart C of 10 CFR 71

General Standards - The materials specified for the package will not produce significant chemical or galvanic reactions. The closure devices specified must be deliberately unfastened. Each of the four lifting lugs will be capable of supporting the loaded container individually, so the system of four lifting lugs will support three times the weight of the loaded container. In addition, the design of the lifting lugs will be such that, under an excessive load, the lug will fail across the hole before it would transmit disruptive stresses to the container. Similarly, the tie-down devices, which will accomodate 1" diameter steel cables, will have adequate strength to meet the static load requirement.

General Criticality Standards - The contents of each package will be so limited that, for a single container, with the contents maximumly moderated and fully reflected, the adjusted k_{eff} of the contents will be ≤ 0.90. No consideration of dispersable material is required because the contents will be limited to clad components. See specific data in Appendix B.

5.3 (continued - CC)

ings will provide sufficient spacing so that any other package in the shipment will be isolated from this combination by a minimum of 12 inches of water.

The Nuclear Engineering Department will use the calculational procedures specified under General Criticality Standards to assure that the adjusted k_{eff} does not exceed 0.98 for the four assemblies in the maximum credible accident (MCA) array.

Since only two packages will combine to form the MCA array with a $k_{eff} \leq 0.98$, and any additional packages can only form similar isolated arrays, any number of the CC packages will be nuclearly safe under hypothetical accident conditions.

5.4 Fissile Class II Limits

Thirty-two (32) packages will be offered as a maximum Fissile Class II shipment. Each package will be assigned 1.2 radiation units.

The nuclear safety evaluations indicate that any number of packages would be safe. The limitations specified in this section have been based on considerations of vehicle capacity, shipment value and other non-nuclear considerations.

10.3 (continued - 2 Barrel)

General Criticality Standards - Table I of TID-7016 shows that a 5 inch diameter, infinitely long cylinder is nuclearly safe for homogeneous uranium at any enrichment under all conditions of moderation and reflection. Calculations using LEOPARD show that an 8 inch diameter, infinitely long cylinder is nuclearly safe under all conditions of moderation and reflection for heterogeneous uranium enriched $\leq$ 5 w/o in the isotope U-235.

Single Package Evaluation - The Double Barrel Scrap Shipping Container is structurally equivalent to, or superior to, the unit reported as "Series-3 Test and Result," page 16, ORNL 3735.[1] The restriction on axial loading to 70 pounds per lineal foot will produce less deformation as a result of impact tests than that reported in the referenced report. The assumption of optimum moderation and reflection obviates the necessity for leak testing. The restriction of the contents to non-pyrophoric forms will obviate the necessity for the Thermal Accident condition.

The accident conditions in Appendix B of Part 71 will not credibly produce an arrangement of special nuclear material more reactive than that analyzed under General Criticality Standards.

[1] Shappert, L.B., "Results of Impact Tests Performed on 55-Gallon Drum Type Birdcage," ORNL-3735.

10.3 (continued - 2 Barrel)

Package Array Evaluation - Calculations using LEOPARD, and considering the parasitic neutron absorption of the packaging walls, show that any number of damaged, optimumly moderated packages in any array would be safe for any degree of interspersed, partial moderation. Thus, any number of packages will be nuclearly safe in any array under any credible conditions.

The calculations considered both homogeneous and heterogeneous material, moderated to H/U-235 ratios ranging from 200-240, depending on the material form. The packages were considered to be spaced on a 22" center-to-center dimension. The density of the interspersed moderation was varied from 5% to 100% of light water density. The maximum adjusted K_∞ was determined to be $\leq$ 0.85 and to occur at approximately 10% of light water density.

10.4 <u>Fissile Class II Limits</u>

Eighty (80) packages will be offered as a maximum Fissile Class II shipment. Each package will be assigned 0.5 of a radiation unit.

10.5 <u>Fissile Class III Limits</u>

A maximum of one hundred-sixty (160) packages will be offered as a Fissile Class III shipment.

Appendix K

Products Shipped in Type RCC-1 Packages

Type	Indian Pt. No. 2
Pellet Parameters	
Material	UO_2
Enrichment (Max)	3.2 w/o
Diameter (Nom)	.372"
Rod Parameters	
Cladding Mt'l	Zirc.
Diameter (Nom)	.422"
Fuel Length (Nom. Max.)	144"
Assy. Parameters	
No. of Rods (Max)	204
Pattern (Basic)	15 X 15 sq
Lattice Pitch (Nom)	.563"
Outside Dimen. (Nom)	8.4" sq
Licensing Criteria	
Total U-235 (Max/Pkg)	30 kg
k_{eff} (Max/Ass'y)	< 0.88
k_{eff} (Max/1 Pkg)	< 0.90
k_{eff} (Max/MCA)	≤ 0.97
Poison Pl. Req'd	No
Net Wt. of Contents (Max)	3200#

I

RECEIVED MAY 2 1968 U.S. ATOMIC ENERGY COMMISSION Regulatory Mail Section

Westinghouse Electric Corporation

3 Gateway Center
Box 2278, Pittsburgh, Pa. 15230

April 29, 1968

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

Attention: Mr. Donald A. Nussbaumer, Chief
Source and Special Nuclear Materials Branch

Subject: Application for Amendment of License SNM-338
Docket 70-337, to Authorize Use of NFD Shipping
Packages ~~For Div of Compliance~~

Gentlemen:

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material to a carrier for transport in the packaging described in the attachment to this letter.

Please send the amendment to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect, (412) 255-3907.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

Attachment: License Amendment
7 copies transmitted

ITEM # 59

B/59

(11) 1563

SNM-338
Shipping - NFD
4/29/68

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder, "Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages," immediately in front of the last previous transmittal letter, dated April 8, 1968.

Revised pages 3, 4, 7.1, 8 and 42 should be inserted in the binder and the old pages removed. Also, the revised tabulations should be inserted in the binder in Appendices A, B and K, and the old pages removed.

New page 50 should be inserted in the binder immediately following page 49. New Appendix M should be inserted immediately following existing Appendix L.

The removed pages may be filed in the back of the binder.

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Appendix D - Yankee Shipping Container drawings
Appendix E - MH-1A Shipping Container drawings
Appendix F - Double Barrel Scrap Shipping Container sketch
Appendix G - Quadruple Barrel Scrap Shipping Container drawing
Appendix H - Triple Barrel Shipping Container drawing
Appendix J - BB 250-1 Shipping Container drawing
Appendix K - RCC-1 Shipping Container drawings
Appendix L - BB 250-2 Shipping Container sketch
Appendix M - RCC-2 Shipping Container drawings

REVISION RECORD (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
13	3/1/68	43-49	Added Section 18, the BB 250-2 package
13	3/1/68	Appendix L	Added
14	3/5/68	Appendix K	Added RGAF data
15	3/14/68	Appendix B	Added SELNI data
16	4/8/68	45	Changed 8 spiders to 12 spring spacers
16	4/8/68	46	Add detail concerning bolting of lid
16	4/8/68	48-49	Revised Footnote /1 to add discussion of nuclear criticality safety. Changed >1000 to >500.
16	4/8/68	Appendix L	Revised drawing to -1
17	4/29/68	8	6300# was 6000#
17	4/29/68	42	7200# was 7000#
17	4/29/68	50	Added Section 19, the RCC-2 package.
17	4/29/68	App. A, B & K	Revised to remove core designations, generalize certain categories, and update specific data
17	4/29/68	Appendix M	Added

1. Introduction

An amendment to License SNM-338, Docket 70-337, is hereby requested to authorize the delivery of special nuclear material to a carrier for transport in the packagings described herein.

2. Correspondence - Return Address

The license amendment and any associated correspondence should be sent to Karl R. Schendel, Westinghouse Electric Corporation, Box 2278, Pittsburgh, Pennsylvania 15230.

3. Administrative Control

The administrative control of the packaging operation will be carried out in accordance with the requirements contained in the Westinghouse Electric Corporation Health Physics Manual, WAED-HP-103, as amended. Currently, the latest revision of this manual is Revision V, dated May, 1966.

4. R.C.C. Packaging

4.1 Packaging Description

Designation - RCC (Rod Cluster Control) Shipping Container B.E. Permit #2254.

Gross Weight - 6,300 pounds

Fabrication - The design and fabrication details for the RCC Shipping Container are given in Equipment Specification E-676200, dated 8/9/65, and Westinghouse drawings EDSK319401F, EDSK319402F and EDSK323133B, which are attached as Appendix A to this application. Westinghouse drawing 684J580 is also included in Appendix A to indicate the location and retention

15.4 Limits and Controls

The Fissile Class II limit, Fissile Class III limit and Procedural Controls presented in Sections 5.4, 5.5 and 5.6, respectively, will apply directly to this package.

16. RCC-1 Packaging

16.1 Packaging Description

Designation - RCC-1 Shipping Container

Gross Weight - 7,200 pounds

Fabrication - The design and fabrication details for the shipping containers in the RCC-1 series are given in Equipment Specification E-676498, Revision O, and Westinghouse drawings 684J898 and 541F351, which are attached as Appendix K to this application. Westinghouse drawing 684J861 is also included in Appendix K to indicate the location of, and the method of retaining, poison plates in the packaging, when they are required.

Coolants - Not applicable

16.2 Contents Description

The descriptions and discussions given in Section 4.2 will be directly applicable in all respects, if "and Appendix K" is added after "Appendix A" and "drawing 684J861" is substituted for "drawing 684J580".

16.3 Compliance with Subpart C of 10 CFR 71

The descriptions and discussions given in Section 4.3 will be directly applicable in all respects, if "Equipment Specification E-676498" is substituted for "Equipment Specification E-676200".

19. RCC-2 Packaging

19.1 Packaging Description

Designation - RCC-2 Shipping Container

Gross Weight - 6,300 pounds

Fabrication - The design and fabrication details for the shipping containers in the RCC-2 series are given in Equipment Specification E-676200 as modified by Addendum A to become Revision 1, and Westinghouse drawings 541F613 and 541F614, which are attached as Appendix M to this application. Westinghouse drawing 684J963 is also included in Appendix M to indicate the location of, and the method of retaining, poison plates in the packaging, when they are required.

Coolants - Not applicable

19.2 Contents Description

The descriptions and discussions given in Section 4.2 will be directly applicable in all respects, if "drawing 684J963" is substituted for "drawing 684J580".

19.3 Compliance with Subpart C of 10 CFR 71

The descriptions and discussions given in Section 4.3 will be directly applicable in all respects. It is understood that the reference to Equipment Specification E-676200 implies the appropriate revision.

19.4 Limits and Controls

The Fissile Class II limit, Fissile Class III limit, and the Procedural Controls presented in Sections 4.4, 4.5, and 4.6, respectively, will apply directly to this package. It is understood that the reference to Equipment Specification E-676200 implies the appropriate revision.

Appendix A

Products Shipped in Type RCC and RCC-2 Packages

Type	14 X 14 Zr Clad Assemblies	14 X 14 SST Clad Assemblies	15 X 15 SST Clad Assemblies
Pellet Parameters			
Material	UO_2	UO_2	UO_2
Highest Enrichment (Nom)	3.7 w/o	3.9 w/o	3.7 w/o
Diameter (Nom)	.367"	.384"	.384"
Rod Parameters			
Cladding Mt'l	Zirc.	SST	SST
Diameter (Nom)	.423"	.422"	.422"
Fuel Lgth (Nom)	120"	120"	122"
Assy. Parameters			
No. of rods (Max)	180	180	204
Pattern (Basic)	14 X 14 sq	14 X 14 sq	15 X 15 sq
Lattice Pitch (Nom)	.556"	.556"	.563"
Outside Dimen. (Nom)	7.8" sq	7.8" sq	8.4" sq
Licensing Criteria			
Total U-235 (Max/pkg)	32.0 kg	36.0 kg	40.0 kg
k_{eff} (Max/ass'y)	0.86	0.86	0.85
k_{eff} (Max/1 pkg)	0.87	0.87	0.87
k_{eff} (Max/MCA)	0.96	0.96	0.96
Poison Pl. Req'd	No	No	No
Net Wt. of Contents (Max)	2200#	2200#	2500#

Appendix B

Products Shipped in Type CC Packages

Type	14 X 14 SST Clad Assemblies	15 X 15 SST Clad Assemblies
Pellet Parameters		
Material	UO_2	UO_2
Highest Enrichment (Nom)	4.1 w/o	4.1 w/o
Diameter (Nom)	0.317"	0.355"
Rod Parameters		
Cladding Mt'l	SST	SST
Diameter (Nom)	0.341"	0.385"
Fuel Lgth (Nom)	105"	106"
Assy. Parameters		
No. of rods (Max)	173	208
Pattern (Basic)	14 X 14 sq	15 X 15 sq
Lattice Pitch (Nom)	0.453"	0.513"
Outside Dimen. (Nom)	6.284"	7.695"
Licensing Criteria		
Total U-235 (Max/pkg)	20 kg	27 kg
k_{eff} (Max/ass'y)	0.74	0.86
k_{eff} (Max/1 pkg)	0.84	0.90
k_{eff} (Max/MCA)	0.98	0.98
Poison Pl. Req'd	N.A.	N.A.
Net Wt. of Contents (Max)	2000#	2200#

Appendix K

Products Shipped in Type RCC-1 Packages

Type	14 X 14 Zr Clad Assemblies	15 X 15 Zr Clad Assemblies
Pellet Parameters		
Material	UO_2	UO_2
Highest Enrichment (Nom)	3.5 w/o	3.2 w/o
Diameter (Nom)	.372"	.372"
Rod Parameters		
Cladding Mt'l	Zirc.	Zirc.
Diameter (Nom)	.422"	.422"
Fuel Length (Nom)	144"	144"
Assy. Parameters		
No. of Rods (Max)	180	204
Pattern (Basic)	14 X 14 sq	15 X 15 sq
Lattice Pitch (Nom)	.556"	.563"
Outside Dimen. (Nom)	7.8" sq	8.4" sq
Licensing Criteria		
Total U-235 (Max/Pkg)	31 kg	30 kg
k_{eff} (Max/Ass'y)	≤ 0.84	< 0.88
k_{eff} (Max/1 Pkg)	≤ 0.86	< 0.90
k_{eff} (Max/MCA)	≤ 0.96	≤ 0.97
Poison Pl. Req'd	No	No
Net Wt. of Contents (Max)	3200#	3200#

EQUIPMENT SPECIFICATION COVER SHEET

WESTINGHOUSE FORM 54064 A

EQUIPMENT SPECIFICATION	DATED	REVISION NO.	DATED	ORIGINAL ISSUE	SUPERSEDES PREVIOUS REVISIONS
676200	August 9, 1965	1	May 26, 1967	☐	☐

PROJECT: 137" Fuel Assembly Shipping Container

SHOP ORDER: General

SYSTEM:

EQUIPMENT: Fuel Assembly Shipping Container

ATTACHMENTS

Drawings: 541F613
541F614

Appendix A

Addendum A

FOR SUPPLIER'S CONVENIENCE

REV. NO.	REVISION ENTERED BY & DATE

WESTINGHOUSE ELECTRIC CORPORATION
Atomic Power Division
P.O. Box 355
Pittsburgh, Pennsylvania, 15230

APPROVAL

	ORIGINAL ISSUE	REV. 1	REV. 2	REV. 3	REV. 4
AUTHOR	J. J. Hutchinson J. J. Hutchinson				
SHOP ORDER HOLDER	H. W. Keller H. W. Keller				
PROJECT MANAGER	H. N. Andrews H. N. Andrews				

ITEM # 60

B/60

ADDENDUM A

Make the following substitution unless it is stated otherwise.

Page 5, Item 1 c

Acceptance testing of production prototype unit using cradle assembly designed by W and shear mounts specified by W.

Page 5, Item 2 o

a) Westinghouse Drawing 541F351
b) Westinghouse Drawing 684J898
c) Delete

Page 6, Item 3.1.1

In addition, the container must satisfy the Department of Transportation (D.O.T.), ICC, and Atomic Energy Commission regulatory standards on container specific design features and structural integrity with regard to nuclear safety.

Page 6, Item 3.1.2

The internals and component parts shall be designed by W.

Page 8, Item 3.1.3.2 f

All components shall be detachable from the container assembly.

Page 9, Item 3.1.3.2

Shock overload monitors will be specified by W.

Page 9, Item 3.1.3.3

Delete: Figure 3 is an example of one type of structural integrity closure clamp fitting that will be acceptable.

The container shall be capable of being pressurized to 10 lb/in^2 gauge with dry air or nitrogen. Sealed closure must be maintained at a pressure of 5 psi gauge under repeated use.

Page 10, Item 3.1.3.4 d

In addition, the container shall be suitable for parallel triangular stacking with one container stacked on top and across two like containers positioned side by side and in contact.

Page 11, Item 3.1.3.5 d

A relief valve actuate at 7.5 ± 1 psi gauge and closing at 5 ± 1 psi gauge shall be provided on the surface of the container with rapid depressurization facility.

Page 12, Item 3.1.3.7

A minimum thickness of .074" steel shall be used for the container assembly shell.

Page 12, Item 3.2

The container shall be of the minimum practicable weight consistent with the performance requirements of this specification.

Page 13, Item 3.6 d

BME Permit No. to read DOT Permit No. and include Model No. on label.

Page 17, Item 4.1.5.2

The container shall be filled with air to 10 psi gauge and tested for leakage by either water immerision test at a loss of gauge pressure test.

Page 18, Item 4.1.5.4 (b)(c)

36" should read 30"

APPENDIX A

1) Neutron poison material is contained when required in the lateral spacing between the fuel assemblies to maintain nuclear safety of the shipment under maximum credible accident conditions.

2) Delete: Brackets are welded to the angle frame members for attachment of the shockmounts.

5) Item 6 - Attach crane to lifting lug at the forward end of the fuel assembly support frame.

   Item 21 - Move outrigger members to their storage position.

I

Westinghouse Electric Corporation

3 Gateway Center
Box 2278, Pittsburgh, Pa. 15230

March 14, 1968

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

Attention: Mr. Donald A. Nussbaumer, Chief
Source and Special Nuclear Materials Branch

Subject: Application for Amendment of License SNM-338 Docket 70-337, to Authorize Use of NFD Shipping Packages

Gentlemen:

The Westinghouse Electric Corporation hereby requests an amendment to the subject license to authorize the delivery of special nuclear material to a carrier for transport in the package described in the attachment to this letter.

Please send the amendment to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect, (412) 255-3907.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

Attachment: License Amendment
7 copies transmitted

ITEM # 61

932

Form 00 - Hdqrs.

SNM-338
Shipping - NFD
3/14/68

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder, "Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages," immediately in front of the last previous transmittal letter, dated March 5, 1968.

Revised pages 7.1 and Appendix B should be inserted in the binder and the old pages removed.

The removed pages may be filed in the back of the binder.

REVISION RECORD (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
13	3/1/68	43-49	Added Section 18, the BB 250-2 package
13	3/1/68	Appendix L	Added
14	3/5/68	Appendix K	Added RGAF data
15	3/14/68	Appendix B	Added SELNI data

Appendix B

Products Shipped in Type CC Packages

Type	CEX	SELNI
Pellet Parameters		
Material	UO_2	UO_2
Enrichment (Nom) High Zone	4.1 w/o	4.1 w/o
Diameter (Nom)	0.317"	0.355"
Rod Parameters		
Cladding Mt'l	SST	SST
Diameter (Nom)	0.341"	0.385"
Fuel Lgth (Max)	102"	102"
Assy. Parameters		
No. of rods (Max)	172	201
Pattern (Basic)	14 X 14 sq	15 X 15 sq
Lattice Pitch (Nom)	0.453"	0.513"
Outside Dimen. (Nom)	6.284"	7.695"
Licensing Criteria		
Total U-235 (Max/pkg)	20 kg	27 kg
k_{eff} (Max/ass'y)	0.74	0.86
k_{eff} (Max/1 pkg)	0.84	0.90
k_{eff} (Max/MCA)	0.98	0.98
Poison Pl. Req'd	N.A.	N.A.
Net Wt. of Contents (Max)	2000#	2200#

REGULATORY OPERATION

Westinghouse Electric Corporation Power Systems

Water Reactor Divisions

Box 355
Pittsburgh Pennsylvania 15230

July 17, 1973

RECEIVED JUL 19 1973

U. S. Atomic Energy Commission
Directorate of Licensing
Washington, D. C. 20545

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

Gentlemen:

Subject: Application for Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material to a carrier for transport in the Model CC Shipping Package described in the attachment to this letter. Please note that this application revises the parameters associated with fuel assembly shipping, only. This change is not intended to affect the authorization which currently exists under Amendment 71-10.

Please send the amended license to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect (412) 373-4652.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

KRS:jh

Attachment

ITEM # 62

17

B/62

5534

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder labelled "Application for Amendment of License SNM-338 for NFD Shipping Package" immediately in front of the transmittal letter dated April 6, 1973.

Revised pages 7.3, Appendix B, and the report, "CC Package Nuclear Criticality Safety Model" should be inserted and the old pages removed.

The removed pages may be filed in the back of the binder.

Revision No. 31
July 17, 1973

Revision Record (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
26	7/23/71	60, 60.1	Added discussion of structural adequacy of MIL inner can.
26	7/23/71	62	Editorial corrections.
26	7/23/71	64 - 66	Added results of Super KENO calculations.
26	7/23/71	Appendix R	Added MS-24347
27	9/3/71	65	H/U of 1.5 was 0.5
27	9/3/71	Appendix R	Added "Single Package Evaluation" and Figures 2 thru 9.
28	10/8/71	18	Updated LEOPARD reference
28	10/8/71	19	.500 inches was .444
28	10/8/71	Appendix B	Added 14 X 14 Assembly with 4.5 w/o enrichment. Also added safety model report.
29	2/25/72	53 - 55	Added provisions for shipping loose rods.
29	2/25/72	55.1	New
29	2/25/72	Appendix P	Added rod shipping nuclear criticality safety model.
30	4/6/73	Appendix B	For 15X15 Ass'y increase enrich. to 4.5 w/o and Total U-235 to 30 kg. Added calculations.
31	7/17/73	Appendix B and Criticality Safety Model report	Changed total ^{235}U to 20 kg. Clarified reactivity model with steel included.

Appendix B

Products Shipped in Type CC Packages

Type	14 X 14 SST Clad Assemblies	15 X 15 SST Clad Assemblies	14 X 14 SST Clad Assemblies
Pellet Parameters			
Material	UO_2	UO_2	UO_2
Highest Enrichment (Nom)	4.1 w/o	4.5 w/o	4.5 w/o
Diameter (Nom)	0.317"	0.355"	0.313"
Rod Parameters			
Cladding Mt'l	SST	SST	SST
Diameter (Nom)	0.341"	0.385"	0.341"
Fuel Lgth (Nom)	105"	106"	90"
Assy. Parameters			
No. of rods (Max)	173	208	173
Pattern (Basic)	14 X 14 sq	15 X 15 sq	14 X 14 sq
Lattice Pitch (Nom)	0.453"	0.513"	0.453"
Outside Dimen. (Nom)	6.284"	7.695"	6.284"
Licensing Criteria			
Total U-235 (Max/pkg)	20 kg	26 kg	20 kg
k_{eff} (Max/ass'y)	0.74	0.86	0.78
k_{eff} (Max/1 pkg)	0.84	0.90	0.84
k_{eff} (Max/MCA)	0.98	0.98	0.98
Poison Pl. Req'd	N.A.	N.A.	N.A.
Net Wt. of Contents (Max)	2000#	2200#	2000#

1. INTRODUCTION

These calculations are in support of an application for an AEC license to ship cruciform core SS clad, SS can uranium assemblies enriched up to 4.5w/o. It is concluded that such assemblies can be safely shipped. A more detailed description of the assembly design is given below, together with details of the calculations performed and their results.

2. ASSEMBLY DESCRIPTION AND ASSUMPTIONS

A cross-section of the assembly appears in Figure 1. There are eleven thick clad rods in corners as shown in the figure. The average rod pitch is .518", the maximum fuel enrichment, 4.5w/o and the density, 95% of theoretical.

The shipping container in which the fuel will be shipped is described in the following Champion Company, Springfield, Ohio, drawings:

Drawing No.	Title
10410	Container - Shipping, Reusable, Metal
10541	Mounting Assembly Bottom
10536	Bottom Assembly (two sheets)
10538	Top Weldment (three sheets)

The manner of placing the two assemblies in each container is such that the sides of the assembly that are recessed to accommodate the cruciform rods, are away from each other as shown in Figure 2. The assemblies have been represented in the spatial x-y calculations accordingly.

The following assumptions have been made which are all conservative from the standpoint of criticality safety:

- The assemblies have been assumed to be of infinite length i.e., they have a zero axial buckling.
- None of the structural material of the cask has been included in the calculations, except the wall thickness in the maximum credible accident (MCA).
- As the fuel is under-moderated in the assembly design, the density of the water has been assumed to be at its maximum value of 1.0 gms/cc.

3. CALCULATIONAL MODEL

Calculations were performed using modified versions of the LEOPARD and PDQ03 codes. The PDQ03 calculations were performed for each of the following cases:

- A single assembly, flooded.
- Two assemblies in a shipping cask, flooded.
- Two shipping casks crushed together and flooded - the MCA. The two assemblies in each cask are assumed to remain intact and separated by their usual distance. The casks are assumed to be crushed together so that both pairs of assemblies are perfectly aligned opposite each other. Only the wall thickness of the two casks are assumed to lie in between the pairs of assemblies. The two pairs of assemblies are then assumed to be separated by that distance which gives the highest multiplication factor.

The geometry, mesh intervals and boundary conditions used in the PDQ03 calculations for each of the above three cases are shown in Figures 3 through 5 respectively.

For the MCA the distance separating the two pairs of assemblies was varied to determine that which gives the maximum multiplication factor. Calculations were performed at the separations of .324", .384", .5", 1" and 2". Initially no cask wall steel was placed in between. The .384" separation gave the highest multiplication. Cask wall steel was then inserted.

4. CALCULATIONAL RESULTS

The results of the above calculations are tabulated in Table 1.

A plot of K_{eff} as a function of the distance separating the two pairs of assemblies in the MCA appears in Figure 6.

The criticality safety criteria for the single assembly flooded and the two assemblies in the cask, flooded, is a K_{eff} of $\leq .90$. For the MCA, with cask wall steel included, the required K_{eff} is $\leq .98$. The corresponding K_{eff} values obtained in the calculations appear at Serial Nos. 1, 2 and 8 respectively, in Table 1. They are all below the criteria and therefore

the package is safe for shipment.

The following additional information is included:

Atom Densities	Table 2
Macroscopic Cross-sections	Table 3

5. CONCLUSIONS

Cruciform core SS clad, SS can uranium fuel as described in this report and enriched up to 4.5w/o can be safely shipped in the Champion Company shipping container.

A. Saeed

Table 1

Multiplication Factors

Serial No.	Case	K_{eff}
1	Single assembly flooded	.8109
2	Two assemblies in cask flooded	.8642
3	MCA (two pairs of assemblies in two casks crushed together) with no cask wall steel in between. Separation between pairs of .324".	.9996
4	Same as 3 with .384" separation	1.00228
5	Same as 3 with .5" separation	1.00195
6	Same as 3 with 1" separation	.9936
7	Same as 3 with 2" separation	.9583
8	Same as Serial No. 3 with cask wall steel in between	.9712

Table 2

Atom Densities
(Atoms/cc, 10^{24} units)

Element	Flooded Fuel Assembly, 4.5w/o	Water	Steel
Hydrogen	.03800	.06688	
Oxygen	.03439	.03344	
Zircaloy	.0001513		
Stainless Steel	.007299		.0897
U-234	.000002854		
U-235	.0003506		
U-236	.000002184		
U-238	.007342		

Table 3

Macroscopic Cross-Sections

(Temperature = 60°F, Water density used = 1.0 gms/cc)

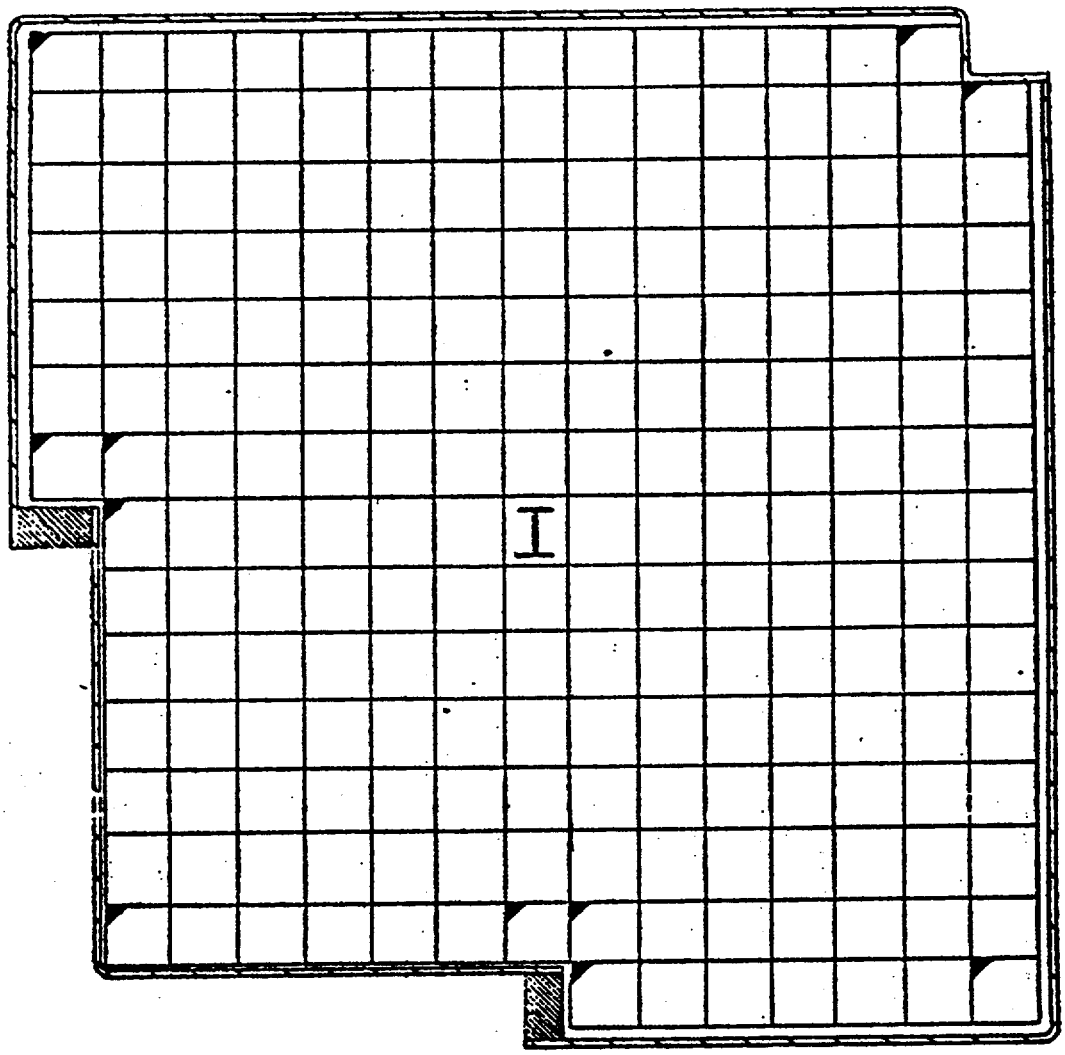
Cross-Section	Flooded Fuel Assembly, 4.5w/o	Water	Steel
Group 1			
D (cm)	1.1306	1.2855	1.18
Σ_a (cm^{-1})	.01119	.0004409	.00055
Σ_R (cm^{-1})	.02146	.04888	.000331
$\upsilon\Sigma_f$ (cm^{-1})	.009583		
Group 2			
D (cm)	.2077	.1642	.337
Σ_a (cm^{-1})	.2353	.0222	.22
$\upsilon\Sigma_f$ (cm^{-1})	.3796		

Table 4

MCA - Row Mesh Intervals
From Row 27 through Row Boundary
(Applies to Figure 5)

Separation Between Pairs of Assemblies Inches	Boundary Row No.	Mesh Intervals Row 27 through Row Boundary, cm
.324	28	.4115
.384	29	.0762, .4115
.5	29	.2235, .4115
1.0	30	.4293, .4293, .4115
2.0	31	.7095, .7095, .7095, .4115

NOTE: The .4115 cm distance represents half the thickness of the cask wall steel between the two pairs of assemblies.



LEGEND:

INSTRUMENT WATER HOLE

THICK CLAD RODS.
24 MIL THICK WALLS

Zr FILLER BAR

THIN CLAD RODS

SS CAN AROUND ASSEMBLY

Figure 1 Assembly Regular and Thick Clad Rod Pattern

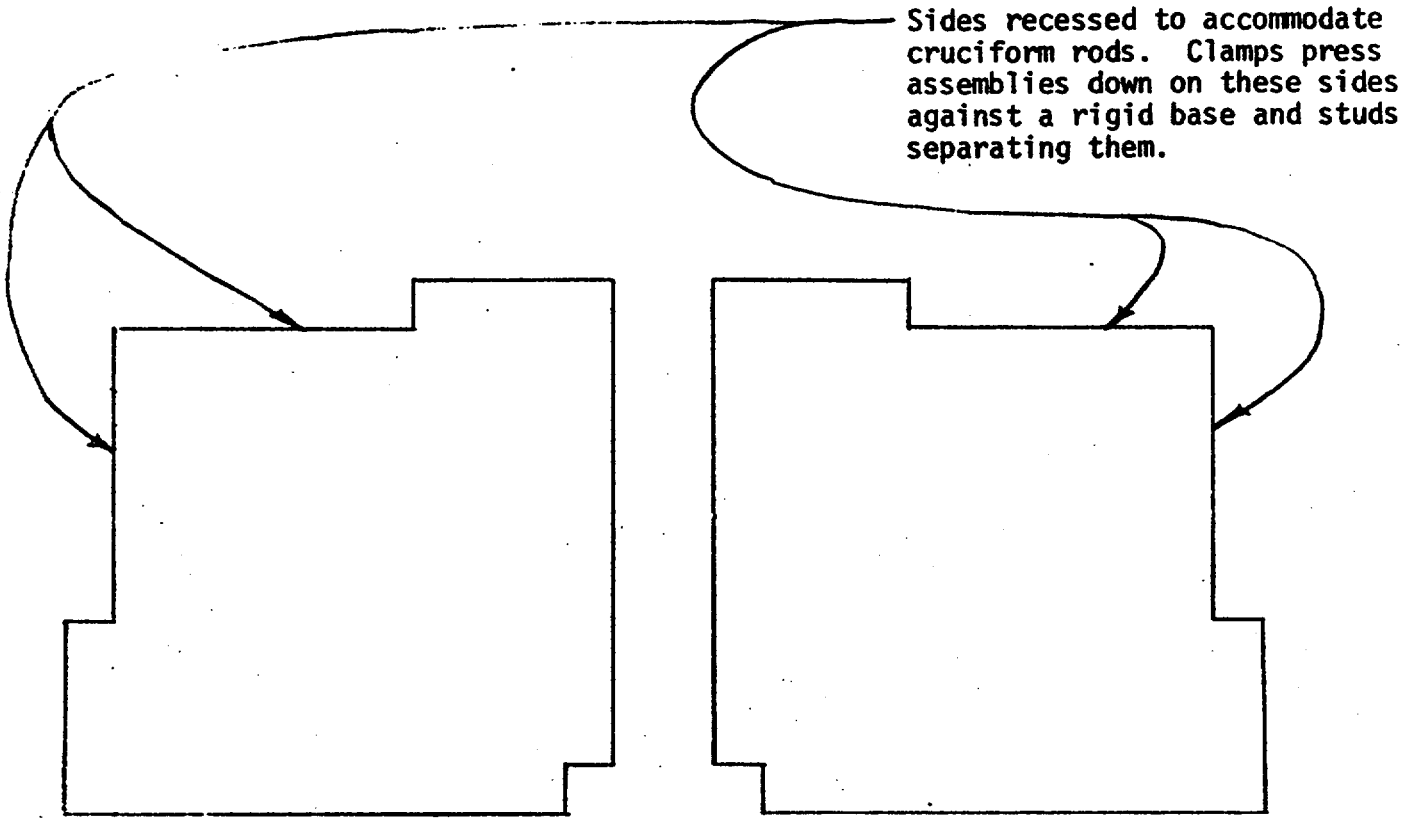
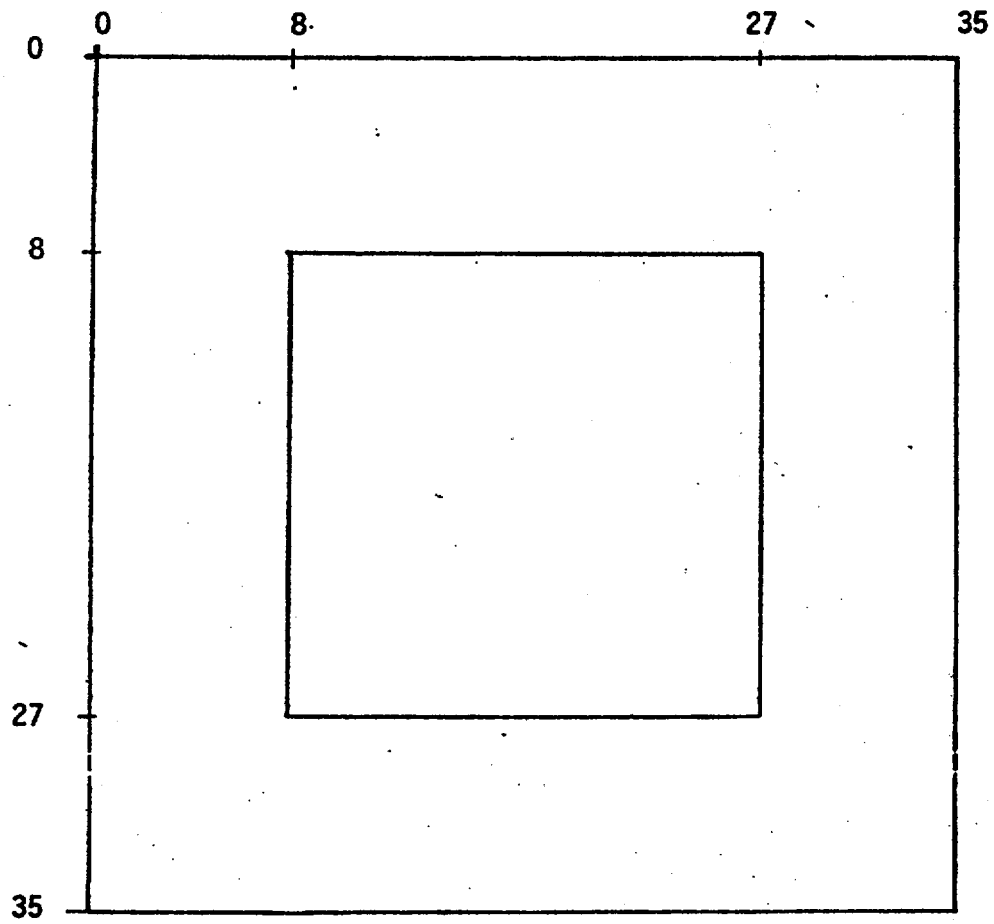


Figure 2 Manner of Placing Cruciform Assemblies in Shipping Container



Boundary conditions: Zero flux on all four sides.

Column mesh intervals in cm:

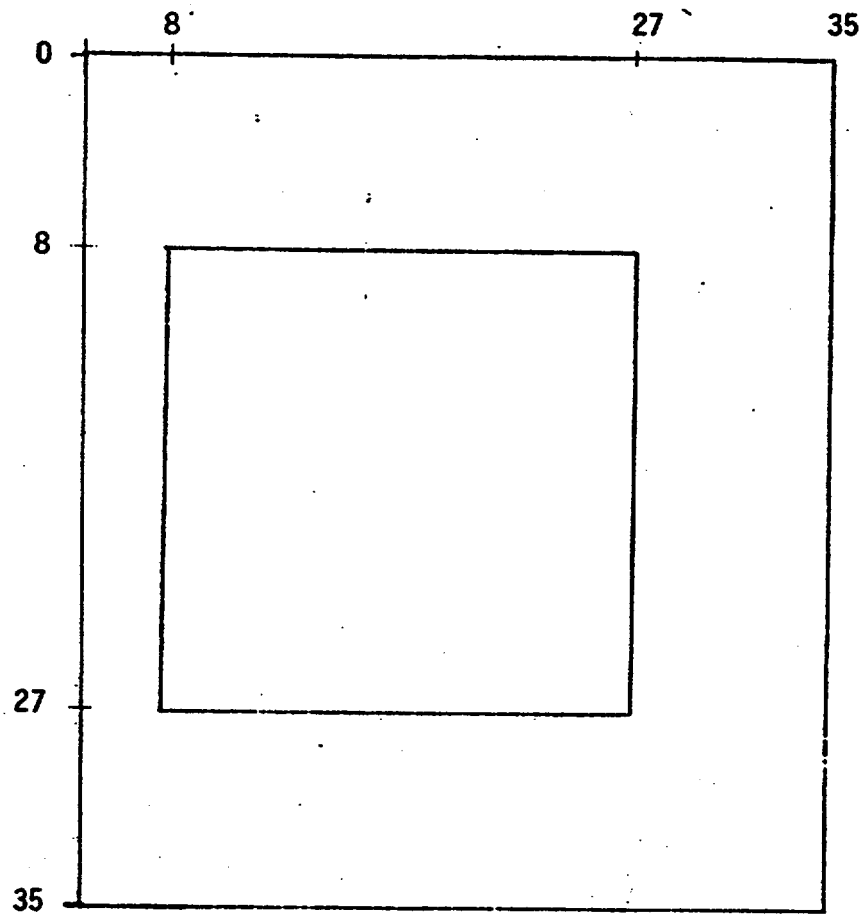
Columns 0 thru 8; reflector: 3.0, 3.0, 3.0, 3.0, 3.0, 2.0, 1.0, .5

Columns 8 thru 27; assembly: .1791, 1.0922, .2235, 13 times 1.3157, .2235, 1.0922, .1791

Columns 27 thru 35; reflector: same as columns 0 thru 8 in reverse

Row mesh intervals: same as column mesh intervals

Figure 3 Geometry and Mesh Intervals for a Single Assembly Flooded



Boundary conditions: Zero current on left, Zero flux on the remaining three sides

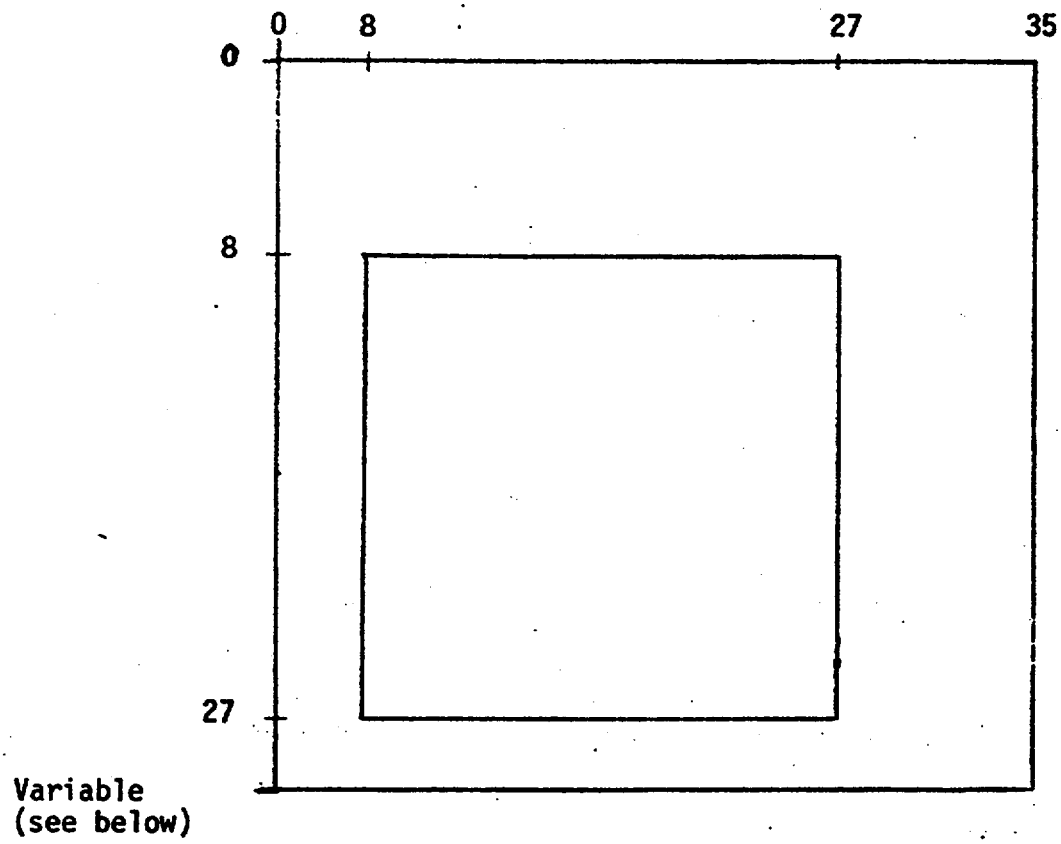
Column mesh intervals in cm:

Columns 0 thru 8: gap between the two assemblies in cask, .51, .51, .51, .51, .51, .51, .50, .25

Columns 8 thru 35, assembly and reflector: same as for columns 8 thru 35 in Figure 3

Row mesh intervals: same as in Figure 3

Figure 4 Geometry and Mesh Intervals for Two Assemblies in Cask Flooded



Boundary conditions: Zero current on left and lower sides, Zero flux on remaining two sides

Column mesh intervals: Same as in Figure 4

Row mesh intervals in cm: Row 0 thru 27, same as in Figure 3
Row 27 thru row boundary, see Table 4

Figure 5 Geometry and Mesh Intervals for the MCA

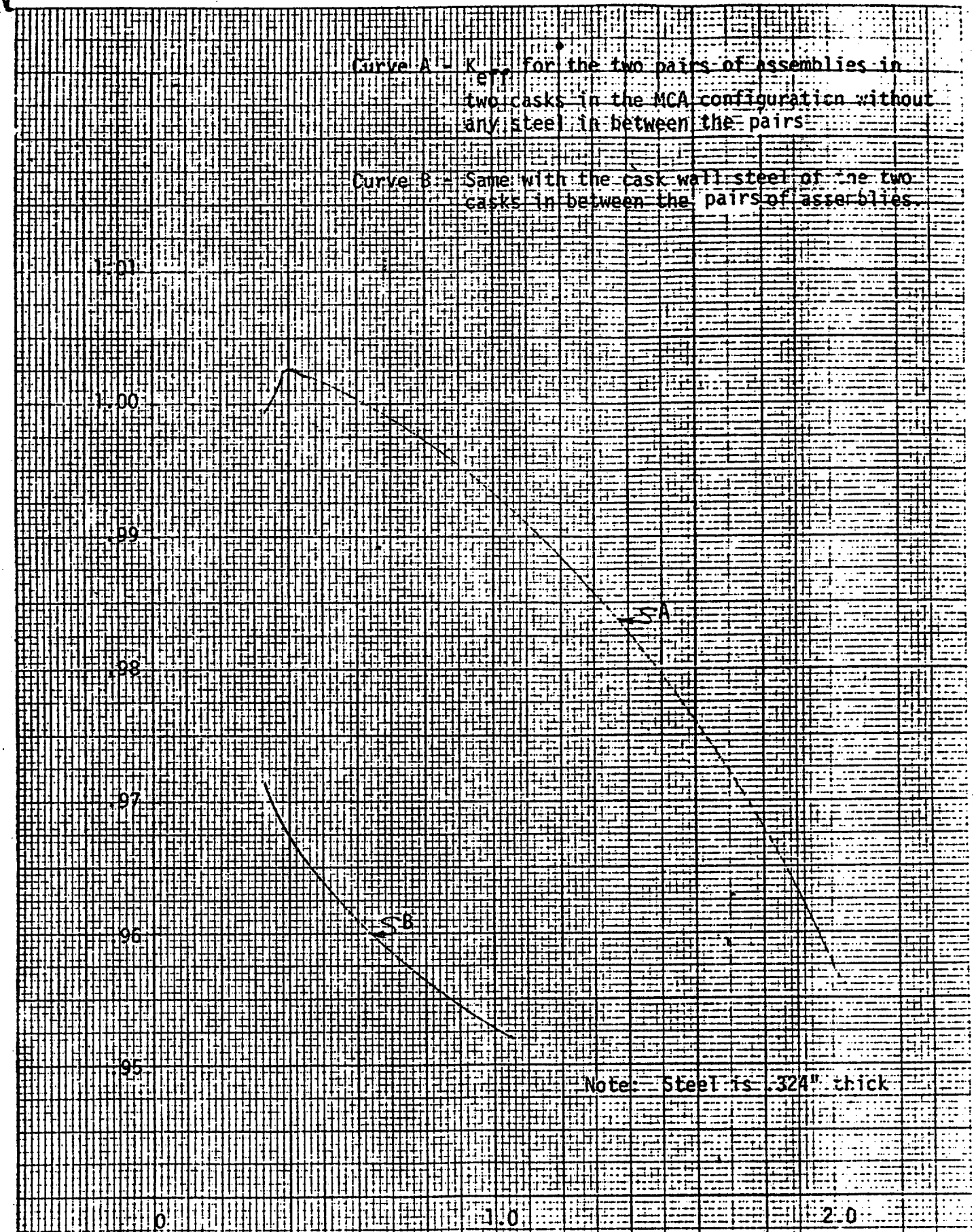


Figure 1 K_{eff} as a Function of Separation Between Pairs of Assemblies in the MCA

10 X 10 TO ½ INCH 46 1320
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 21 1970

:OEM
-337
-338, Amendments Nos. 71-37, 71-38

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C. E. MacDonald, DML, w/encl
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DML R/F, w/o encl

Westinghouse Electric Corporation
Attn: Mr. Karl R. Schendel
Westinghouse Building
3 Gateway Center
Pittsburgh, Pennsylvania 15222

Gentlemen:

Enclosed are Amendments Nos. 71-37 and 71-38 to Special Nuclear Material License No. SNM-338 authorizing the delivery of special nuclear material to a carrier for transport in the RCC and RCC-1 packages. These amendments supersede amendments previously issued for these packages.

Please note that the amendments do not authorize the transport of special nuclear material. Such transport is normally subject to regulation by the Department of Transportation (DOT). Questions regarding their requirements should be directed to DOT.

Sincerely,

Original Signed by
Leland C. Rouse

for Donald A. Nussbaumer, Chief
Fuel Fabrication and
Transportation Branch
Division of Materials Licensing

Enclosures:
As stated

cc: Mr. Alfred W. Grella
Department of Transportation

ITEM # 63

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

OCT 23 1970

DML:CEM
70-337
SNM-338, Amendments Nos. 71-35, 71-36

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A. Cabell, ADM:DR, w/encl
R. L. Stevenson, DML, w/encl
C. E. MacDonald, DML, w/encl (2)
Branch R/F, w/encl
DML R/F, w/o encl

Westinghouse Electric Corporation
Attn: Mr. Karl R. Schendel
Westinghouse Building
3 Gateway Center
Pittsburgh, Pennsylvania 15222

Gentlemen:

Enclosed are Amendments Nos. 71-35 and 71-36 to Special Nuclear Material License No. SNM-338 authorizing the delivery of special nuclear material to a carrier for transport in the RCC and RCC-1 packages. These amendments supersede amendments previously issued for these packages.

Please note that the amendments do not authorize the transport of special nuclear material. Such transport is normally subjected to regulation by the Department of Transportation (DOT). Questions regarding their requirements should be directed to DOT.

Sincerely,

Original Signed by
Donald A. Nussbaumer

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

Enclosures:
As stated

cc: Mr. Alfred W. Grella
Department of Transportation

ITEM # 64

Form. AEC-401a
(7/70)

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OCT 23 1970

UNITED STATES
ATOMIC ENERGY COMMISSION

- - - - - -

LICENSE AMENDMENT
for
DELIVERY OF RADIOACTIVE MATERIAL
to a
CARRIER FOR TRANSPORT

Pursuant to the Atomic Energy Act of 1954 and Title 10, Chapter 1, Code of Federal Regulations, Part 30, "Rules of General Applicability to Licensing of Byproduct Material", Part 70, "Special Nuclear Material", as appropriate, and Part 71, "Packaging of Radioactive Material for Transport", the following amendment to the license identified below is hereby issued, authorizing the licensee to deliver radioactive material to a carrier for transport, and is subject to the conditions specified in that license and to the conditions specified below:

LICENSEE	
1. Name: Westinghouse Electric Corporation	3. License No. SNM-338
2. Address: 3 Gateway Center Box 2278 Pittsburgh, Pennsylvania 15222	Amendment No. 71-35 Docket No. 70-337

CONDITIONS

4. (a) Packaging

(1) Model number	RCC
(2) Description	Steel fuel element cradle assembly consisting of a strongback and adjustable fuel element clamping assembly, shock mounted to a minimum 0.074" steel outer container by shear mounts. Neutron absorber plates are required for the contents described in 4(b)(1)(ii).
(3) Drawings	Container constructed in accordance with Westinghouse Electric Corporation Drawings EDSK319401F, EDSK319402F, EDSK323133B, and 684J580 or 684J963, 541F613, 541F614, and EDSK323133B.

COPY

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(b) Contents

(1) Type and form of material

(i) Uranium dioxide as zircaloy or stainless steel clad unirradiated fuel elements of the following specifications:

Type	14 x 14 Zr Clad	14 x 14 SST Clad	15 x 15 SST Clad
Pellet diameter (Nom)	0.367"	0.384"	0.384"
Rod diameter (Nom)	0.423"	0.422"	0.422"
Maximum Fuel Length	120"	120"	122"
Maximum Rods/element	180	180	204
Maximum Cross Section (Nom)	7.8" sq	7.8" sq	8.4" sq
Maximum U-235/element	16 kgs	18 kgs	20 kgs
Maximum U-235 enrichment	3.7 w/o	3.9 w/o	3.7 w/o

(ii) Uranium dioxide as zircaloy or stainless steel clad unirradiated fuel elements. Two (2) neutron absorber plates consisting of 0.19" thick, full length stainless steel containing 1.3% minimum boron or 0.19" thick OFHC copper are required between fuel elements of the following specifications:

Type	14 x 14 Zr Clad	14 x 14 SST Clad	15 x 15 Zr Clad	15 x 15 SST Clad
Pellet diameter (Nom)	0.367"	0.384"	0.367"	0.384"
Rod diameter (Nom)	0.422"	0.422"	0.422"	0.422"
Maximum Fuel Length	120"	120"	120"	120"
Maximum rods/element	180	180	204	204
Maximum Cross Section (Nom)	7.8" sq	7.8" sq	8.4" sq	8.4" sq
Maximum U/235/element	16.5 kgs	18.5 kgs	18.0 kgs	20.5 kgs
Maximum U-235 enrichment	3.85 w/o	4.0 w/o	3.59 w/o	4.0 w/o

(2) Maximum quantity of material per package

For the contents described in 4(b)(1)(i) or 4(b)(1)(ii):

Two fuel elements containing not more than 41 kilograms U-235.

COPY

(c) Fissile Class II and III

(1) Minimum transport index to be shown on label for Class II	1.5
(2) Maximum number of packages per shipment for Class III	60 packages

5. This amendment supersedes, in its entirety, Amendment No. 71-32 to SNM-338, dated March 24, 1970.

6. The package authorized by this amendment is hereby approved for use under the general license provisions of Paragraph 71.7(b) of 10 CFR Part 71.

REFERENCES

Licensee's application dated November 18, 1966, requesting approval to deliver special nuclear material to a carrier for transport in the RCC package.

Supplements dated May 25, 1967, January 30, April 29, 1968, February 18, and October 20, 1970.

FOR THE ATOMIC ENERGY COMMISSION

Original Signed by
Donald A. Nussbaumer

Date of Amendment OCT 23 1970

Donald A. Nussbaumer
Division of Materials Licensing

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Form AEC-401a
(7/70)

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UNITED STATES
ATOMIC ENERGY COMMISSION

- - - - - -

LICENSE AMENDMENT
for
DELIVERY OF RADIOACTIVE MATERIAL
to a
CARRIER FOR TRANSPORT

Pursuant to the Atomic Energy Act of 1954 and Title 10, Chapter 1, Code of Federal Regulations, Part 30, "Rules of General Applicability to Licensing of Byproduct Material", Part 70, "Special Nuclear Material", as appropriate, and Part 71, "Packaging of Radioactive Material for Transport", the following amendment to the license identified below is hereby issued, authorizing the licensee to deliver radioactive material to a carrier for transport, and is subject to the conditions specified in that license and to the conditions specified below:

LICENSEE	
1. Name: Westinghouse Electric Corporation	3. License No. SNM-338
2. Address: 3 Gateway Center Box 2278 Pittsburgh, Pennsylvania 15222	Amendment No. 71-36 Docket No. 70-337

CONDITIONS

4. (a) Packaging

(1) Model number	RCC-1
(2) Description	Steel fuel element cradle assembly consisting of a strongback and adjustable fuel element clamping assembly, shock mounted to a 14-gage steel outer container by shear mounts. Neutron absorber plates are required for the contents described in 4(b)(1)(ii).
(3) Drawings	Container constructed in accordance with Westinghouse Electric Corporation Drawings 541F351, 684J861 and 684J898.
(4) Fuel rod container	Reinforced 13-gage steel box approximately 9" x 9" x 160" constructed in accordance with Westinghouse Electric Corporation Drawing C5650D55.

COPY

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(b) Contents

(1) Type and form of material

(i) Uranium dioxide as zircaloy or stainless steel clad unirradiated fuel elements of the following specifications:

Type	15 x 15 Zr Clad	14 x 14 Zr Clad	14 x 14 Zr Clad	14 x 14 SST Clad	15 x 15 SST Clad
Pellet diameter (Nom)	0.367"	0.367"	0.367"	0.384"	0.384"
Rod diameter (Nom)	0.422"	0.422"	0.423"	0.422"	0.422"
Maximum Fuel Length	144"	144"	120"	120"	122"
Maximum Rods/element	204	180	180	180	204
Maximum Cross Section (Nom)	8.4" sq	7.8" sq	7.8" sq	7.8" sq	8.4" sq
Maximum U-235/element	15 kgs	15.5 kgs	16 kgs	18 kgs	20 kgs
Maximum U-235 enrichment	3.2 w/o	3.5 w/o	3.7 w/o	3.9 w/o	3.7 w/o

(ii) Uranium dioxide as zircaloy or stainless steel clad unirradiated fuel elements. Two (2) neutron absorber plates consisting of 0.19" thick, full length stainless steel containing 1.3% minimum boron or 0.19" thick OFHC copper are required between fuel elements of the following specifications:

Type	14 x 14 Zr Clad	15 x 15 Zr Clad	14 x 14 Zr Clad	14 x 14 SST Clad	15 x 15 Zr Clad	15 x 15 SST Clad
Pellet diameter (Nom)	0.367"	0.367"	0.367"	0.384"	0.367"	0.384"
Rod diameter (Nom)	0.422"	0.422"	0.422"	0.422"	0.422"	0.422"
Maximum Fuel Length	144"	144"	120"	120"	120"	120"
Maximum Rods/element	180	204	180	180	204	204
Maximum Cross Section (Nom)	7.8" sq	8.4" sq	7.8" sq	7.8" sq	8.4" sq	8.4" sq
Maximum U-235/element	17 kgs	17 kgs	16.5 kgs	18.5 kgs	18.0 kgs	20.5 kgs
Maximum U-235 enrichment	3.85 w/o	3.59 w/o	3.85 w/o	4.0 w/o	3.59 w/o	4.0 w/o

(iii) Uranium dioxide as zircaloy or stainless steel clad unirradiated fuel rods of the following specifications:

Type	SST Clad	Zr Clad
Pellet diameter (Nom)	0.372"	0.372"
Rod diameter (Nom)	0.422"	0.422"
Fuel length (Max)	144"	144"
Maximum U-235 enrichment	3.9 w/o	3.7 w/o

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(2) Maximum quantity of material per package

(i) For the contents described in 4(b)(1)(i) or 4(b)(1)(ii):

Two fuel elements containing not more than 41 kilograms U-235.

(ii) For the contents described in 4(b)(1)(iii)

Two inner containers described in 4(a)(4) containing not more than 66 kilograms U-235.

(c) Fissile Class	II and III
(1) Minimum transport index to be shown on label for Class II	1.5
(2) Maximum number of packages per shipment for Class III	60

5. Fuel rods shall be closely packed in the fuel rod container on no more than an equivalent metal-to-metal square lattice. Partially loaded fuel rod containers shall be fitted with a minimum of three, equally spaced blocks, of which the non-combustible portion of the block shall assure that the rods are maintained on no more than an equivalent metal-to-metal square lattice within the fuel rod container.

6. This amendment supersedes, in its entirety, Amendment No. 71-33 to SNM-338, dated March 24, 1970.

7. The package authorized by this amendment is hereby approved for use under the general license provision of Paragraph 71.7(b) of 10 CFR Part 71.

REFERENCES

Licensee's application dated December 8, 1967, requesting approval to deliver special nuclear material to a carrier for transport in the RCC-1 package.

Supplements dated January 30, March 1, March 5, April 29, 1968; May 28, July 28, 1969, February 18, and October 20, 1970.

FOR THE ATOMIC ENERGY COMMISSION

Original Signed by
Donald A. Nussbaumer

Date of Amendment OCT 23 1970

Donald A. Nussbaumer
Division of Materials Licensing

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MR CHARLES MACDONALD
U. S. ATOMIC ENERGY COMMISSION
DIVISION OF MATERIALS LICENSING
FUEL FABRICATION & TRANSPORTATION BRANCH
WASHINGTON, D. C.
10-20-70 3.07P

CAF Div of Compliance

THE WESTINGHOUSE ELECTRIC CORPORATION HEREBY REQUESTS AMENDMENTS TO LICENSE SNM-338, DOCKET 70-337, TO REVISE EXISTING LICENSE AMENDMENTS 71-32 AND 71-33 TO ADD THE FOLLOWING FUEL ASSEMBLY VPPARAMETERS-

PELLET MATERIAL	UO_2
HIGHEST ENRICHMEND /NOM./	4.0 W/O
DIAMETER /NOM./	.384"
ROD CLADDING MATERIAL	SST
DIAMETER /NOM./	.422"
FUEL LENGTH /NOM./	120"
ASSEMBLY NUMBER OF RODS /MAX./	204
LATTICE PITCH /NOM./	.563"
OUTSIDE DIMENSION /NOM./	8.4" SQ.

TOTAL	U /MAX/PKG/	41 KG
K EFF	/MAX/MCA/	LESS THAN 0.98
POISON PLATE REQUIRED		OFHC COPPER
NET WEIGHT /MAX./		3100 LBS

PLEASE SEND THE AMENDMENTS TO ME AT WESTINGHOUSE ELECTRIC CORPORATION, WESTINGHOUSE BUILDING, GATEWAY CENTER, PITTSBURGH, PA. 15222.

IF YOU HAVE ANY QUESTIONS TELEPHONE COLLECT AT 412-255-3907.

KARK R. SCHENDEL, LICENSE ADMINISTRATOR WESTINGHOUSE ELEC CORP., GATEWAY CENTER, PITTSBURGH, PA.

50284

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INCOMING

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UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

MAY 19 1972

L:FM:CEM
70-337
SNM-338, Amendment No. 71-43

Westinghouse Electric Corporation
ATTN: Mr. Karl R. Schendel
Box 355
Pittsburgh, Pennsylvania 15230

Gentlemen:

Enclosed is Amendment No. 71-43 to Special Nuclear Material License No. SNM-338 authorizing the delivery of special nuclear material to a carrier for transport in the RCC, RCC-1, and RCC-2 packages. This amendment supersedes in its entirety, Amendment No. 71-34 to this license.

Note that this amendment does not authorize the transport of special nuclear material. Such transport is normally subject to regulation by the Department of Transportation (DOT). Questions regarding their requirements should be directed to DOT.

Sincerely,

Charles E. MacDonald

Charles E. MacDonald, Chief
Transportation Branch
Directorate of Licensing

Enclosure:
As stated

cc: Mr. Alfred W. Grella
Department of Transportation

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ITEM # 65

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Form AEC-401a
(7/70)

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UNITED STATES
ATOMIC ENERGY COMMISSION

MAY 19 1972

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LICENSE AMENDMENT
for
DELIVERY OF RADIOACTIVE MATERIAL
to a
CARRIER FOR TRANSPORT

Pursuant to the Atomic Energy Act of 1954 and Title 10, Chapter 1, Code of Federal Regulations, Part 30, "Rules of General Applicability to Licensing of Byproduct Material", Part 70, "Special Nuclear Material", as appropriate, and Part 71, "Packaging of Radioactive Material for Transport", the following amendment to the license identified below is hereby issued, authorizing the licensee to deliver radioactive material to a carrier for transport, and is subject to the conditions specified in that license and to the conditions specified below:

LICENSEE	
1. Name: Westinghouse Electric Corporation	3. License No. SNM-338
2. Address: Box 355 Pittsburgh, Pennsylvania 15230	Amendment No. 71-43 Docket No. 70-337

CONDITIONS

4. (a) Packaging

(1) Model number	RCC, RCC-1, and RCC-2
(2) Description	Steel fuel element cradle assembly consisting of a strongback and adjustable fuel element clamping assembly, shock mounted to a 14-gage steel outer container by shear mounts. Neutron absorber plates are required for the contents as specified.
(3) Drawings	Containers constructed in accordance with Westinghouse Electric Corporation Drawings EDSK319401F, EDSK319042F, EDSK323133B, 684J580 for the RCC, 541F351, 684J861, 684J898 for the RCC-1, and 684J963, 541F614 and EDSK323133B for the RCC-2.
(4) Fuel rod container	Reinforced 13-gage steel box approximately 8" x 8" x 160" constructed in accordance with Westinghouse Electric Corporation Drawing C5650D55.

COPY

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(b) Contents

(1) Type and form of material

(i) Mixed PuO_2 in natural UO_2 as pressed sintered pellets fully clad in leak-tight zircaloy of minimum 0.018" thickness as fuel rods which are assembled into fuel elements. Two (2) neutron absorber plates consisting of 0.9" thick, full length stainless steel containing 1.3% minimum boron or 0.19 thick, full length OFHC copper are required between fuel elements of the following specifications:

Type	14 x 14
Pellet diameter (Nom)	0.367"
Rod diameter (Nom)	0.429"
Maximum Fuel Length	120"
Maximum Rods/element	180
Maximum Cross Section (Nom)	7.8" sq.
Maximum Pu/element	14.5 kgs.
Maximum Pu fissile/element	3.31 w/o

(ii) Mixed PuO_2 in natural UO_2 as pressed sintered pellets fully clad in leak-tight zircaloy of minimum 0.018" thickness as fuel rods of the following specifications:

Pellets diameter (Nom)	0.367"
Rod diameter (Nom)	0.422"
Fuel length (Nom)	120"
Highest w/o Pu fissile (Nom)	3.6 w/o

(2) Maximum quantity material per package

(i) For the contents described in 4(b)(1)(i):

Two fuel elements containing not more than 29 kilograms plutonium.

(ii) For the contents described in 4(b)(1)(ii):

Two inner containers described in 4(a)(4) containing not more than 66 kilograms Pu.

COPY

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(c) Fissile Class II and III

(1) Minimum transport index to be shown on label for Class II	1.5
(2) Maximum number of packages per shipment for Class III	60

5. Fuel rods shall be closely packed in the fuel rod container on no more than an equivalent metal-to-metal square lattice. Partially loaded fuel rod containers shall be fitted with a minimum of three, equally spaced blocks, of which the noncombustible portion of the blocks and the method by which they are secured shall assure that the rods are maintained on no more than an equivalent metal-to-metal square lattice within the fuel rod container.

6. This amendment supersedes, in its entirety, Amendment No. 71-34 to this license dated June 11, 1970.

7. The package authorized by this amendment is hereby approved for use under the general license provision of Paragraph 71.9(b) of 10 CFR Part 71.

REFERENCES

Licensee's application dated March 13, 1970, requesting approval to deliver special nuclear material to a carrier for transport in the above packages.

Supplements dated March 19, May 22, 1970, and February 25, 1972.

FOR THE ATOMIC ENERGY COMMISSION

Original Signed By
Charles E. MacDonald

Date of Amendment MAY 1 0 1972

Directorate of Licensing
Washington, D. C. 20545

COPY

Westinghouse Electric Corporation Power Systems

Box 355
Pittsburgh Pennsylvania 15230

February 25, 1972

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

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

Gentlemen:

For Div. of Compliance

Subject: Application for Amendment of License SNM-338, Docket 70-337 to Authorize Use of NFD Shipping Packages

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material to a carrier for transport in the Model RCC Series Shipping Packages described in the attachment to this letter. Please note that this application revises the parameters associated with plutonium fuel shipping, only. This change will revise amendment 71-34 but is not intended to affect the authorizations that currently exist under Amendments 71-37 and 71-38.

Please send the amended license to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect (412) 373-4652.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

KRS:jh

Attachment

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder labelled "Application for Amendment of License SNM-338 for NFD Shipping Package" immediately in front of the transmittal letter dated October 8, 1971.

Revised pages 7.3, 53, 54, and 55 should be inserted and the old pages removed.

New page 55.1 should be inserted immediately following page 55. The new report, Rod Shipment - Nuclear Criticality Safety Model should be inserted immediately following the second page of calculations in Appendix P.

The removed pages may be filed in the back of the binder.

Revision No. 29
February 25, 1972

Revision Record (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
26	7/23/71	60, 60.1	Added discussion of structural adequacy of MIL inner can.
26	7/23/71	62	Editorial corrections.
26	7/23/71	64 - 66	Added results of Super KENO calculations
26	7/23/71	Appendix R	Added MS-24347
27	9/3/71	65	H/U of 1.5 was 0.5
27	9/3/71	Appendix R	Added "Single Package Evaluation" and Figures 2 thru 9.
28	10/8/71	18	Updated LEOPARD reference
28	10/8/71	19	.500 inches was .444
28	10/8/71	Appendix B	Added 14 X 14 Assembly with 4.5 w/o enrichment Also added safety model report.
29	2/25/72	53 - 55	Added provisions for shipping loose rods.
29	2/25/72	55.1	New
29	2/25/72	Appendix P	Added rod shipping nuclear criticality safety model.

20.3 (continued)

If one box of loose rods and one fuel assembly are loaded in a single package, the resulting reactivity values would be some intermediate values, so that a mixed load will also be nuclearly safe.

20.4 Limits and Controls

The Fissile Class II limit, Fissile Class III limit and Procedural Controls presented in Section 4.4 or 16.4, will apply directly to this package.

21. Mixed Oxide Fuel Shipping Package

21.1 Packaging Description

The RCC, RCC-1 or RCC-2 Packagings described in Sections 4.1, 16.1 and/or 19.1 will be used. When loose rods are being shipped, the inner box of #13 Ga. steel described in Section 20.2 will be used.

21.2 Contents Description

Radioactivity - 250,000 curies, maximum

Identification of SNM - The SNM will be plutonium at several weight percentages (not to exceed 4.4 w/o) in natural uranium.

Form of SNM - The SNM will be in the form of plutonium oxide mixed with natural uranium oxide. The mixture will have been pressed and sintered into pellets, clad in Zircaloy as fuel rods and , possibly, assembled into clad fuel assemblies. Tests have established that the clad fuel rods meet the criteria for special form material

21.2 (continued)

Specific data on maximum parameters are:

Pellet Material	PuO_2 - UO_2	PuO_2 - UO_2
Highest w/o Pu (Nom.)	3.31 w/o Fissile	3.6 w/o Fissile
Diameter (Nom.)	.367"	.367"
Rod Cladding Material	Zircaloy	Zircaloy
Diameter (Nom.)	.429"	.422
Fuel Lgth. (Nom.)	120"	120"
Cladding Thick. (Min.)	0.018"	0.018"
No. of Rods per Assy or Box (Max)	180	361
Pattern (Basic)	14 x 14 sq.	Sq.-Close Packed
Lattice Pitch	.556" (Nom)*	.556 (Max)
Outside Dimen. (Nom.)	7.8" sq.	8.2" sq.

*See Appendix P for enrichment pattern

Total Pu (Max/pkg.)	29 kg	66 kg
k_{eff} (Max/MCA)	0.97	0.977
Poison Pl. Req'd	OFHC Copper	Steel Box
Net Wt. (Max.)	2500#	5500#

The descriptions and discussions contained in Sections 4.2, 16.2, 19.2 and/or 20.2 will be directly applicable if references to Appendix A and Appendix K are superseded by the specific data in this Section.

21.3 Compliance with Subpart C of 10CFR71

The descriptions and discussions contained in Sections 4.3, 16.3, 19.3 and 20.3 will be directly applicable, provided that:

(1) The references to Appendix A and Appendix K are superseded by the specific data in this Section.

(2) The reference to the nuclear criticality safety of unmoderated uranium enriched $\leq$ 5 w/o is superseded by the statement that LEOPARD, PDQ-03 calculations have established that an infinite lattice

21.3 (continued)

of mixed oxide fuel assemblies as described in Section 21.2 will have k_∞ <1 in the unmoderated condition. Therefore, any number of unmoderated packages will be nuclearly safe.

The requirements of § 71.32 are readily fulfilled by this package. Calculations of the stresses which would occur in the packaging shell when transporting fuel assemblies result in a computed maximum stress of ∿ 7,250 psi for a 36,000 lb (5 X 7200 lb) uniformly distributed load. When transporting boxed fuel rods, the maximum stress is calculated to be approximately 10,300 psi. These values both are well below the accepted yield strength value of even a mild steel, and the maximum stress values are conservative since the calculations do not consider the effects of the rest of the packaging structure, such as the very rigid support members that carry the shock mounts. Basic computations are supplied in Appendix P.

With regard to pressure resistance, the package loading is restricted to clad fuel rods. Regarding each fuel rod as the containment vessel for the fuel pellets within it, each containment vessel is designed to withstand, without failure, an external pressure of 2250 psi at elevated temperatures. The 25 psi external pressure criteria is very conservatively less than these design working parameters.

21.3 (continued)

The nuclear criticality safety model used to evaluate the transportation of boxed rods is supplied in Appendix P.

21.4 Limits and Controls

The Fissile Class II limit, Fissile Class III limit and the Procedural Controls presented in Sections 4.4, 4.5, 4.6, 16.4 and/or 19.4, as appropriate, will apply directly to this package.

ROD SHIPMENT - NUCLEAR CRITICALITY SAFETY MODEL

1.0 INTRODUCTION

Criticality calculations were performed as an analytical backup for a licensing request to ship PuO_2-UO_2 rods. Three basic configurations were considered; (1) one flooded box of rods surrounded by an infinite amount of water, (2) two boxes in a single package flooded, and (3) the Maximum Credible Accident (MCA) which consists of two packages crushed top-to-top with a separation of 1.7 inches between assemblies in different packages with both packages flooded. For these configurations, two cases were used to describe the geometry of the rods, which will not be in assembly form but will be stacked in close contact. For one case, the rods are assumed to have a square pitch of 0.422 inches, which allows them to remain in contact with one another. The second case assumes loose packing such that an effective square pitch of .556 inches is obtained. This second case is more reactive and this study assumes that an effective pitch greater than .556 inches will be prevented by the method of packing the plutonium fuel rods.

Geometry and model considerations are described in the Figure on Page 5. Atom densities and two group cross sections are listed on Pages 6 and 7. Table 1 summarizes the calculations performed.

TABLE 1

k_{eff} For Considered Configurations

Configuration	Pitch (Inches)	Calculated k_{eff}
One assembly, flooded	.422	0.582
	.556	0.818
One package (two boxes) flooded	.422	0.686
	.556	0.899
MCA	.422	0.768
	.566	0.977

2.0 DISCUSSION

The ARK, PDQ-03 calculational model was used to determine k_{eff} for the various configurations. (The ARK Code is an updated versior of LEOPARD). Cross sections for water for all cases correspond to water at 68° F and density equal to 1 gm/cm^3.

The PuO_2-UO_2 rods to be shipped include three different plutonium enrichments. These enrichments are nominally 4.2, 3.40, and 2.6 w/o total plutonium, where enrichment is defined by the following:

$$\text{Total Plutonium Enrichment} = \frac{PuO_2}{PuO_2 + UO_2}$$

Natural uranium is the constituent uranium with a ^{235}U weight percent of 0.711. Although the proportion of the 4.2 w/o rods will be only approximately 70% of the total number of rods, it was assumed for calculation purposes that all rods were of the highest enrichment which was taken to be 4.4 w/o instead of 4.2 w/o. It was further assumed that the material retained the isotopic distribution measured in July, 1971.

2.0 (continued)

That measured Pu isotopic distribution is given below:

Isotope	w/o
Pu-238	0.09
Pu-239	78.13
Pu-240	18.27
Pu-241	3.05
Pu-242	.47

$$\frac{\text{Pu-239 + Pu-241}}{\text{Total Pu}} = 81.2$$

The dimensions of the shipping box were taken to be 8.4" x 8.4" which is slightly larger than the nominal 8.2" x 8.2" as indicated by the shipping box drawing. The geometric configuration was assumed to be infinitely long so $B_z^2 = 0.0$ for all configurations. No cask or shipping box steel was included in the calculations for a single flooded assembly or single flooded package. For the MCA a 0.15 inch thickness of steel is inserted between the packages. This amount (and placement) of steel is conservative since this thickness is exceeded by the shipping boxes alone, without considering package steel. The above ground rules and geometric configurations are similar to those discussed in a recent criticality study for fuel assemblies. (1)

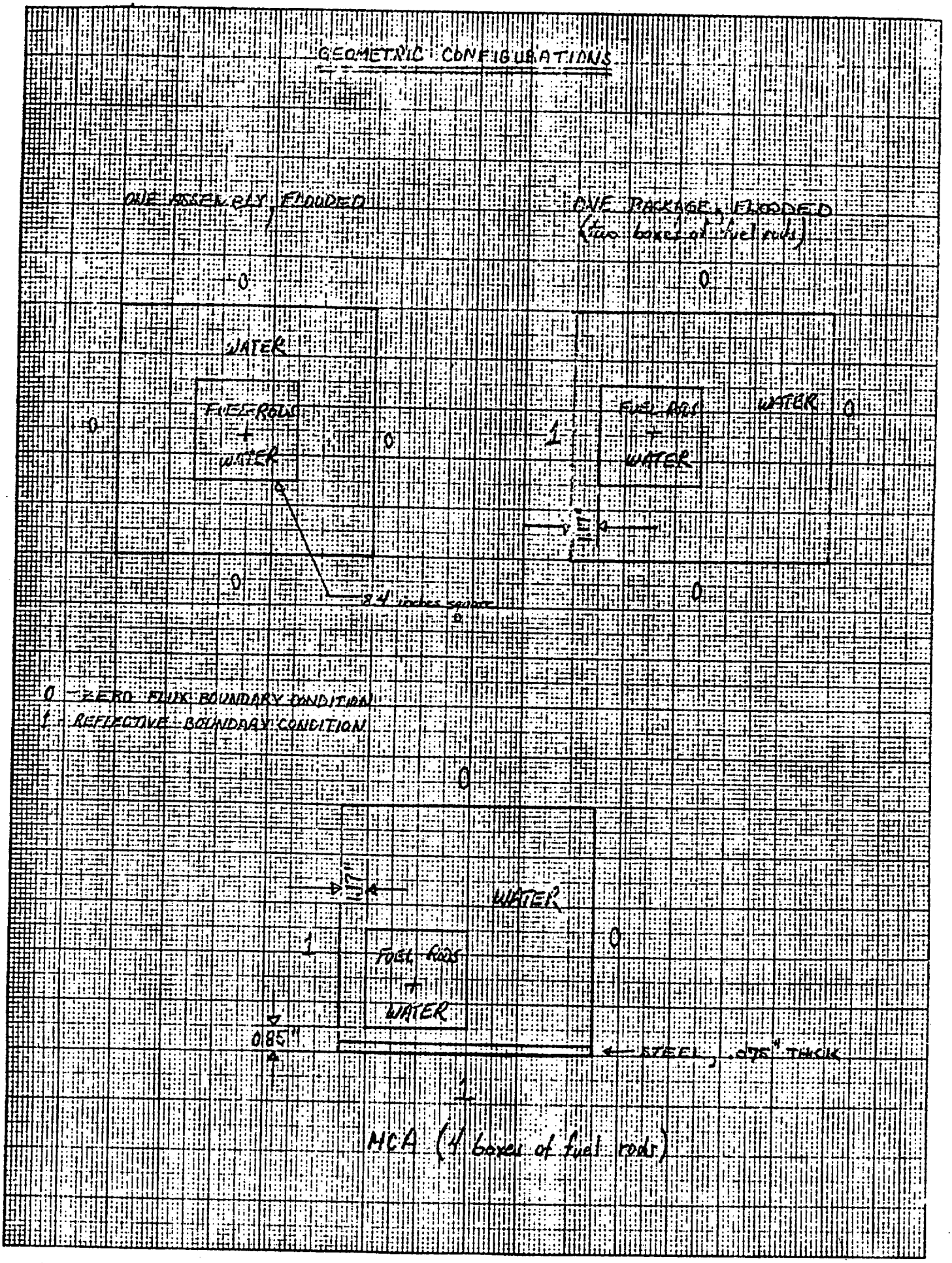
Sealed rods of partial length containing pellets (a means of shipping PuO_2-UO_2 archive pellets) at compositions up to 4.4 w/o PuO_2 will also be covered by the above calculations so long as the geometric conditions are the same as used for full length rods. Neutron leakage due to the finite length of the fuel rod was not included in the calculations.

(1) See Appendix B of this application.

2.0 (continued)

Specifically, short rods should be loaded end-to-end to approximate full length rods. They may not be interspersed with long rods in a box such that a significant fraction of the long rods (regular fuel rods) has an effective pitch greater than 0.556 inches.

GEOMETRIC CONFIGURATIONS



KEUFFEL & ESSER CO. MADE IN U.S.A.

SAFETY MODEL ATOM DENSITIES (10^{24})

Pitch = 0.422 Inches

Element	Flooded Box Enrichment = 4.4 w/o	Water
Hydrogen	0.01435	0.0669
Oxygen	0.03332	0.0334
Zirc-2	0.007375	
U-234	0.0000003749	
U-235	0.00008999	
U-236	0.000001075	
U-238	0.01241	
Pu-239	0.0004487	
Pu-240	0.0001045	
Pu-241	0.00001734	
Pu-242	0.000002649	

Pitch = 0.556 Inches

Element	Flooded Box Enrichment = 4.4 w/o	Water
Hydrogen	0.03662	0.0669
Oxygen	0.03337	0.0334
Zirc	0.004249	
U-234	0.0000002160	
U-235	0.00005184	
U-236	0.0000006192	
U-238	0.007147	
Pu-239	0.0002585	
Pu-240	0.00006020	
Pu-241	0.000009994	
Pu-242	0.000001526	

SAFETY MODEL NUCLEAR CONSTANTS
(All Temperatures = 68°F)

		Flooded Fuel			
A.	Group 1	Pitch = .422	Pitch = .556	Water	Steel
	D (cm)	1.199	1.217	1.2333	1.18
	$\Sigma_a (cm^{-1})$	0.01617	0.0139	0.000471	0.00055
	$\Sigma_R (cm^{-1})$	0.00355	0.0179	0.04760	0.000331
	$\nu\Sigma_f (cm^{-1})$	0.01524	0.0113	0.0	0.0
B.	Group 2 (0.0 - 0.625 ev)				
	D (cm)	0.2825	0.2077	0.165465	0.337
	$\Sigma_a (cm^{-1})$	1.011	0.407	0.022210	0.22
	$\nu\Sigma_f (cm^{-1})$	1.717	0.6921	0.0	

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

NOV 28 1972

L:TB:RHO
70-337
SNM-338, Amendment No. 71-42,
Rev. 1

Westinghouse Electric Corporation
ATTN: Mr. Karl R. Schendel
Box 355
Pittsburgh, Pennsylvania 15230

Gentlemen:

Pursuant to 10 CFR Parts 30, 70 and 71, Item 6 of Amendment No. 71-42 dated April 5, 1972 to AEC License No. SNM-338 is hereby deleted.

All other conditions of this license shall remain the same.

FOR THE ATOMIC ENERGY COMMISSION

Original Signed by
Charles E. MacDonald

Charles E. MacDonald, Chief
Transportation Branch
Directorate of Licensing

cc: See attached list

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ITEM # 66

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NOV 28 1972

Mr. Alfred W. Grella
Office of Hazardous Materials
Department of Transportation
400 - 6th Street, S.W.
Washington, D.C. 20590

Nuclear Materials and Equipment
Corporation
ATTN: Mr. E. K. Reitler
Apollo, Pennsylvania 15613

Nuclear Fuel Services, Inc.
ATTN: Mr. C. J. Michel
Erwin, Tennessee 37650

Babcock & Wilcox Company
ATTN: Mr. R. H. Clark
P.O. Box 1260
Lynchburg, Virginia 24505

Nuclear Engineering Company, Inc.
ATTN: Mr. Barney Roberts
Box 146
Morehead, Kentucky 40351

Protective Packaging, Inc.
ATTN: Mr. John D. Simchuk
P.O. Box 1192
Tacoma, Washington 98401

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

APR 5 1972

DML:CEM
70-337
SNM-338, Amendment No. 71-42

Westinghouse Electric Corporation
ATTN: Mr. Karl R. Schendel
Box 355
Pittsburgh, Pennsylvania 15230

Gentlemen:

Enclosed is Amendment No. 71-42 to Special Nuclear Material License No. SNM-338 authorizing the delivery of fissile and large quantity radioactive material to a carrier for transport in the Super Tiger package. Please note that for Fissile Class I shipment the concentration in the 55-gallon drum is limited to not more than 5 grams fissile material in any liter. This amendment supersedes, in its entirety, Amendment No. 71-39 to this license. We have registered this package for use under the general license provisions of Paragraph 71.9(b) of 10 CFR Part 71 for Special Nuclear Material Licenses Nos. SNM-124, SNM-778, SNM-414 and Byproduct Material License No. 04-03766-01.

Note that this amendment does not authorize the transport of radioactive material. Such transport is normally subject to regulation by the Department of Transportation (DOT). Questions regarding their requirements should be directed to DOT.

Sincerely,

Original signed by
Donald A. Nussbaumer

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

Enclosure:
As stated

cc: w/enclosure
see attached list

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Rosenzweig, DRS
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Hinshaw, OGC
Muller, SDI
Cunningham, DRS
Vollmer, DRS
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ITEM # 67

(6) B/67

Mr. Alfred W. Grelle
Office of Hazardous Materials
Department of Transportation
400 - 6th Street, S.W.
Washington, D.C. 20590

Nuclear Materials and Equipment
Corporation
ATTN: Mr. K. K. Reitler
Apollo, Pennsylvania 15613

Nuclear Fuel Services, Inc.
ATTN: Mr. C. J. Michel
Erwin, Tennessee 37650

Babcock & Wilcox Company
ATTN: Mr. R. H. Clark
P.O. Box 1260
Lynchburg, Virginia 24505

Nuclear Engineering Company, Inc.
ATTN: Mr. Barney Roberts
Box 146
Morehead, Kentucky 40351

Protective Packaging, Inc.
ATTN: Mr. John D. Simchuk
P.O. Box 1192
Tacoma, Washington 98401

Form AEC-401a
(7/70)

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APR 5 1972

UNITED STATES
ATOMIC ENERGY COMMISSION

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LICENSE AMENDMENT
for
DELIVERY OF RADIOACTIVE MATERIAL
to a
CARRIER FOR TRANSPORT

Pursuant to the Atomic Energy Act of 1954 and Title 10, Chapter 1, Code of Federal Regulations, Part 30, "Rules of General Applicability to Licensing of Byproduct Material", Part 70, "Special Nuclear Material", as appropriate, and Part 71, "Packaging of Radioactive Material for Transport", the following amendment to the license identified below is hereby issued, authorizing the licensee to deliver radioactive material to a carrier for transport, and is subject to the conditions specified in that license and to the conditions specified below:

LICENSEE	
1. Name: Westinghouse Electric Corporation	3. License No. SNM-338
2. Address: Box 355 Pittsburgh, Pennsylvania 15230	Amendment No. 71-42 Docket No. 70-337

CONDITIONS

4. (a) Packaging

(1) Model number — Super Tiger

(2) Description — A protective overpack which provides containment, impact resistance and thermal resistance for its contents. The containment vessel (cavity) is approximately 76" x 76" x 172" constructed of 3/16" thick and 10-gage mild steel. Closure of the containment vessel is by a 1/4" thick aluminum plate with silicone rubber gasket which is bolted to the containment vessel. A pressure fitting with cap on the closure plate provides a means for leak testing. The containment vessel is centered and supported in an outer 3/16" thick steel jacket by approximately 32" of polyurethane foam insulation at the end and 10" on the sides. A removable section or cap consisting of approximately 34" of

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(a) (2) Description contd.

polyurethane foam insulation encased in steel with a silicone rubber gasket is bolted to the main outer steel jacket. The overall dimensions of the package are approximately 8' x 8' x 20'. Vent holes are provided on the sides and ends of the container. Set into each corner of the outer container are standard I.S.O. steel castings. The total weight including weight of the contents is 45,000 pounds.

Packaging is constructed in accordance with Protective Packaging, Inc., Drawings Nos. 32106, Sheet 1, Revision D and 32106, Sheet 2.

(b) Contents

(1) Type and form of material

(i) Radioactive material including fissile material as solids or liquids, in normal or special form packaged within secondary containers that meet the performance requirements for Type A packaging as defined in Paragraph 173.389(j) of 49 CFR Part 173.

(ii) Radioactive material including fissile material as solids, in normal or special form packaged in DOT Specification 17C or 17H 55-gallon steel drums. Fissile material concentration shall be no more than 5 grams fissile material in any liter.

(iii) Radioactive material including fissile material as solids, in normal or special form packaged within secondary containers that meet the performance requirements for Type A packaging as defined in Paragraph 173.389(j) of 49 CFR Part 173.

(2) Maximum quantity of material per package

(i) For the contents described in 4(b)(1)(i):

Fissile material not to exceed the generally licensed quantities as defined in Section 71.8 of 10 CFR Part 71 and/or large quantity licensed material.

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(b) (2) Contents contd.

(ii) For the contents described in 4(b)(1)(ii):

Forty-two 17C or 17H 55-gallon steel drums. Each drum is limited to a maximum of 200 grams fissile material with no more than 5 grams fissile material in any liter and a maximum of 200 pounds of graphite and/or large quantity licensed material.

(iii) For the contents described in 4(b)(1)(iii):

Not more than 5 grams/ft^3 fissile material and/or large quantity licensed material.

(c) Fissile Class — I, II and III

(1) Fissile Class I — For the contents described in 4(b)(1)(ii) and 4(b)(1)(iii) and limited in 4(b)(2)(ii) and 4(b)(2)(iii).

(2) Minimum transport index to be shown on label for Class II — For the contents described in 4(b)(1)(i) and limited in 4(b)(2)(i):

As prescribed by Section 71.8 of 10 CFR Part 71.

(3) Maximum number of packages per shipment for Class III — For the contents described in 4(b)(1)(i) and limited in 4(b)(2)(i):

One (1)

5. The maximum weight of the contents including secondary containers, dunnage, shoring and bracing must not exceed 30,000 pounds.

6. The external dose rate must not exceed 10 mrem/hr 3 feet from the surface of the package.

7. The maximum decay heat generation per package must not exceed:

(i) 30 watts and the heat sources are distributed throughout the cavity such that the temperature at any point within the cavity does not exceed 200°F or

(ii) 235 watts provided combustible solids or liquids are not present and the heat sources are distributed throughout the cavity such that the internal surface temperature of the cavity walls will nowhere exceed 350°F.

COPY

8. The contents described in 4(b)(1)(ii) and limited in 4(b)(2)(ii) may be intermixed with the contents described in 4(b)(1)(iii) and limited in 4(b)(2)(iii).

9. For less than full loads, sufficient dunnage, shoring and/or bracing shall be utilized to minimize secondary impact of the Type A packages within the cavity under normal and accident conditions.

10. Protrusions from Type A packaging such as lifting eyes, etc., shall be positioned such that they will not contact the cavity walls, or shoring shall be provided to prevent puncture of the cavity walls by the protusions under the normal and accident conditions.

11. Radiation shielding as required shall be part of the Type A packages.

12. Contents shall be positioned in the cavity such that the center of gravity of the loaded package is substantially the same as the center of gravity of an empty package.

13. A leak test shall be conducted of each Super Tiger package prior to delivery to a carrier for transport to ensure that it is properly sealed.

14. Shipment of liquids where freezing may be encountered must receive approval with regard to arrangements made to prevent freezing of the contents.

15. The package authorized by this amendment is hereby approved for use under the general license provisions of Paragraph 71.9(b) of 10 CFR Part 71.

16. This amendment supersedes, in its entirety, Amendment No. 71-39 to this license dated October 5, 1971.

REFERENCES

Mechanics Research, Inc., Report C2378, "Engineering Evaluation of the Super Tiger Overpack Designed for the Shipment of Large Quantities of Hazardous Materials," submitted with the licensee's application dated May 28, 1971.

Protective Packaging, Inc., Drawing Nos. 32106, Sheet 1, Revision D and 32106, Sheet 2 submitted with the licensee's application dated February 4, 1971.

Nuclear Materials and Equipment Corporation's application dated September 17, 1971, as supplemented January 6, 1972, Docket 70-364, requesting approval to deliver special nuclear material to a carrier for transport in the Super Tiger package.

FOR THE ATOMIC ENERGY COMMISSION

Original signed by
Donald A. Nussbaumer

Date of Amendment APR 5 1972

Donald A. Nussbaumer
Division of Materials Licensing

COPY

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

NOV 3 1971

DML:CEM
70-337
SNM-338, Amendment No. 71-41

Westinghouse Electric Corporation
ATTN: Mr. Karl R. Schendel
Box 355
Pittsburgh, Pennsylvania 15230

Gentlemen:

Enclosed is Amendment No. 71-41 to Special Nuclear Material License No. SNM-338 authorizing the delivery of special nuclear material to a carrier for transport in the Model CC package.

Please note that this amendment does not authorize the transport of special nuclear material. Such transport is normally subject to regulation by the Department of Transportation (DOT). Questions regarding their requirements should be directed to DOT.

Sincerely,

Original Signed by
Donald A. Nussbaumer

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

Enclosure:
As stated

cc: Mr. Alfred W. Grella
Department of Transportation

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EWeber, SNM
CDWThornton, RMS
ACabell, ATM:DR
RLStevenson, DML (2)
CEMacDonald, DML (2)
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ITEM # 68

13

B/68

Form AEC-401a
(7/70)

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UNITED STATES
ATOMIC ENERGY COMMISSION

- - - - - -

LICENSE AMENDMENT
for
DELIVERY OF RADIOACTIVE MATERIAL
to a
CARRIER FOR TRANSPORT

Pursuant to the Atomic Energy Act of 1954 and Title 10, Chapter 1, Code of Federal Regulations, Part 30, "Rules of General Applicability to Licensing of Byproduct Material", Part 70, "Special Nuclear Material", as appropriate, and Part 71, "Packaging of Radioactive Material for Transport", the following amendment to the license identified below is hereby issued, authorizing the licensee to deliver radioactive material to a carrier for transport, and is subject to the conditions specified in that license and to the conditions specified below:

LICENSEE	
1. Name: Westinghouse Electric Corporation	3. License No. SNM-338
2. Address: Box 355 Pittsburgh, Pennsylvania 15230	Amendment No. 71-41
	Docket No. 70-337

CONDITIONS

4. (a) Packaging

(1) Model number — CC

(2) Description — Steel fuel element cradle assembly consisting of a strongback and fuel element clamping assembly, shock mounted to a 14-gage steel outer container by shear mounts.

(3) Drawings — Container constructed in accordance with The Champion Company Drawings 10410, 10536, 10538, and 10541.

(b) Contents

(1) Type and form of material — Uranium dioxide as stainless steel clad unirradiated fuel elements of the following specifications:

Type	14 x 14	15 x 15	14 x 14
Pellet diameter (Nom)	0.317"	0.355"	0.313"
Rod diameter (Nom)	0.341"	0.385"	0.341"
Maximum Fuel Length	105"	106"	90"
Maximum Rods/element	173	208	173

COPY

COPY

5. (b) (1) (Continued)

Type	14 x 14	15 x 15	14 x 14
Maximum Cross Section (Nom)	6.284"	7.695"	6.284"
Maximum U-235/element	10 kgs	13.5 kgs	10 kgs
Maximum U-235 enrichment	4.1 w/o	4.1 w/o	4.5 w/o

(2) Maximum quantity of material per package — Two fuel elements containing not more than 27 kilograms U-235

(c) Fissile Class II and III

(1) Minimum transport index to be shown on label for Class II — 1.5

(2) Maximum number of packages per shipment for Class III — 60 packages

6. This amendment supersedes, in its entirety, Amendment No. 71-23 to SNM-338, dated May 28, 1968.

7. The package authorized by this amendment is hereby approved for use under the general license provisions of Paragraph 71.7(b) of 10 CFR Part 71.

REFERENCES

Licensee's application dated November 18, 1966, requesting approval to deliver special nuclear material to a carrier for transport in the CC package.

Supplements dated May 25, December 12, 1967, January 30, March 14, April 29, 1968, and October 8, 1971.

FOR THE ATOMIC ENERGY COMMISSION

Original Signed by
Donald A. Nussbaumer

Date of Amendment NOV 3 1971

Donald A. Nussbaumer
Division of Materials Licensing

COPY

DOCKET NO. 70-337

Westinghouse Electric Corporation Power Systems

PWR Systems Division
Box 355
Pittsburgh Pennsylvania 15230

October 8, 1971

For Div. of Compliance

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

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

Gentlemen:

Subject: Application for Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material to a carrier for transport in the Model CC Shipping Package described in the attachment to this letter. Please note that this application revises the parameters associated with fuel assembly shipping, only. This change is not intended to affect the authorization which currently exists under Amendment 71-10.

Please send the amended license to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect (412) 373-4652.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

KRS:jh

Attachment

412

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder labelled "Application for Amendment of License SNM-338 for NFD Shipping Package" immediately in front of the transmittal letter dated September 3, 1971.

Revised pages 7.3, 18 and 19 should be inserted and the old pages removed.

The new report, CC Package Nuclear Criticality Safety Model should be inserted immediately following drawing SKA-219 in Appendix B.

The removed pages may be filed in the back of the binder.

Revision No. 28
October 8, 1971

Revision Record (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
26	7/23/71	60, 60.1	Added discussion of structural adequacy of MIL inner can.
26	7/23/71	62	Editorial corrections.
26	7/23/71	64 - 66	Added results of Super KENO calculations.
26	7/23/71	Appendix R	Added MS-24347
27	9/3/71	65	H/U of 1.5 was 0.5
27	9/3/71	Appendix R	Added "Single Package Evaluation" and Figures 2 thru 9.
28	10/8/71	18	Updated LEOPARD reference
28	10/8/71	19	.500 inches was .444
28	10/8/71	Appendix B	Added 14 X 14 Assembly with 4.5 w/o enrichment. Also added safety model report.

5.3 (continued - CC)

The calculations will be made by the Nuclear Engineering Department using LEOPARD/1 or PDQ-03/2 or similar experimentally verified procedures. The requirement that fuel be in assemblies in a fixed array will assure that these calculations will be accurate and directly applicable.

Single Package Evaluation - Westinghouse requests that the test conditions specified in paragraphs 4.4.2, 4.4.3, 4.4.5, 4.4.6, 4.4.7 and 4.4.8 of specification MIL-C-5584B be approved as normal conditions of transport in lieu of those specified in Appendix A of Part 71. A written test report will be available demonstrating that a preproduction prototype package fulfilled the test requirements.

The accident conditions specified in Appendix B of Part 71 will not credibly produce an arrangement more reactive than that analyzed under General Criticality Standards. The clearance between the massive vertical member of the internal components and the shell of the container will be such that a fuel assembly will not pass. Any crushing due to the Accident Free Drop would only decrease the clearance. The necessity for evaluating the Accident Puncture and the Water Immersion conditions is obviated by the assumption of maximum moderation and full reflection.

/1 Barry, R.F., "The Revised LEOPARD Code - A Spectrum Dependent Non-Spatial Depletion Code" WCAP-2759 (March 1965)

/2 Caldwell, W.R., "PDQ-03 - A Program for the Solution of the Neutron Diffusion Equations in Two Dimensions on the IBM 704," WAPD-TM-179 (May, 1960).

5.3 (continued - CC)

The necessity for evaluating an Accident Thermal condition is obviated by the limitation of the contents to clad fuel assemblies.

Package Array Evaluation - Any number of undamaged, unmoderated CC packages will be nuclearly safe, since uranium enriched to 5 w/o or less in U-235 is nuclearly safe in any quantities under any conditions. Any number of undamaged but flooded packages will also be nuclearly safe, since a single package will have a k_{eff} of $\leq$ 0.90 and there will be a minimum of 12 inches of water between the contents of any two packages. If the water drains away, the contents will also drain, so that the array returns to an unmoderated condition.

For the low-enriched assemblies under consideration, studies using LEOPARD and PDQ-03 demonstrate that a rise in k_{eff} (above the single package value) for an unlimited array does not occur at any reduced water density, due to the parasitic neutron absorption by the container walls and internal structure. Consequently, no degree of interspersed partial moderation can produce an array k_{eff} in excess of the single package k_{eff} resulting from complete flooding.

The maximum credible accident condition is conceived to involve only two packages, crushed top-to-top so that the spacing between the pairs of assemblies will be .500 inches, and aligned parallel to each other. This array is then assumed to be flooded. The heavy structural members of the base and the internal component support structures of the packag-

Appendix B

Products Shipped in Type CC Packages

Type	14 X 14 SST Clad Assemblies	15 X 15 SST Clad Assemblies	14 X 14 SST Clad Assemblies
Pellet Parameters			
Material	UO_2	UO_2	UO_2
Highest Enrichment (Nom)	4.1 w/o	4.1 w/o	4.5 w/o
Diameter (Nom)	0.317"	0.355"	0.313"
Rod Parameters			
Cladding Mt'l	SST	SST	SST
Diameter (Nom)	0.341"	0.385"	0.341"
Fuel Lgth (Nom)	105"	106"	90"
Assy. Parameters			
No. of rods (Max)	173	208	173
Pattern (Basic)	14 X 14 sq	15 X 15 sq	14 X 14 sq
Lattice Pitch (Nom)	0.453"	0.513"	0.453"
Outside Dimen. (Nom)	6.284"	7.695"	6.284"
Licensing Criteria			
Total U-235 (Max/pkg)	20 kg	27 kg	20 kg
k_{eff} (Max/ass'y)	0.74	0.86	0.78
k_{eff} (Max/1 pkg)	0.84	0.90	0.84
k_{eff} (Max/MCA)	0.98	0.98	0.98
Poison Pl. Req'd	N.A.	N.A.	N.A.
Net Wt. of Contents (Max)	2000#	2200#	2000#

CC PACKAGE NUCLEAR CRITICALITY

SAFETY MODEL

This report describes the nuclear model used for the Model CC Shipping Package nuclear criticality safety analysis. Figure 1 details the geometrical model. Table 1 gives the element atom densities and Table 2 the nuclear constants used in the two-group criticality calculations.

The model is given for a single flooded assembly; for two flooded assemblies (one package); and for the MCA, which is two packages crushed to a separation of 0.5 inches between assemblies (the maximum reactivity configuration). The model is conservative in two respects:

1. The container material is deleted from most of the calculations. The MCA was run with and without the steel and a k_{eff} less than 0.98 was obtained in both cases, and
2. The transverse leakage, B_z^2, was set equal to zero.

Since the maximum k_{eff} computed using these conservative assumptions was less than the specified maximum for each case, the CC Shipping Package nuclear criticality safety has been amply demonstrated.

FIGURE 1

SAFETY STUDY GEOMETRICAL MODEL

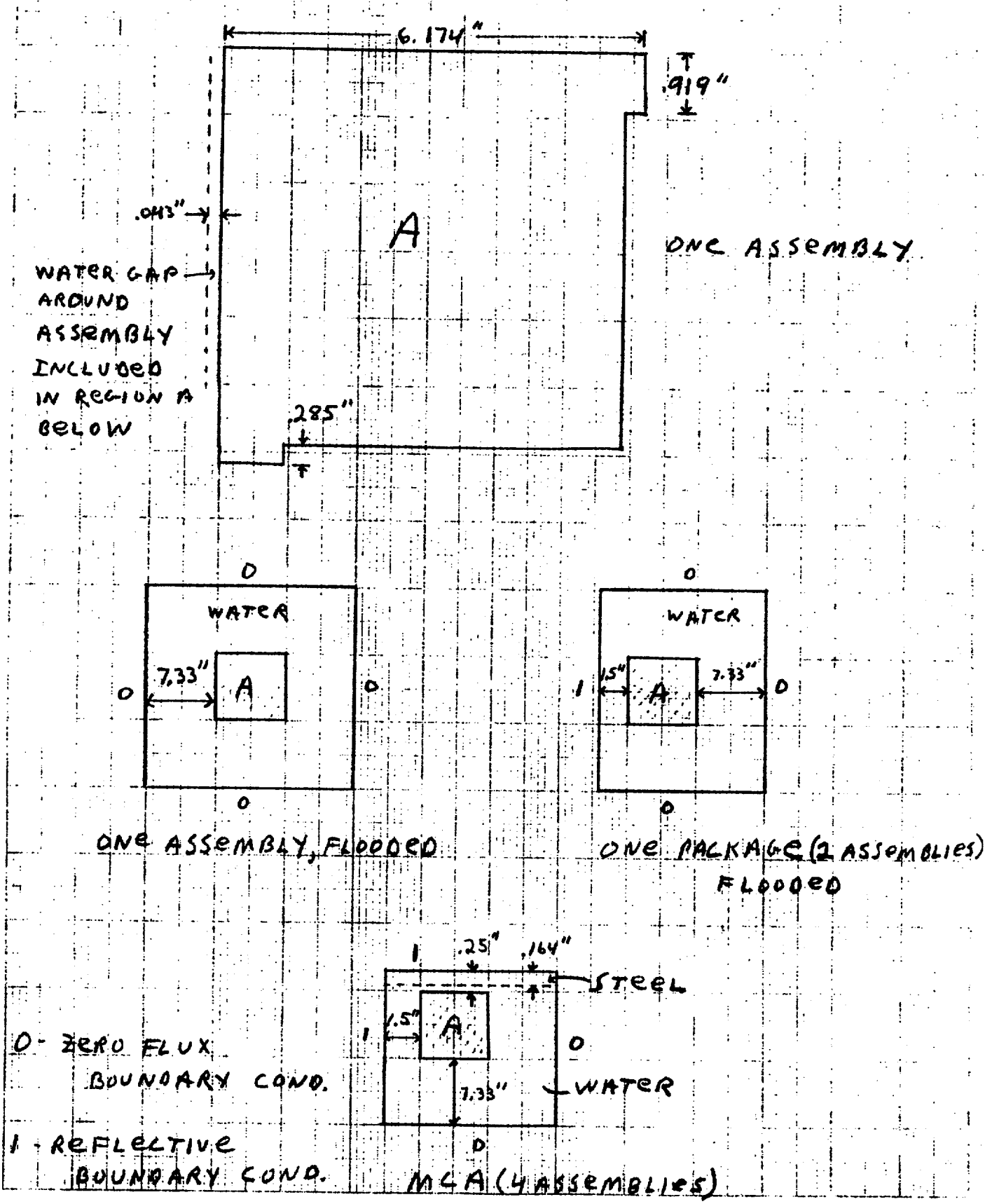

TABLE 1

SAFETY MODEL ATOM DENSITIES (10^{24})

Element	Assembly (flooded), Enrichment = 4.5 w/o	Water (ρ=1.0g/cc)
Hydrogen	.03993	.0667
Oxygen	.03451	.0333
Stainless Steel	.006415	
^{235}U	.0003292	
^{236}U	.00000218	
^{238}U	.006938	
^{234}U	.00000195	

TABLE 2

SAFETY MODEL NUCLEAR CONSTANTS

(All Temperatures = 68° F)

	Assembly	Water	Steel
A. Group 1			
D (cm)	1.16104	1.2333	1.18
Σ_α (cm^{-1})	.012944	0.000471	0.00055
Σ_r (cm^{-1})	.02144	0.04760	0.000331
$\nu\Sigma_f$ (cm^{-1})	.010846	0.0	0.0
B. Group 2 (0.0 - 0.625 ev)			
D (cm)	0.21435	0.165465	0.337
Σ_α (cm^{-1})	0.264446	0.022210	0.22
$\nu\Sigma_f$ (cm^{-1})	0.440723	0.0	0.0

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

SEP 20 1971

DML:CEM
70-337
SNM-338, Amendment No. 71-40

Westinghouse Electric Corporation
ATTN: Mr. Karl R. Schendel
Box 355
Pittsburgh, Pennsylvania 15230

Gentlemen:

Enclosed is Amendment No. 71-40 to Special Nuclear Material License No. SNM-338 authorizing the delivery of special nuclear material to a carrier for transport in the BB 250-2 package. This amendment supersedes in its entirety Amendment No. 71-26 to this license.

Note that Condition 4.(b)(2)(ii) requires four (4) steel drums for each shipping insert and a U-235 mass limitation per drum for the contents as specified. Also note that this amendment does not authorize the transport of special nuclear material. Such transport is normally subject to regulation by the Department of Transportation (DOT). Questions regarding their requirements should be directed to DOT.

Sincerely,

Original Signed by
Donald A. Nussbaumer

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

Enclosure:
As stated

cc: Mr. Alfred W. Grella
Department of Transportation

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ITEM # 69

B/69

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(7/70)

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SEP 20 1971

UNITED STATES
ATOMIC ENERGY COMMISSION

- - - - - -

LICENSE AMENDMENT
for
DELIVERY OF RADIOACTIVE MATERIAL
to a
CARRIER FOR TRANSPORT

Pursuant to the Atomic Energy Act of 1954 and Title 10, Chapter 1, Code of Federal Regulations, Part 30, "Rules of General Applicability to Licensing of Byproduct Material", Part 70, "Special Nuclear Material", as appropriate, and Part 71, "Packaging of Radioactive Material for Transport", the following amendment to the license identified below is hereby issued, authorizing the licensee to deliver radioactive material to a carrier for transport, and is subject to the conditions specified in that license and to the conditions specified below:

LICENSEE	
1. Name: Westinghouse Electric Corporation	3. License No. SNM-338
2. Address: Box 355 Pittsburgh, Pennsylvania 15230	Amendment No. 71-40
	Docket No. 70-337

CONDITIONS

4. (a) Packaging

(1) Model number — BB 250-2

(2) Description — Inner container is 11.5" ID, 16-gage steel cylinder, 63.5" long, with bolted and gasketed top flange closure and seal welded bottom plate. Inner container is centered and supported in a 22.5" ID by minimum 74" long 16-gage steel drum by 1/4" diameter spring steel rods and vermiculite. Container is constructed in accordance with Westinghouse Electric Corporation Sketch SKA-252-1.

(b) Contents

(1) Type and form of material — (i) Bulk uranium oxide (UO_2 or U_3O_8) powder with a maximum density of 2 g U/cc and enriched to a maximum 4 w/o in the U-235 isotope. The maximum H/U atomic ratio, considering all sources of hydrogenous material within the inner container shall not exceed 1.13.

COPY

(1) Type and form of material contd.

(ii) Uranium compounds which will not decompose at temperatures up to 750°F. Uranium may be enriched to a maximum 5 w/o in the U-235 isotope. The maximum H/U atomic ratio, considering all sources of hydrogenous material within the inner container shall not exceed 1.5.

(2) Maximum quantity of material per package

(i) For the contents described in 4.(b)(1)(i):

Total contents not to exceed 250 pounds, with the U-235 content not to exceed four (4) kilograms.

(ii) For the contents described in 4.(b)(1)(ii):

Total contents not to exceed 250 pounds, with the U-235 content not to exceed five (5) kilograms. Four (4) steel drums containing not more than 1.3 kilograms U-235 each shall be packaged in the shipping insert within the inner container as shown in Westinghouse Electric Corporation Sketch SKA-252-1 and Drawing C7108D10. The steel drums shall be constructed in accordance with US Military Standard MS 24347 with a maximum ID of 8.5" and a nominal height of 15.38".

(c) Fissile Class — II and III

(1) Minimum transport index to be shown on label for Class II — 0.5

(2) Maximum number of packages per shipment for Class III — 200 packages

5. The package authorized by this amendment is hereby approved for use under the general license provisions of Paragraph 71.7(b) of 10 CFR Part 71

6. This amendment supersedes, in its entirety, Amendment No. 71-26 to this license dated June 17, 1968.

REFERENCES

Licensee's application dated March 1, 1968, requesting approval to deliver special nuclear material to a carrier for transport in the BB 250-2 package.

Supplements dated April 8, May 21, 1968, May 21, July 23 and September 3, 1971.

FOR THE ATOMIC ENERGY COMMISSION

Original Signed by
Donald A. Nussbaumer

Date of Amendment SEP 20 1971

Donald A. Nussbaumer
Division of Materials Licensing

DOCKET NO. 70-337

Div of Compliance

Vestinghouse Electric Corporation Power Systems

Box 355
Pittsburgh Pennsylvania 15230

December 6, 1971

RECEIVED
DEC 9 1971
U.S. ATOMIC ENERGY COMMISSION
Regulatory
Mail Section

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

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

Gentlemen:

Subject: Application for Shipping Package Amendment

Our application, dated September 3, 1971, on Docket 70-337, that requested authorization to deliver our BB 250-2 package to a carrier for transport contains data that was subsequently determined to be in error. The results of calculations acrried out using the Super KENO code, as given on revised page 65 of the application should read:

Interspersed H_2O Density - g/cc	K_{eff} of Array
0.0	0.062
0.05	0.576
0.10	0.607
0.30	0.417
1.00	0.350

These results do indicated mild reactivity peaking at about 10% water density. This increase in array reactivity does not even approach critical, however, so the nuclear criticality safety of the array is not jeopardized.

The discrepant data was supplied to Westinghouse by Battelle Pacific Northwest Laboratories. By letter dated November 10, 1971, Battelle provided the following statement regarding the situation:

5332

W. .nghouse Electric Corporation Power Systems

PWR Systems Division
Box 355
Pittsburgh Pennsylvania 15230

May 21, 1971

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

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

Gentlemen:

Subject: Application for Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages for Div of Compliance

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material to a carrier for transport in the Pellet Shipping Package described in the attachment to this letter. Please note that the Pellet Shipping Package represents an additional application of our BB 250-2 packaging, so that the requested authorization should be issued in addition to all existing license amendments.

Please send the amended license to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect (412) 373-4652.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

KRS:jh

Attachment

2140

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder labelled "Application for Amendment of License SNM-338 for NFD Shipping Package" immediately in front of the transmittal letter dated February 4, 1971.

Revised pages 4 and 7.2 should be inserted and the old pages removed.

New page 4.1 should be inserted immediately following page 4. New pages 60 through 64 should be inserted immediately following page 59. New Appendix R should be inserted immediately following Appendix Q.

The removed pages may be filed in the back of the binder.

Revision No. 25

5/21/71

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Appendix E - MH-1A Shipping Container drawings
Appendix F - Double Barrel Scrap Shipping Container sketch
Appendix G - Quadruple Barrel Scrap Shipping Container drawing
Appendix H - Triple Barrel Shipping Container drawing
Appendix J - BB 250-1 Shipping Container drawing
Appendix K - RCC-1 Shipping Container drawings
Appendix L - BB 250-2 Shipping Container sketch
Appendix M - RCC-2 Shipping Container drawings
Appendix N - Fuel Rod Shipping Container drawing
Appendix P - Enrichment Pattern - SCE Mixed Oxide Assembly
Appendix Q - Super Tiger Shipping Container drawing and Accident Test Report
Appendix R - Pellet Packing drawing and Nuclear Criticality Safety Data.

REVISION RECORD (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
19	5/28/69	51 to 53	Added Section 20, the RCC Fuel Rod Shipping Package
19	5/28/69	Appendix N	Added
20	2/18/70	10	Added OFHC copper as poison material.
20	2/18/70	11	Changed "$\leq$ 0.90" to "obviously less than the 0.98 values.... (MCA) situation."
20	2/18/70	13	Changed "$\leq$ 0.90" to "obviously <0.98."
20	2/18/70	Appendix A & K	Deleted k_{eff} (Max/ass'y) and k_{eff} (Max/pkg). Added fuel assembly descriptions requiring OFHC copper poison plates.
21	3/13/70	4	Added Section 21.
21	3/13/70	53 - 55	Added Section 21, the Mixed Oxide Fuel Shipping Package
21	3/13/70	Appendix P	Added
22	5/22/70	53	Added Rod Cladding Thick.(Min.)
22	5/22/70	54	Revised to specify compliance with 10CFR71.32.
22	5/22/70	55	Retyped.
22	5/22/70	Appendix P	Added computations.
23	11/24/70	51 - 53	Revised to add RCC and RCC-2 pkgs. for fuel rods.
23	11/24/70	Appendix A	Added 15 X 15 SST Clad Parameters for poisoned package per 10/20/70 TWX.
24	2/4/71	56 - 59	Added Section 22, Super Tiger Shipping Package
24	2/4/71	Appendix Q	Added
25	5/21/71	60 - 64	Added Section 23, the Pellet Shipping Package
25	5/21/71	Appendix R	Added

23. Pellet Shipping Package

23.1 Packaging Description

The packaging will be the BB 250-2 packaging as described in Part 18.

23.2 Contents Description

Radioactivity - Not applicable

Identification and enrichment of SNM -

The SNM will be unirradiated uranium enriched to a maximum of 5 w/o in the isotope ^{235}U.

Form of SNM -

The SNM will be solid uranium compounds that will not react chemically or decompose at temperatures below 750° F. The material will be enclosed within a container constructed of steel having a 24-gage specified minimum thickness. The container will have a maximum ID of 8.5" and a nominal height of 15.375", and will utilize a gasketed lid with locking ring. The container will be constructed in accordance with US Military Standard MS 24374. A maximum of four of these containers will be inserted in each package. The maximum allowable H/U ratio, considering all sources of hydrogenous material within this inner cylinder of the packaging will not exceed 1.5. A typical arrangement for shipping material in the form of pellets is shown in Westinghouse Drawing C7108D10, which is enclosed as part of Appendix R.

Neutron Absorbers, etc. -

None

Maximum Weight of Fissile Content -

5.0 kilograms contained ^{235}U.

Maximum Net Weight of Contents -

250 pounds of uranium compounds.

Maximum Decay Heat - Not applicable

23.3 Compliance With Subpart C of 10CFR71

General Standards -

The materials which have been specified for this package will not result in significant chemical or galvanic reactions. There will be no specific lifting or tie down devices.

General Criticality Standards -

Figure 1.8.1.6 on Page 55 of our application, dated December 16, 1969, as amended, which was submitted on Docket 70-337, indicated that the inner containers' specified maximum inside diameter is equal to the recommended maximum permissible diameter for an infinitely long, fully reflected cylinder of heterogeneous uranium enriched $\leq$ 5.0 w/o in ^{235}U, under any conditions of moderation. The 8.5" diameter is conservatively safe for homogeneous material of the same specifications.

Normal and Accident Condition

Evaluation - The physical condition of the package under normal and accident conditions will be that described in Part 18.

Single Package Evaluation -

The restriction of SNM to a maximum permissible cylinder diameter will assure the nuclear criticality safety of a single package under any conditions of transport, as demonstrated under General Criticality Standards.

Package Array Evaluation -

The basic nuclear criticality safety data for heterogeneous UO_2 rods at an enrichment of 5 w/o are listed in Table I, and are partially plotted in Figure I, of Appendix R.

In Part 18, it was shown that under both normal and accident conditions, the seal integrity of the 11" ID inner cylinder of the packaging would not be violated. Similarly, the 8 1/2" inner containers would provide an additional layer of

23.3 Compliance With Subpart C of 10CFR71 (continued)

Package Array Evaluation -

containment. Therefore, the maximum moderation within the inner containers will be the specified maximum $^{H}/U$ ration of 1.5, which represents a maximum $^{H}/^{235}U$ ration of 30 for 5 w/o enriched uranium.

The H/U ratio of the pellet packaging described in Westinghouse drawing C 7108D10 is conservatively calculated to be 0.6. However, a specification limit value of H/U $\leq$ 1.5 was selected to provide some flexibility in selecting contents or cushioning materials.

From Figure I of Appendix R, the critical unreflected mass of heterogeneous material at 5 w/o enrichment is 62 kg ^{235}U for the specified H/U limit of 1.5, which corresponds to an $H/^{235}U$ of 30 at 5 w/o.

Then, the critical reflected mass of an array can be calculated from:

$$M_c\ (refl) \geq \frac{M_c\ (bare)}{F_r\ F_m} \left(\frac{\bar{\rho}}{\rho_o}\right)^{-s} \quad /1$$

Where: M_c (refl) = critical reflected mass of an array.

M_c (bare) = critical unreflected mass of an array.

F_r = reflector factor for an array = 8/1.

F_m = interspersed moderator factor for an array = 1.46/1.

$\bar{\rho}$ = average density of ^{235}U in array.

ρ_o = Initial density of ^{235}U in array

= 0.3080 g/cc (From Table I data by interpolation at $^{H}/X=30$)

s = 2 (1-fraction critical)

/1 Data from AEC Report SC-RR-65-98, Proceedings International Symposium for Packaging and Transportation of Radioactive Materials. "Criticality Safety Evaluation of Packages for the Transport of Fissile Material," D.R. Smith, January, 1965

23.3 Compliance With Subpart C of 10CFR71 (continued)

Then, for the undamaged condition, $\bar{\rho}$

$$= \frac{5000g}{(3.14)\ (11.25in)^2\ (74in)\ (16.4cc/in^3)}$$

$$= \frac{5000g}{482,000\ cc.} = 0.0104\ g/cc.$$

For the accident condition, $\bar{\rho}$

$$= \frac{5000g}{(3.14)\ (10)^2\ (70)\ (16.4)}$$

$$= \frac{5000}{360,472} = 0.0139\ g/cc.$$

Also, the fraction critical equals $\frac{5,000}{62,000} = 0.081$,
so, $s = (2)\ (1-0.081)$
$s = (2)\ (0.92) = 1.84$

Substituting in the equation for the critical reflected mass:

$$M_c(refl) \geq \frac{62,000}{(8)\ (1.46)} \left(\frac{0.0104}{0.3080}\right)^{-1.84}$$

$$\geq (5308)\ (0.0338)^{-1.84}$$

$$\geq (5308)\ (509)$$

$M_c(refl) \geq 2,702,000$ g for undamaged packages.

Then the number of undamaged packages required to provide this critical reflected mass in an array containing interspersed moderation is:

$$N_c \geq \frac{2,702,000}{5000} \geq 540 \text{ packages}$$

23.3 Compliance With Subpart C of 10CFR71 (continued)

For the damaged packages, the corresponding calculations are:

$$M_{c(refl)} \geq \frac{62,000}{(8)(1.46)} \left(\frac{0.0139}{0.3080}\right)^{-1.84}$$

$$\geq (5308)\ (0.0451)^{-1.84}$$

$$\geq (5308)\ (299)$$

$$M_{c(refl)} \geq 1,587,000 \text{ grams}$$

$$N_c \geq \frac{1,587,000}{5000} \geq 317 \text{ packages}$$

Therefore, the allowable number of undamaged packages in a Fissile Class II shipment is $\frac{540}{5}$ or 108 packages. In a Fissile Class III shipment, the allowable number would be $\frac{540}{2}$ = 270 packages.

For the damaged condition, the corresponding allowable numbers would be $\frac{317}{2}$ or 158 packages and 317 packages. Therefore, the undamaged package limits will govern.

23.4 Fissile Class II Limits

One hundred (100) packages will be offered as a maximum Fissile Class II shipment. Each package will be assigned a transport index of 0.5.

23.5 Fissile Class III Limits

A maximum of two hundred (200) packages will be offered as a Fissile Class III shipment.

23.6 Procedural Controls

The contents of Section 10.6 of this application will be directly applicable to this package in all aspects.

As part of the necessary controls, the $^{H}/U$ ratio, including all hydrogenous material within the inner cylinder of the packaging in any computations, will be determined to assure that the $^{H}/U \leq 1.5$ requirement is observed.

TABLE I

CRITICAL MASSES OF URANIUM OXIDE (5w/o U-235) – WATER SYSTEMS IN WHICH THE URANIUM OXIDE IS IN THE FORM OF 0.300" DIAMETER RODS

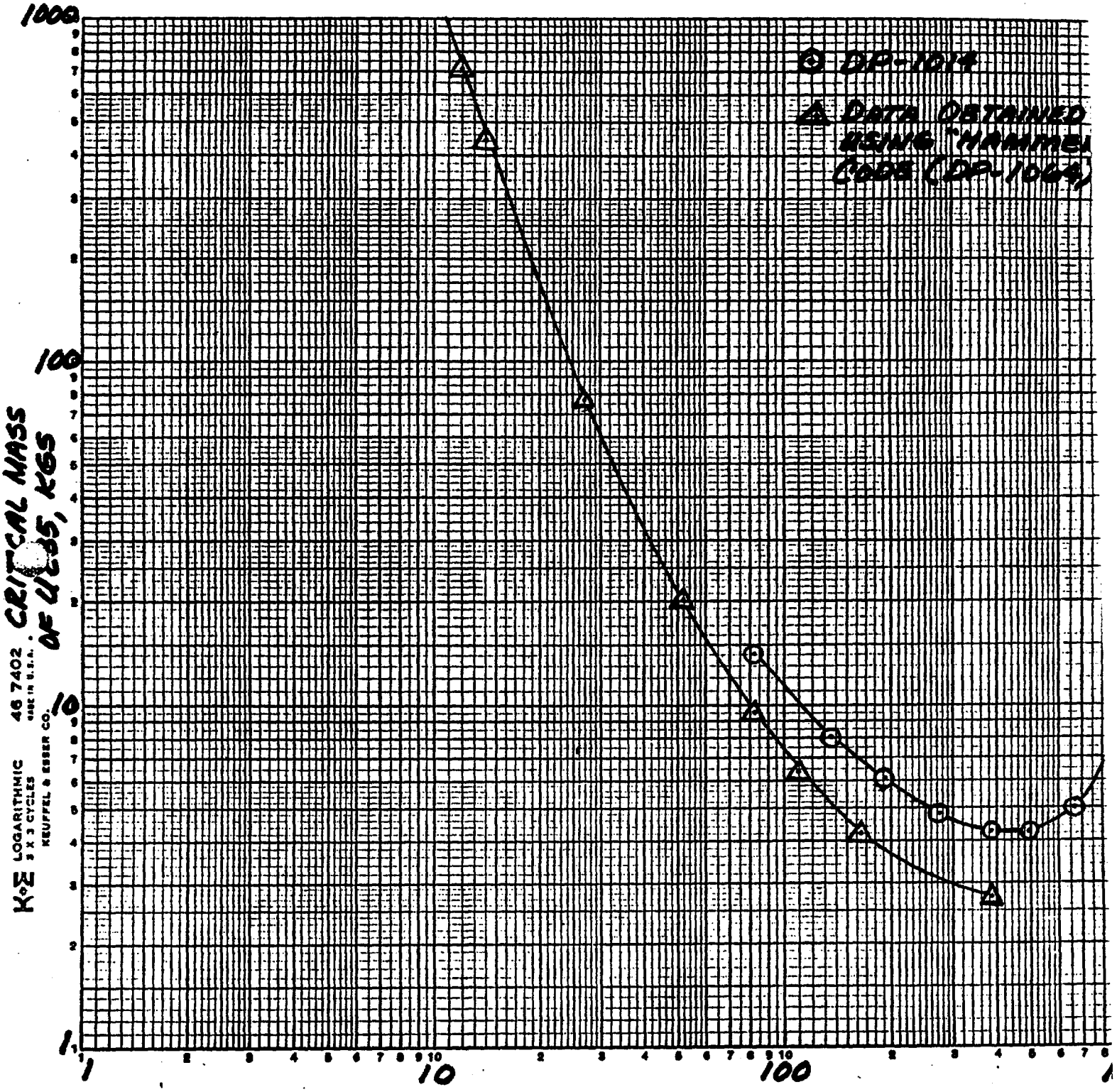
Concentration of U-235 (g/ℓ)	H/X *	Critical Masses (Kgs. U-235)			
		Bare (1)	Refl. (1)	Bare (2)	Refl.
435.70	5	–	–	∞	∞
320.10	27	–	–	77.22	46.4[illegible]
245.10	52	–	–	20.03	11.7[illegible]
190.13	83	14.08	5.42	9.53	5.7[illegible]
158.28	110	10.10	3.82	6.43	3.96
135.57	138	8.05	3.05	–	–
118.56	165	6.85	2.62	4.14	2.68
105.35	193	6.06	2.35	–	–
94.78	221	5.51	2.17	–	–
78.94	276	4.83	1.97	–	–
67.64	331	4.47	1.89	–	–
59.17	386	4.29	1.88	2.75	2.01
52.59	442	4.24	1.93	–	–
47.32	497	4.31	2.03	–	–
43.01	552	4.47	2.19	–	–
36.39	663	5.05	2.66	4.07	–
31.53	773	6.30	3.60	–	–
27.82	884	8.63	5.33	–	–
24.89	994	13.36	8.98	–	–

* Values calculated from U-235 concentrations

(1) Data obtained from AEC research and development report number DP-1014.

(2) Data obtained from computer calculations using the "Hammer" code.

FIGURE I: CRITICAL UNREFLECTED MASS OF U-235 VS ATOMIC RATIO OF HYDROGEN TO U-235



Westinghouse Electric Corporation Power Systems

PWR Systems Division
Box 355
Pittsburgh Pennsylvania 15230

DOCKET NO. 70-337

For Dir. of Compliance

July 23, 1971

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

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

Gentlemen:

Subject: Application for Amendment of License SNM-338, Docket 70-337, to Authorize Use of ~~NFD Shipping~~ Packages

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material to a carrier for transport in the Pellet Shipping Package described in our application dated May 21, 1971 and the attachment to this letter. Please note that the Pellet Shipping Package represents an additional application of our EB 250-2 packaging, so that the requested authorization should be issued in addition to all existing license amendments dealing with that packaging.

Please send the amended license to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect (412) 373-4652.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

KRS:jh

Attachment

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder labelled "Application for Amendment of License SNM-338 for NFD Shipping Package" immediately in front of the transmittal letter dated May 21, 1971.

Revised pages 60, 62 and 64 should be inserted and the old pages removed.

New page 7.3 should be inserted immediately following page 7.2. New pages 65 and 66 should be inserted immediately following page 64. New drawing MS-24347 should be inserted into Appendix R immediately following existing Figure I.

The removed pages may be filed in the back of the binder.

Revision No. 26
July 23, 1971

Revision Record (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
26		60, 60.1	Added discussion of structural adequacy of MIL inner can.
26		62	Editorial corrections.
26		64 - 66	Added results of Super KENO calculations
26		Appendix R	Added MS-24347

23. Pellet Shipping Package

23.1 Packaging Description

The packaging will be the BB 250-2 packaging as described in Part 18.

23.2 Contents Description

Radioactivity - Not applicable

Identification and enrichment of SNM -

The SNM will be unirradiated uranium enriched to a maximum of 5 w/o in the isotope ^{235}U.

Form of SNM -

The SNM will be solid uranium compounds that will not react chemically or decompose at temperatures below 750° F. The material will be enclosed within a container constructed of steel having a 24-gage specified minimum thickness. The container will have a maximum ID of 8.5" and a nominal height of 15.375", and will utilize a gasketed lid with bolted locking ring. The container will be constructed in accordance with US Military Standard MS 24347. As an inner container within the BB-250-2 packaging's inner cylinder, it is considered completely adequate to retain the SNM under the hypothetical accident conditions. A comparison between the structural features of this container and a DOT Spec. 17-H container is shown in Table 23.2.1. A maximum of four of these containers will be inserted in each package. The maximum allowable H/U ratio, considering all sources of hydrogenous material within the inner cylinder of the packaging will not exceed 1.5. A typical arrangement for shipping material in the form of pellets is shown in Westinghouse Drawing C7108D10, which is enclosed as part of Appendix R. Military Standard MS 24347 also is enclosed as part of Appendix R.

Neutron Absorbers, etc. -

None

Maximum Weight of Fissile Content -

5.0 kilograms contained ^{235}U

23.2 Contents Description (continued)

Maximum Net Weight of Contents -

250 pounds of uranium compounds.

Maximum Decay Heat - Not applicable

Table 23.2.1

Structural Feature	MS24347 Container	Spec. 17-H Container
Capacity (gal.)	3.5	5
Type	Straight Side	Straight Side
Diameter (in.)	8.5	11.25
Height (in.)	15.375	12.75
Metal Gauge		
Body	24	24
Cover	24	20
Bottom	24	24
Closure	Bolted Locking Ring	Multiple Lugs
Construction	Welded Seam	Welded Seam

23.3 Compliance With Subpart C of 10CFR71 (continued)

Package Array Evaluation -

containment. Therefore, the maximum moderation within the inner containers will be the specified maximum $^{H}/U$ ratio of 1.5, which represents a maximum $^{H}/^{235}U$ ratio of 30 for 5 w/o enriched uranium.

The H/U ratio of the pellet packaging described in Westinghouse drawing C 7108D10 is conservatively calculated to be 0.6. However, a specification limit value of H/U $\leq$ 1.5 was selected to provide some flexibility in selecting contents or cushioning materials.

From Figure I of Appendix R, the critical unreflected mass of heterogeneous material at 5 w/o enrichment is 62 kg ^{235}U for the specified H/U limit of 1.5, which corresponds to an $H/^{235}U$ of 30 at 5 w/o.

Then, the critical reflected mass of an array can be calculated from:

$$M_c \text{ (refl)} \geq \frac{M_c \text{ (bare)}}{F_r \, F_m} \left(\frac{\bar{\rho}}{\rho_o}\right)^{-s} \qquad /1$$

Where: M_c (refl) ≡critical reflected mass of an array.

M_c (bare) ≡critical unreflected mass of an array.

F_r ≡reflector factor for an array = 8/1.

F_m ≡interspersed moderator factor for an array - 1.46/1.

$\bar{\rho}$ ≡average density of ^{235}U in array.

ρ_o ≡initial density of ^{235}U in array.

≡0.3080 g/cc (From Table I data by interpolation at $^{H}/X=30$)

s ≡2 (1-fraction critical)

/1 Data from AEC Report SC-RR-65-98, Proceedings International Symposium for Packaging and Transportation of Radioactive Materials. "Criticality Safety Evaluation of Packages for the Transport of Fissile Material," D. R. Smith, January, 1965

23.3 Compliance With Subpart C of 10CFR71 (continued)

For the damaged packages, the corresponding calculations are:

$$M_c \text{ (refl)} \geq \frac{62,000}{(8)\ (1.46)} \left(\frac{0.0139}{0.3080}\right)^{-1.84}$$

$$\geq (5308)\ (0.0451)^{-1.84}$$

$$\geq (5308)\ (299)$$

$$M_c \text{ (refl)} \geq 1,587,000 \text{ grams}$$

$$N_c \geq \frac{1,587,000}{5000} \geq 317 \text{ packages}$$

Mathematically, the allowable number of undamaged packages in a Fissile Class II shipment is $\frac{540}{5}$ or 108 packages. In a Fissile Class III shipment, the allowable number would be $\frac{540}{2}$ = 270 packages.

For the damaged condition, the corresponding allowable number would be $\frac{317}{2}$ or 158 packages and 317 packages. Therefore, the undamaged package limits will govern.

The requirements for determining the transport index specify that it shall be $\frac{50}{108}$ = 0.463, which rounds up to 0.5. Therefore, one hundred (100) packages will constitute a Fissile Class II shipment.

The nuclear criticality safety of the shipping array limitations determined by these density analog calculations have been independently verified using Monte Carlo type computer methods.

The latest Oak Ridge version of the Monte Carlo code, Super KENO, with Hanson-Roach 16-group cross-sections was used to calculate the Keff of the array of packages. The limit of 100 packages in a Fissile Class II shipment implies that the minimum critical number of packages must exceed 500. For the BB 250-2 package, the most nearly cubic array containing this number is 13X13X3 high array that involves 507 packages. However, the computer code uses a rectangular

23.3 Complinace With Subpart C of 10CFR71 (continued)

lattice, so a 14X14X4 high array (784 packages) was used in the calculations. Uranium enriched to 5 w/o, as a homogeneous UO_2-water mixture at 2g U/ml and a moderating ratio (H/U) of 0.5 was assumed to fill the inner container; and at this low moderating ratio, the results derived using this material can be considered equally applicable to packages containing heterogeneous material. A full density water reflector was assumed around the array and the density of water within the outer container and the spaces among the containers was varied to determine the effect of various degrees of interspersed moderator. The results of these calculations are as follows:

Interspersed H_2O Density g/cc	keff of Array
0.0	<0.1
0.1	$0.101 \pm .003$
0.5	$0.273 \pm .010$
0.7	$0.319 \pm .009$
1.0	$0.394 \pm .012$

Check calculations of a critical, single, cylindrical, stainless-steel container of uranium at 4.89 w/o enrichment as UO_2F_2 with full water reflection gave a Keff of $1.008 \pm .010$ with the Super KENO code, and $1.007 \pm .012$ with the GEM-4 code.

These calculations indicate that the 500 package array, considered to approach the minimum critical number of packages, is in fact very subcritical under all conditions of interspersed water moderation.

Furthermore, the k_∞ implied from the ratio of fissions to absorptions from the Super KENO output indicates that an infinite array would be subcritical. The steel in the packagings is apparently sufficient to reduce the k_∞ and eliminate the interaction packaging caused by interspersed moderators in the array.

23.4 Fissile Class II Limits

One hundred (100) packages will be offered as a maximum Fissile Class II shipment. Each package will be assigned a transport index of 0.5.

23.5 Fissile Class III Limits

A maximum of two hundred (200) packages will be offered as a Fissile Class III shipment.

23.6 Procedural Controls

The contents of Section 10.6 of this application will be directly applicable to this package in all respects.

As part of the necessary controls, the $^{H}/U$ ratio, including all hydrogenous material within the inner cylinder of the packaging in any computations, will be determined to assure that the $^{H}/U \leq 1.5$ requirement is observed.

DOCKET NO. 70-337

For Div. of Compliance

W Inghouse Electric Corporation Power Systems

PWR Systems Division

Box 355
Pittsburgh Pennsylvania 15230

September 3, 1971

RECEIVED SEP 7 1971 U.S. ATOMIC ENERGY COMMISSION Regulatory Mail Section

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

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

Gentlemen:

Subject: Application for Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material to a carrier for transport in the Pellet Shipping Package described in our application dated May 21, 1971 as amended by our application dated July 25, 1971, and the attachment to this letter. Please note that the Pellet Shipping Package represents an additional application of our BB 250-2 packaging, so that the requested authorization should be issued in addition to all existing license amendments dealing with that packaging.

Please send the amended license to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect (412) 373-4652.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

KRS:jh

Attachment

ITEM # 70

(10) 3337

FILING INSTRUCTIONS

The transmittal letter should be filed in the binder labelled "Application for Amendment of License SNM-338 for NFD Shipping Package" immediately in front of the transmittal letter dated July 23, 1971.

Revised pages 7.3 and 65 should be inserted and the old pages removed.

The new report, "Single Package Evaluation" and Figures 2 through 9 should be inserted immediately following drawing MS-24347.

The removed pages may be filed in the back of the binder.

Revision No. 27
September 3, 1971

Revision Record (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
26	7/23/71	60, 60.1	Added discussion of structural adequacy of MIL inner can.
26	7/23/71	62	Editorial corrections.
26	7/23/71	64 - 66	Added results of Super KENO calculations
26	7/23/71	Appendix R	Added MS-24347
27	9/3/71	65	H/U of 1.5 was 0.5
27	9/3/71	Appendix R	Added "Single Package Evaluation" and Figures 2 thru 9.

23.3 Complinace With Subpart C of 10CFR71 (continued)

lattice, so a 14X14X4 high array (784 packages) was used in the calculations. Uranium enriched to 5 w/o, as a homogeneous UO_2-water mixture at 2g U/ml and a moderating ratio (H/U) of 1.5 was assumed to fill the inner container; and at this low moderating ratio, the results derived using this material can be considered equally applicable to packages containing heterogeneous material. A full density water reflector was assumed around the array and the density of water within the outer container and the spaces among the containers was varied to determine the effect of various degrees of interspersed moderator. The results of these calculations are as follows:

Interspersed H_2O Density g/cc	keff of Array
0.0	<0.1
0.1	$0.101 \pm .003$
0.5	$0.273 \pm .010$
0.7	$0.319 \pm .009$
1.0	$0.394 \pm .012$

Check calculations of a critical, single, cylindrical, stainless-steel container of uranium at 4.89 w/o enrichment as UO_2F_2 with full water reflection gave a Keff of $1.008 \pm .010$ with the Super KENO code, and $1.007 \pm .012$ with the GEM-4 code.

These calculations indicate that the 500 package array, considered to approach the minimum critical number of packages, is in fact very subcritical under all conditions of interspersed water moderation.

Furthermore, the k_∞ implied from the ratio of fissions to absorptions from the Super KENO output indicates that an infinite array would be subcritical. The steel in the packagings is apparently sufficient to reduce the k_∞ and eliminate the interaction packaging caused by interspersed moderators in the array.

APPENDIX R

SINGLE PACKAGE EVALUATION

A single Pellet Shipping Package was subjected to a "free drop" test as outlined in 10CFR71, Appendix B, to determine its effect on the integrity of the inner containers. The complete Pellet Shipping Package consists of a Model BB-250-2 Shipping Package, handling insert, and four (4) inner containers constructed in accordance with US Military Standard MS 24347 and described in Section 23.2 of this application.

Prior to the test, each of the four pellet (or inner) containers was filled with sixty (60) pounds of loose dry sand and pieces of scrap metal to simulate the same weight of UO_2. One of these filled containers is shown in Figure 2 (Note the absence of any Fiberpak drum or other lining). The pellet containers were then loaded into the handling insert as shown in Figure 3. Each of them was separated by a 3/4" thick polystyrene disc eight inches in diameter. Finally, the loaded insert was placed in the Model BB-250-2 Shipping Package and the complete Pellet Shipping Package was transported approximately 10 miles to the test site.

A tractor-tread crane equipped with a forty (40) foot boom and a 45,000 pound capacity electromagnet pickup was used to perform the drop test.

The Pellet Shipping Package was raised to a height of thirty (30) feet above ground level and then dropped onto a 1/2 inch thick steel plate lying on a flat, horizontal dirt surface well compacted by heavy equipment travel. The impact occurred on the bottom edge of the package with the longitudinal axis in a nearly vertical position. Following the drop test, the Pellet Shipping Package was transported approximately 10 miles back to Westinghouse NFD in a horizontal position.

Although the bottom edge of the outer package was compressed somewhat, the damage was not extensive as is shown in Figure 4. The inner cylinder of the outer package suffered no apparent damage and consequently, there was no reduction in the integrity of the water tight, gasketed and bolted closure of the inner cylinder.

Figure 5 shows the loaded handling insert immediately after its removal from the outer package. The pellet container stack height was reduced approximately 3 inches by the free fall. This can be seen by a comparison of Figure 3 and Figure 5. The reduction in stack height was caused by compression of the polystyrene spacers and the two bottom pellet containers. Figure 6 and Figure 7 show two views of

APPENDIX R - SINGLE PACKAGE EVALUATION (continued)

pellet containers after they were removed from the handling insert. Damage to either of the two top pellet containers was very minor and the gasketed and bolted locking ring closures were intact. The pellet container (Figure 8) immediately above the bottom one suffered greater damage. One side of the top rim was compressed approximately one inch and the lid was forced down into the body of the container on the opposite side. There was also minor damage to the bottom rim. Although the gasketed lid was displaced, the seal between the lid and the body of the container was sufficient to prevent any leakage of sand from the container. Damage to the bottom pellet container was very similar to the one above it, but somewhat more severe (Figure 9). The lid and one side of the top rim were compressed approximately 2 inches and at one point on the perimeter of the lid there was a small gap between the lid and the body of the container through which approximately 55 grams (45 cc) of the loose sand leaked out. The fact that the package was transported in a horizontal position during the 10 mile return trip to Westinghouse NFD undoubtedly contributed to the leakage of sand from the container.

In every case the integrity of the welded seams was maintained. Also, the safe geometry of the system was effectively maintained.

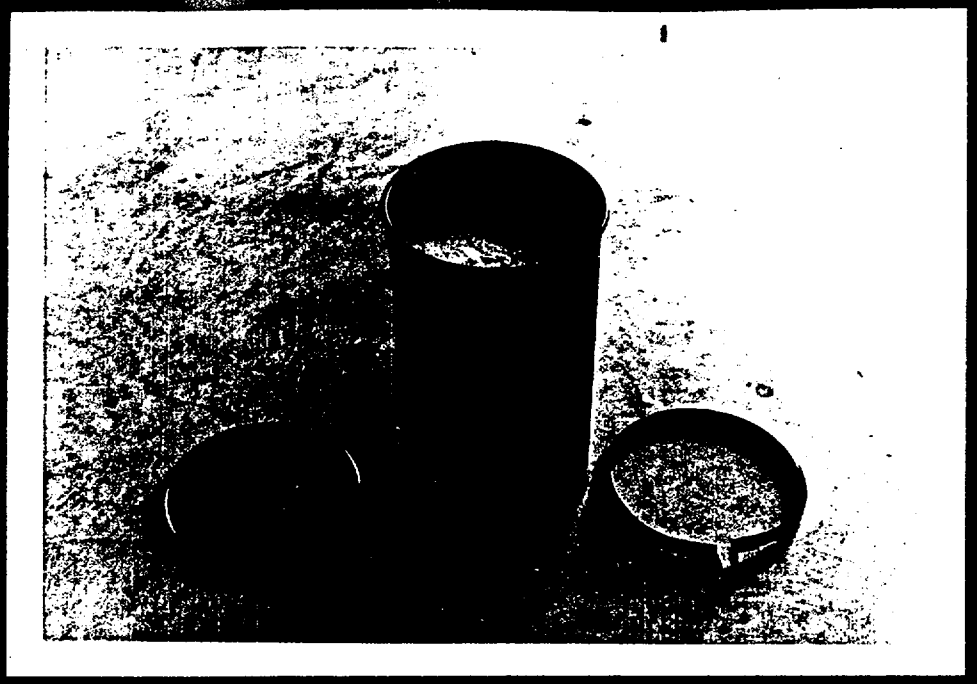


Figure 2: Undamaged Pellet Container
(US Military Standard MS 24347)

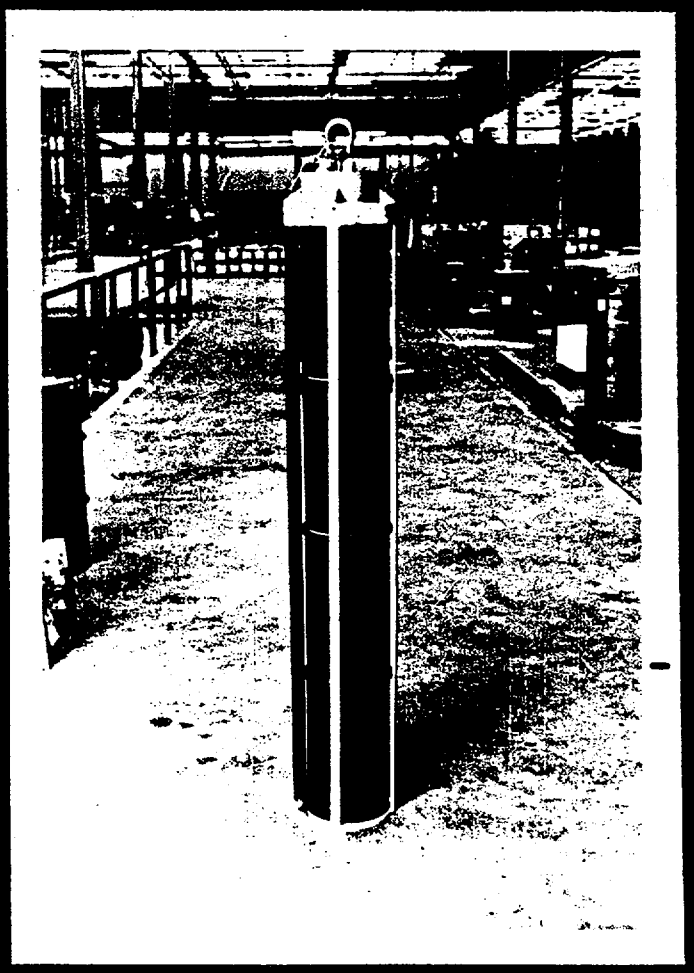


Figure 3: Loaded Handling Insert
Prior to Drop Test

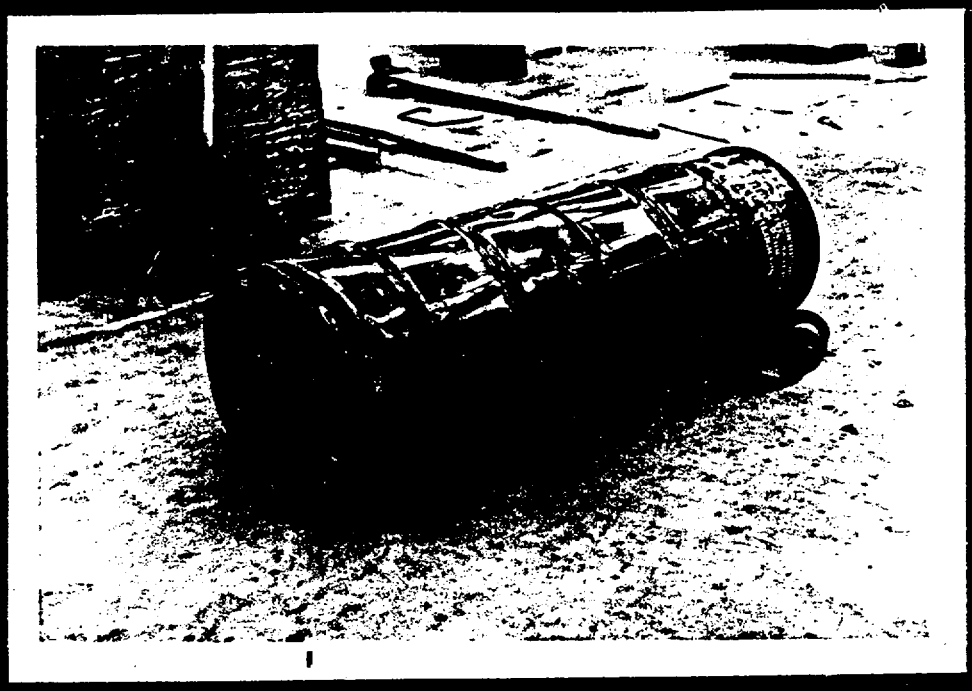


Figure 4: Damaged Model BB-250-2
Shipping Package

Figure 5: Damaged Pellet Containers
As Removed from Outer
Package
(Left to Right, Bottom to Top)

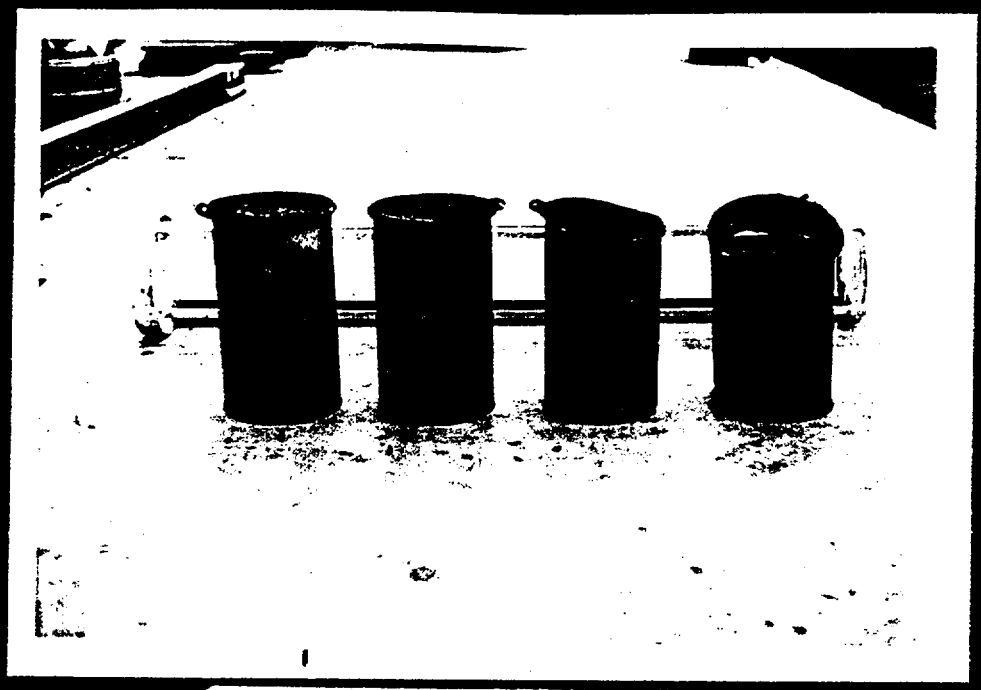


Figure 6: Side View of Damaged Pellet Containers (Left to Right, Top to Bottom)

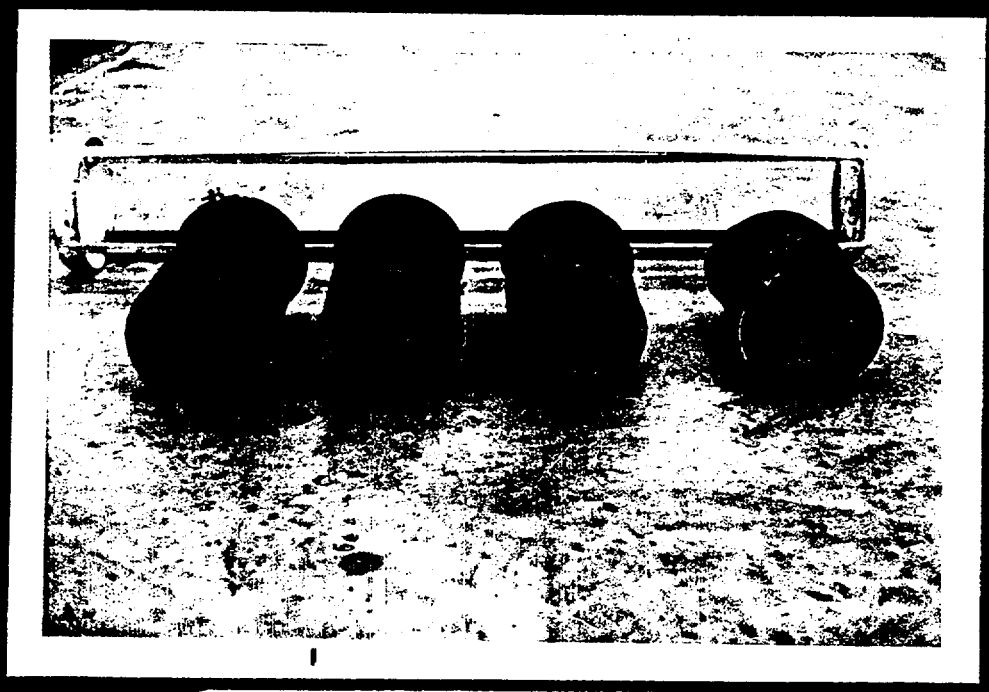


Figure 7: Bottom End View of Damaged Pellet Containers (Left to Right, Top to Bottom)

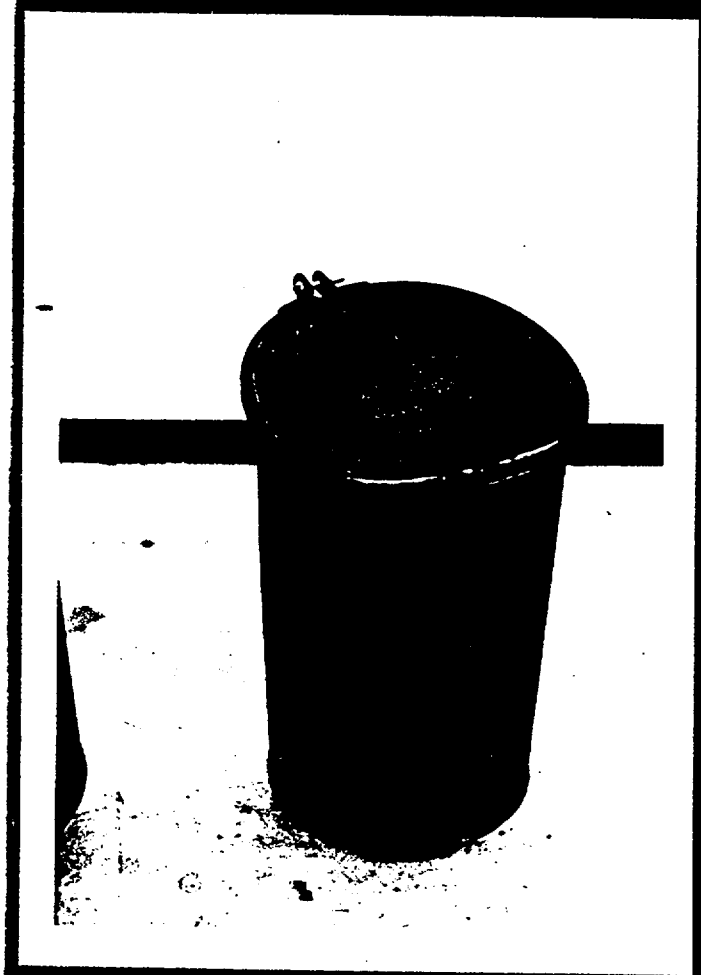


Figure 8: Damaged Pellet Container in Next to Bottom Position

Figure 9: Damaged Pellet Container in Bottom Position

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

OCT 5 1971

DML:CEM
70-337
SNM-338, Amendment No. 71-39

Westinghouse Electric Corporation
ATTN: Mr. Karl R. Schendel
Gateway Center
Pittsburgh, Pennsylvania 15222

Gentlemen:

Enclosed is Amendment No. 71-39 to Special Nuclear Material License No. SNM-338 authorizing the delivery of large quantity radioactive material to a carrier for transport in the Super Tiger package.

Please note that this amendment does not authorize the transport of radioactive material. Such transport is normally subject to regulation by the Department of Transportation (DOT). Questions regarding their requirements should be directed to DOT.

Sincerely,

Original Signed by
Donald A. Nussbaumer

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

Enclosure:
As stated

cc: Mr. Alfred W. Grella
Department of Transportation

Protective Packaging, Inc.
ATTN: Mr. John D. Simchuck
P.O. Box 1192
Tacoma, Washington 98401

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ITEM # 71

Form AEC-401a
(7/70)

COPY

OCT 5 1971

UNITED STATES
ATOMIC ENERGY COMMISSION

- - - - - -

LICENSE AMENDMENT
for
DELIVERY OF RADIOACTIVE MATERIAL
to a
CARRIER FOR TRANSPORT

Pursuant to the Atomic Energy Act of 1954 and Title 10, Chapter 1, Code of Federal Regulations, Part 30, "Rules of General Applicability to Licensing of Byproduct Material", Part 70, "Special Nuclear Material", as appropriate, and Part 71, "Packaging of Radioactive Material for Transport", the following amendment to the license identified below is hereby issued, authorizing the licensee to deliver radioactive material to a carrier for transport, and is subject to the conditions specified in that license and to the conditions specified below:

LICENSEE	
1. Name: Westinghouse Electric Corporation 2. Address: Box 355 Pittsburgh, Pennsylvania 15222	3. License No. SNM-338 Amendment No. 71-39 Docket No. 70-337

CONDITIONS

4. (a) Packaging

(1) Model number — Super Tiger

(2) Description — A protective overpack which provides containment, impact resistance and thermal resistance for its contents. The containment vessel (cavity) is approximately 76" x 76" x 172" constructed of 3/16" thick and 10-gage mild steel. Closure of the containment vessel is by a 1/4" thick aluminum plate with silicone rubber gasket which is bolted to the containment vessel. A pressure fitting with cap on the closure plate provides a means for leak testing. The containment vessel is centered and supported in an outer 3/16" thick steel jacket by approximately 32" of polyurethane foam insulation at the end and 10" on the sides. A removable section or cap consisting of approximately 34" of polyurethane foam insulation encased in

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(a) (2) Description contd.

steel with a silicone rubber gasket is bolted to the main outer steel jacket. The overall dimensions of the package are approximately 8' x 8' x 20'. Vent holes are provided on the sides and ends of the container. Set into each corner of the outer container are standard I.S.O. steel castings. The total weight including weight of the contents is 45,000 pounds.

Packaging is constructed in accordance with Protective Packaging, Inc., Drawings Nos. 32106, Sheet 1, Revision D and 32106, Sheet 2.

(b) (1) Type and form of material

Radioactive material including fissile material as solids or liquids, in normal or special form packaged within secondary containers that meet the performance requirements for Type A packaging as defined in Paragraph 173.389(j) of 49 CFR Part 173.

(2) Maximum quantity of material per package

Fissile material not to exceed the generally licensed quantities as defined in Section 71.6 of 10 CFR Part 71 and/or large quantity licensed material provided the maximum weight of the contents including secondary containers, dunnage, shoring, and bracing does not exceed 30,000 pounds, the external dose rate does not exceed 10 mrem/hr 3 feet from the surface of the package and the maximum decay heat generation per package does not exceed

(i) 30 watts and the heat sources are distributed throughout the cavity such that the temperature at any point within the cavity does not exceed 200°F or

(ii) 235 watts provided combustible solids or liquids are not present and the heat sources are distributed throughout the cavity such that the internal surface temperature of the cavity walls will nowhere exceed 350°F.

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(c) Fissile Class II and III

(1) Minimum transport index to be shown on label for Class II — As prescribed by Section 71.6 of 10 CFR Part 71.

(2) Maximum number of packages per shipment for Class III — One (1)

5. For less than full loads, sufficient dunnage, shoring and/or bracing shall be utilized to minimize secondary impact of the Type A packages within the cavity under normal and accident conditions.

6. Protrusions from Type A packaging such as lifting eyes, etc., shall be positioned such that they will not contact the cavity walls, or shoring shall be provided to prevent puncture of the cavity walls by the protusions under the normal and accident conditions.

7. Radiation shielding as required shall be part of the Type A packages.

8. Contents shall be positioned in the cavity such that the center of gravity of the loaded package is substantially the same as the center of gravity of an empty package.

9. A leak test shall be conducted of each Super Tiger package prior to delivery to a carrier for transport to ensure that it is properly sealed.

10. Shipment of liquids where freezing may be encountered must receive approval with regard to arrangements made to prevent freezing of the contents.

11. The package authorized by this amendment is hereby approved for use under the general license provisions of Paragraph 71.7(b) of 10 CFR Part 71.

REFERENCES

Mechanics Research, Inc., Report C2378, "Engineering Evaluation of the Super Tiger Overpack Designed for the Shipment of Large Quantities of Hazardous Materials," submitted with the licensee's application dated May 28, 1971.

Protective Packaging, Inc. Drawings Nos. 32106, Sheet 1, Revision D and 32106, Sheet 2 submitted with the licensee's application dated February 4, 1971.

FOR THE ATOMIC ENERGY COMMISSION

Original Signed by
Donald A. Nussbaumer

Date of Amendment OCT 5 1971

Donald A. Nussbaumer
Division of Materials Licensing

COPY

Westinghouse Electric Corporation

Westinghouse Building
Gateway Center
Pittsburgh Pennsylvania 15222

RECEIVED FEB 5 1971

February 4, 1971

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

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

For Div of Compliance

Gentlemen:

Subject: Application for Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material to a carrier for transport in Protective Packaging, Inc., "Super Tiger" packaging described in the attachment to this letter.

Please send the amendment to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect, (412) 255-3907.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

KRS: sw

Attachment: License Amendment
7 copies transmitted

ITEM # 72

B/72

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FILING INSTRUCTIONS

The transmittal letter should be filed in the binder labelled "Application for Amendment of License SNM-338 for NFD Shipping Package" immediately in front of the transmittal letter dated 11/24/70.

Revised pages 4, and 7.2 should be inserted and the old pages removed.

New pages 56 through 59 should be inserted immediately following page 55. New Appendix Q should be inserted immediately following Appendix P.

The removed pages may be filed in the back of the binder.

Revision No. 24
2/4/71

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Appendix A - RCC Shipping Container drawings
Appendix B - CC Shipping Container drawings
Appendix C - FF Shipping Container drawings
Appendix D - Yankee Shipping Container drawings
Appendix E - MH-1A Shipping Container drawings
Appendix F - Double Barrel Scrap Shipping Container sketch
Appendix G - Quadruple Barrel Scrap Shipping Container drawing
Appendix H - Triple Barrel Shipping Container drawing
Appendix J - BB 250-1 Shipping Container drawing
Appendix K - RCC-1 Shipping Container drawings
Appendix L - BB 250-2 Shipping Container sketch
Appendix M - RCC-2 Shipping Container drawings
Appendix N - Fuel Rod Shipping Container drawing
Appendix P - Enrichment Pattern - SCE Mixed Oxide Assembly
Appendix Q - Super Tiger Shipping Container drawing and Accident Test Report

REVISION RECORD (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
19	5/28/69	51 to 53	Added Section 20, the RCC Fuel Rod Shipping Package
19	5/28/69	Appendix N	Added
20	2/18/70	10	Added OFHC copper as poison material.
20	2/18/70	11	Changed "$\leq$ 0.90" to "obviously less than the 0.98 values.... (MCA) situation."
20	2/18/70	13	Changed "$\leq$ 0.90" to "obviously <0.98."
20	2/18/70	Appendix A & K	Deleted k_{eff} (Max/ass'y) and k_{eff} (Max/pkg). Added fuel assembly descriptions requiring OFHC copper poison plates.
21	3/13/70	4	Added Section 21.
21	3/13/70	53 - 55	Added Section 21, the Mixed Oxide Fuel Shipping Package
21	3/13/70	Appendix P	Added
22	5/22/70	53	Added Rod Cladding Thick.(Min.
22	5/22/70	54	Revised to specify compliance with 10CFR71.32.
22	5/22/70	55	Retyped.
22	5/22/70	Appendix P	Added computations.
23	11/24/70	51 - 53	Revised to add RCC and RCC-2 pkgs. for fuel rods.
23	11/24/70	Appendix A	Added 15 X 15 SST Clad Parameters for poisoned package per 10/20/70 TWX.
24	2/4/71	56 - 59	Added Section 22, Super Tiger Shipping Package
24	2/4/71	Appendix Q	Added

22. Super Tiger Packaging

22.1 Packaging Description

Designation - Super Tiger Shipping Container DOT SP 6400

Gross Weight - 45,000 pounds, maximum

Fabrication - The package will consist of two, rectangular, essentially concentric, steel boxes. The space between the boxes is filled with a rigid, foamed plastic. The overall dimensions of the outside shell will be approximately 8' X 8' X 20'. The design and fabrication details for the PPI Super Tiger Shipping Container are given in PPI Drg. 32106 which is attached as Appendix Q. The contents will be further enclosed in a DOT Spec. 7A, or equivalent, packaging. The inner packaging will be tied down or braced so as to withstand the forces specified in 10CFR71.31(d).

Coolants - Not required.

22.2 Contents Description

Radioactivity - Not to exceed 2500 curies of recycle plutonium.

Fissile constituent - Recycle plutonium possibly mixed with enriched uranium. Total Pu plus ^{235}U will not exceed 300 grams.

Form of SNM - The SNM will be in the form of a solid, non-pyrophoric dispersion as a contaminant on or mixed with otherwise non-radioactive material. The non-radioactive base material may be metal, plastic,

22.2 (continued)

wood, paper, rag, inert absorbent, or any other solid that will not ignite or decompose at less than 350°F. The contaminated material will be double bagged in plastic before being inserted into the DOT-7A inner container.

Neutron Absorbers, etc. - Not applicable

Maximum Net Weight of Contents - The maximum net weight of the contents (including all DOT-7A packagings and tie-downs or bracing) will not exceed 28,000 pounds.

Maximum Decay Heat - Not to exceed 30 watts, total.

22.3 Compliance with Subpart C of 10CFR71

General Standards - The material of the packaging is such that it will not react with the inner packaging(s) or its tiedown or bracing. The inner DOT-7A packaging will be constructed such that there will be no reaction with the plastic bagging material.

The package will be equipped with a positive closure device and sealing means.

The specified system of lifting eyes will support 135,000 pounds without material yielding, as demonstrated on pages 21 and 22 of the attached Mechanics Research, Inc. (MRI) Report No. C2378, which is attached as part of Appendix Q. The same data demonstrates the adequacy of the tiedown arrangements.

22.3 (continued)

Standards for Large Quantity Packagings - The ability of the package to withstand a static, uniformly distributed load of 5 times the gross weight of the package is calculated on pages 13 and 14 of MRI Report C2378.

The resistance to a 25 psi external compressive force is computed on pages 19, 20 and 21 of that report.

Criticality Standards - Not applicable.

Standards for Normal Conditions - The requirements specified for a package under normal conditions of operation will be met as a result of providing a DOT-7A inner packaging. The Super Tiger packaging will provide significant redundant containment.

Standards for Accident Conditions - The ability of the Super Tiger packaging to provide superior protection to the DOT-7A inner packaging is documented in MRI Report C2378. The report clearly demonstrates that there would be no mechanical or thermal event which would affect the inner steel box as a result of undergoing the hypothetical accident conditions. As a result, the containment effectiveness of the inner box would be unimpaired and the stresses imposed on the inner DOT-7A packaging would be significantly reduced.

22.4 Fissile Classifications

As a practical matter, each Super Tiger package will constitute a full load shipment, due to its size. Each package will be assigned a Fissile Class as prescribed in 10CFR71.6. When the quantity of SNM requires a Fissile Class III designation, the exclusive use of vehicle will be specified on the shipping papers.

22.5 Procedural Controls

For each use, prior to closing the Super Tiger, the DOT-7A package will be inspected for general quality and acceptability, the tiedowns or braces used to secure the DOT-7A package will be checked and the Super Tiger gasket will be inspected to assure that it is complete and free from defects.

Following closure, the package will be inspected to assure the presence of all closure bolts for which provision is made in the packaging. The lifting eyes and tiedown eyes also will be visually inspected to assure that they do not display any cracks, thin sections, or other gross defects.

The Nuclear Materials Management group will be responsible to maintain the required records on each shipment.

PROPRIETARY DATA
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1/29/71

ENGINEERING EVALUATION OF THE SUPER TIGER OVERPACK DESIGNED FOR THE SHIPMENT OF LARGE QUANTITIES OF HAZARDOUS MATERIALS

C2378 May 4, 1970

Prepared for: Protective Packaging, Inc.
15 North Broadway
Tacoma, Washington 98403

Prepared by: L. J. Hansen

Approved by: R. T. Haelsig

REGISTERED PROFESSIONAL ENGINEER
RICHARD T. HAELSIG
No. 16538
CIVIL
STATE OF CALIFORNIA

Prepared by:
Mechanics Research, Inc.
15 North Broadway
Tacoma, Washington 98403

1.0 INTRODUCTION

The purpose of this test report is to verify that the proposed Super Tiger shipping container is capable of meeting the performance criteria set forth on 10 CFR 71 and 49 CFR 171, (Reference 1 and 2).

The Super Tiger overpack will be used to transport packages meeting criteria of Department of Transportation regulations enumerated in the Department of Transportation's Hazardous Materials Regulations, (Title 49 CFR, Part 171, Para. 173.396). In all cases the packages will be approved appropriate specification containers or U.S.A.E.C. approved containers for fissile radioactive material shipments by the AEC or one of its contractors or licensees.

The Super Tiger will be transported in a vehicle assigned sole use of the consignor, with a total transport index of 50 for fissile class 2 shipments or the maximum number of packages in accordance with DOT regulations (Para. 173.396 "Table of Authorized Contents") for fissile class 3 shipments. In all cases of fissile class 3 shipments, transport controls will be exercised to protect against loading, transporting or storing of that shipment together with other fissile material. This criteria was established to simulate hypothetical accidents in which any package containing hazardous materials must be capable of surviving. The proposed container will be used for hauling approved specification containers of Type A, Type B and large quantities of radioactive materials in solid, liquid and gas form.

Maximum payload weight is approximately 28,700 lbs. with gross weight of 45,000 lbs. The DOT design discussed in this report is depicted on ~~MRI Drawing No. 121350~~. (PPI 32106)

KRS 1/29/7

~~PROPRIETARY DATA~~

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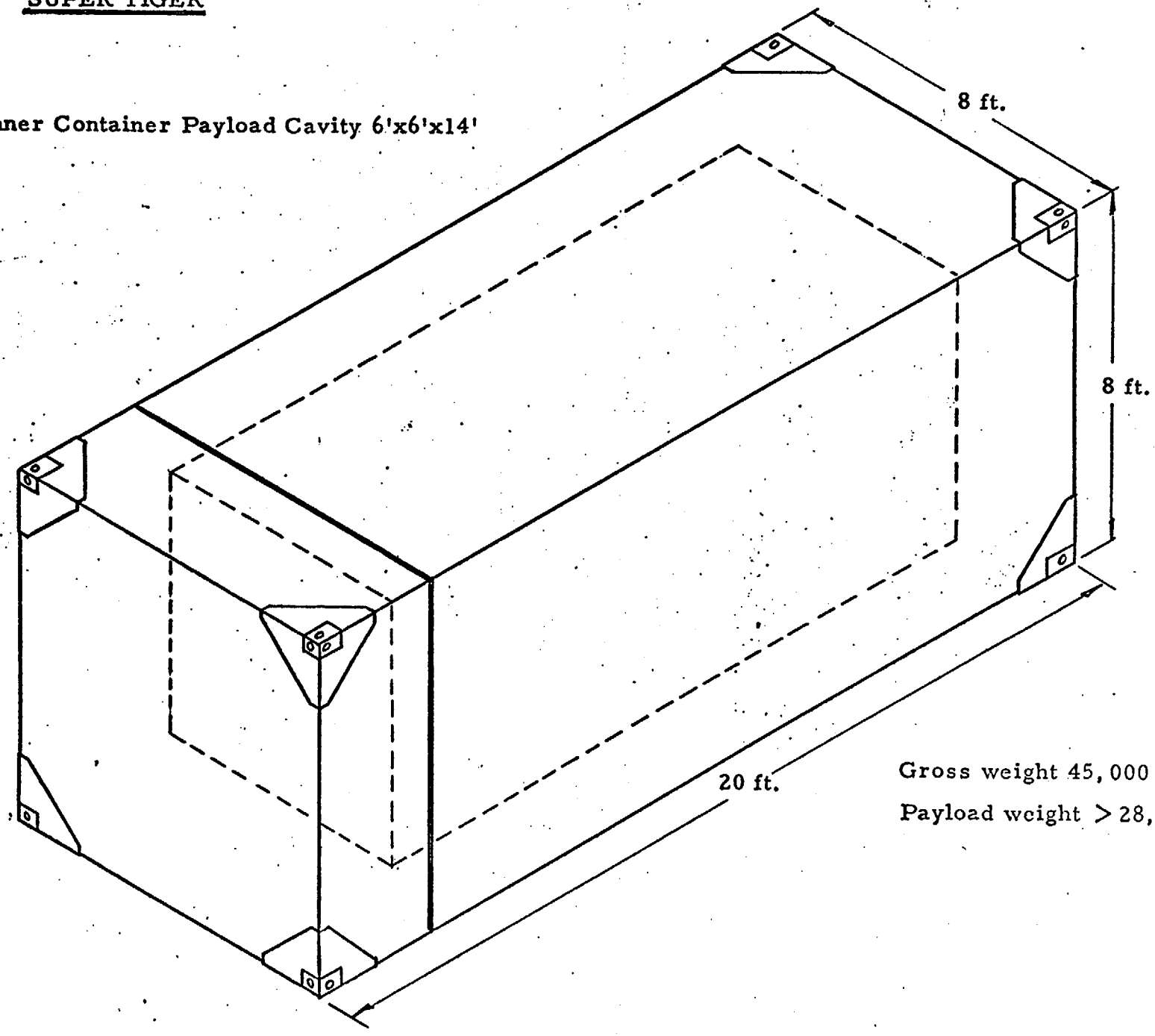
SUPER TIGER

Inner Container Payload Cavity 6'x6'x14'



Gross weight 45,000 lbs

Payload weight > 28,700 lbs

2.0 SUMMARY

Since the Super Tiger is intended to act as a protective overpack for the shipment of large quantities of hazardous materials, it was felt that the design should be substantiated not only by engineering evaluations but also by physical testing. The design philosophy was to use proven computer routines and analysis techniques to evaluate and size the prototype design. Once this was complete, a full scale container was fabricated and subjected to those tests critical to its acceptance.

After all the testing had been completed, the following results were noted:

- 30 foot Drop Test - The container, loaded with a combination of liquids and solids, was dropped 30 feet onto the corner of its lid. The outside shell indented less than 14 inches with no deformation whatsoever to the inner container.
- 40 inch Puncture Test - Side No. 3 sustained two - 40 inch drops onto a 6 inch diameter pin resulting in no yielding or indentation of the inner container wall.
- Fire Test - Temperatures in excess of 1500°F for over 30 minutes were sustained with a rise in contents temperature to a level of less than 150°F.

By combining these test results with additional analysis, it has been concluded that the Super Tiger possesses the ability to protect its liquid, gas or solid contents from exposure while meeting those AEC and DOT regulations stated in Reference 1 and 2. All cargo will be supported in a manner capable of producing no more severe loading on the internal container than that of the tested prototype. Overall container dimensions and foam thickness can be scaled down as a function of impact pressures.

3.0 CONFIGURATION

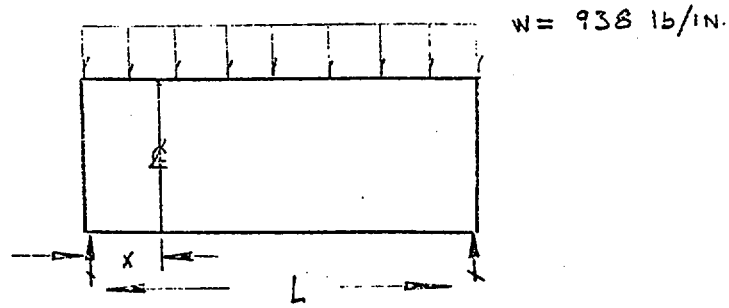
The overpack was designed as a general use container for the shipment of Type B hazardous materials. It was configured to possess the appearance and

dimensions of a standard 8' x 8' x 20' modal cargo container, (see photo 1). Since it utilizes the universal I.S.O. corner fittings, it can be handled, stored and shipped in the same manner as any standardized shipping container. This provides obvious economic advantages over any system implying a non-conventional container.

The overpack basically consists of two rectangular steel shells separated with rigid fire retardent polyurethane foam. Steel shells being fabricated from a low carbon steel are extremely ductile, thus allowing large distortions with no tearing. In addition to providing puncture and penetration resistance, the shell also acts as a durable flame shield. Since the thermal conductivity of polyurethane foam is considerably lower than that of the best rockwool or fiberglass insulation, excellent thermal protection is provided. Due to its low cost and high energy absorbing capability, polyurethane foam also provides an ideal shock isolation media. ~~MRI~~ PPI Drawing No. ~~121350~~ 32106 is attached to provide all construction details.

Photo 1

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



A) Bending moment at bolt centerline:

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

$x = 35$

$L = 240$

$M_{\mathfrak{C}} = wx(L - x)/2$

$M_{\mathfrak{C}} = (938)(35)(240 - 35)/2$

$M_{\mathfrak{C}} = 3,365,000$ in.-lb.

Conservatively assume only the bottom two bolts react this load:

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

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

Allowable Bolt Load = 80,700 at 125 ksi

∴ Margin of Safety (Bolts)

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

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

B) Max. Shell Bending Moment:

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

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

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

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

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

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

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

$$f_c = M/2hA$$

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

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

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

Margin of Safety:

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

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

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

Therefore, the full scale prototype design utilized this technique. A different wall configuration was used for each of the four walls. They were:

- Side 1 - 3/16ths plus 3/16ths plus 3/16th
- Side 2 - 3/16ths plus 3/16ths plus 1/8th
- Side 3 - 3/16th plus 1/8th plus 1/8th
- Side 4 - 3/16th plus 3/16

In each case, the inner plates were to be tack welded so as to release on impact. This was true with all but Side 4, since during fabrication a near accident resulted in a plate being solidly welded. The effects were shown in the actual testing of this side. See Section 5.4 - 40 Inch Puncture Test.

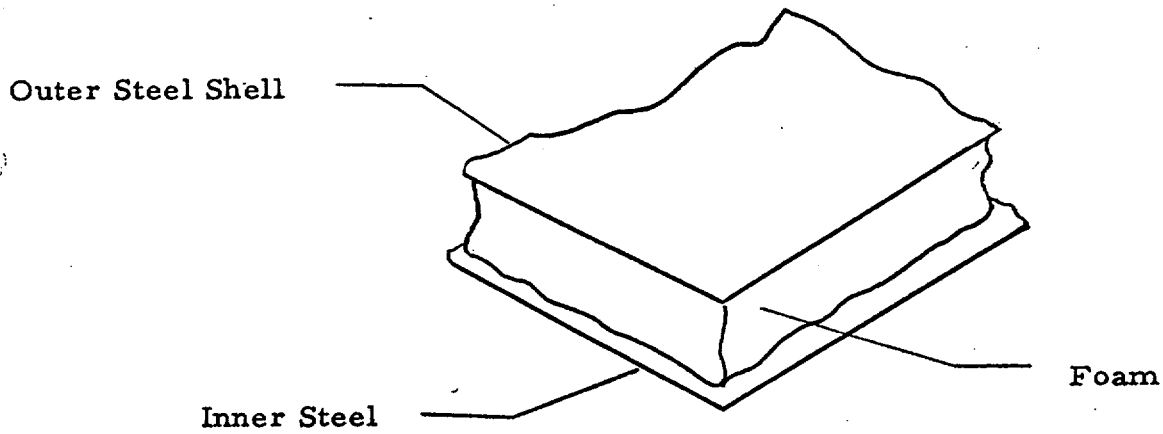
4.3 Thermal Analysis

Appendix 3 contains a thermal analysis on an overpack resembling the Super Tiger. The container was analytically subjected to the required 1475°F fire test for a 30 minute period, using a transient electrical network analogy program, (Reference 3). The results show that the content's temperature will at no time be raised more than 10°. Since this analysis was for the urethane thickness of only 7", it was felt that the Super Tiger would have no trouble surviving the actual fire test.

4.4 Compression

Paragraph 71.32b, Reference 2, requires that packaging shall be adequate to assure that the containment vessel will suffer no loss of contents if subjected to an external pressure of 25 psig.

Since the inner and outer skins are attached by means of the rigid polyurethane foam, a stress skin design of the following configuration is provided.



Therefore, the external pressure loads will be carried in the form of plate bending when the outside sheet is in compression and the inner sheet is in tension. Foam compression strengths in excess of 100 psi are present at all points.

The moments in a rectangular uniform load homogenous plate with clamped edges is given in Timoshenko "Theory of Plates and Shells", page 228, Reference 4, as:

$$\frac{b}{a} = \frac{192}{76} = 2.5$$

$q = 25$ psi

1. $(M_x)_{x=a/2,\, y=0} = -.085\, qa^2 = 12,300$ in-lb

2. $(M_y)_{x=0,\; y=b/2} = -.057\, qa^2 = 8,230$ in-lb

The resultant are as follows:

	Load Component	Outer Skin	Inner Skin
1.	M_x edge	-6600	+11750
2.	M_y edge	-4410	+7850

$f_b = 11750$ psi $< F_{TU} = 63,000$ psi

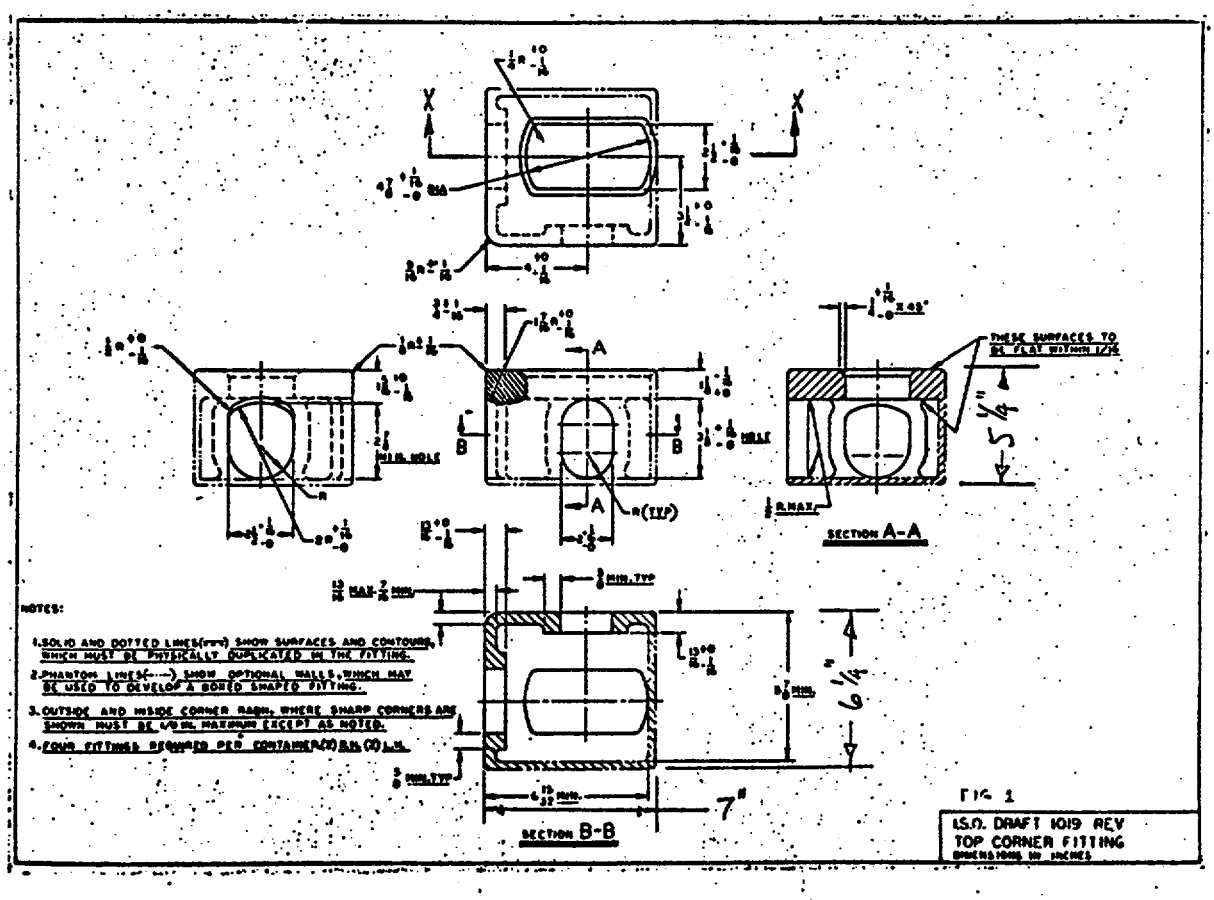
$$M.S. = \frac{63,000}{11,750} - 1 = + \text{Large}$$

Therefore the container can react 25 psig without loss of contents.

4.5 Tie Downs

Paragraph 71.31c, of Reference 2, requires the tiedown fitting be capable of reacting a load of three times the package weight vertically and ten times the weight in direction of travel. All eight of the tie down fittings are standard International Organization for Standardization (I.S.O.) corner fittings for freight containers, (Reference 5).

Typical section properties can be found below.



A guaranteed minimum material yield strength of 46,500 psi assures high reliability. Primary loads are reacted through Section X-X producing a net cross section area of (1-1/8 x 1-9/16) or 1.76 in^2.

The allowable load per casting will be:

$$P_{allow} = (F_s)(A_s) = \left(\frac{46,500}{2}\right)(2)(1.76)$$

$$P_{allow} = 82,000 \text{ lbs/fitting}$$

Assuming four fittings to be used for lifting, then the net capacity is:

$$G's = \frac{(82,000 \text{ lb/fitting})(4 \text{ fitting})}{(45,000 \text{ lbs})}$$

$$G's = 7.28 \text{ g (vertical capability)}$$

Assuming eight fittings to be used for tie down, then the net capacity is:

$$G's = \frac{(82,000 \text{ lbs/fitting})(8 \text{ fittings})}{(45,000 \text{ lbs})}$$

$$G's = 14.5 \text{ g (fore and aft)}$$

Therefore the standard I.S.O. fitting does possess the required strength to meet tie down requirements as set forth in Reference 2.

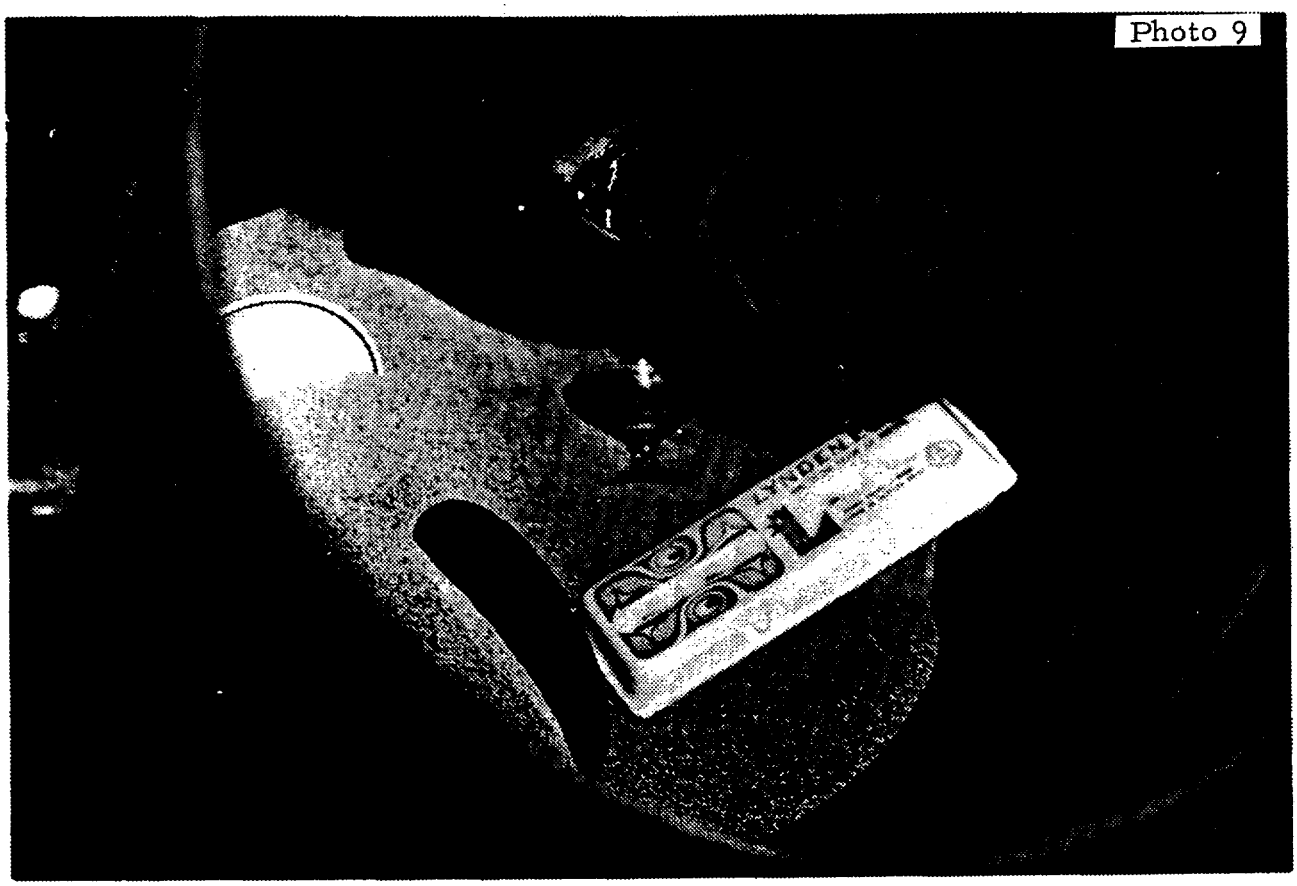
5.0 FULL SCALE TESTING

A full scale prototype container was fabricated by Star Iron and Steel Company, Tacoma, Washington and subjected to the required testing as outlined in Reference 1 and 2. Mr. A. O. Dodd, Nuclear Safety Branch, H&S Division, Richland, Washington, acted as official test witness for the AEC.

glamourless subject, it also served as a thermal indicator.

To establish a level of fragility to the payload, one drum was loaded with a dozen eggs, two pieces of china, a glass and a bottle of beverage, (see photos 8 and 9).

Photo 8



The inner and outer container covers were secrued making the container ready for drop testing.

5.3 30 Foot Drop Test

Super Tiger was trucked from the fabrication and loading site at Star Iron to the Port of Tacoma facility for the drop sequence. On route the truck trailer rig was weighed at a registered truck scale which determined the gross Super Tiger weight to be 45,260 lbs.

After a considerable amount of design review it was concluded that the most critical drop orientation would be a diagonal drop onto the corner of the cover.

A quick release device was rigged between the crane and container to provide instaneous release. The drop height was measured by a 30' length of rope attached to the lower corner. The container was then raised to a point where the lower corner was over the target area. Upon release the container was allowed to free fall 30' onto the steel plates, (See photos 10 through 14).

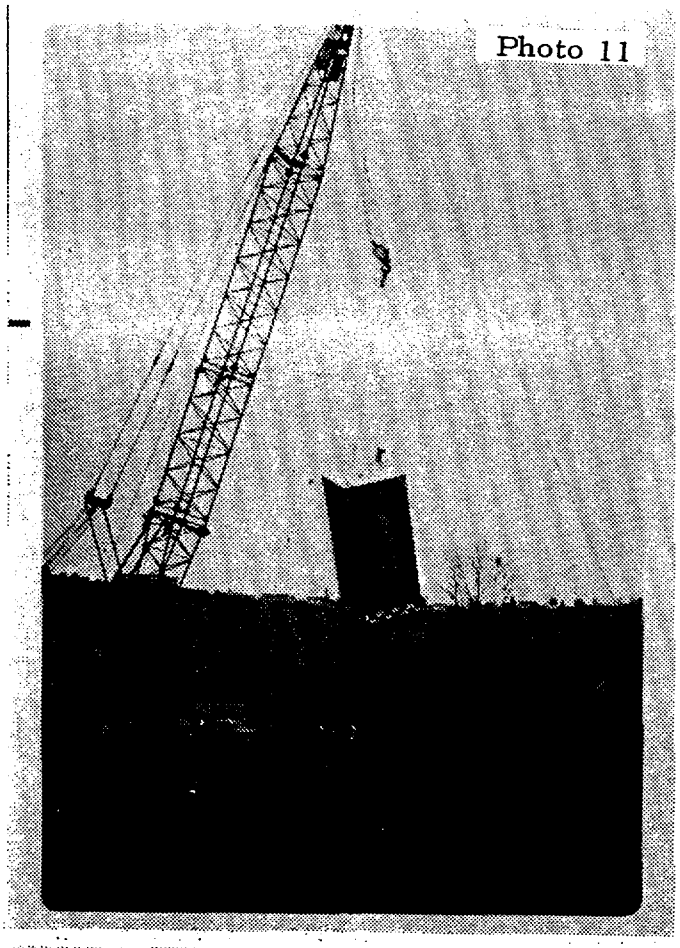


Photo 11

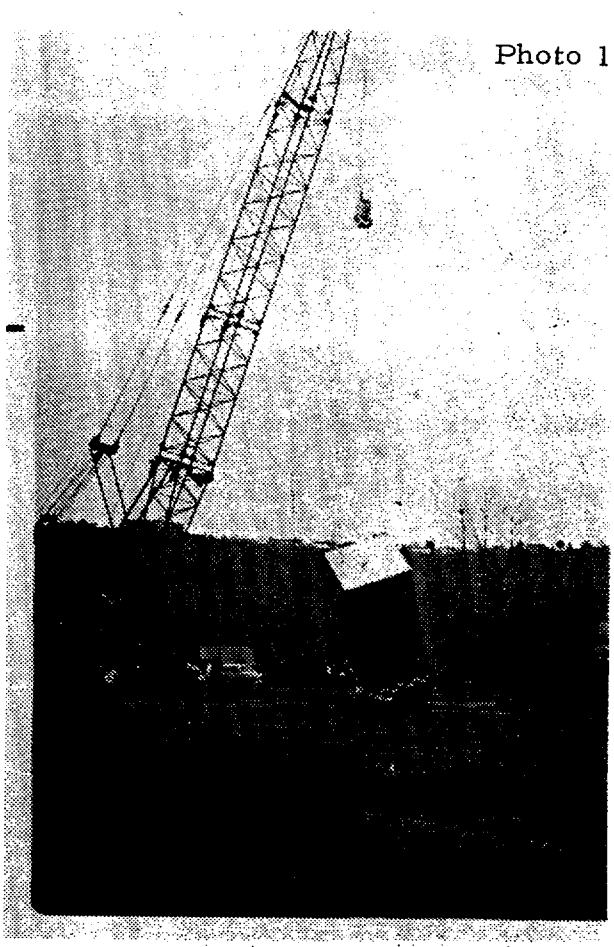


Photo 1

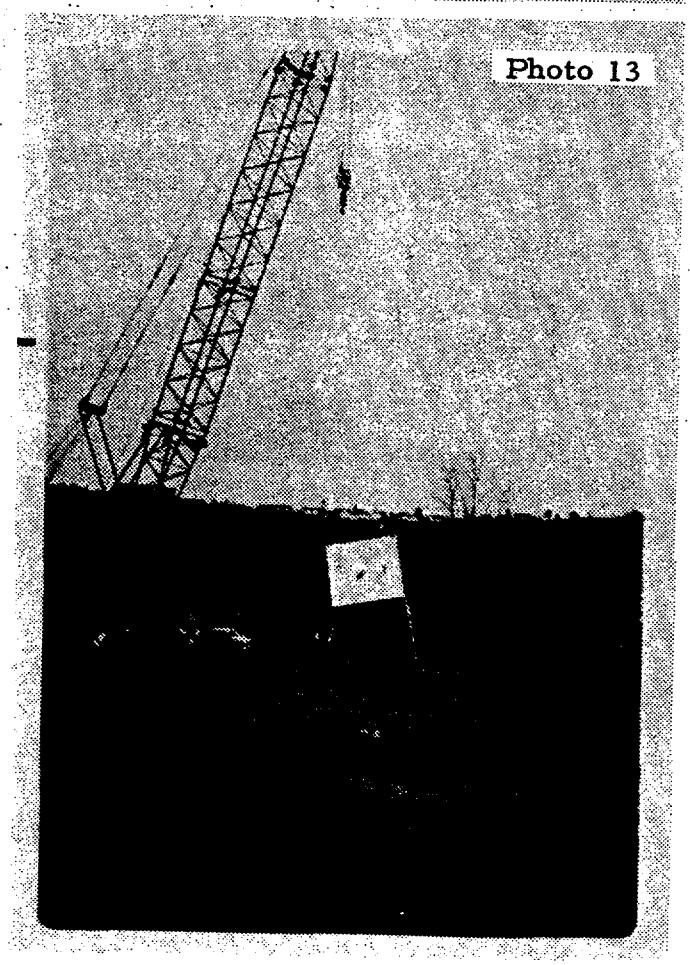


Photo 13

Photo 1

On impact the external skin buckled in the region between the corner fitting and the interface closure area, (see photo 15 through 18). The ductility of the plate is evidenced in the 180 degree bends or wrinkles of the external skin. An external seam weld at the edge tore for approximately 10". This introduced no problem since the full area was backed with the diagonal gusset plate. Maximum corner identation was less than 14".

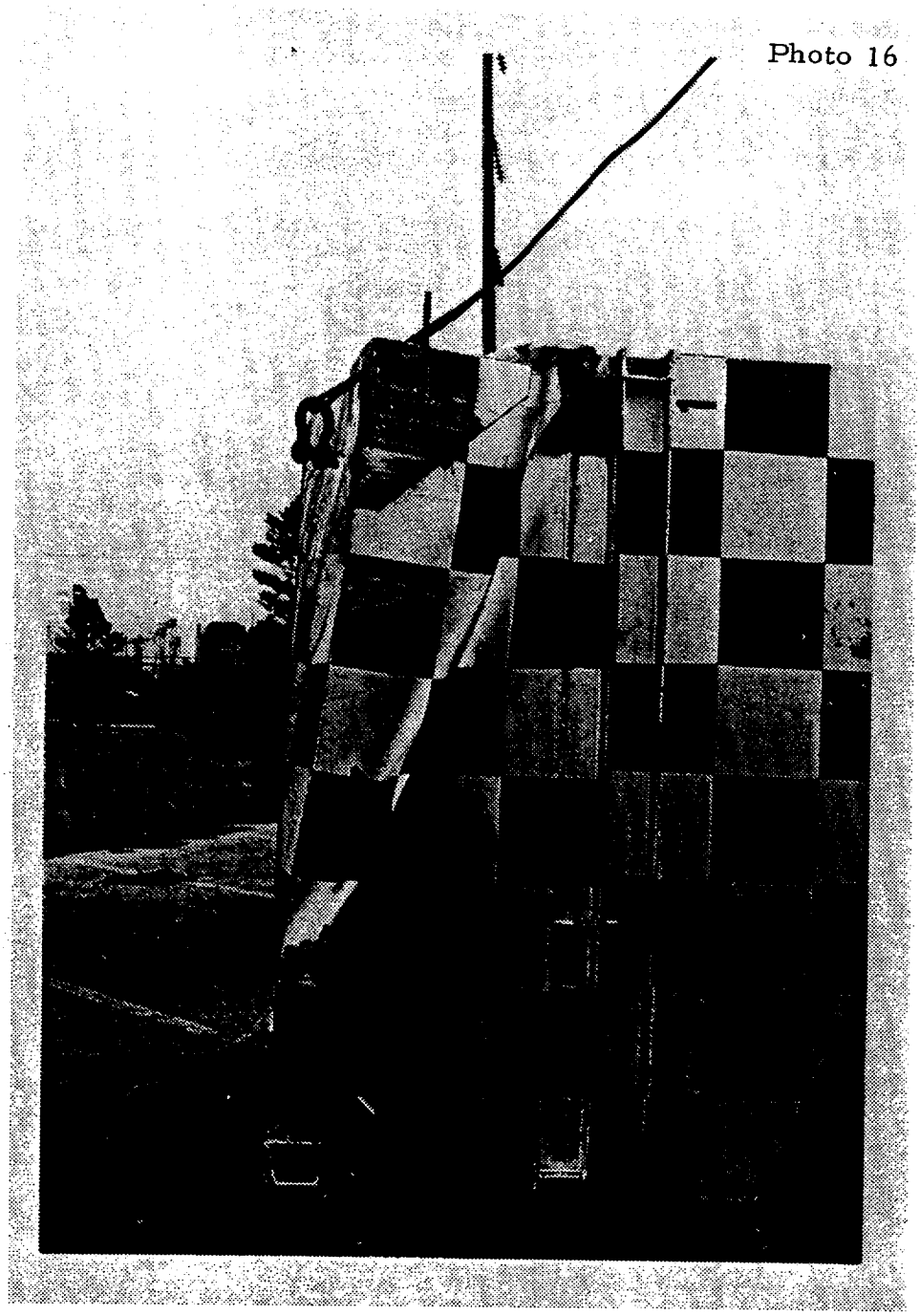


Photo 16

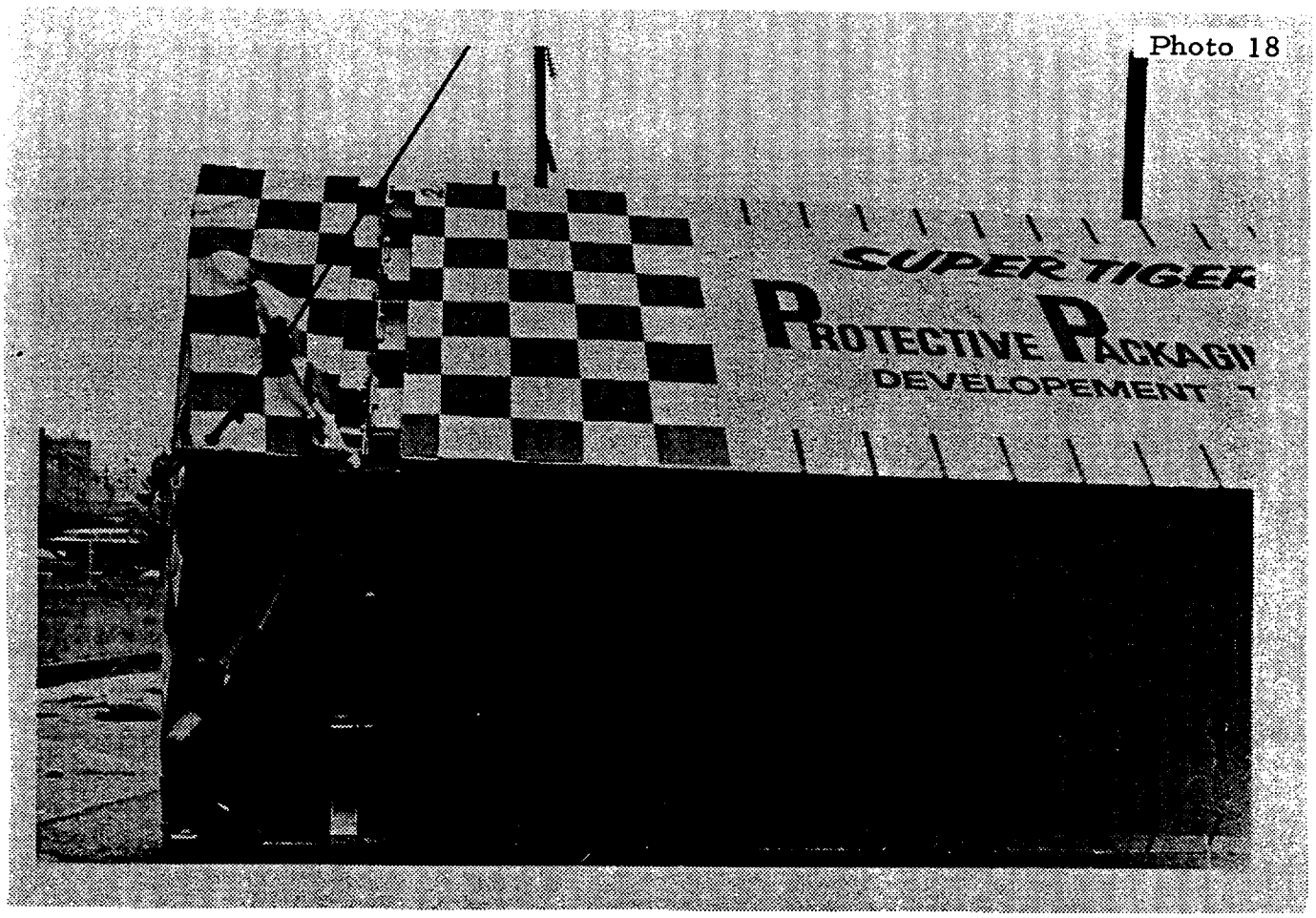


Photo 18

Material yielding appeared restricted to this area. Later, on removal of the cover, it was apparent that deformation was wholly restricted to the cap. (see photos 19 and 20). It was felt that if the cap were to be replaced the net effect of the 30' drop would have been undetectable to the remainder of the container. The inner cavity saw no deformation whatsoever.

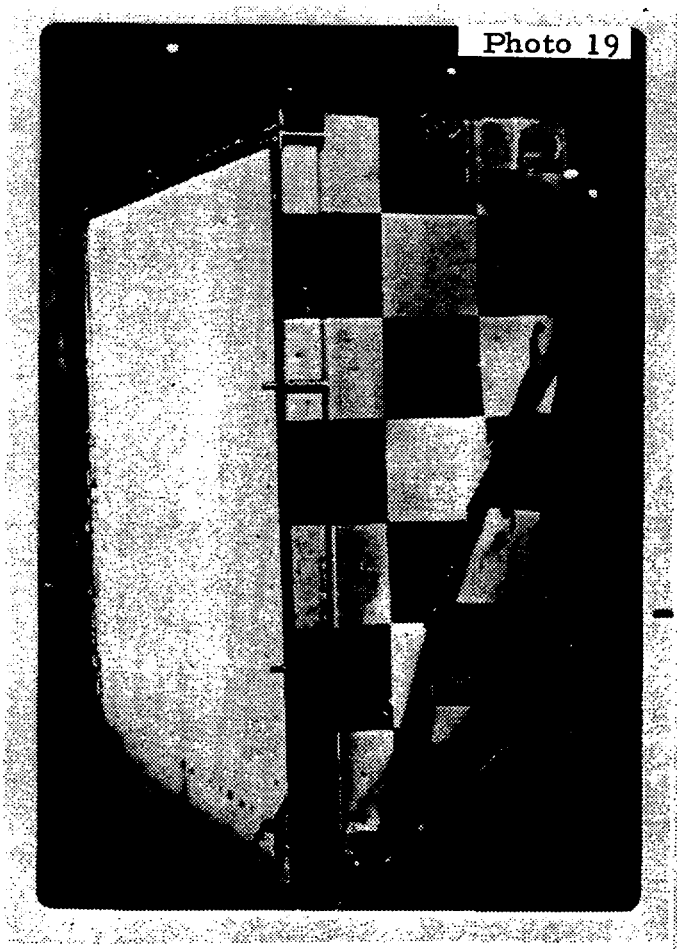


Photo 19

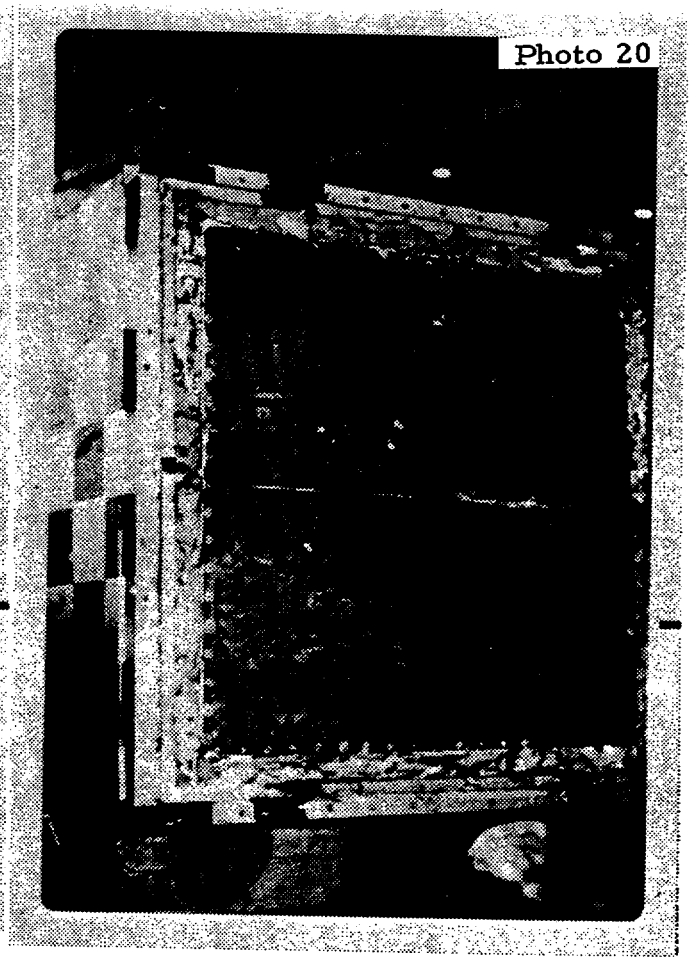


Photo 20

5.4 40" Puncture Test

Four separate 40" drop tests were conducted. As explained in Section 4.2, each of the four sides represented a slightly different configuration. The purpose of the drop test was not only to qualify the container but also to provide a design evaluation of the different types of construction. The test went as follows:

Test 1 - a 40" drop onto the center of Side No. 3

This side contained three layers of steel plate (3/16+1/8+1/8). On impact, (photo 21 and 22) the pin produced a local indentation approximately 2-1/2" deep. As can be seen from photo 23 and 24 the external skin was not cut or torn in any way. Post test inspection of the inner container failed to show any evidence of the puncture test. No indentation or deflections were detectable on the inner container. This was true for the first three tests. There was also no evidence that the 8" tall pin had bottomed out.

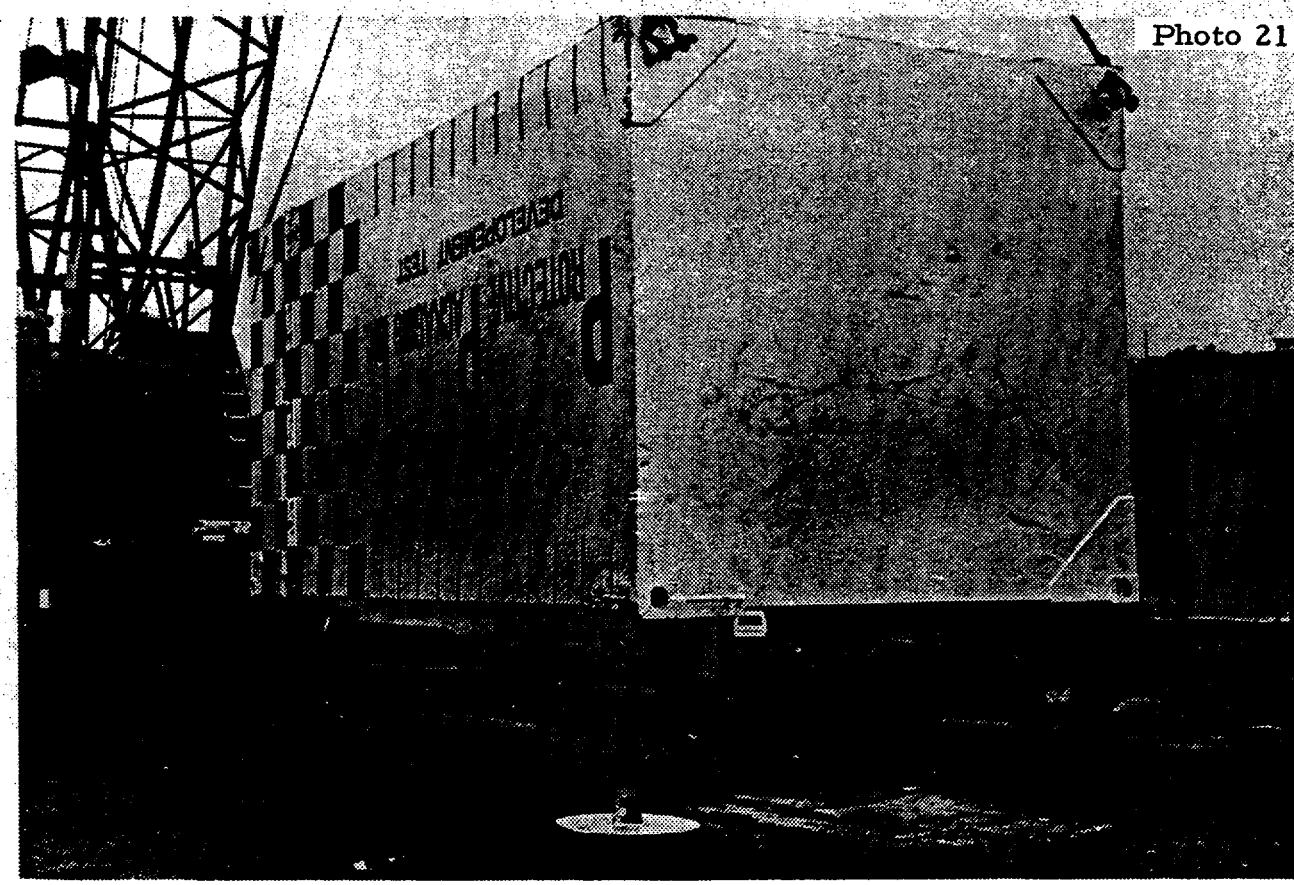


Photo 21

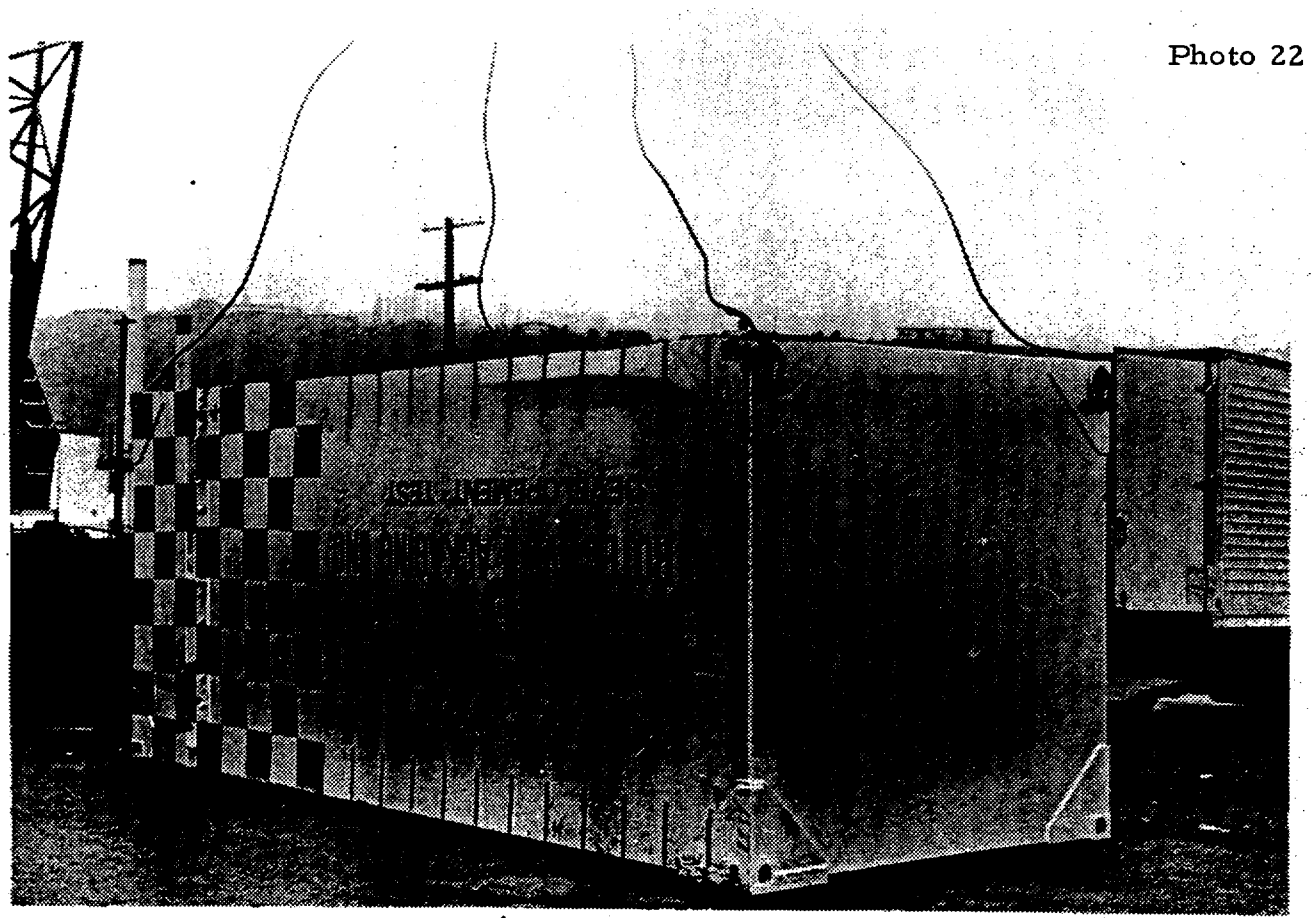


Photo 22

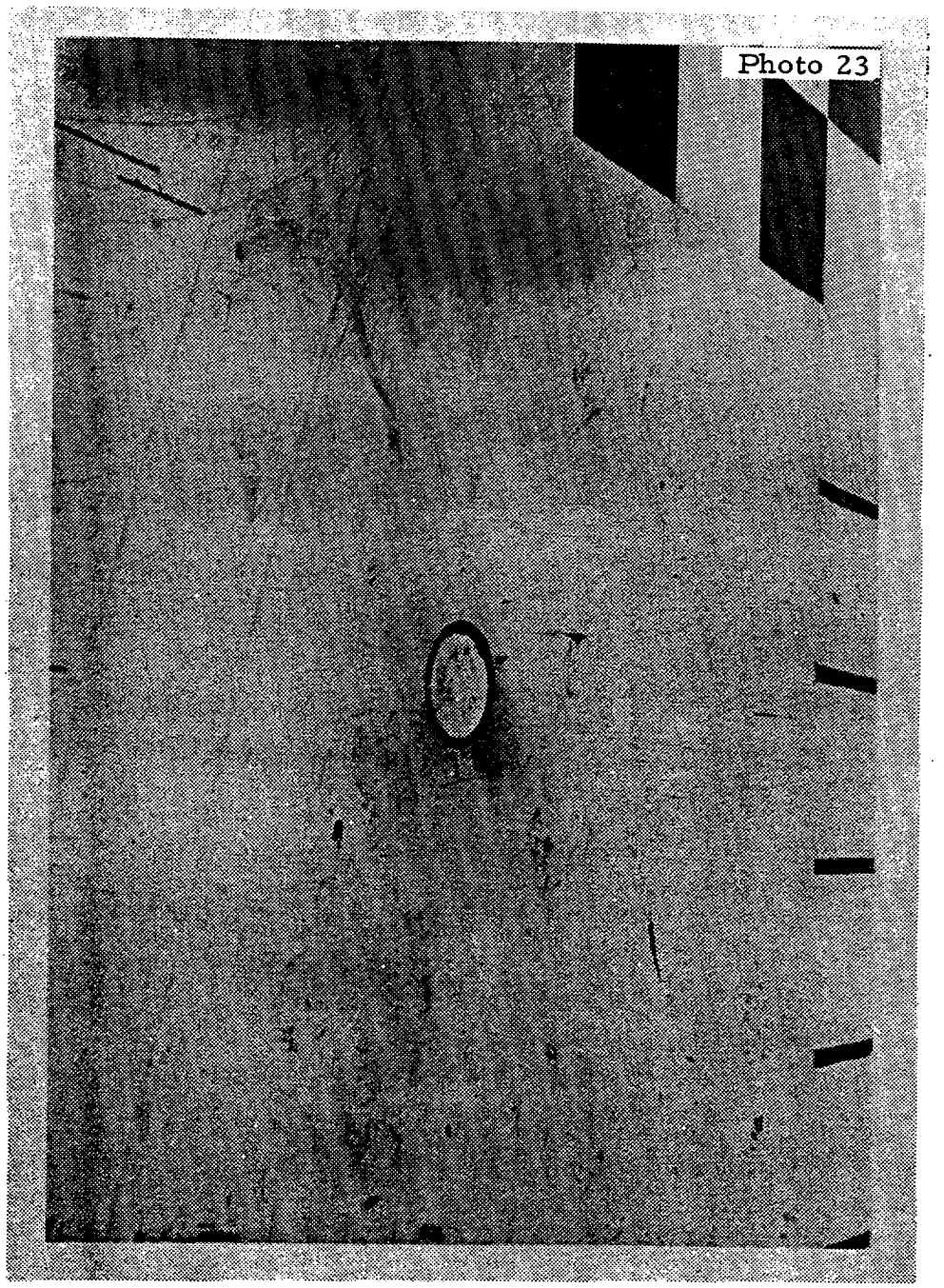


Photo 23

Photo 24

Test No. 3 - Test No. 2 was duplicated on Side No. 2. In this case the maximum indentation of less than 4" was observed, (see photos 27 and 28).

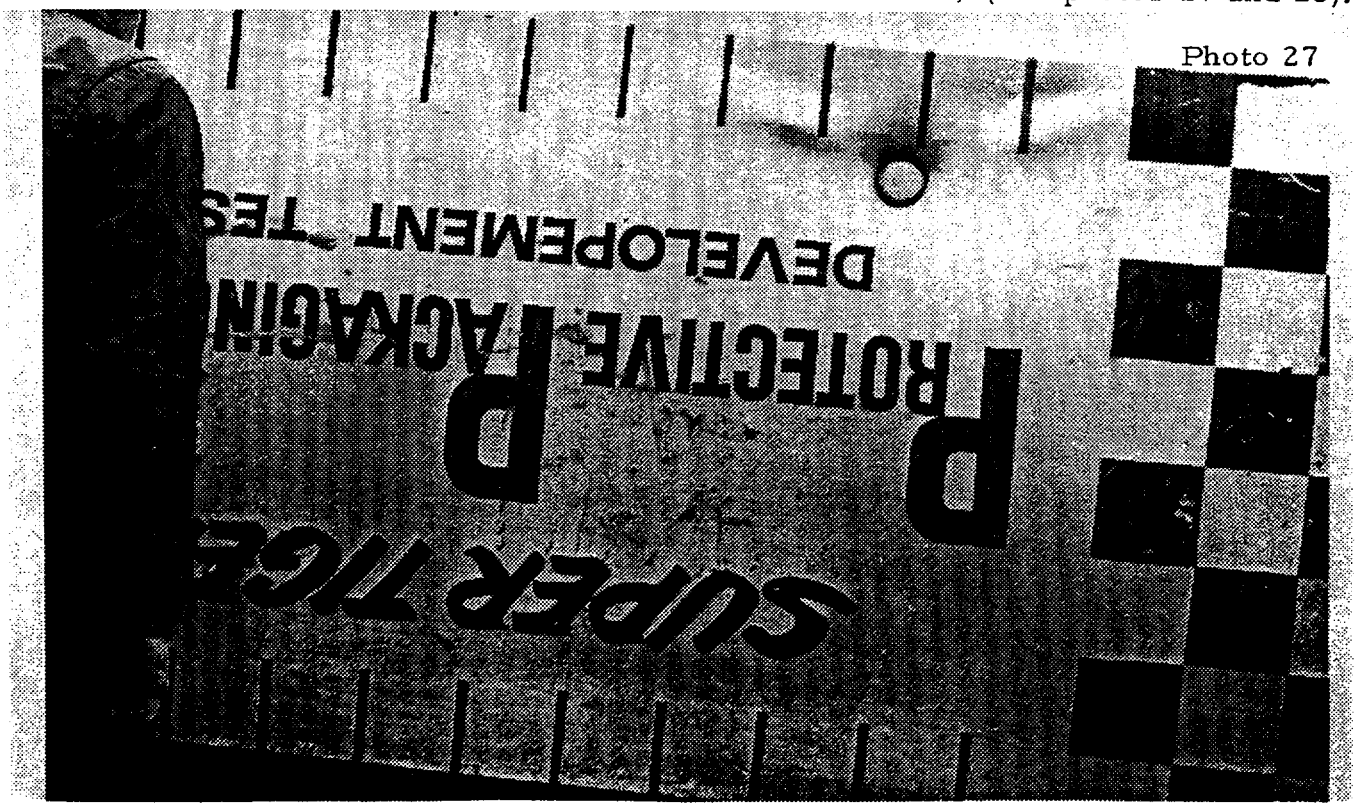


Photo 27

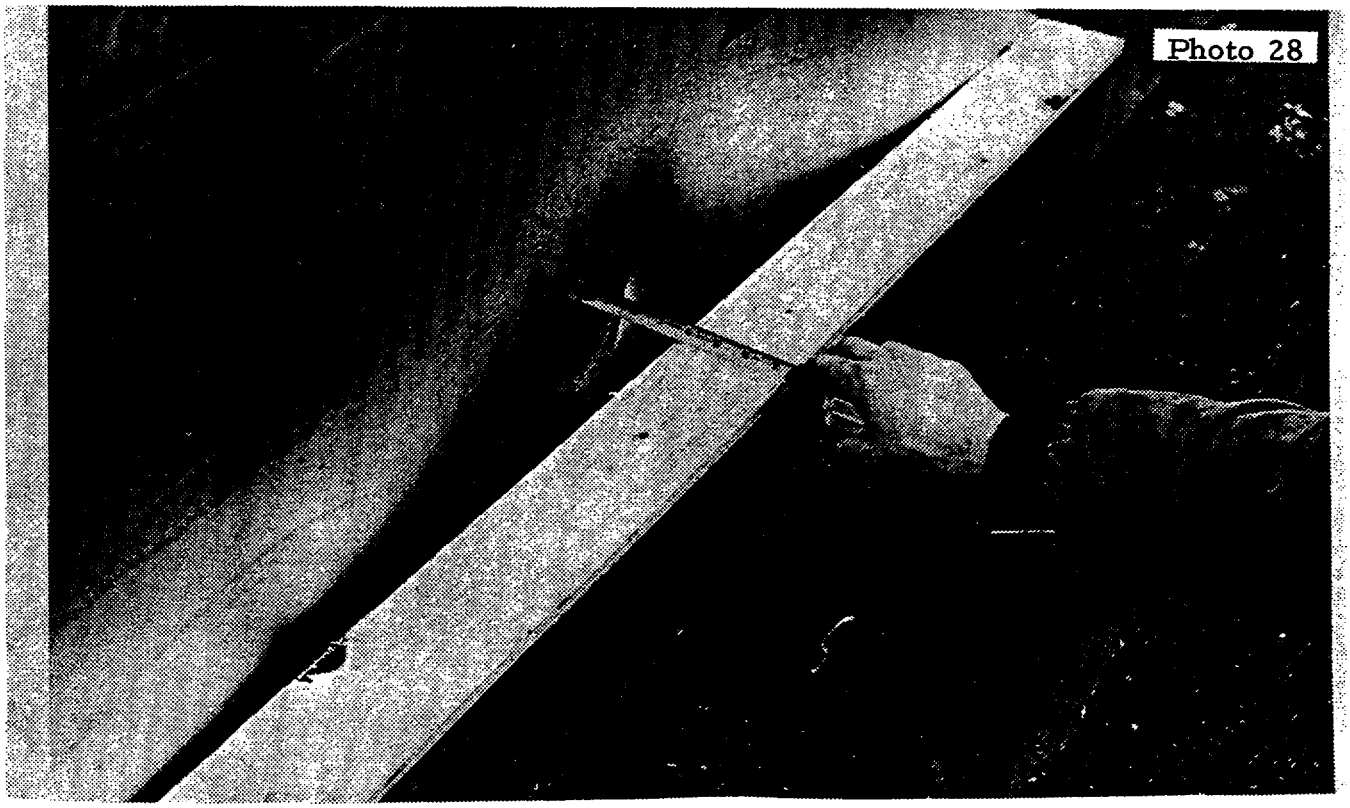
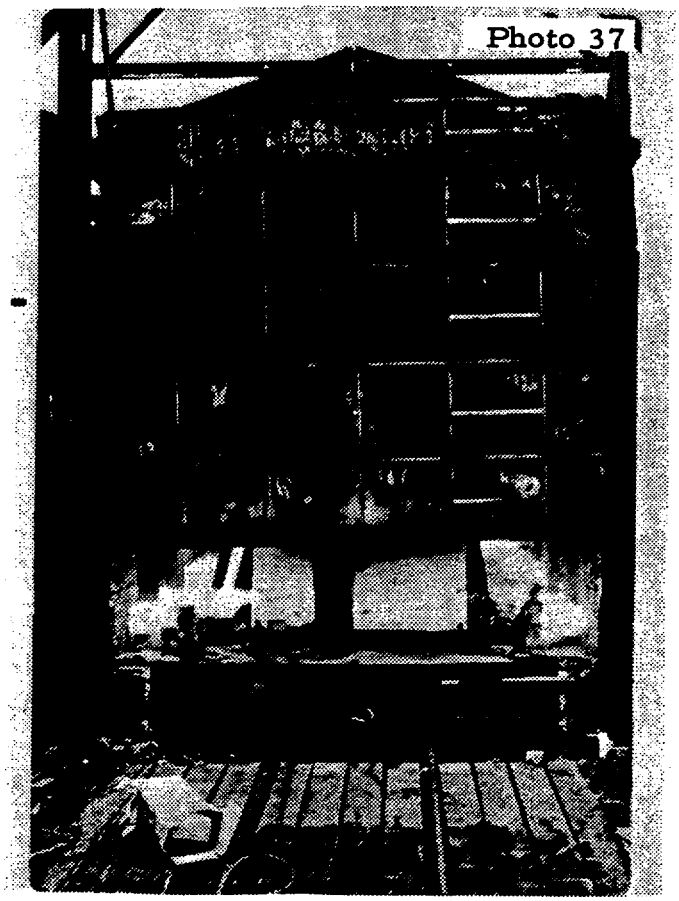


Photo 28

represent a conservative test arrangement since in practicality the container would remain on top of the puncturing device during an accidential fire.

5.5.2 Fire

All twelve burners were ignited and the furnace door closed. Surface temperatures of the steel shell exceeded 500° within the first five minutes of testing. On reaching approximately 600° the virgin urethane foam begins to locally decompose creating a very dense pungent gas. Since sufficient oxygen to support combustion was not present within the shell, the gases must exhaust through the pressure port and burn external to the container. In theory the velocity of the excaping gases is higher than the rate of flame propogation making sure that the combustion reaction is always exothermic, therefore taking heat away from the container rather than adding heat to it. Inspection ports in the furnace wall verified this to be the case. Large quantities of smoke and flame were apparent. (see photos 37 and 38).



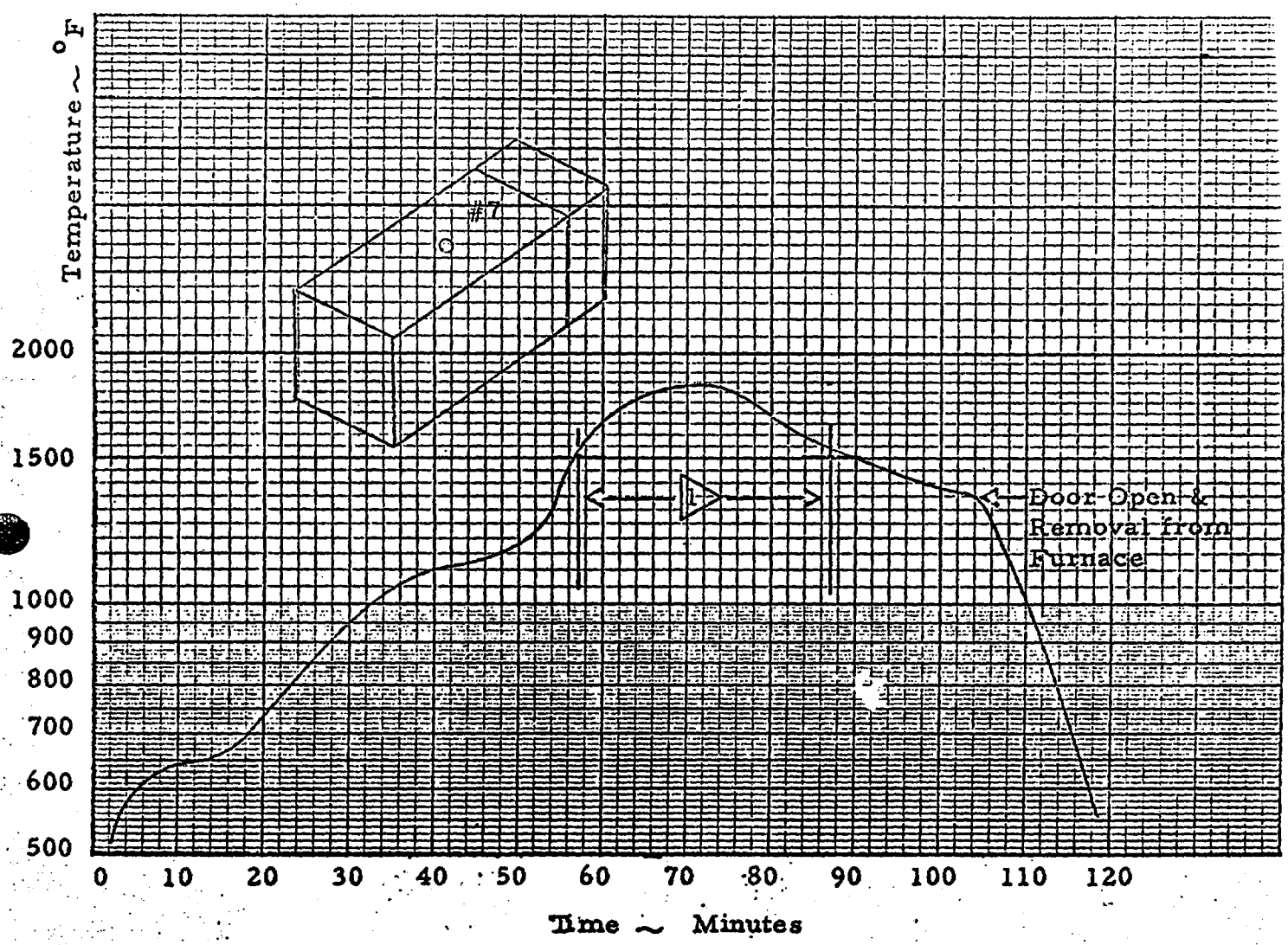


Figure 2 - Fire Test, Skin Temperature at Point #7

I ▷ Required test of ~1500°F for 30 minutes

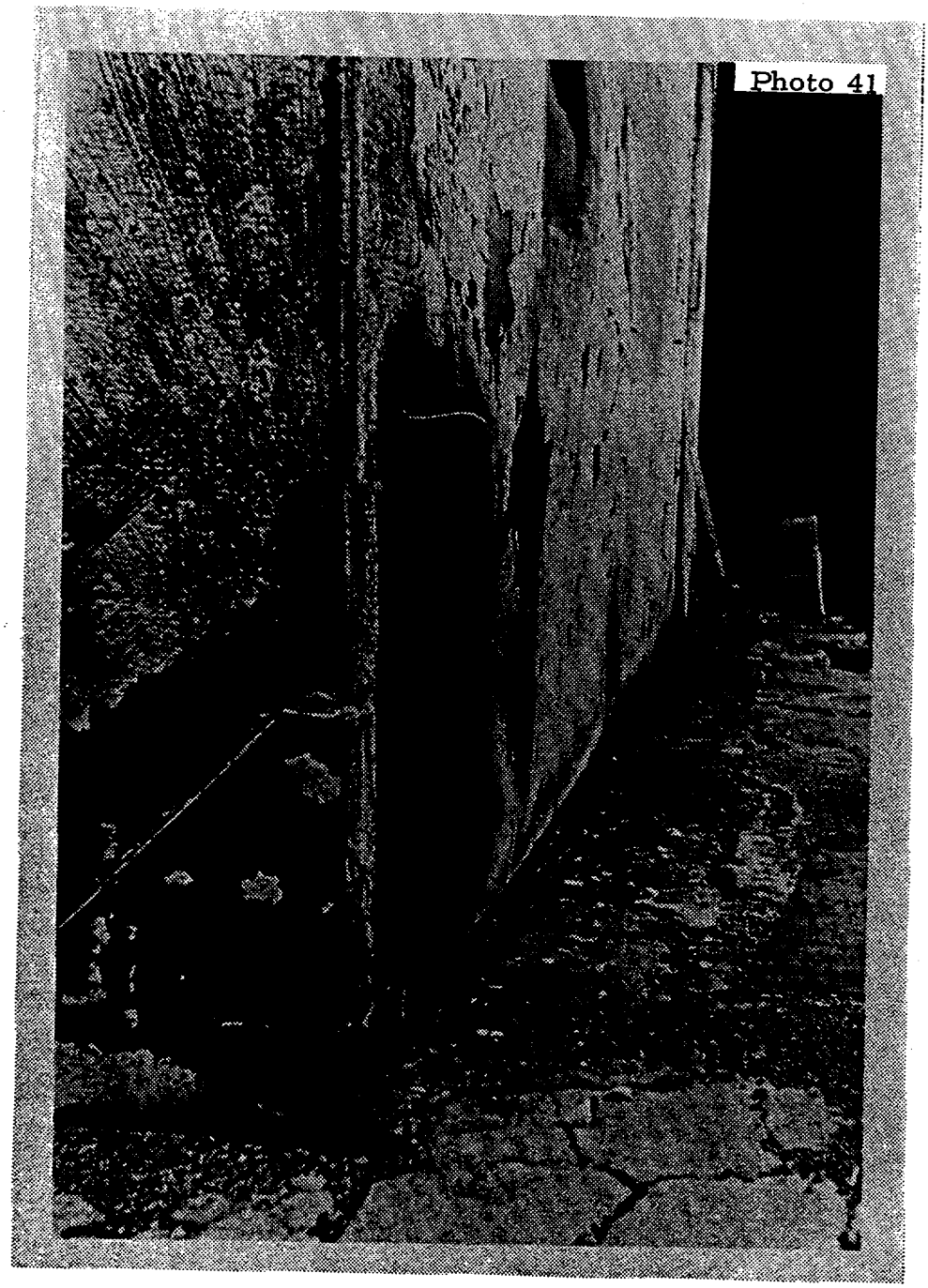


Photo 41

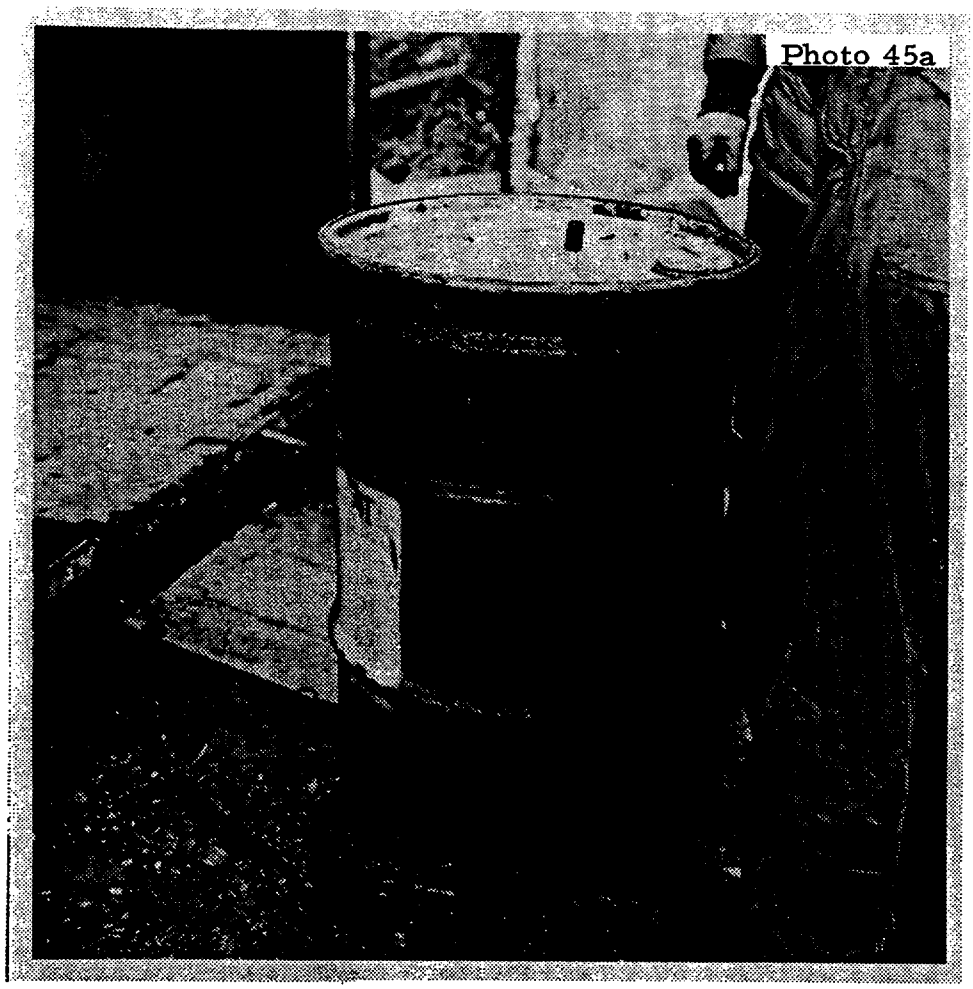


Photo 45a

Contained within one of the 17H drums was a carton of eggs, a drinking glass, a few dishes, a bottle, etc. There was no damage to any of these items, (see photo 46).

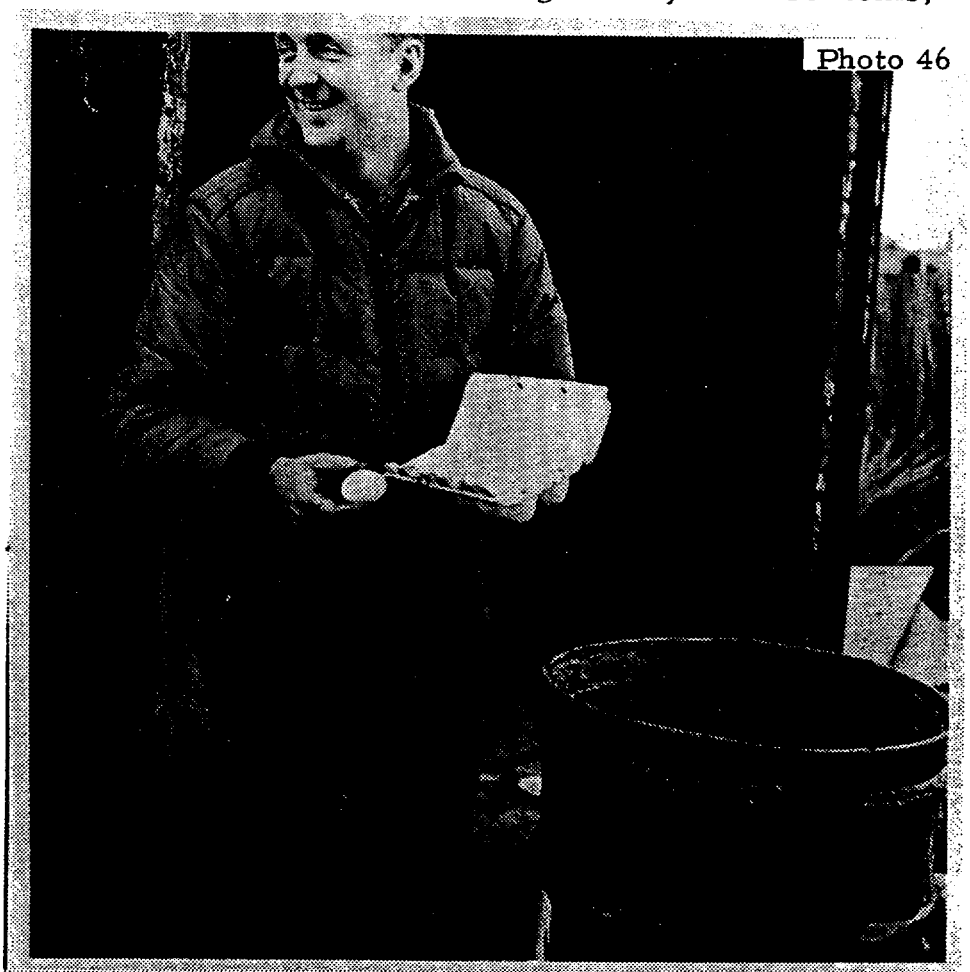


Photo 46

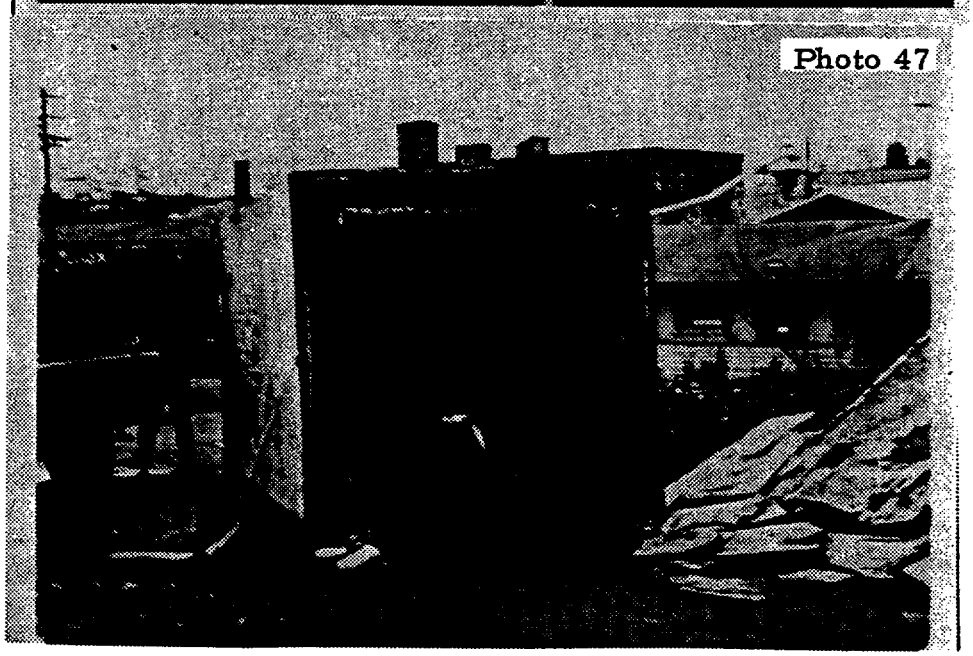


Photo 47

inghouse Electric Corporation Power Systems

PWR Systems Division
Box 355
Pittsburgh Pennsylvania 15230

May 28, 1971

U. S. Atomic Energy Commission
Division of Materials Licensing
Washington, D. C. 20545

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

Gentlemen:

Subject: Application for Amendment of License SNM-338, Docket 70-337, to Authorize Use of NFD Shipping Packages

The Westinghouse Electric Corporation hereby requests amendment of the subject license to authorize the delivery of special nuclear material described in our application dated February 4, 1971, to a carrier for transport in Protective Packaging, Inc., "Super Tiger" packaging described in our application dated February 4, 1971, as modified by the amendment to this letter.

Please send the amendment to me at the above address.

If you have any questions, please write to me at the above address or telephone me collect, (412) 373-4652.

Very truly yours,

Karl R. Schendel

Karl R. Schendel
License Administrator

KRS:jh

Attachment: License Amendment
7 copies transmitted

RECEIVED
JUN 1 1971

ITEM # 73

B/73

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FILING INSTRUCTIONS

The transmittal letter should be filed in the binder labelled "Application for Amendment of License SNM-338 for NFD Shipping Package" immediately in front of the transmittal letter dated May 5, 1971.

Revised Report C2378 should be inserted into Appendix Q and the abridged Report removed.

New page 7.3 should be inserted immediately following page 7.2.

The removed pages may be filed in the back of the binder.

Revision No. 26

5/28/71

REVISION RECORD (continued)

Revision No.	Date of Revision	Pages Revised	Revision Reason
26		Appendix Q	Unabridged Report C2378 inserted.

PATENT PENDING

ENGINEERING EVALUATION OF THE
SUPER TIGER OVERPACK DESIGNED
FOR THE SHIPMENT OF LARGE QUANTITIES
OF HAZARDOUS MATERIALS

C2378 May 4, 1970

Prepared for: Protective Packaging, Inc.
15 North Broadway
Tacoma, Washington 98403

Prepared by: L. J. Hansen

Approved by: R. T. Haelsig

PATENT PENDING

Prepared by:

Mechanics Research, Inc.
15 North Broadway
Tacoma, Washington 98403

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1.0 INTRODUCTION

The purpose of this test report is to verify that the proposed Super Tiger shipping container is capable of meeting the performance criteria set forth on 10 CFR 71 and 49 CFR 171, (Reference 1 and 2).

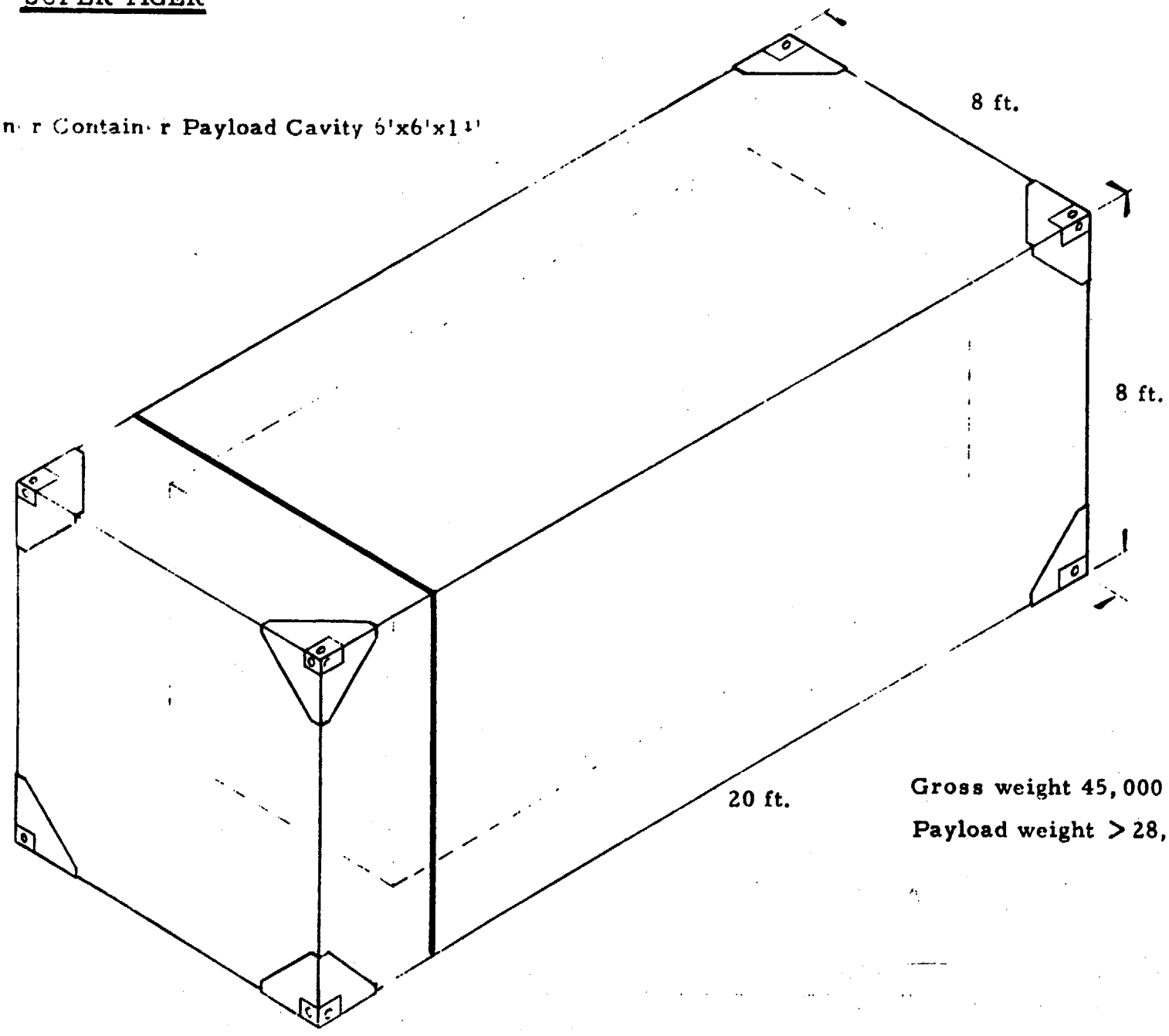
The Super Tiger overpack will be used to transport packages meeting criteria of Department of Transportation regulations enumerated in the Department of Transportation's Hazardous Materials Regulations, (Title 49 CFR, Part 171, Para. 173.396). In all cases the packages will be approved appropriate specification containers or U. S. A. E. C. approved containers for fissile radioactive material shipments by the AEC or one of its contractors or licensees.

The Super Tiger will be transported in a vehicle assigned sole use of the consignor, with a total transport index of 50 for fissile class 2 shipments or the maximum number of packages in accordance with DOT regulations (Para. 173.396 "Table of Authorized Contents") for fissile class 3 shipments. In all cases of fissile class 3 shipments, transport controls will be exercised to protect against loading, transporting or storing of that shipment together with other fissile material. This criteria was established to simulate hypothetical accidents in which any package containing hazardous materials must be capable of surviving. The proposed container will be used for hauling approved specification containers of Type A, Type B and large quantities of radioactive materials in solid, liquid and gas form.

Maximum payload weight is approximately 28,700 lbs. with gross weight of 45,000 lbs. The DOT design discussed in this report is depicted on MRI Drawing No. 121350.

SUPER TIGER

Inner Container Payload Cavity 6'x6'x14'



Gross weight 45,000 lbs

Payload weight > 28,700 lbs

PATENT PENDING

2.0 SUMMARY

Since the Super Tiger is intended to act as a protective overpack for the shipment of large quantities of hazardous materials, it was felt that the design should be substantiated not only by engineering evaluations but also by physical testing. The design philosophy was to use proven computer routines and analysis techniques to evaluate and size the prototype design. Once this was complete, a full scale container was fabricated and subjected to those tests critical to its acceptance.

After all the testing had been completed, the following results were noted:

- 30 foot Drop Test - The container, loaded with a combination of liquids and solids, was dropped 30 feet onto the corner of its lid. The outside shell indented less than 14 inches with no deformation whatsoever to the inner container.
- 40 inch Puncture Test - Side No. 3 sustained two - 40 inch drops onto a 6 inch diameter pin resulting in no yielding or indentation of the inner container wall.
- Fire Test - Temperatures in excess of 1500°F for over 30 minutes were sustained with a rise in contents temperature to a level of less than 150°F.

By combining these test results with additional analysis, it has been concluded that the Super Tiger possesses the ability to protect its liquid, gas or solid contents from exposure while meeting those AEC and DOT regulations stated in Reference 1 and 2. All cargo will be supported in a manner capable of producing no more severe loading on the internal container than that of the tested prototype. Overall container dimensions and foam thickness can be scaled down as a function of impact pressures.

3.0 CONFIGURATION

The overpack was designed as a general use container for the shipment of Type B hazardous materials. It was configured to possess the appearance and

dimensions of a standard 8' x 8' x 20' modal cargo container, (see photo 1). Since it utilizes the universal I.S.O. corner fittings, it can be handled, stored and shipped in the same manner as any standardized shipping contain This provides obvious economic advantages over any system implying a non conventional container.

The overpack basically consists of two rectangular steel shells separated w rigid fire retardent polyurethane foam. Steel shells being fabricated from a low carbon steel are extremely ductile, thus allowing large distortions with no tearing. In addition to providing puncture and penetration resistance the shell also acts as a durable flame shield. Since the thermal conductivity of polyurethane foam is considerably lower than that of the best rockwool or fiberglass insulation, excellent thermal protection is provided. Due to its low cost and high energy absorbing capability, polyurethane foam also provi an ideal shock isolation media. MRI Drawing No. 121350 is attached to prov all construction details.

Photo 1

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3.1 Outer Steel Shell

The entire outer steel shell is fabricated from very ductile low carbon steel plate 3/16th of an inch thick. The elongation of this material is nearly 40% thus allowing the shell to undergo large deformations without fracturing. (see Table 1). Since energy is required to produce these distortions, the shell itself will be capable of absorbing a large amount of energy.

All corners are lap doubled and continuously seam welded along the overlapping edge. All welds are full penetration. In addition, all external edges are protected with a diagonal gusset plate of 12 gage steel, (see photo 2). This gusset plate performs many functions. Should any of the external seam welds fail during impact, the diagonal plate would form not only a redundant load path, but also a secondary seal for the seam.

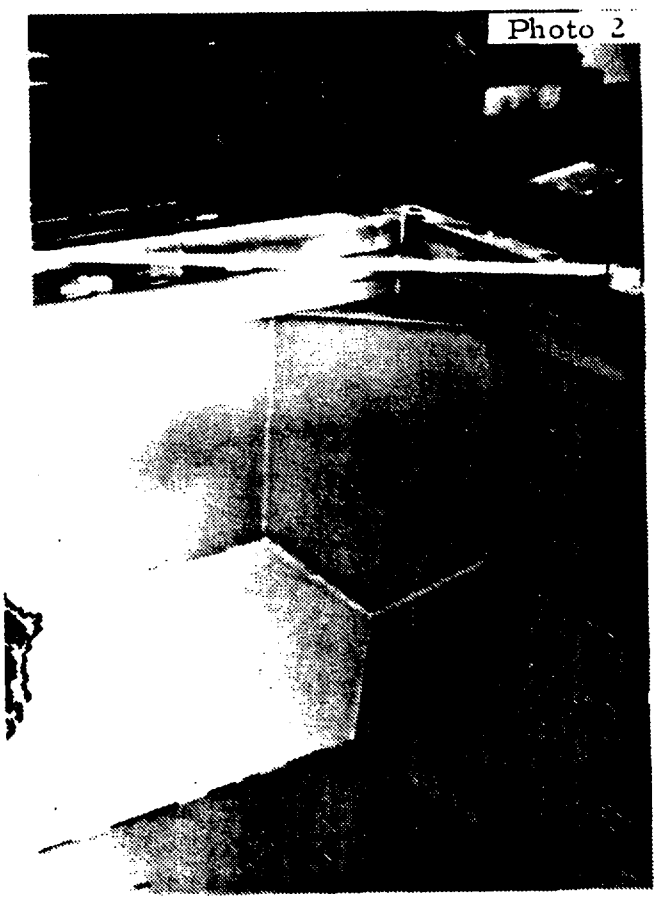


Photo 2

PATENT PENDING

MECHANICAL PROPERTIES OF STEEL

The information shown represents average results and is offered as a general guide to the probable mechanical expectancy of the steels listed. In individual tests these steels may develop results differing widely from the averages shown. The properties shown are based on a 1" Rd. section except for the heat treated steels on which the size range is shown.

Properties shown are for steel in the AS ROLLED or AS DRAWN condition unless otherwise stated.

AISI Number	Condition of Steel	Tensile Strength PSI	Yield Point PSI	% Elong. in 2"	% Red. of Area	Hardness Brinell	Hardness Rockwell	% Machinability Rating
CASE HARDENING OR LOW CARBON TYPES								
Low Carbon Steel	H.R.	63,000	46,000	38	62	126	B72	50
	C.D.	77,000	65,000	20	60	156	B83	63
C1015	H.R.	61,000	45,500	39	61	126	B72	50
	C.D.	74,000	62,000	24	57	143	B79	58
C1018	H.R.	69,000	48,000	38	62	143	B79	52
	C.D.	82,000	70,000	20	57	163	B85	65
	Carburized at 1700° F., cooled in box, reheated to 1425° F., water quenched, tempered at 350° F.—Core properties:							
		92,000	56,000	27	48	197	B91	..
C1019	H.R.	71,000	51,000	37	60	149	B81	53
	C.D.	84,000	72,000	20	56	170	B87	67
C1020	H.R.	65,000	43,000	36	59	143	B79	50
	C.D.	78,000	66,000	20	55	156	B83	60
C1025	H.R.	67,000	45,000	36	58	143	B79	50
	C.D.	80,000	68,000	20	55	163	B85	60
B1112	C.D.	82,500	71,000	15	43	170	B87	100
B1113	C.D.	83,500	72,000	14	40	170	B87	130
Ledloy	C.D.	79,000	71,000	16	52	163	B86	180
C1117	H.R.	70,600	44,300	33	63	137	B76	85
	C.D.	84,000	74,000	21	52	170	B87	90
C1213	C.D.	76,000	68,000	18	53	156	B83	130
4615	H.R.	82,000	62,000	28	65	183	B90	58
	C.D.	99,000	84,600	19	61	207	B95	64
	Carburized at 1700° F., cooled in box, reheated to 1550° F., oil quenched, tempered at 300° F.—Core properties:							
		110,000	80,000	25	61	229	C20	..
4620	H.R.	85,000	63,000	28	64	183	B90	59
	C.D.	101,000	85,000	22	60	207	C15	64
	Carburized at 1700° F., cooled in box, reheated to 1550° F., oil quenched, tempered at 300° F.—Core properties:							
		120,000	89,000	22	55	248	C24	..
4815	H.R.	99,000	70,000	25	60	207	B94	50
	C.D.	110,000	95,000	23	55	223	C19	55
	Carburized at 1700° F., cooled in box, reheated to 1525° F., oil quenched, tempered at 300° F.—Core properties:							
		156,000	132,000	15	55	331	C36	..
E8615	H.R.	82,000	60,000	31	62	149	B81	70
	Carburized at 1700° F. for 8 hours, pot cooled, reheated to 1550° F., oil quenched, tempered at 300° F.—Core properties:							
		109,000	76,000	17	52	255	C25	..
8620	H.R.	89,000	65,000	25	63	192	B90	60
	C.D.	102,000	85,000	22	58	212	C16	63
	Carburized at 1700° F., cooled in box, reheated to 1550° F., oil quenched, tempered at 300° F.—Core properties:							
		129,000	99,000	21	52	255	C25	..

Table 1

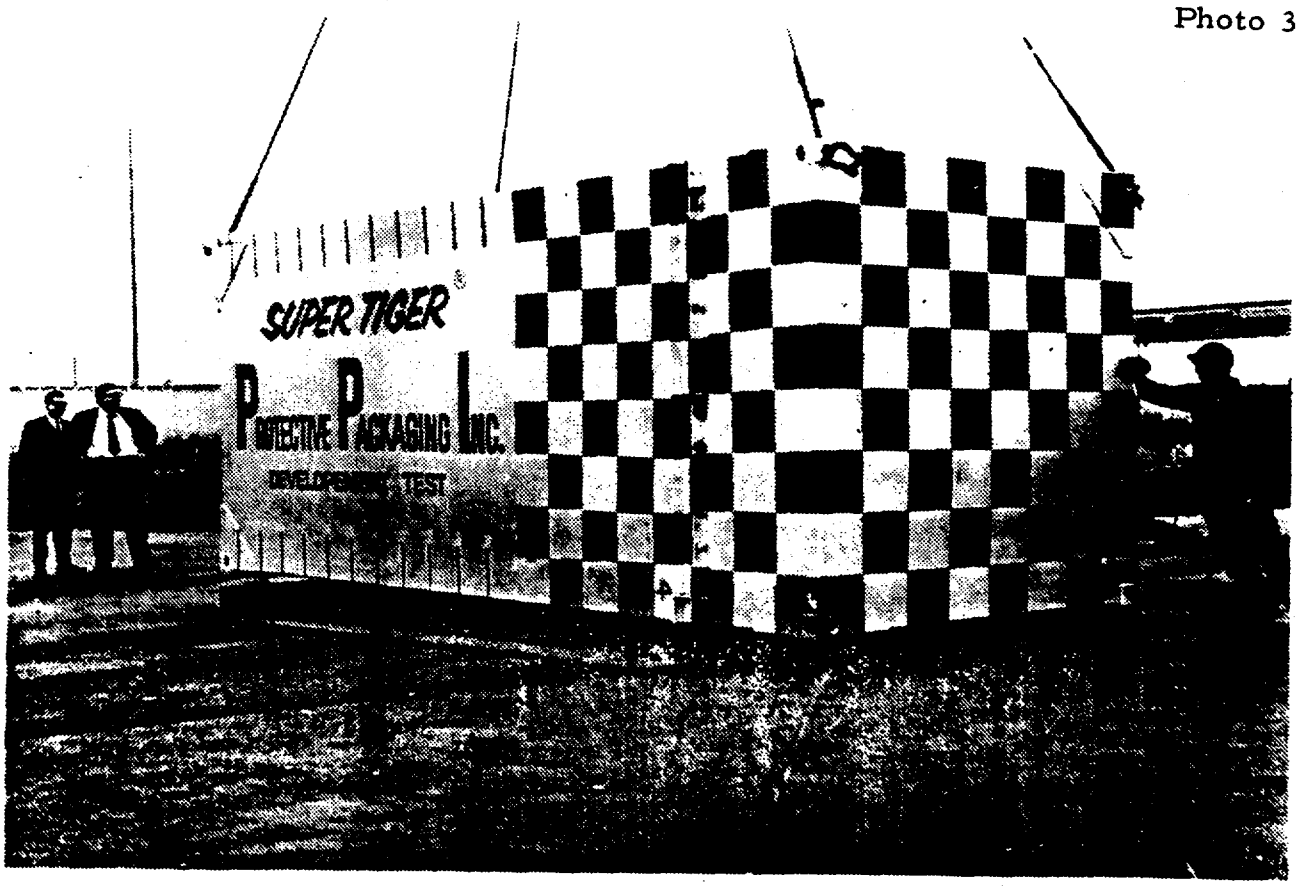
PATENT PENDING

Secondly, by backing all the external edges with the diagonal gusset and foam filling the triangular cavity, a foam stabilized frame assembly is constructed. This provides efficient corner columns capable of reacting compressive and impact loads.

In the event of edge drops, the gusset eliminates the tendency of the external skin to spread. This assures a large contact or compressive surface for the energy absorbing foam.

All eight corners are reinforced with a layer of 3/16th steel plate bent around the edges and welded. This provides a high degree of local integrity and assures that no tearing will originate in the corner areas. (see photo 3).

Photo 3



Set into each corner assembly is a standard I.S.O. steel casting. Each is continuously welded to the side plates and external corner reinforcements.

As can be seen from the drawing, one end of the outer container is removable. Ten high strength 1" diameter bolts tie the container cap to the body. In addition to securing the external cover, these both also provide a means of sealing or locking the container thus hindering unauthorized access and diversion of its contents. The local interface consists of the matching of two 6" ship channels. Since these are welded internal to the skin, a rigid box beam is formed around the mouth of both the cap and the container. This not only assures accurate match up of the assembly but also provides an extremely rigid connection capable of reacting and distributing large concentrated loads. Additional joint integrity is provided by four 1" diameter steel dowl pins. These also assure accurate alignment of the cover to the body during assembly.

From Section A-A of the drawing it can be seen that the steel angle welded to the cap channel forms a lip for sealing action. The intent here is to provide both a redundant load path for shear and a mechanical seal over the joint area.

To accommodate the internal pressure buildup due to thermal exposure, two 1-1/2" diameter threaded drum closures are welded into each side. These are closed off with standard gasketed plastic plugs.

3.2 Polyurethane Foam

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

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

PATENT PENDING

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

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

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

Foam densities can be regulated thereby varying the crush strength. In this design, higher density foam is placed in the ends and along all edges. Figure 1 shows the actual load deflection plot of material sample taken during prototype assembly.

3.3 Inner Container

The inner container consists of a gas tight steel shell approximately 6 feet by 6 feet by 14 feet long, with a removable end cover. All edges or joints in the shell are overlapping and double seam welded, thus applying the same technique material and inherent advantages used in the external shell.

The inner cover is attached by means of a bolt pattern common to the mouth of the inner container. See Section A-A of Drawing 121350. Compressed between the inner face and bonded to the cover is a soft silicone rubber seal. Silicone is used so that in the event a fire exceeds those of Reference 1 and 2, the high temperature capacity of silicone rubber will guarantee a positive seal.

PATENT PENDING

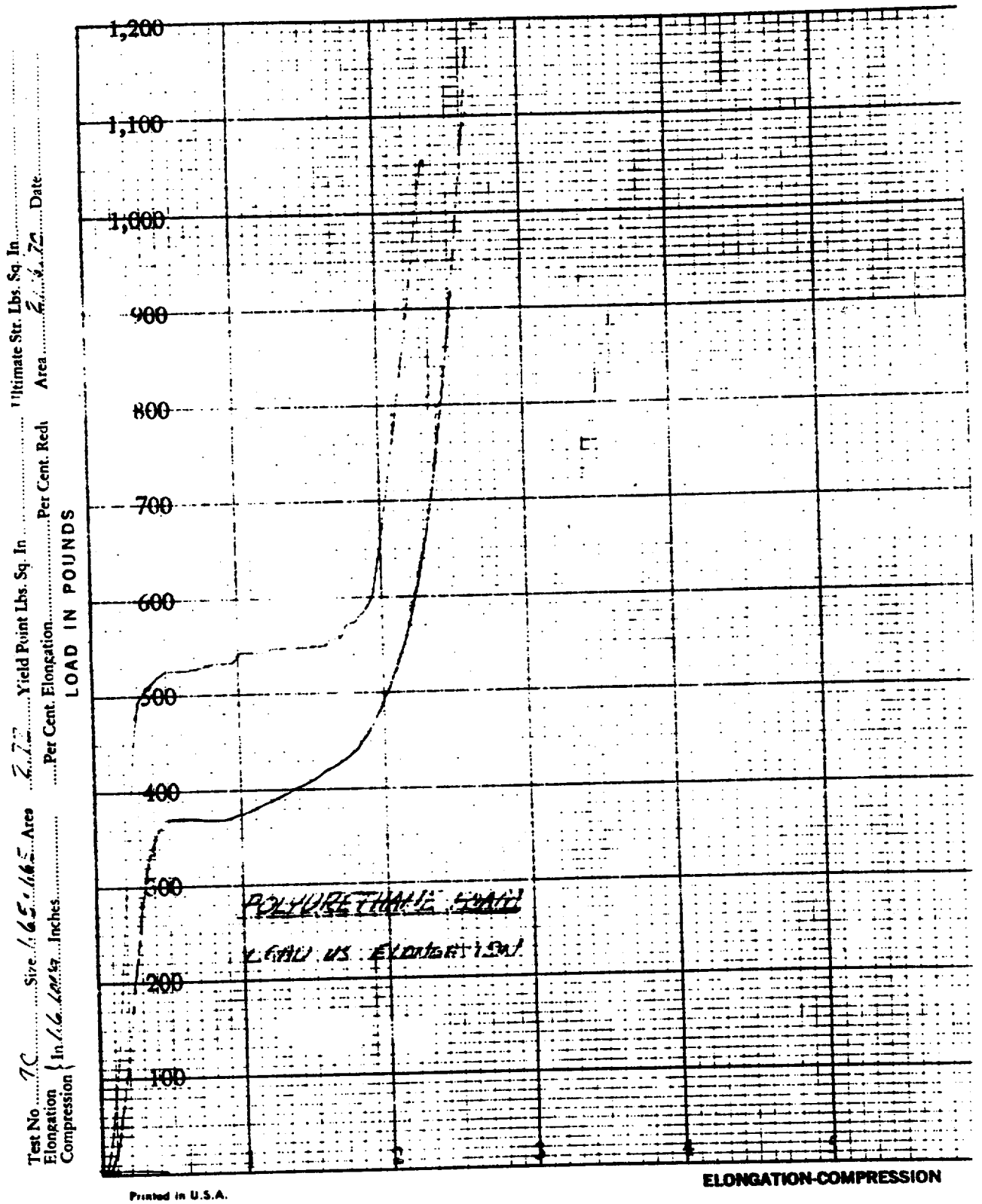


Figure 1

Uniform sealing pressure is assured by the presence of a rolled flange on the cover and local stiffness of the angle doubler welded to the inner container

4.0 ANALYTICAL DESIGN

Department of Transportation Hazardous Material Regulations (Reference 1 and 2, Para. 173.398b, and c) stipulate that for Type B containers the following conditions should be evaluated.

4.1 30 Foot Drop

In order for the shipping container to survive the hypothetical 30' drop the overpack must be capable of totally absorbing all the generated energy. The manner in which the container absorbs energy is through elastic or inelastic deformation of the overpack itself. This is the primary function of the rigid urethane foam. Under the effects of dynamic forces on the foam, the minute cells will tend to collapse and in so doing absorb a small amount of energy per cell. When this action takes place over a large area, considerable amounts of energy are absorbed. Work or energy is defined as a force acting over a distance. In this case the impact force acts to crush a thickness of foam. Average crush strength of the foam used in the sides and corners will be 196 psi and 200 psi respectively.

The 30' free drop of the package has been evaluated using the nonlinear computer analysis approach. In this evaluation only the energy absorbing capabilities of the crush media are considered. For conservatism, the energy absorbed by the frame and the shell is ignored. In this analysis the package is checked for impact effects versus all possible orientations on the package to an unyielding surface. Specifically the following impact orientations were considered:

- Flat on end 96" x 96"
- Flat on side 96" x 240"

- Edge, along edge 96"
- Edge, along edge 240"
- Corner

The analytic features of the analysis are discussed in Appendix A. The results of the impact analysis are presented in Table 2.

Orientation of Impact	Regional Crush Strength q_{cr} (psi)	Peak g's	Duration of Crush Event (sec)	Crush Depth (in)
1. Flat, end	100	19.7	.0688	18.39
2. Flat, side	100	50.6	.0264	7.14
3. Edge, 240	200	39.4	.0540	18.79
4. Edge, 96	200	24.9	.0870	30.12
5. Corner	200	25.0	.1240	47.21

Table II - 30 Foot Impact Results

A detailed impact response time history for each orientation can be found on the following pages. Therefore, on a basis of these calculations, the prototype was constructed with approximately 3 feet of foam on the ends and one foot along the sides. Approximately 2-1/2 feet of foam could be replaced by a crushable honeycomb material possessing a dynamic compressive strength at 200 psi. This will still allow for 6 inches of polyurethane to be placed along the outside skin providing adequate thermal protection. It is apparent that the required cursh depth of foam is a direct function of the impact pressure (weight projected area x g's) developed by the package contents. For example, if the package weight is cut in half the impact pressure is reduced to 1/2 its original value and only 1/2 the original foam thickness would be required. This allows tl foam thickness and container dimensions to be scaled down in proportion to carg impact pressures.

4.2 40 Inch Drop Test

The container must survive a 40" drop onto a 6" diameter pin.

The analysis and initial sizing for this condition were done utilizing the MRI developed computer program PUNCH, fully described in Appendix B. The analysis approach assumes a membrane backed by a crushed foam media.

*** INELASTIC IMPACT ANALYSIS PROGRAM

PATENT PENDING

***BASIC ENGINEERING PROPERTIES

WEIGHT OF PACKAGE (LBS) = 45000.

CRUSH STRENGTH (PSI) = 100.

DENSITY OF CRUSH MEDIA (LBS/FT3) = 4.

DROP HEIGHT (FT) = 30.

***CASE DATA

CASE IDENTITY (RFLAT EDGWD EDSID CORNR): RFLAT

RECTANGULAR LENGTH & WIDTH (IN) : 96.,240.

IMPACT RESPONSE TIME HISTORY***

TIME (SEC)	CRUSH DEPTH (IN)	VEL. (IN/SEC)	ACCEL. (G)
0.0000	0.00	527.	-50.2
0.0008	0.42	512.	-50.2
0.0016	0.82	496.	-50.2
0.0152	5.77	231.	-50.6
0.0160	5.95	216.	-50.6
0.0168	6.12	200.	-50.6
0.0176	6.27	185.	-50.6
0.0184	6.41	169.	-50.6
0.0192	6.54	153.	-50.6
0.0200	6.66	138.	-50.6
0.0208	6.76	122.	-50.6
0.0216	6.85	106.	-50.6
0.0224	6.93	91.	-50.6
0.0232	7.00	75.	-50.6
0.0240	7.05	59.	-50.6
0.0248	7.09	44.	-50.6
0.0256	7.12	28.	-50.6
0.0264	7.14	12.	-50.6
0.0272	7.14	-3.	-50.6

CASE IDENTITY (RFLAT EDGWD EDSID C NR): RFINFLAT

RECTANGULAR LENGTH & WIDTH (IN) : 96.,96.

IMPACT RESPONSE TIME HISTORY***

PATENT PENDING

TIME (SEC)	CRUSH DEPTH (IN)	VEL. (IN/SEC)	ACCEL. (G)
0.0000	0.00	527.	-19.5
0.0008	0.42	521.	-19.5
0.0016	0.83	515.	-19.5
0.0024	1.24	509.	-19.5
0.0032	1.65	503.	-19.5
0.0040	2.05	497.	-19.5
0.0048	2.45	491.	-19.5
0.0056	2.84	485.	-19.5
0.0064	3.22	479.	-19.5
0.0072	3.60	473.	-19.5
0.0080	3.98	467.	-19.5
0.0088	4.35	461.	-19.5
0.0096	4.72	455.	-19.5
0.0104	5.08	449.	-19.5
0.0112	5.43	443.	-19.5
0.0120	5.79	437.	-19.5
0.0128	6.13	431.	-19.5
0.0136	6.48	425.	-19.5
0.0512	17.10	140.	-19.6
0.0520	17.21	134.	-19.6
0.0528	17.32	128.	-19.6
0.0536	17.42	122.	-19.7
0.0544	17.51	116.	-19.7
0.0552	17.60	110.	-19.7
0.0560	17.69	104.	-19.7
0.0568	17.77	98.	-19.7
0.0576	17.84	91.	-19.7
0.0584	17.92	85.	-19.7
0.0592	17.98	79.	-19.7
0.0600	18.04	73.	-19.7
0.0608	18.10	67.	-19.7
0.0616	18.15	61.	-19.7
0.0624	18.20	55.	-19.7
0.0632	18.24	49.	-19.7
0.0640	18.27	43.	-19.7
0.0648	18.31	37.	-19.7
0.0656	18.33	31.	-19.7
0.0664	18.36	25.	-19.7
0.0672	18.37	19.	-19.7
0.0680	18.39	13.	-19.7
0.0688	18.39	6.	-19.7
0.0696	18.40	0.	-19.7
0.0704	18.39	-6.	-19.7

***CASE DATA

CASE IDENTITY (N°LAT EDGWD EDSID CORNR): EDSID

EDGE LENGTH (IN) : 240.

IMPACT RESPONSE TIME HISTORY***

PATENT PENDING

TIME (SEC)	CRUSH DEPTH (IN)	VEL. (IN/SEC)	ACCEL. (G)
0.0000	0.00	527.	1.0
0.0020	1.06	527.	-1.3
0.0040	2.11	526.	-3.5
0.0060	3.16	522.	-5.7
0.0080	4.19	517.	-8.0
0.0100	5.22	510.	-10.1
0.0120	6.23	501.	-12.3
0.0140	7.22	491.	-14.4
0.0160	8.19	479.	-16.5
0.0180	9.14	465.	-18.5
0.0200	10.05	450.	-20.5
0.0220	10.94	433.	-22.4
0.0240	11.79	415.	-24.2
0.0260	12.60	396.	-26.0
0.0280	13.37	375.	-27.6
0.0300	14.10	353.	-29.2
0.0320	14.78	330.	-30.7
0.0340	15.42	306.	-32.1
0.0360	16.01	281.	-33.3
0.0380	16.54	254.	-34.5
0.0400	17.02	227.	-35.5
0.0420	17.45	200.	-36.5
0.0440	17.82	171.	-37.3
0.0460	18.13	142.	-38.0
0.0480	18.39	112.	-38.5
0.0500	18.56	82.	-38.9
0.0520	18.72	52.	-39.2
0.0540	18.79	22.	-39.4
0.0560	18.81	-9.	-39.4

*** INELASTIC IMPACT ANALYSIS PROGRAM

PATENT PENDING

***BASIC ENGINEERING PROPERTIES

WEIGHT OF PACKAGE (LBS) = 45000.

CRUSH STRENGTH (PSI) = 200.

DENSITY OF CRUSH MEDIA (LBS/FT3) = 7.

DROP HEIGHT (FT) = 30.

***CASE DATA

CASE IDENTITY (RFLAT EDGWD EDSID CORNR): EDSID

EDGE LENGTH (IN) : 96.

IMPACT RESPONSE TIME HISTORY***

TIME (SEC)	CRUSH DEPTH (IN)	VEL. (IN/SEC)	ACCEL. (G)
0.0000	0.00	527.	1.0
0.0030	1.58	528.	-0.4
0.0060	3.17	527.	-1.7
0.0090	4.74	524.	-3.0
0.0120	6.31	520.	-4.4
0.0150	7.86	514.	-5.7
0.0180	9.39	506.	-7.0
0.0210	10.89	497.	-8.3
0.0510	23.68	333.	-19.3
0.0540	24.64	311.	-20.1
0.0570	25.54	287.	-20.9
0.0600	26.36	262.	-21.6
0.0630	27.11	237.	-22.3
0.0660	27.78	210.	-22.9
0.0690	28.37	184.	-23.4
0.0720	28.89	156.	-23.8
0.0750	29.31	128.	-24.2
0.0780	29.66	100.	-24.5
0.0810	29.91	72.	-24.7
0.0840	30.09	43.	-24.9
0.0870	30.17	14.	-24.9
0.0900	30.17	-15.	-24.9

***CASE DATA

CASE IDENTITY (XFLAT EDGED EDSID COINK)(COINK

IMPACT RESPONSE TIME HISTORY***

TIME (SEC)	CRUSH DEPTH (IN)	VEL. (IN/SEC)	ACCEL. (G)
0.0000	0.00	527.	1.0
0.0040	2.11	529.	0.9
0.0080	4.23	530.	0.8
0.0120	6.36	531.	0.5
0.0160	8.48	532.	0.2
0.0200	10.61	532.	-0.3
0.0240	12.74	531.	-0.9
0.0280	14.86	529.	-1.5
0.0320	16.97	526.	-2.3
0.0360	19.06	522.	-3.2
0.0400	21.14	516.	-4.2
0.0440	23.19	509.	-5.2
0.0480	25.21	500.	-6.3
0.0520	27.19	489.	-7.5
0.0560	29.12	477.	-8.8
0.0600	31.00	462.	-10.1
0.0640	32.81	445.	-11.5
0.0680	34.56	427.	-12.8
0.0720	36.22	406.	-14.2
0.0760	37.80	383.	-15.6
0.0800	39.28	356.	-16.9
0.0840	40.66	330.	-18.2
0.0880	41.92	301.	-19.4
0.0920	43.07	270.	-20.6
0.0960	44.08	238.	-21.6
0.1000	44.97	204.	-22.5
0.1040	45.71	168.	-23.3
0.1080	46.31	132.	-24.0
0.1120	46.77	94.	-24.5
0.1160	47.07	56.	-24.8
0.1200	47.22	18.	-25.0
0.1240	47.21	-21.	-24.9

PATENT PENDING

PATENT PENDING

Based on this analysis, membrane outer sheet thickness of approximately .40 inches is required.

From this information 1/4 scale models were fabricated using foam back steel sheets. Actual drop tests utilizing scaled weights, pin diameter, foam skin gages and skin gage arrangement were conducted. Two conclusions were reached: (1) more resistance to penetration was offered with laminated sheet than by single sheet thickness, (2) analysis was somewhat conservative.

Using the laminated sheet approach, it was found a greater penetration load could be reacted by providing a soft membrane, i.e., lower bending stiffness. By allowing the inner skins to move independent of the outer skin, the stiffness of the two sheets of equal thickness would be 1/4 that of one sheet of the same total thickness. Secondly, should the face sheet fail, the tendency was for the inner sheet to be picked up by the pin and distribute the load over a large area. The attached photo of the scaled test demonstrate this action. (see photo 4).

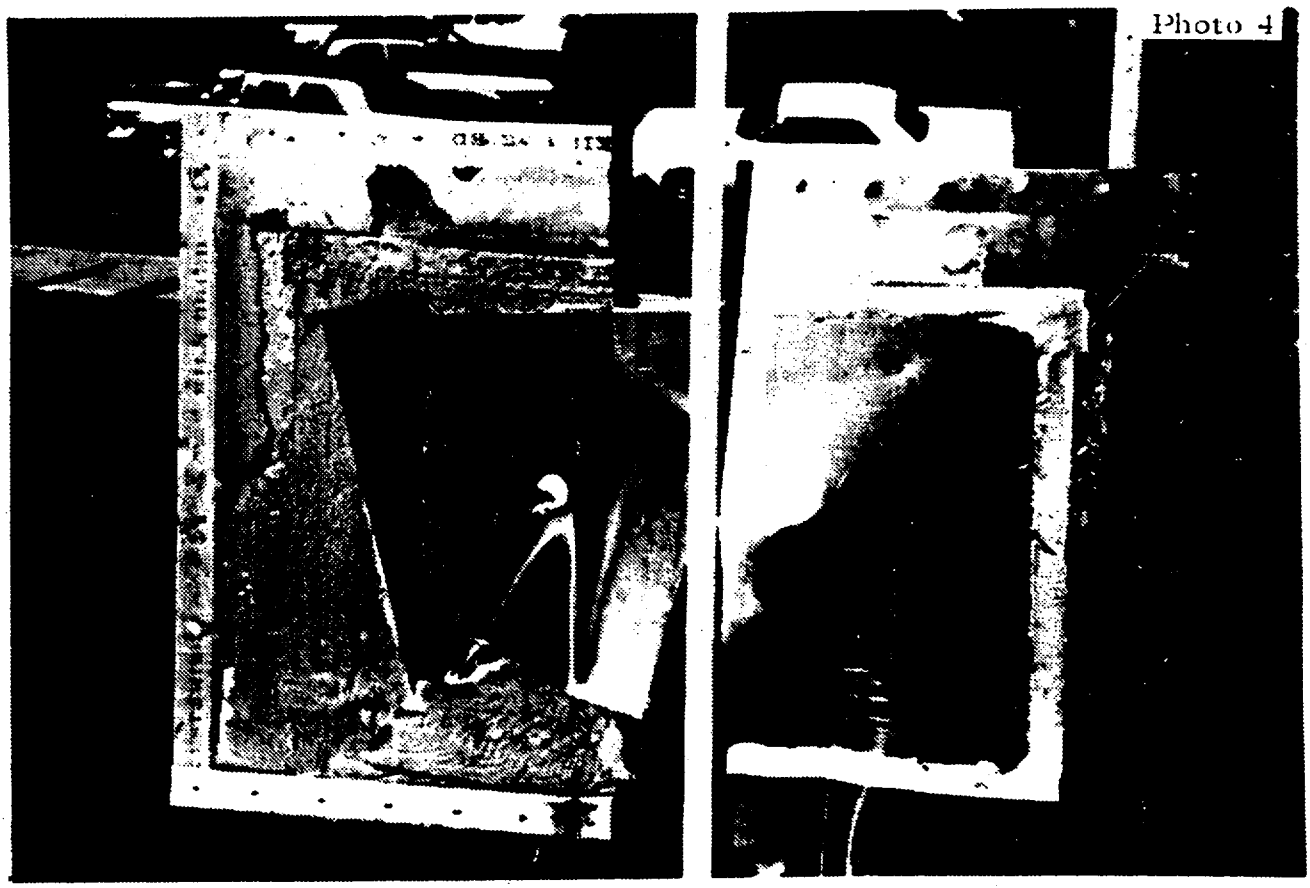


Photo 4

Therefore, the full scale prototype design utilized this technique. A different wall configuration was used for each of the four walls. They were:

- Side 1 - 3/16ths plus 3/16ths plus 3/16th
- Side 2 - 3/16ths plus 3/16ths plus 1/8th
- Side 3 - 3/16th plus 1/8th plus 1/8th
- Side 4 - 3/16th plus 3/16

In each case, the inner plates were to be tack welded so as to release on impact. This was true with all but Side 4, since during fabrication a near accident resulted in a plate being solidly welded. The effects were shown in the actual testing of this side. See Section 5.4 - 40 Inch Puncture Test.

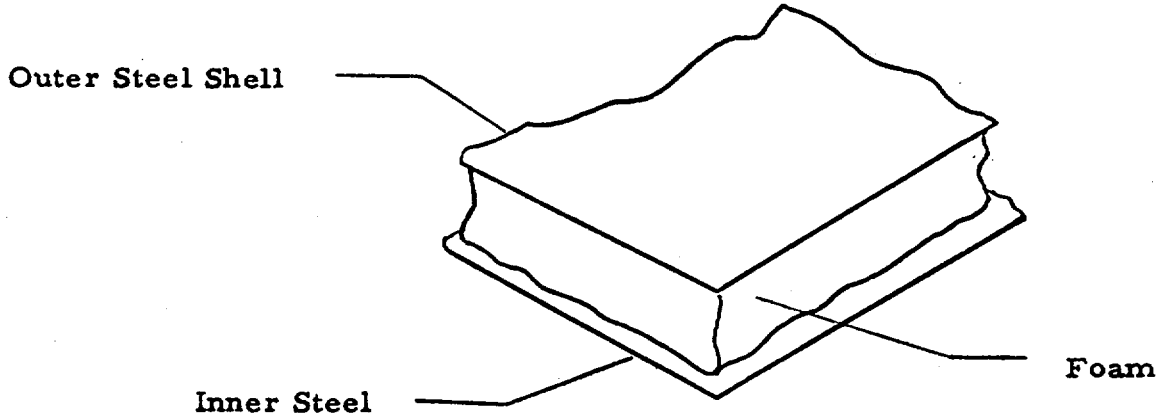
4.3 Thermal Analysis

Appendix 3 contains a thermal analysis on an overpack resembling the Super Tiger. The container was analytically subjected to the required 1475°F fire test for a 30 minute period, using a transient electrical network analogy program, (Reference 3). The results show that the content's temperature will at no time be raised more than 10°. Since this analysis was for the urethane thickness of only 7", it was felt that the Super Tiger would have no trouble surviving the actual fire test.

4.4 Compression

Paragraph 71.32b, Reference 2, requires that packaging shall be adequate to assure that the containment vessel will suffer no loss of contents if subjected to an external pressure of 25 psig.

Since the inner and outer skins are attached by means of the rigid polyurethane foam, a stress skin design of the following configuration is provided.



PATENT PENDING

Therefore, the external pressure loads will be carried in the form of plate bending when the outside sheet is in compression and the inner sheet is in tension. Foam compression strengths in excess of 100 psi are present at all points.

The moments in a rectangular uniform load homogenous plate with clamped edges is given in Timoshenko "Theory of Plates and Shells", page 228, Reference 4, as:

$$\frac{b}{a} = \frac{192}{76} = 2.5$$

$q = 25$ psi

1. $(M_x)_{x=a/2,\, y=0} = -.085\, qa^2 = 12,300$ in-lb

2. $(M_y)_{x=0,\, y=b/2} = -.057\, qa^2 = 8,230$ in-lb

The resultant are as follows:

	Load Component	Outer Skin	Inner Skin
1.	M_x edge	-6600	+11750
2.	M_y edge	-4410	+7850

$f_b = 11750$ psi $< F_{TU} = 63,000$ psi

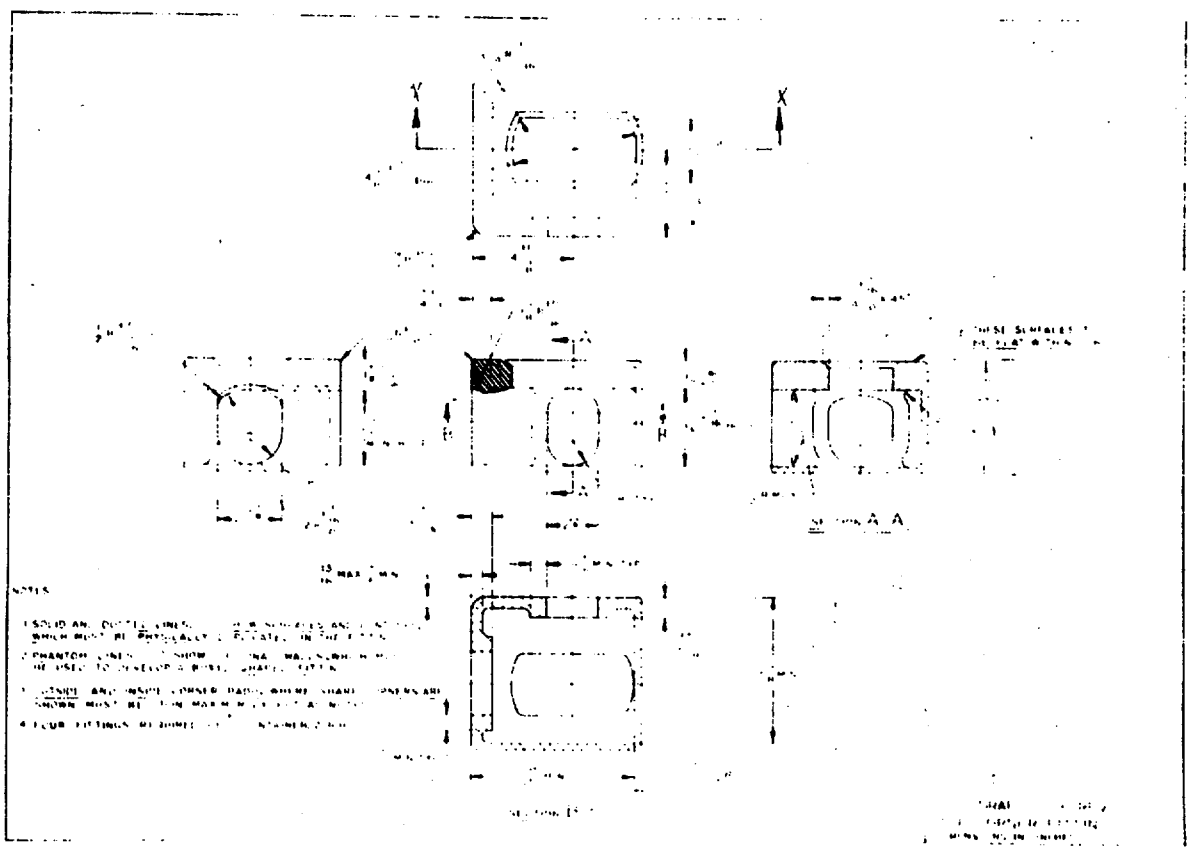
M.S. $\frac{63,000}{11,750}$ 1 Large

Therefore the container can react 25 psig without loss of contents.

4.5 Tie Downs

Paragraph 71.31c, of Reference 2, requires the tiedown fitting be capable of reacting a load of three times the package weight vertically and ten times the weight in direction of travel. All eight of the tie down fittings are standard International Organization for Standardization (I.S.O.) corner fittings for freight containers, (Reference 5).

Typical section properties can be found below.



A guaranteed minimum material yield strength of 46,500 psi assures high reliability. Primary loads are reacted through Section X-X producing a net cross section area of (1-1/8 x 1-9/16) or 1.76 in^2.

The allowable load per casting will be:

$$P_{allow} = (F_s)(A_s) = \left(\frac{46,500}{2}\right)(2)(1.76)$$

$$P_{allow} = 82,000 \text{ lbs/fitting}$$

Assuming four fittings to be used for lifting, then the net capacity is:

$$G's = \frac{(82,000 \text{ lb/fitting})(4 \text{ fitting})}{(45,000 \text{ lbs})}$$

G's = 7.28 g (vertical capability)

Assuming eight fittings to be used for tie down, then the net capacity is:

$$G's = \frac{(82,000 \text{ lbs/fitting})(8 \text{ fittings})}{(45,000 \text{ lbs})}$$

G's = 14.5 g (fore and aft)

Therefore the standard I.S.O. fitting does possess the required strength to meet tie down requirements as set forth in Reference 2.

5.0 FULL SCALE TESTING

A full scale prototype container was fabricated by Star Iron and Steel Company, Tacoma, Washington and subjected to the required testing as outlined in Reference 1 and 2. Mr. A. O. Dodd, Nuclear Safety Branch, H&S Division, Richland, Washington, acted as official test witness for the AEC.

5.1 Test Equipment

PATENT PENDING

5.1.1 Drop Crane

A ninety ton portable crane with an 80 foot boom was leased from Cooney Crane Company, Tacoma, Washington. The crane was used for both the 30' and 40" drop tests. A quick release device triggered by the air pressure was utilized to assure instaneous release.

5.1.2 Impact Surface

An essentially unyielding surface was provided by placing three sheets of 7/8" thick steel plate over a road bed. The bed consisted of approximately 8" of seasoned surfacing poured directly over an existing railroad track spur line. A 6" diameter steel rod 8" long was welded to a 3/4" steel plate and placed over the 7/8" thick steel plates for the 40" drop test. (see photo 5 & 5a).

Photo 5

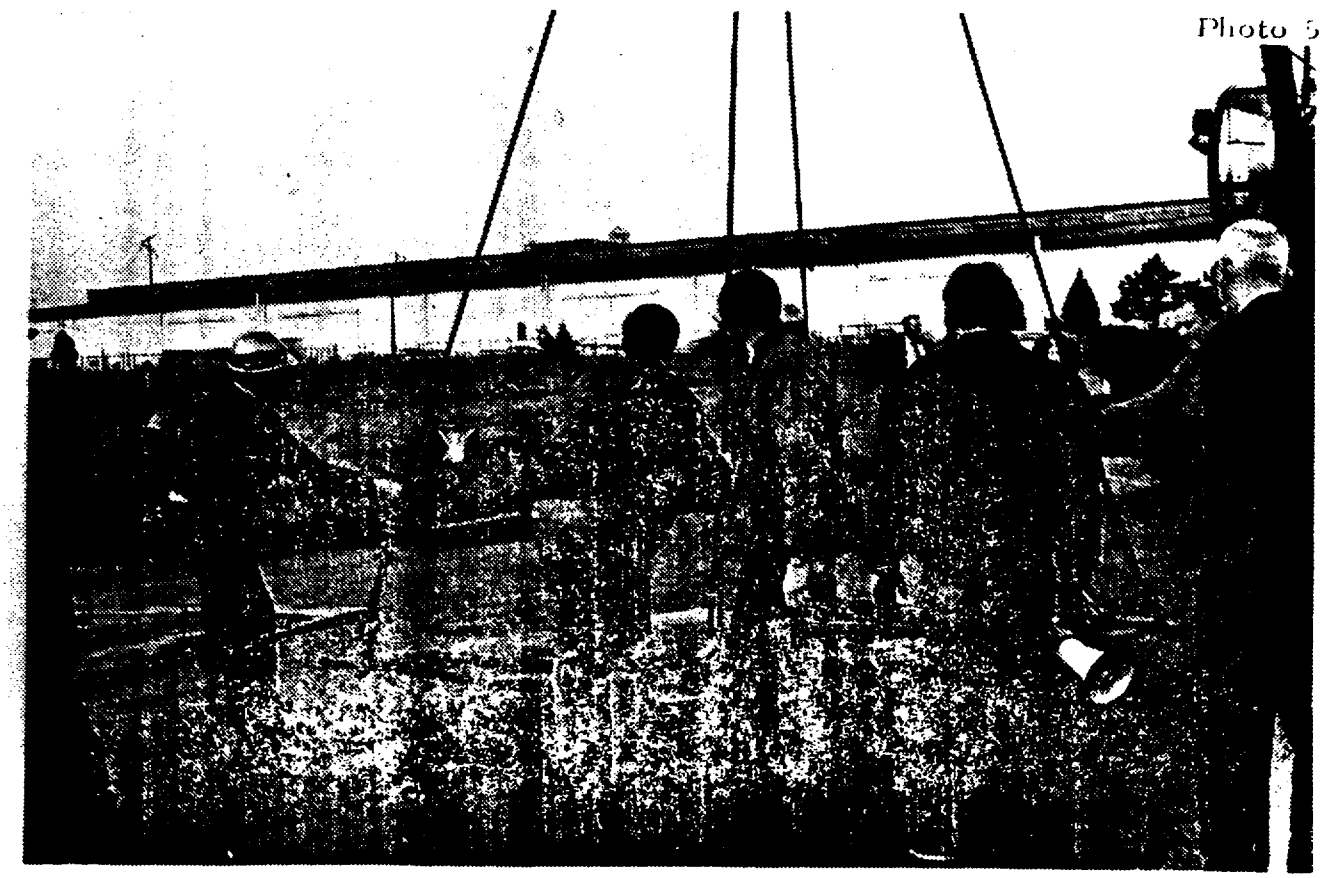


Photo 5a

5.1.3 Thermal Test Equipment

The thermal test was conducted in a large heat treatment furnace at Seattle Boiler Works, East Marginal Way, Seattle, Washington. The internal cavity of the furnace measured 13' wide, 32' 10" long and 12' high. The oven was fully instrumented with 8 thermal couples. It was felt that the environmental control provided by the furnace operation would be more desirable in thermal evaluation than that of an open pit fire. The furnace was fired with No. 2 disel oil.

5.1.4 Water Immersion

Since the container possesses a positive bouyancy force of over 35,000 lbs, the possibility of actually sinking it during an immersion test becomes unrealistic.

PATENT PENDING

It should be noted that in the event of a hypothetical accident in which a truck trailer rig carrying a Super Tiger was plunged into a river or lake, the Super Tiger's bouyancy is sufficiently great that it would support not only its own 45,000 pounds but also the entire weight of the rig, with 4 ton of capacity to spare.

5.2 Loading

The Super Tiger was designed to accommodate a maximum number of 55 gallon drums in addition to general cargo. Dimensions for the inner cavity measure approximately 6' x 6' x 14' thereby providing room for 42 loaded 55 gallon drums. Drums were not lashed or secured in any way to the inner container.

For the drop test a cargo of hazardous material was simulated with 42 drums, one half sand and one half liquid (water). This brought the total package weight up to 45,268 lbs. Representing a typical maximum cargo weight of the standard 40 foot semi-truck trailer rig. The drums were laid on their sides and rolled into place, two wide and three high, (see photo 6).

PATENT PENDING

Those drums located at each of the eight corner locations were instrumented with temperature sensitive marking sticks, trade name Tempostik. At a predetermined temperature the mark produced by the Tempostik would irreversibly change color. Temperature marks ranging from 150° to 900° were employed, (see photo 7).

Photo 7

Other graphic illustrations of environmental conditions were also included. A centerfold of the latest monthly was taped to the inner container wall (photo not included). In addition to providing a little glamour to a somewhat

glamourless subject, it also served as a thermal indicator.

To establish a level of fragility to the payload, one drum was loaded with a dozen eggs, two pieces of china, a glass and a bottle of beverage. (see photos 8 and 9).

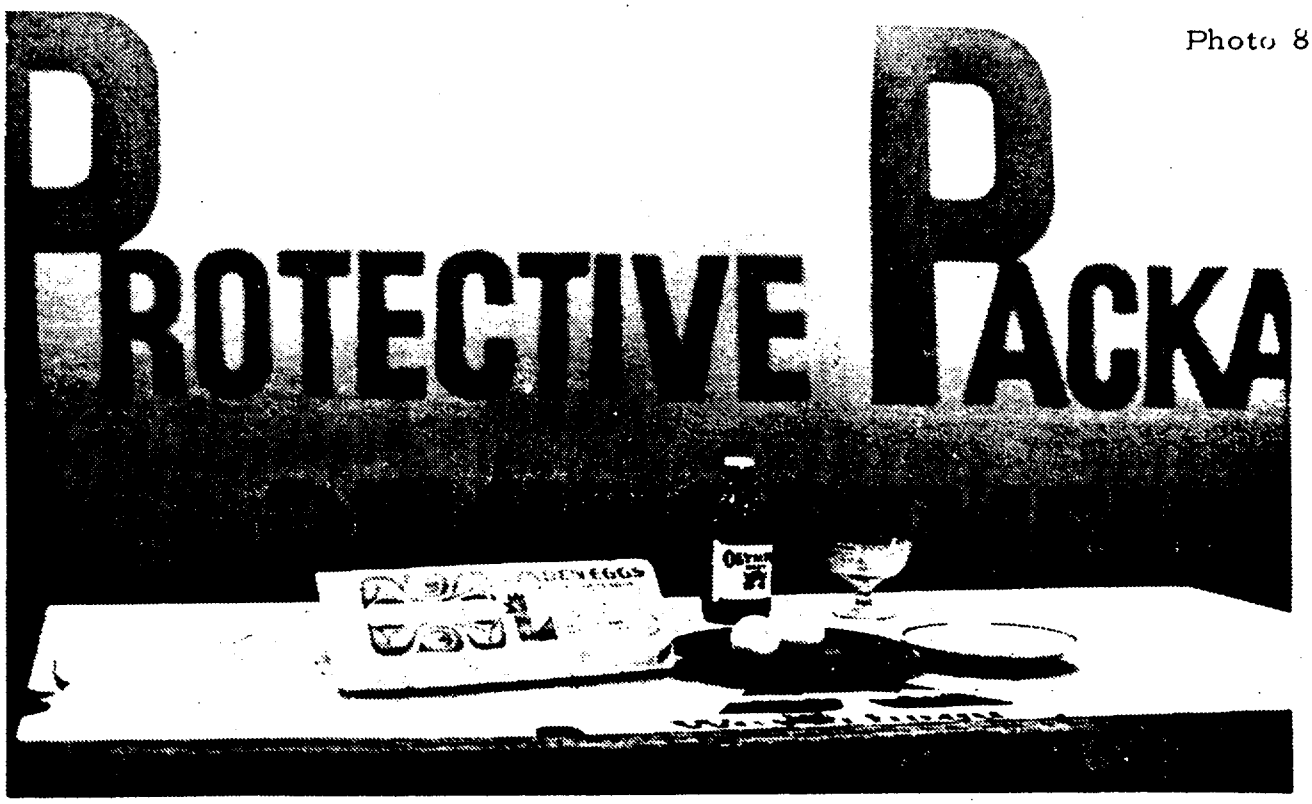
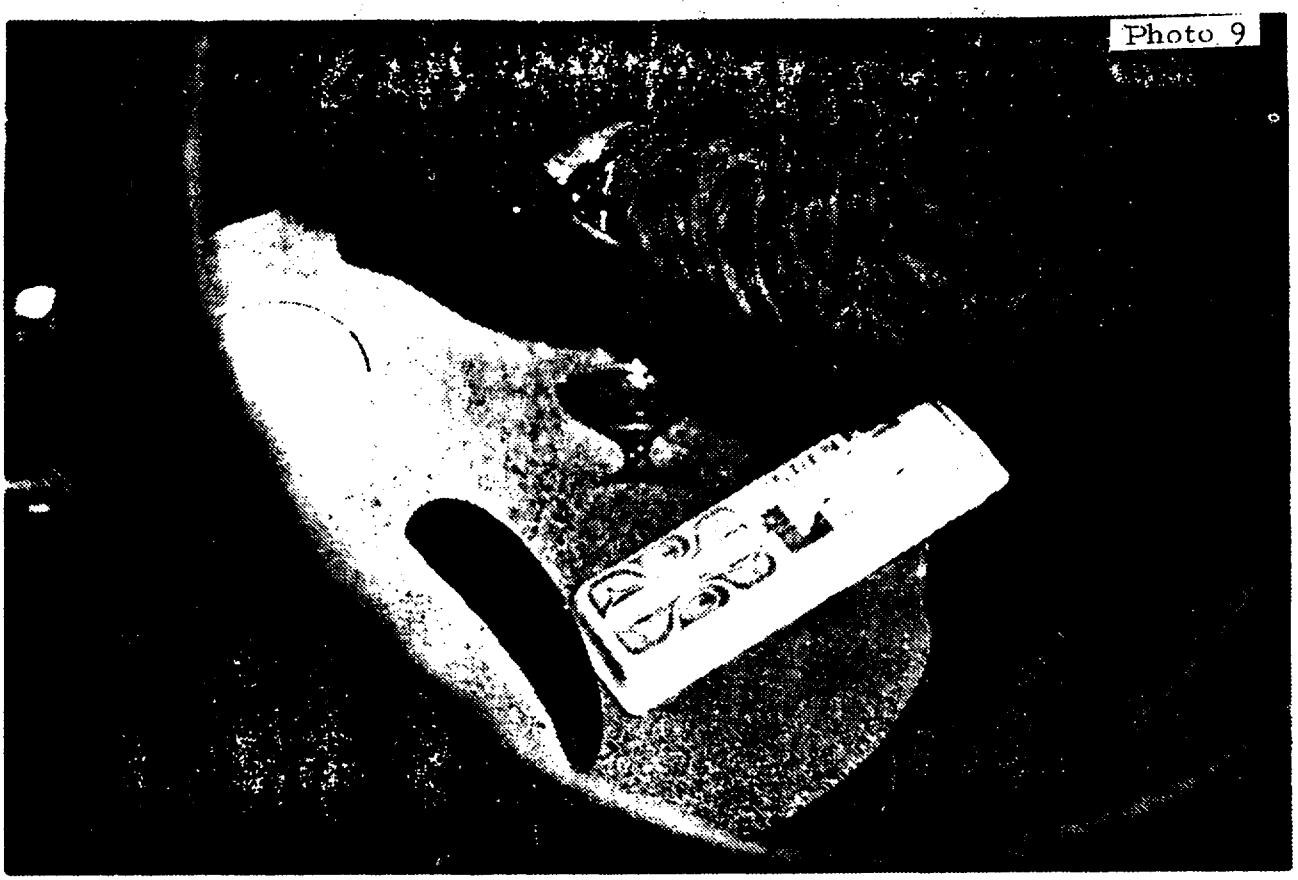


Photo 8

PATENT PENDING



The inner and outer container covers were secured making the container ready for drop testing.

5.3 30 Foot Drop Test

Super Tiger was trucked from the fabrication and loading site at Star Iron to the Port of Tacoma facility for the drop sequence. On route the truck trailer rig was weighed at a registered truck scale which determined the gross Super Tiger weight to be 45,200 lbs.

After a considerable amount of design review it was concluded that the most critical drop orientation would be a diagonal drop onto the corner of the cover.

PATENT PENDING

A quick release device was rigged between the crane and container to provide instaneous release. The drop height was measured by a 30' length of rope attached to the lower corner. The container was then raised to a point where the lower corner was over the target area. Upon release the container was allowed to free fall 30' onto the steel plates. (See photos 10 through 14).

Photo 10

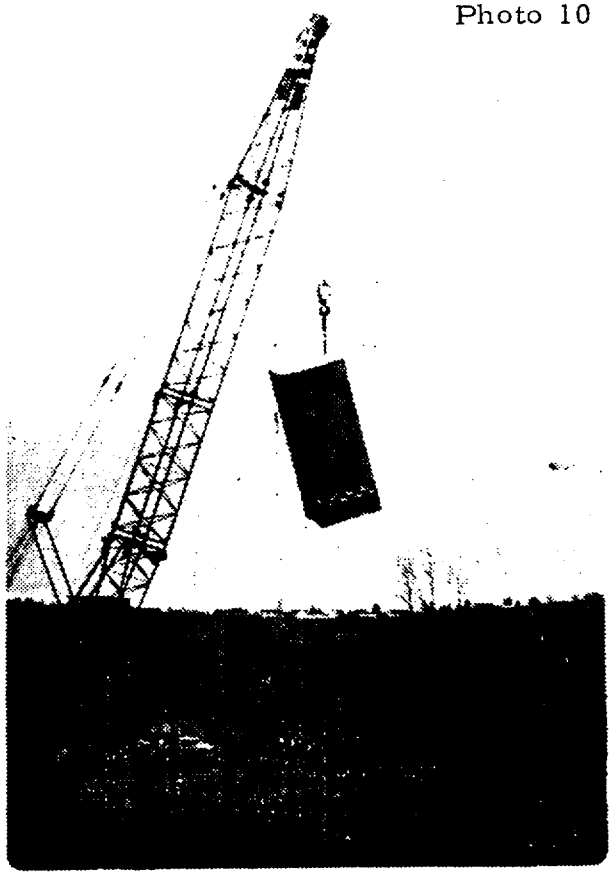


Photo 11

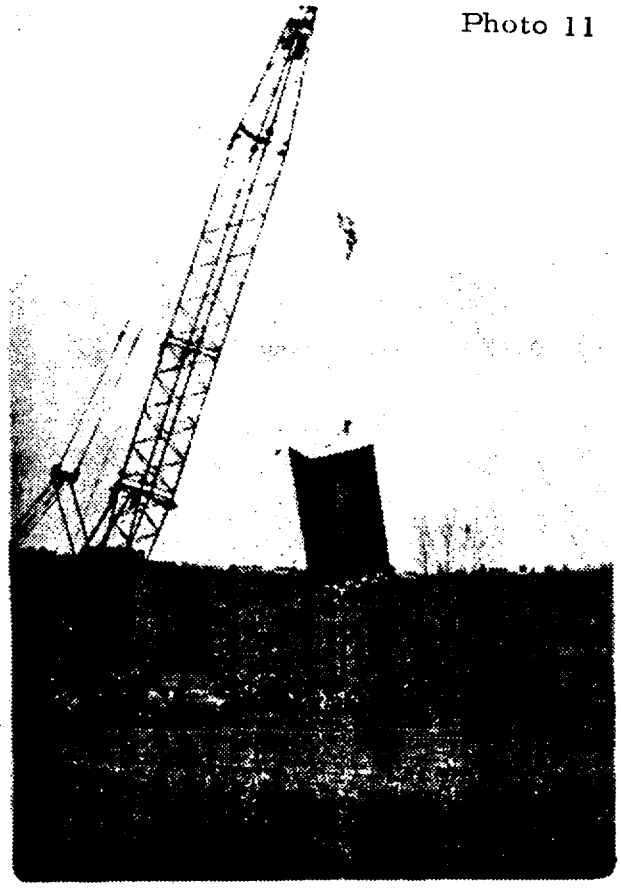


Photo 12

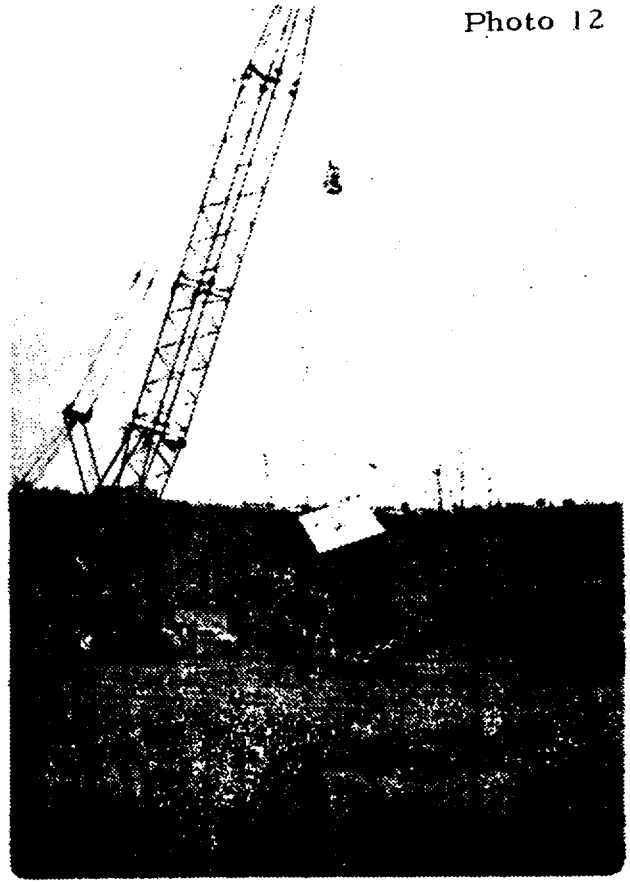


Photo 13

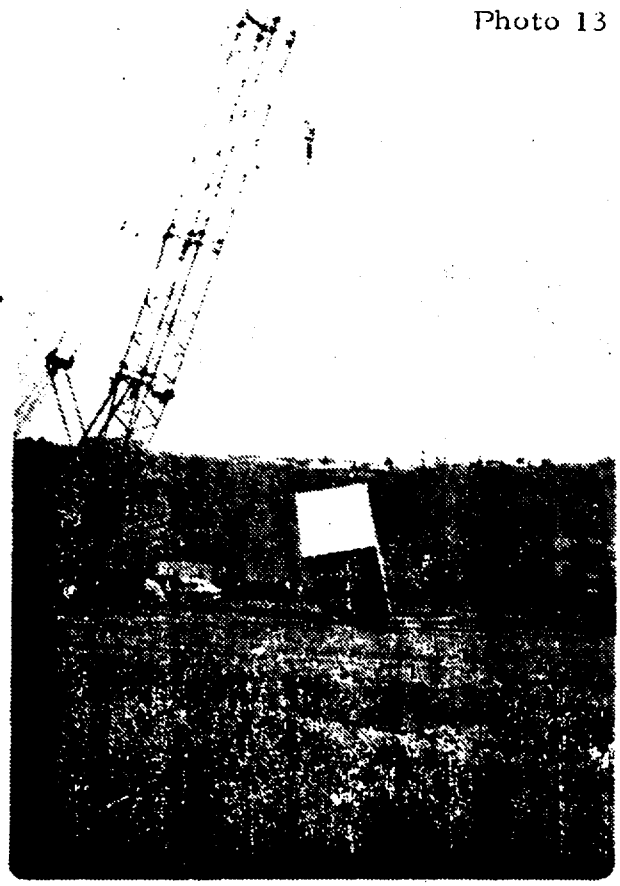


Photo 14

PATENT PENDING

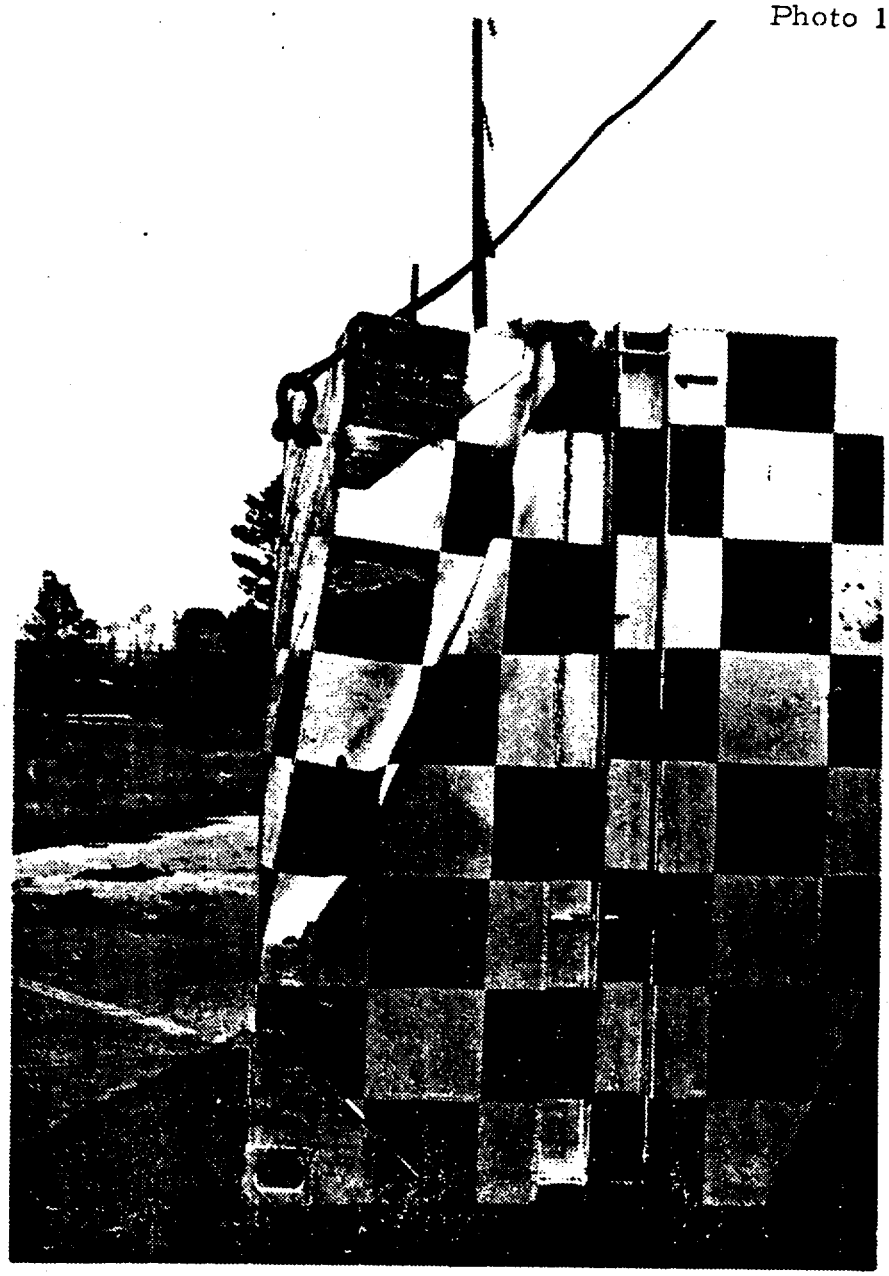
PATENT PENDING

On impact the external skin buckled in the region between the corner fitting and the interface closure area, (see photo 15 through 18). The ductility of the plate is evidenced in the 180 degree bends or wrinkles of the external skin. An external seam weld at the edge tore for approximately 10". This introduced no problem since the full area was backed with the diagonal gusset plate. Maximum corner indentation was less than 14".

Photo 15

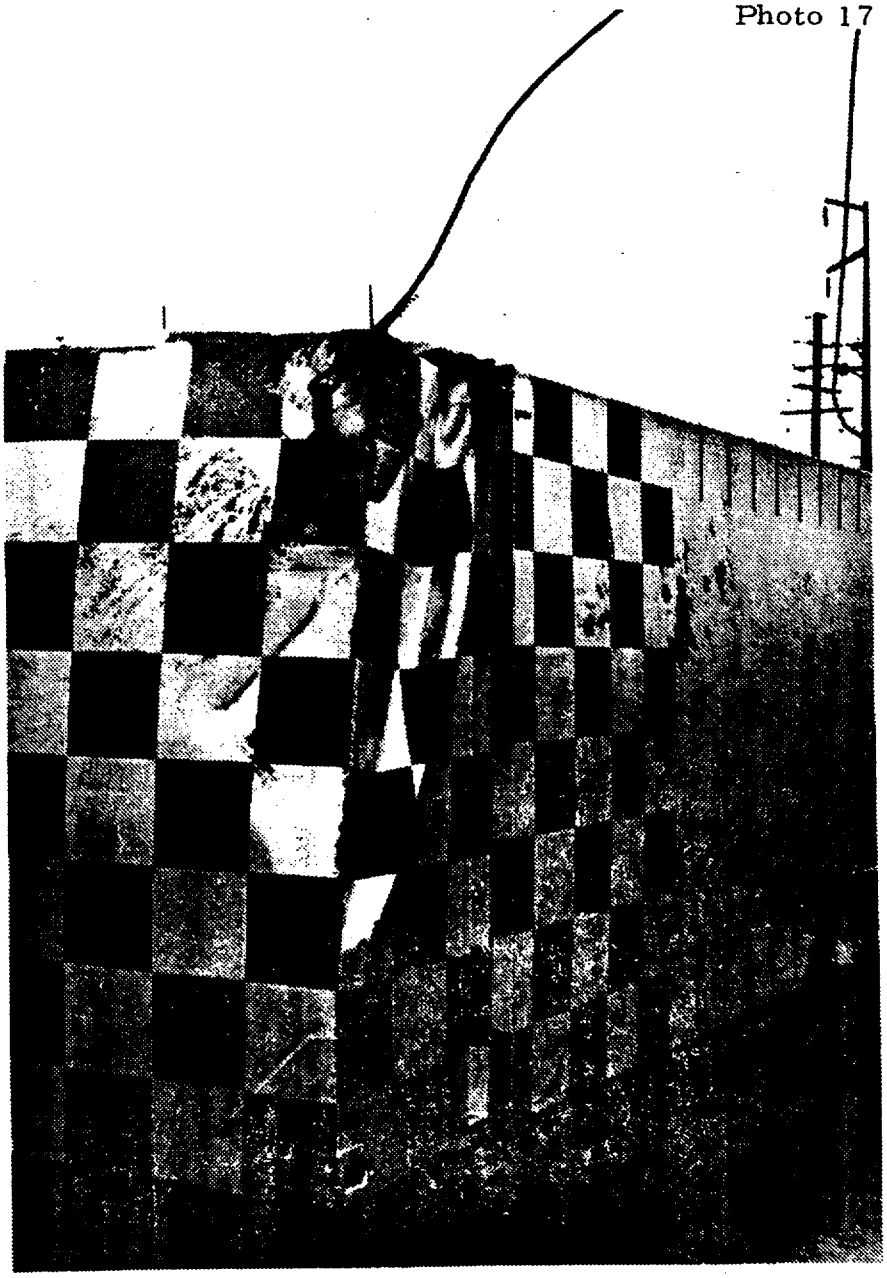
PATENT PENDING

Photo 16



PATENT PENDING

Photo 17



PATENT PENDING

Photo 18

PATENT PENDING

Material yielding appeared restricted to this area. Later, on removal of the cover, it was apparent that deformation was wholly restricted to the cap. (see photos 19 and 20). It was felt that if the cap were to be replaced the net effect of the 30' drop would have been undetectable to the remainder of the container. The inner cavity saw no deformation whatsoever.

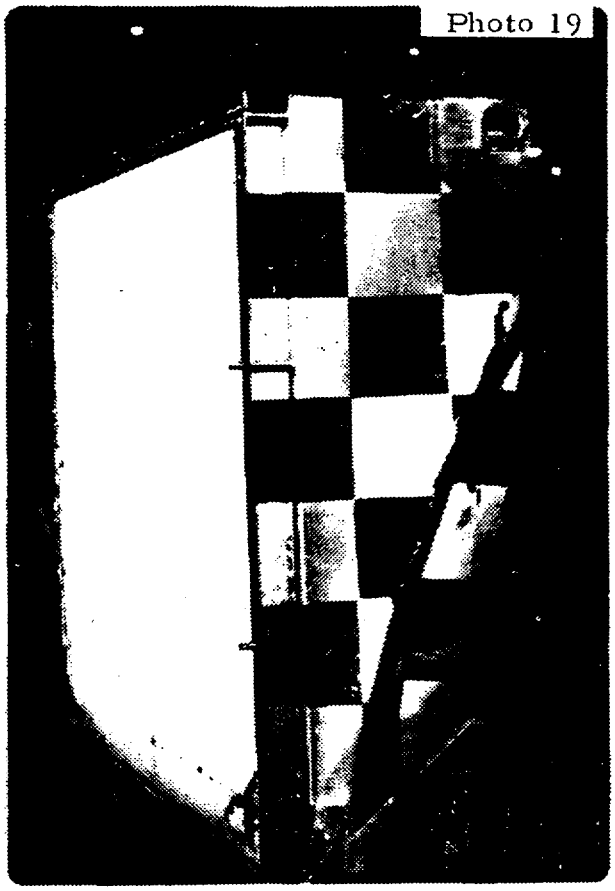


Photo 19

Photo 20

PATENT PENDING

5.4 40" Puncture Test

Four separate 40" drop tests were conducted. As explained in Section 1.2, each of the four sides represented a slightly different configuration. The purpose of the drop test was not only to qualify the container but also to provide a design evaluation of the different types of construction. The test went as follows:

Test 1 - a 40" drop onto the center of Side No. 3

This side contained three layers of steel plate (3/16+1/8+1/8). On impact, (photo 21 and 22) the pin produced a local indentation approximately 2-1/2" deep. As can be seen from photo 23 and 24 the external skin was not cut or torn in any way. Post test inspection of the inner container failed to show any evidence of the puncture test. No indentation or deflections were detectable on the inner container. This was true for the first three tests. There was also no evidence that the 8" tall pin had bottomed out.

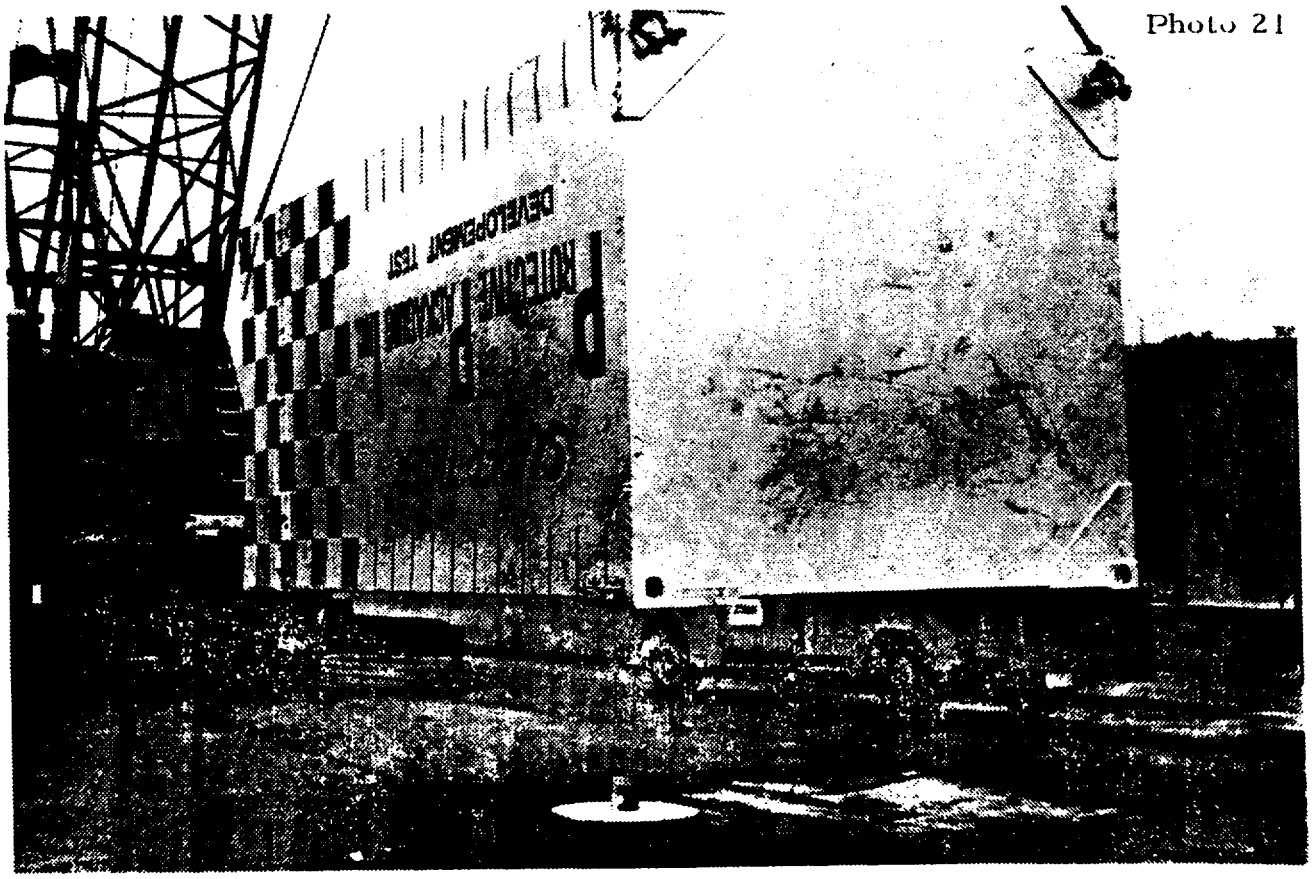


Photo 21

PATENT PENDING

Photo 22

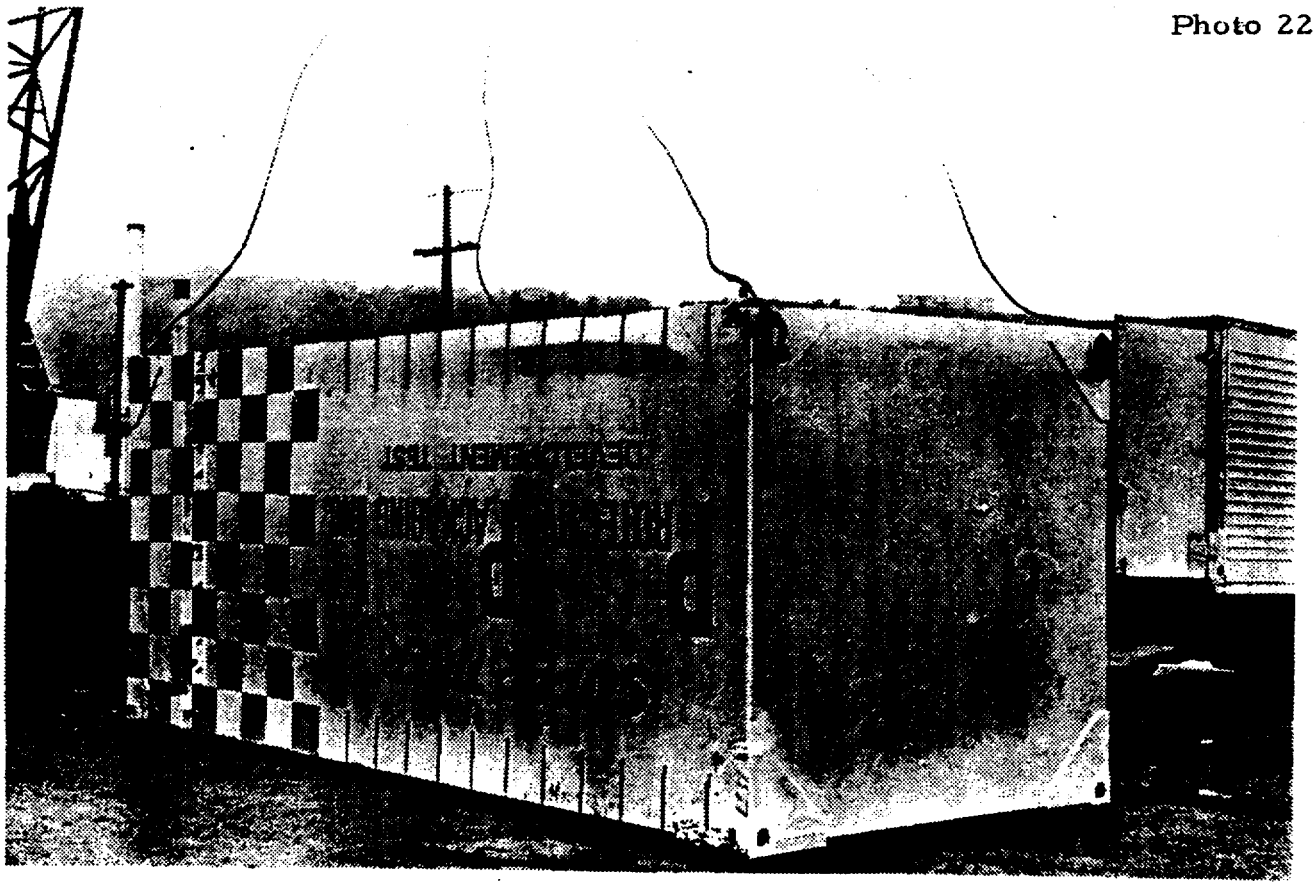


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Photo 23

PATENT PENDING

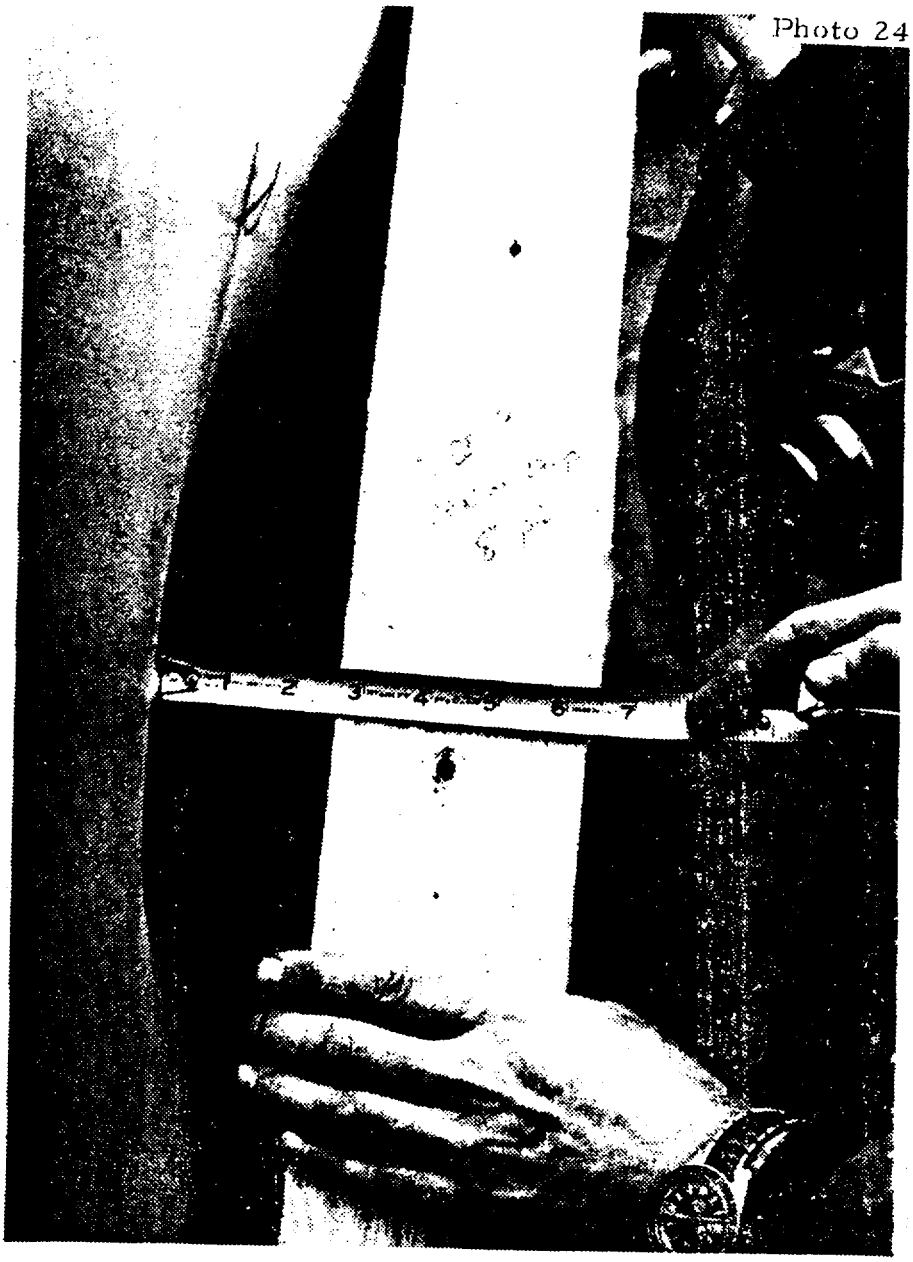


Photo 24

Test No. 2 - a second test was conducted on the same Side No. 3, but with the point of impact moved to approximately 16" from one edge. From photos 25 and 26 it can be seen that a hole was cut through the external skin along 1/2 the circumference with a maximum identation of approximately 6". Since the internal container sidewall is separated from the outer skin by nearly a foot of foam, an indentation of less than 6" caused no evidence of load whatsoever. There was no indication of the 8" pin bottoming out as shown in photo 26a. This fact was also borne out in the results of a frame by frame analysis of the high speed motion picture coverage of the drops.

Photo 25

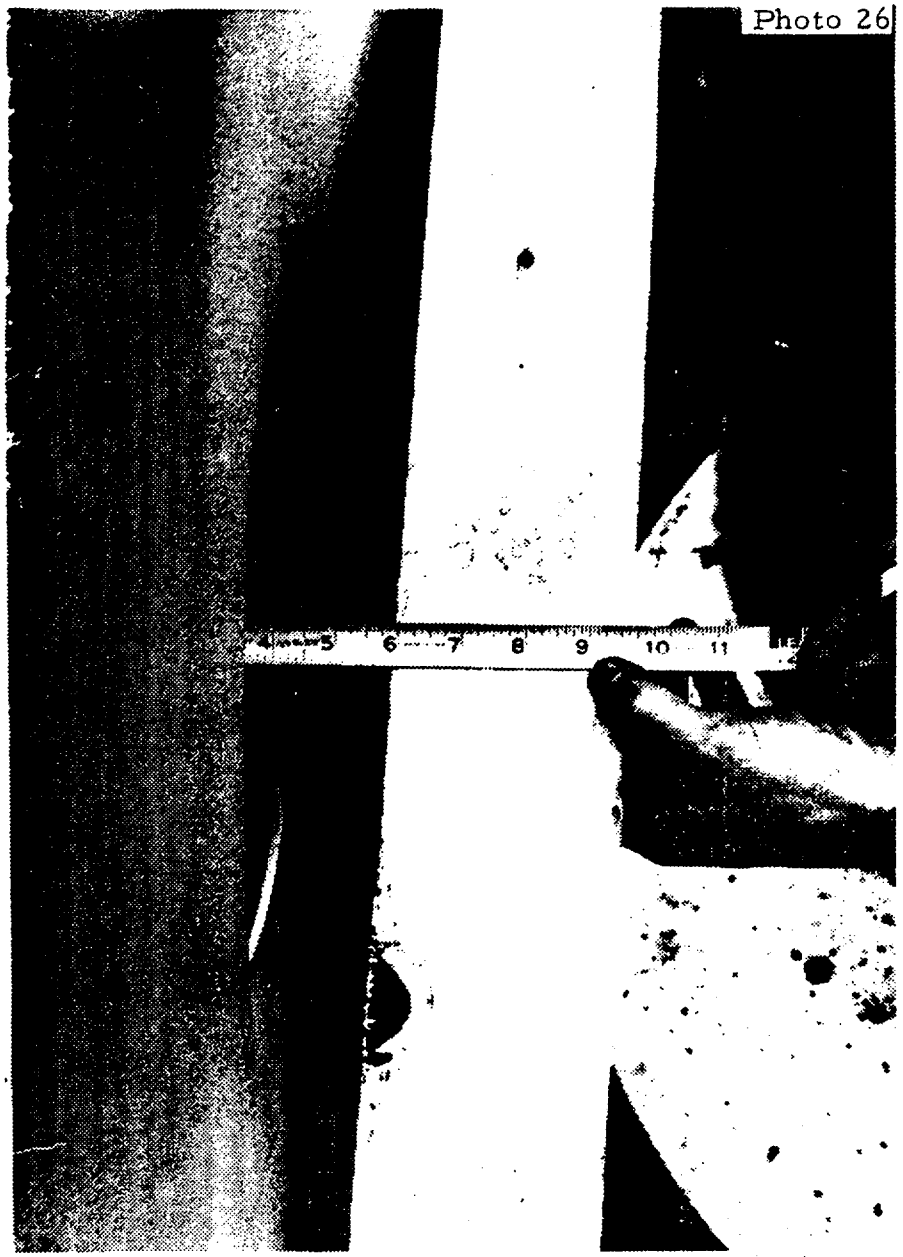


Photo 26

Photo 26a

PATENT PENDING

Test No. 3 - Test No. 2 was duplicated on Side No. 2. In this case the maximum indentation of less than 4" was observed. (see photos 27 and 28).

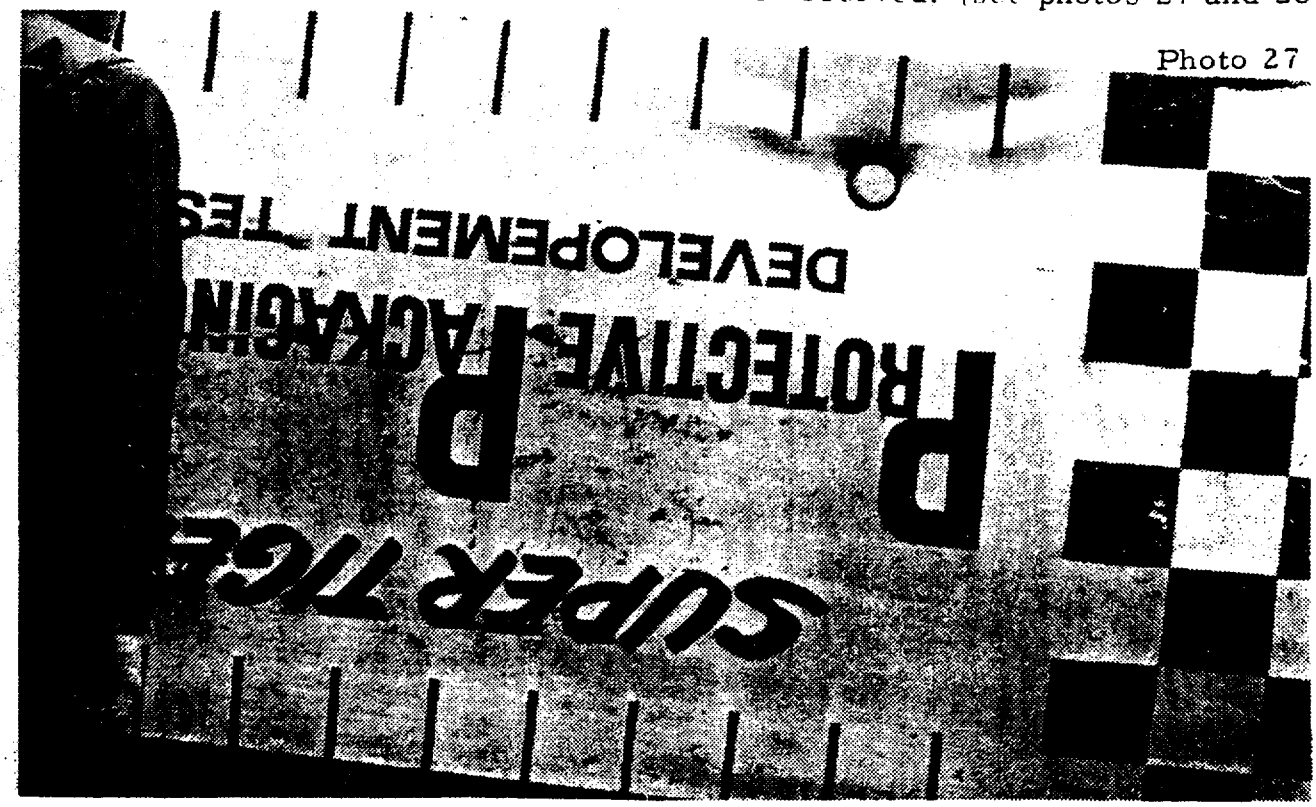


Photo 27

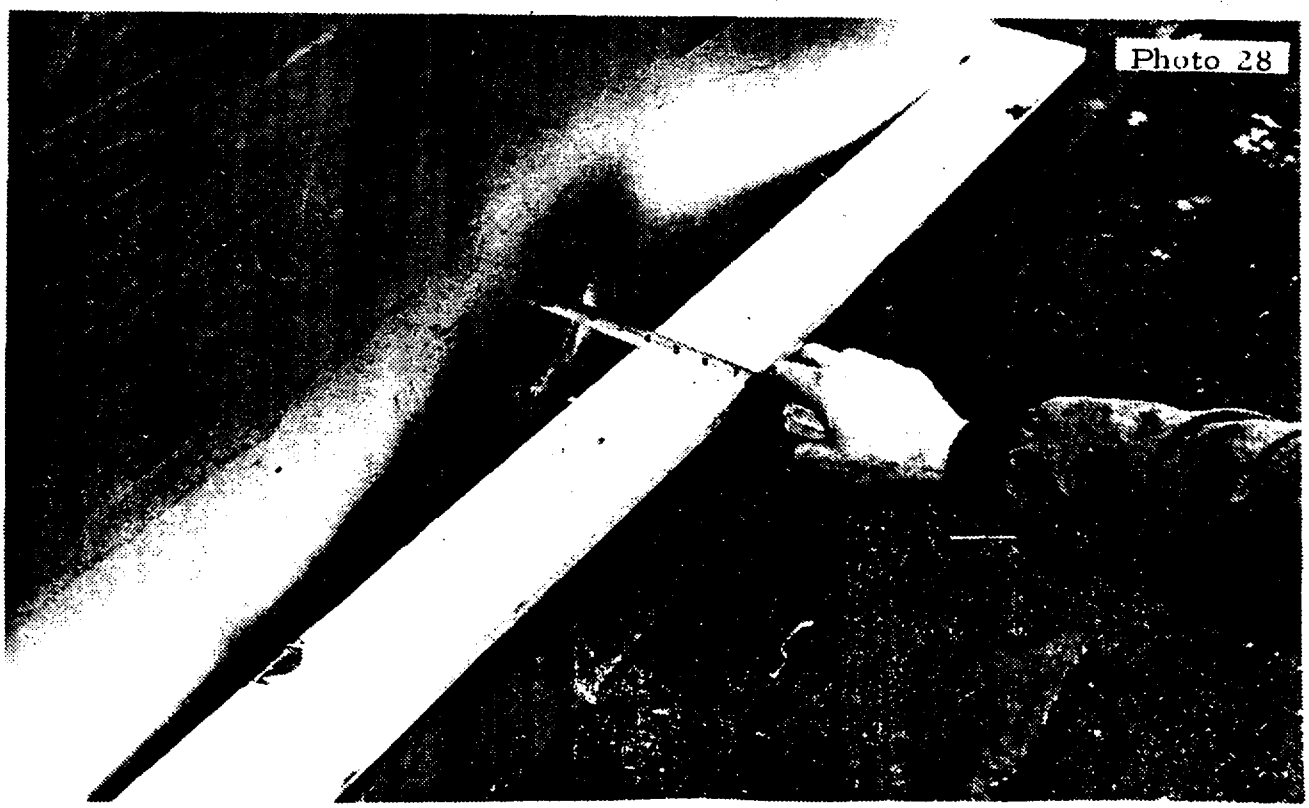


Photo 28

A tear in the external skin extended for approximately 5" of the 18.8" of pin circumference. It existed only in the external skin and not in any of the backup sheets. Again there was no indication that the 8" tall pin had bottomed.

Test No. 4 - this was the last of the development tests and consisted of a 40" drop onto side 4 which was fabricated with only one back up sheet of 3/16 material. As noted in Section 4.2, the construction of this side differed not only in the sheet arrangement but also in the manner in which the backup sheet was attached. In this case the backup sheet had been structurally welded to the face sheet, thereby negating the breakaway effect.

It was felt that in the event that the external skin totally failed, an 8" tall pin would not reach the inner cavity, thereby making it impossible to totally evaluate the net effect on the container. Therefore, for engineering and evaluation purposes only, the standard 8" tall pin was replaced with one approximately 2' tall, (see photo 29).

The container was raised to a point 40" above the top of the pin or 64" above the ground and released. On impact the pin penetrated approximately 20 inches puncturing both the inner and outer walls, (see photos 30 and 31).

Upon rolling the container over, there was no evidence of spillage or leakage of the contents. This was primarily due to the tightness in which the skins held the pin. The crane was required to extract it.

It was apparent that this combination of thinner wall .3875 versus .4375 and the nonbreakaway technique was an unacceptable design configuration.

PATENT PENDING

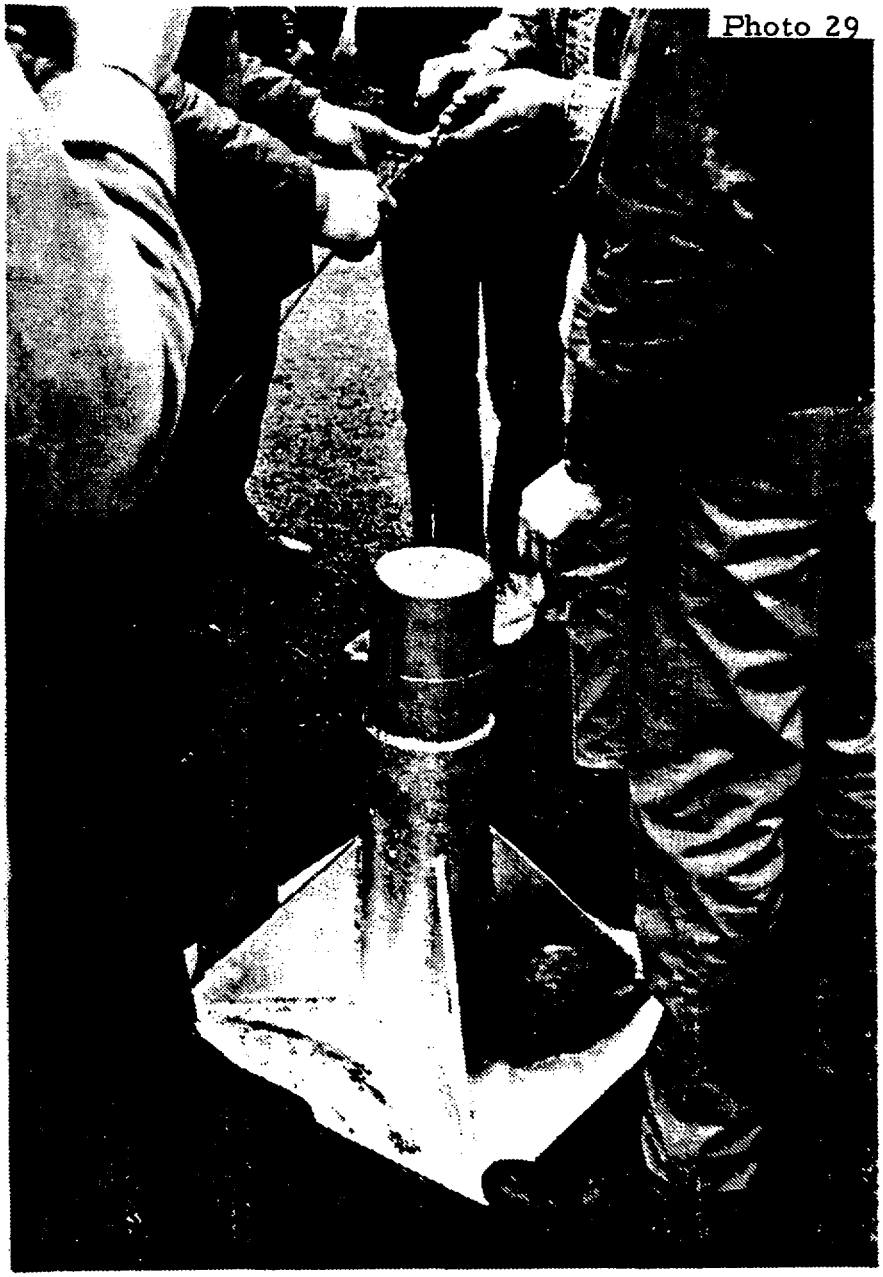


Photo 29

PATENT PENDING

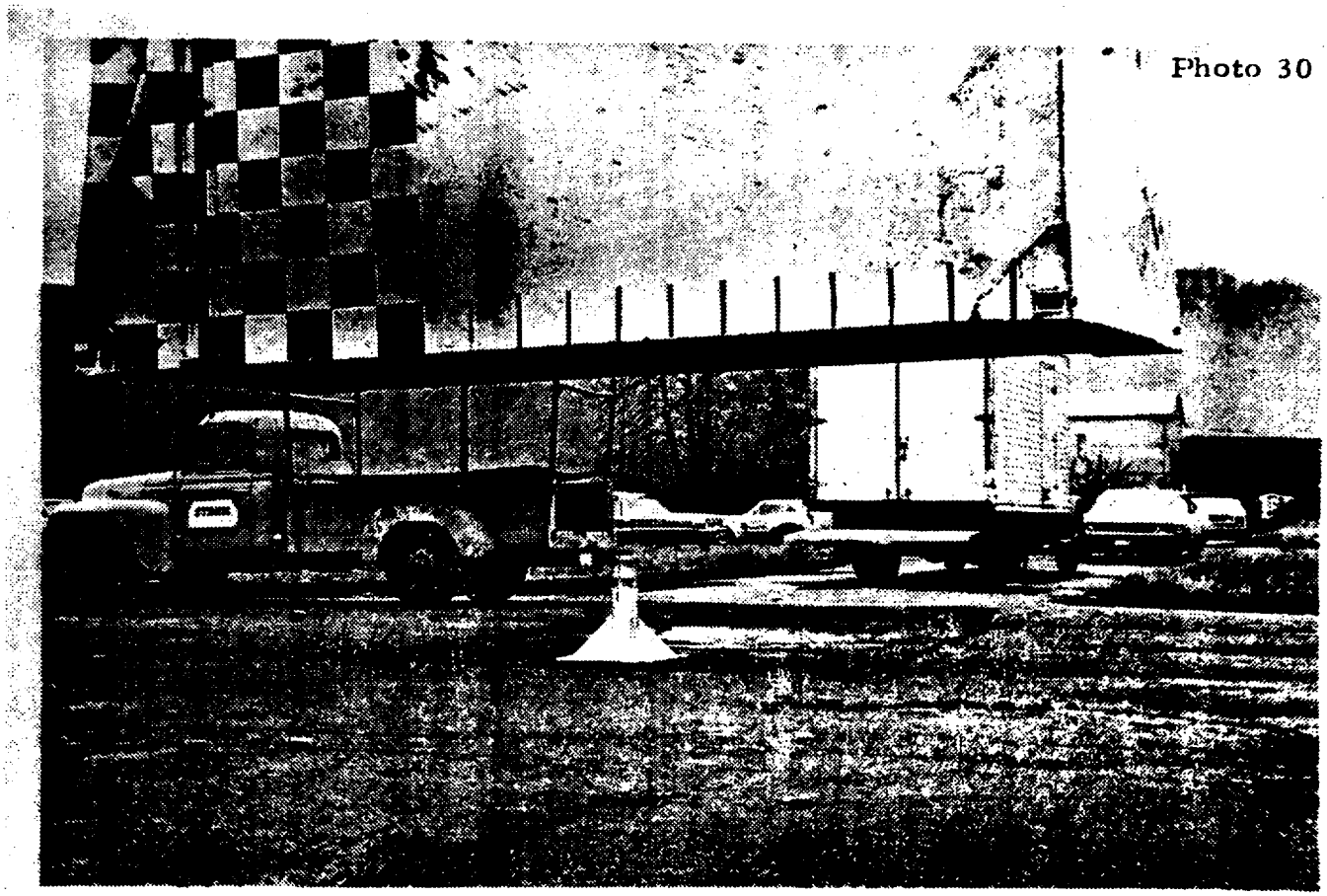
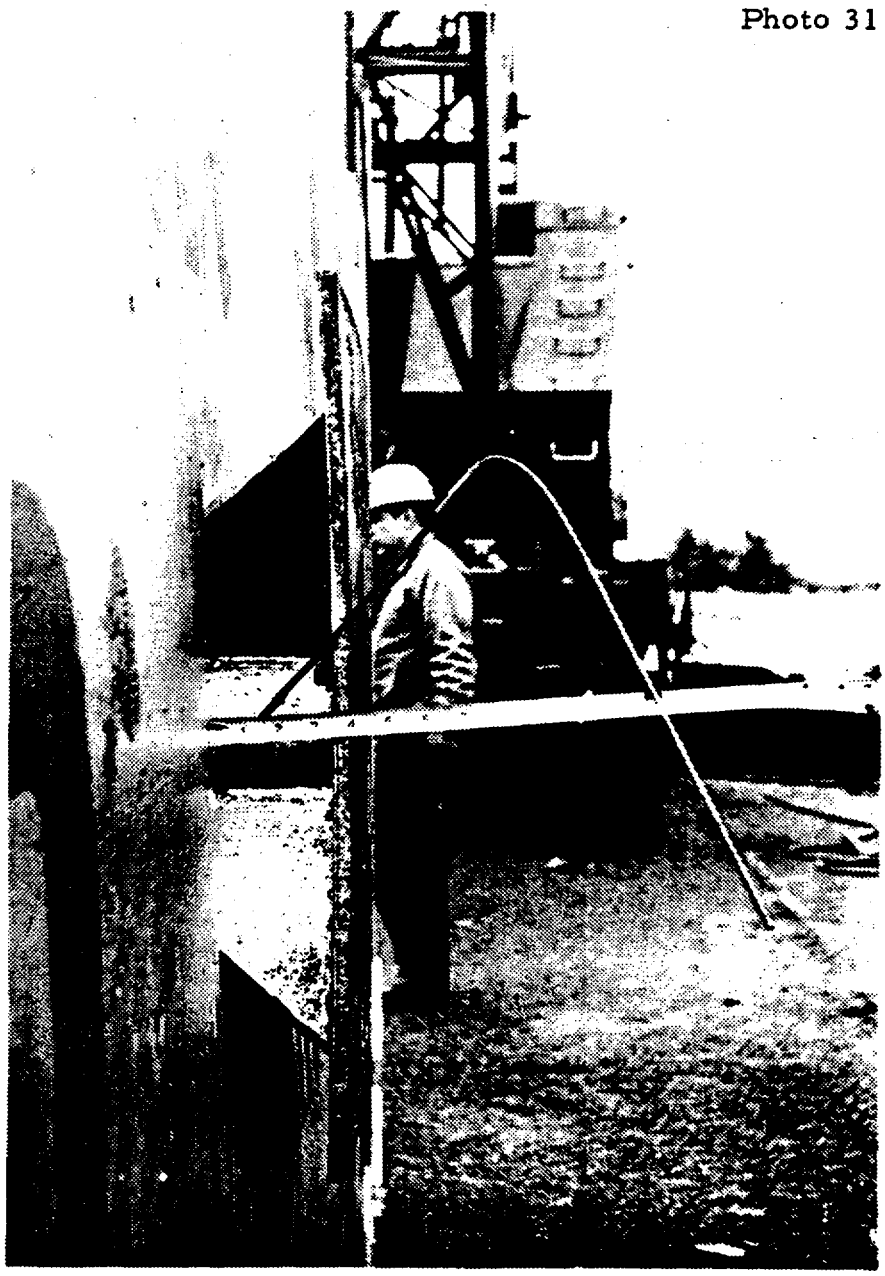


Photo 30

PATENT PENDING

Photo 31



PATENT PENDING

After drop testing was completed, the container was transported back to the fabrication area for a more detailed inspection. From the results of the puncture test, it was concluded that Side No. 3 would represent the final design configuration. It had received two 40" drops, Test No. 1 and Test No. 2 and would be placed in the fire test unaltered. Sides 2 and 4, useful for engineering evaluation only, were patched. In the case of side4, both the inner and outer skins were welded over and refoamed between the two, (see photos 32 and 33).

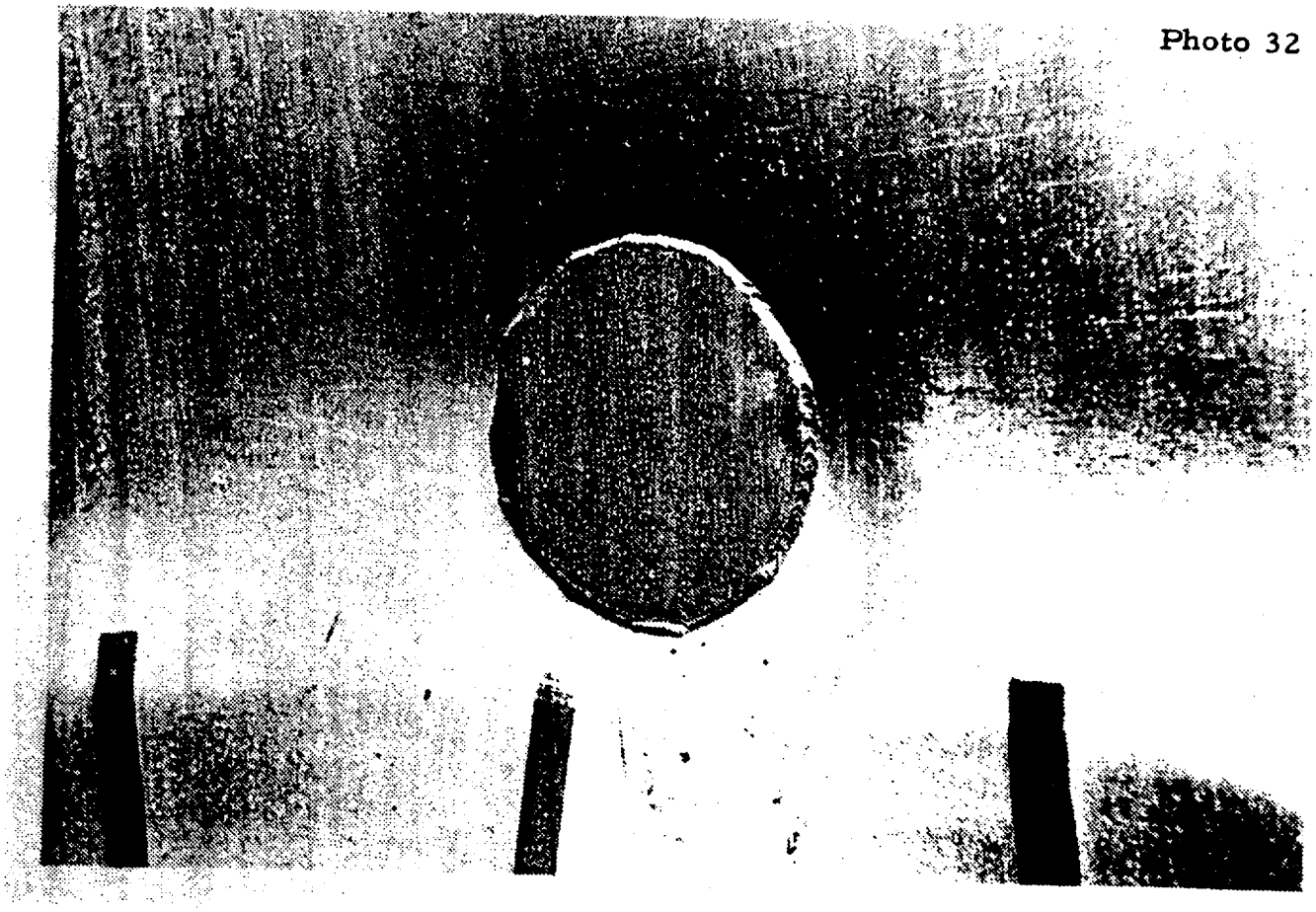


Photo 32

PATENT PENDING

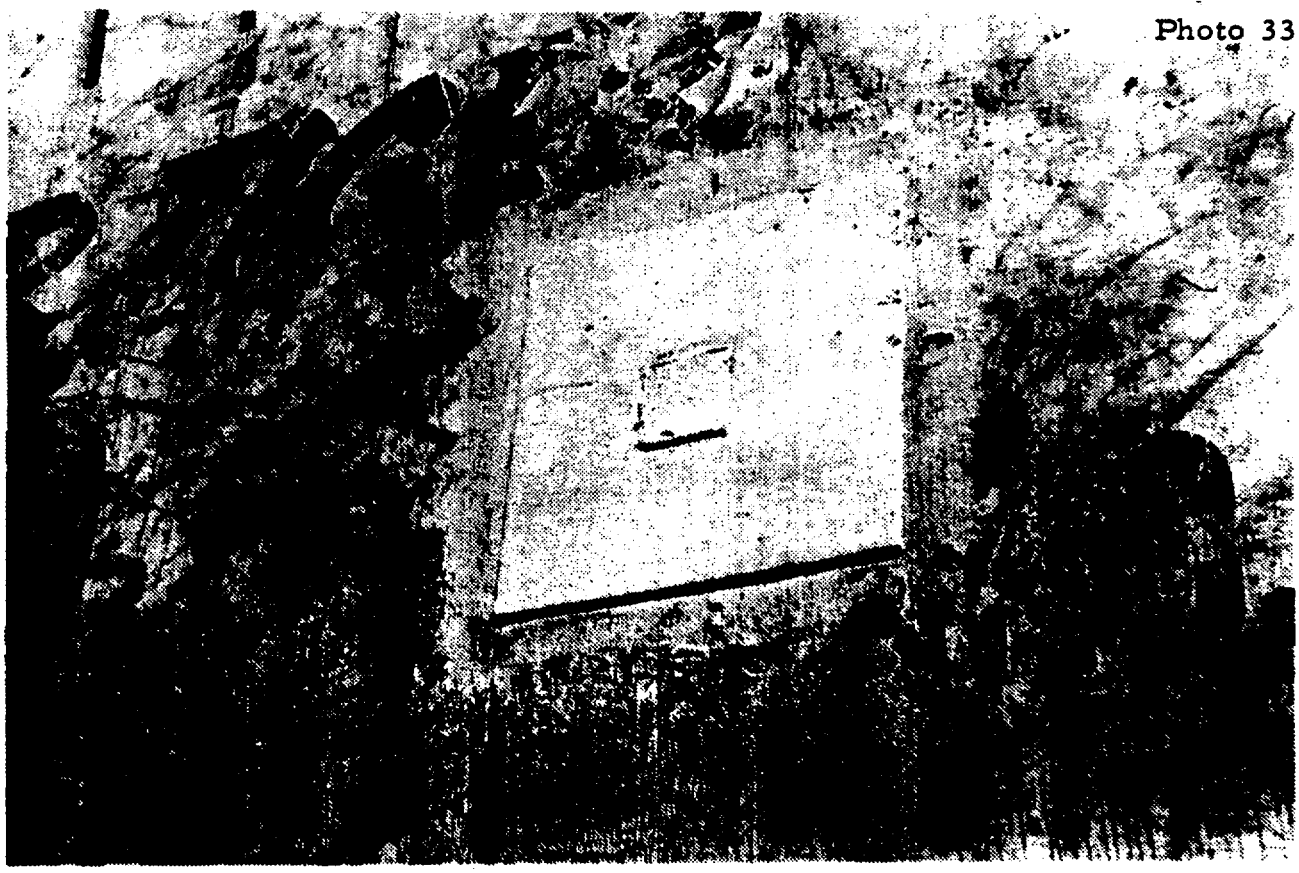


Photo 33

PATENT PENDING

The external end cap was removed and damage effects noted, [illegible] photos 19 and 20). It can be seen that the drop damage did not [illegible] the cap interface. By applying the internal pressure to the inner [illegible] it was established that a small leak [illegible] at the gasketed [illegible] A soap solution was mopped over the [illegible] from photo 34 note the the air bubble produced by the leaking air. A post fire inspection [illegible] that faulty installation of a silicone room sealant was the cause of the [illegible]

Photo 34

As shown in photo [illegible], [illegible] gas[illegible] [illegible] not been installed along the bolt pattern with a net result b[illegible] an area totally without a gasket seal. No attempt was made to correct the s[illegible] efficiency prior to the fire test.

PATENT PENDING

It should be noted that a realistic attempt was made to provide an unyielding surface. Since on impact, compressive loads in excess of 1,000,000 pounds were being applied to very small areas (1 to 3 in^2), stress levels over 300,000 psi were present. Surfaces capable of reacting these loads without some yielding are nearly unattainable and totally impractical for testing in the physical world. Over 27,000 ft^3 of concrete would be required to approach the necessary mass level let alone the local compressive requirements. As the result of these large concentrated loads, the steel plates used were locally sheared on impact. It is felt that the net effect of this local yielding had little effect on the overall damage received by the container on impact.

The total series of four 40" drop tests and one 30 foot drop test produced no noticeable effect on the inner container.

The end cap was reinstalled and the container was trucked to Seattle Boiler Works for subsequent fire test.

5.5 Fire Test

Finding a fire test facility that could accommodate the 45,000 lb container with these dimensions was no small problem. It was felt that the controlled thermal environment provided by a furnace was more desirable in making engineering evaluations than that of an open pit fire. As an example, a small cross wind in a pit fire can cause the flame to be blown away from the test article, thereby effecting the validity of the test. Photo 36 shows the container being removed from the truck. Since the prime function of this furnace is to provide heat treatment temperature for large boiler parts it possessed adequate heating ability.

PATENT PENDING

Photo 36

5.5.1 Test Set Up

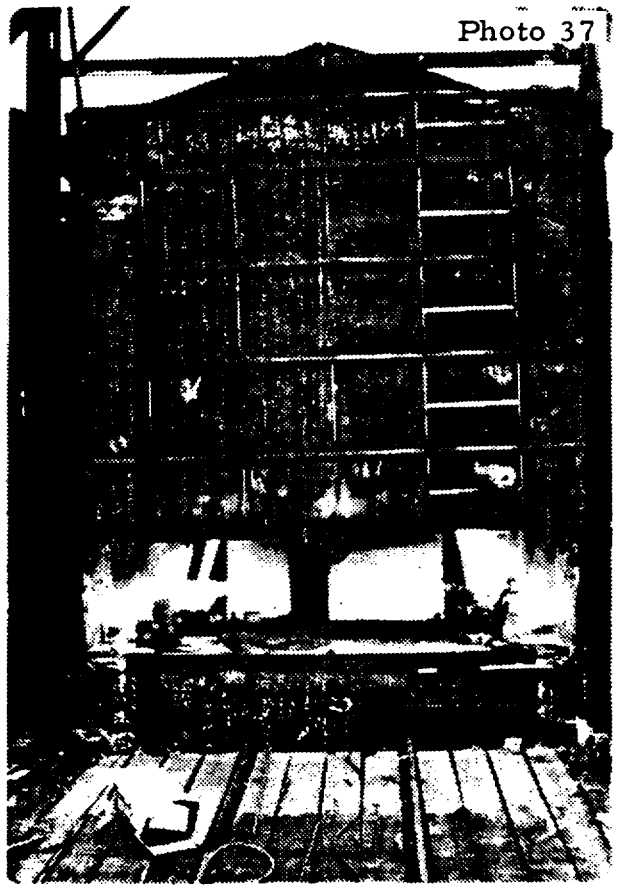
The container was positioned within the furnace in such a manner that all 12 burners would exhaust directly at it. In order to produce a radiant atmosphere as rapidly as possible, 3/16" steel plates were placed near the burner ports. Temperatures of the plates very quickly got up to and exceeded the 1500° mark. These would not only radiate directly to the container but also radiate to the furnace walls. In this way the highly convective atmosphere could also possess the desired radiation characteristics stated in Reference 1 and 2. The container was placed in the furnace with the exposed puncture test results on the top. It was felt that any leaks around the mouth would tend to form a natura chimney up through the skin tear at the puncture area. This would therefore

represent a conservative test arrangement since in practicality the container would remain on top of the puncturing device during an accidential fire.

5.5.2 Fire

All twelve burners were ignited and the furnace door closed. Surface temperatures of the steel shell exceeded 500° within the first five minutes of testing. On reaching approximately 600° the virgin urethane foam begins to locally decompose creating a very dense pungent gas. Since sufficient oxygen to support combustion was not present within the shell, the gases must exhaust through the pressure port and burn external to the container. In theory the velocity of the excaping gases is higher than the rate of flame propogation making sure that the combustion reaction is always exothermic, therefore taking heat away from the container rather than adding heat to it. Inspection ports in the furnace wall verified this to be the case. Large quantities of smoke and flame were apparent. (see photos 37 and 38).

Photo 37



PATENT PENDING

Photo 38

As surface foam temperatures rise, remaining residue forms a hard porous char layer resembling the clinker commonly found in a coal fire furnace. This char layer serves to insulate and protect the virgin foam from additional decomposition while at the same time allowing the decomposition gases to be passed and carry heat away. Again due to the urethanes outstanding insulation characteristics, material a short distance away will experience no increase in temperature, therefore, once the protective char layer is formed, the foam decomposition rate is very slow. Maximum thickness of char experienced was later found to be less than 4".

An example of skin temperature is shown in Figure 2. Temperature rise rate at this point was somewhat slower than at other locations due primarly to receival of only convective heating initially. Once the furnace temperatures stabilized radiant heat from the fire brick ceiling became effective.

Because of the furnace size and its thermal shock sensitivity, it wasn't possible to preheat. Exposing hot furnace refractory to ambient air would have caused extensive damage. Because of this the container was subjected to more than 30 minutes at 1500°. As shown in Figure 2, the container remained in the furnace for nearly one hour while test temperatures were being reached. Skin temperatures were over 1500° for more than 33 minutes and at times exceeded 1800°. An additional thirty minutes of post test heating was experienced during the cool down phase before the furnace doors could be opened. For more than two hours, the container experienced temperatures in excess of 500°. The net result of this sequence was a conservative fire test.

As a point of interest, over 200 gallons of #2 diesel fuel were burned stoichiometrically in the direct presence of the container. This is twice the maximum fuel load carried by the normal semi trailer rig. Heat flux levels of approximately 39,000 Btu/ft^2/hr were realized.

Photos 39, 40 and 41 show the container after its removal from the furnace.

5.6 Post Test Inspection

Once the container had cooled, it was trucked to a storage area for post test inspection.

Even though a 1600° high temperature paint was used, erosion of the outside steel shell was obvious. Iron oxide coating of approximately one mil could be found over much of the container. Pressure check identical to the one

PATENT PENDING

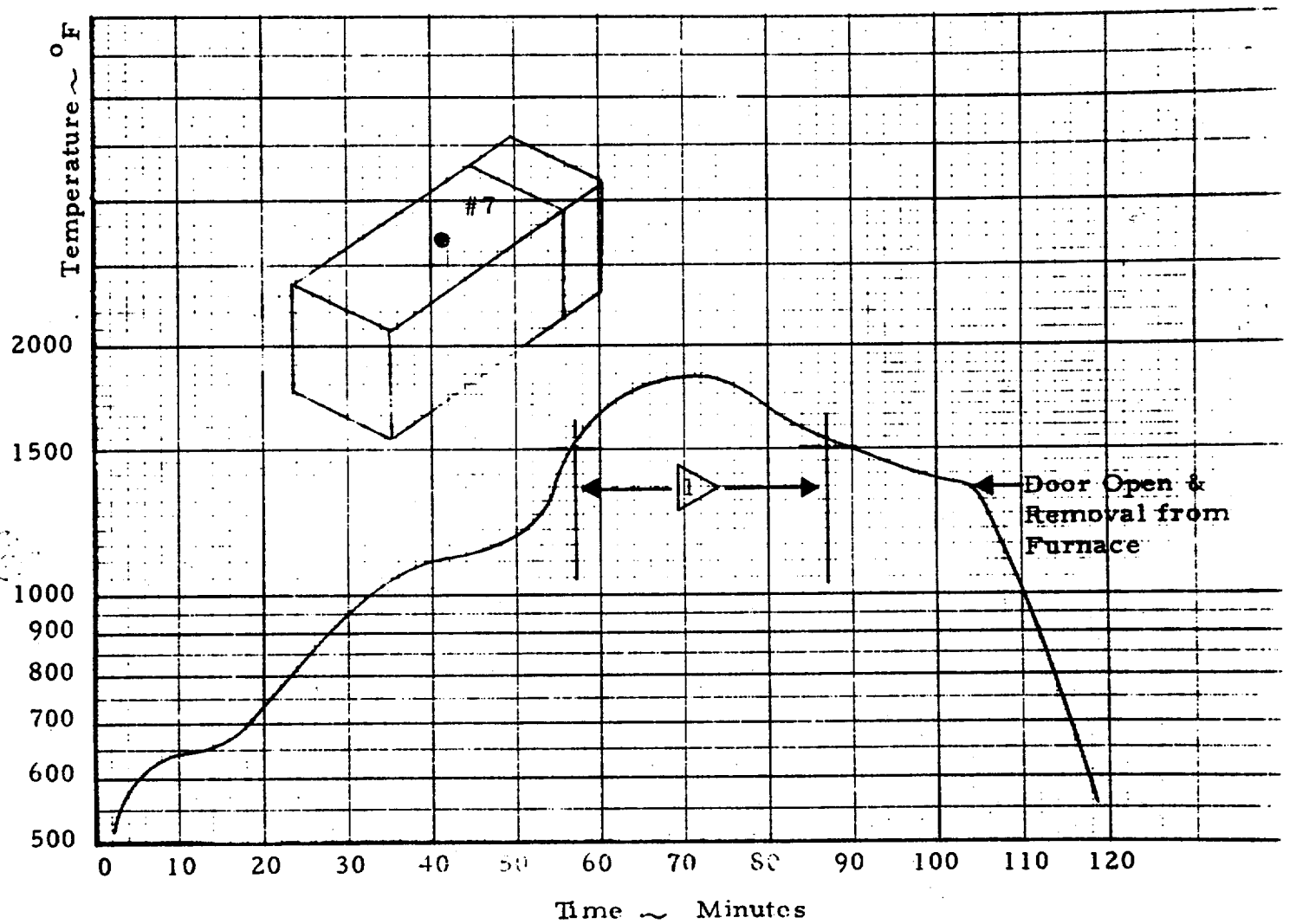


Figure 2 - Fire Test, Skin Temperature at Point #7

1 Required test of ~1500°F for 30 minutes

PATENT PENDING

Photo 39

PATENT PENDING

Photo 40

PATENT PENDING

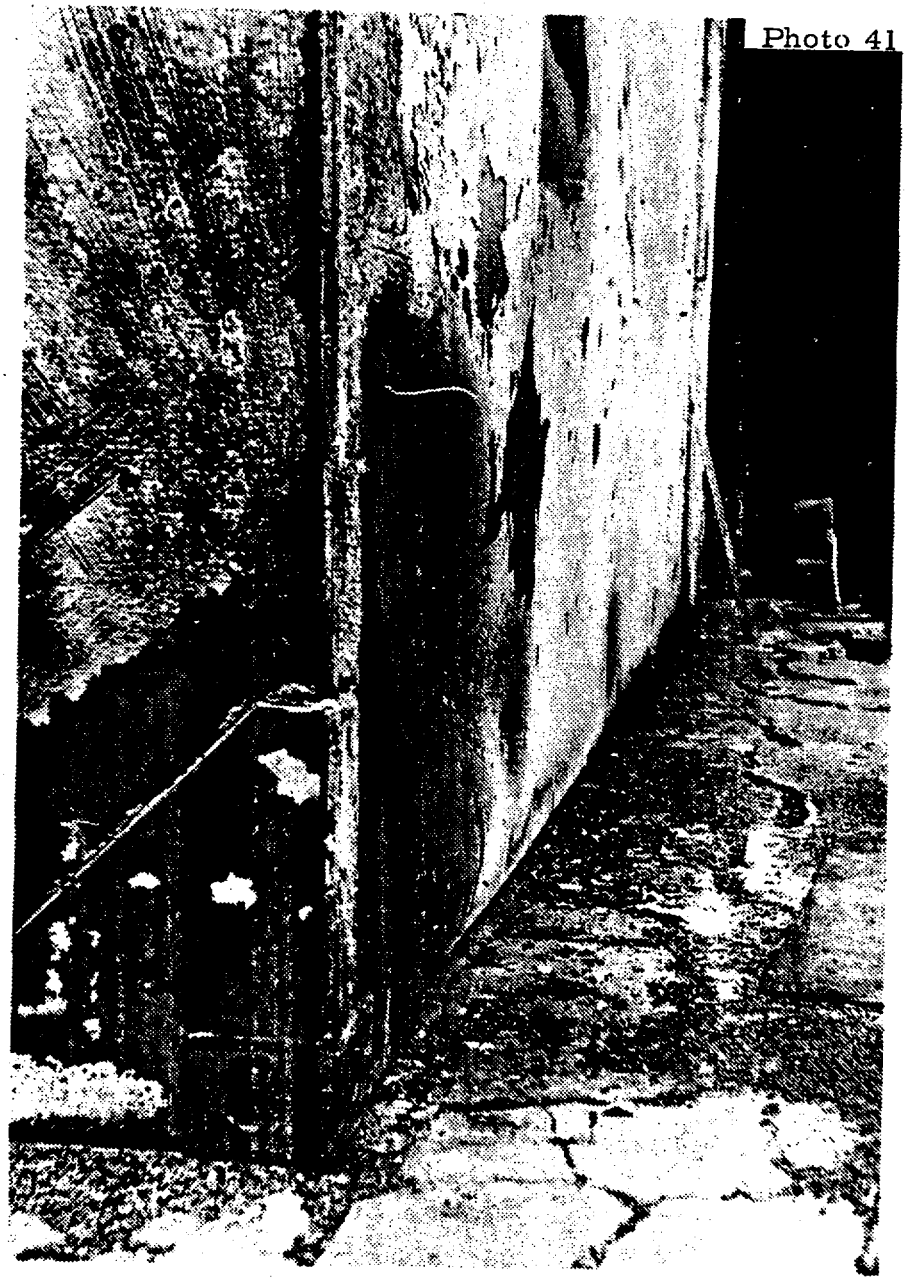


Photo 41

prior to the fire test was repeated. Identical leak rates were recorded indicating no thermal degradation of the seal had taken place. The external cap was removed exposing the inner face and the inner cavity cover as shown in photo 42. A plywood cover over the inside of the cap had been charred around the edges for approximately 1 to 3". This was expected since it had been attached directly to the external skin. In-board of this point discoloration from distilled resins was the only noticeable change. A hole was cut through the outside steel shell and a core sample of the underlayment foam was taken. As shown in photo 42a the char depth was restricted to less than 1" leaving more than 6" of unaffected virgin material. Upon removal of the container cover it was evident that the very slow pressure leak previously noted resulted from a faulty installation of the silicone seal, (see photo 43). Had the seal been positioned correctly during assembly, the inner container would be totally pressure tight during and after testing.

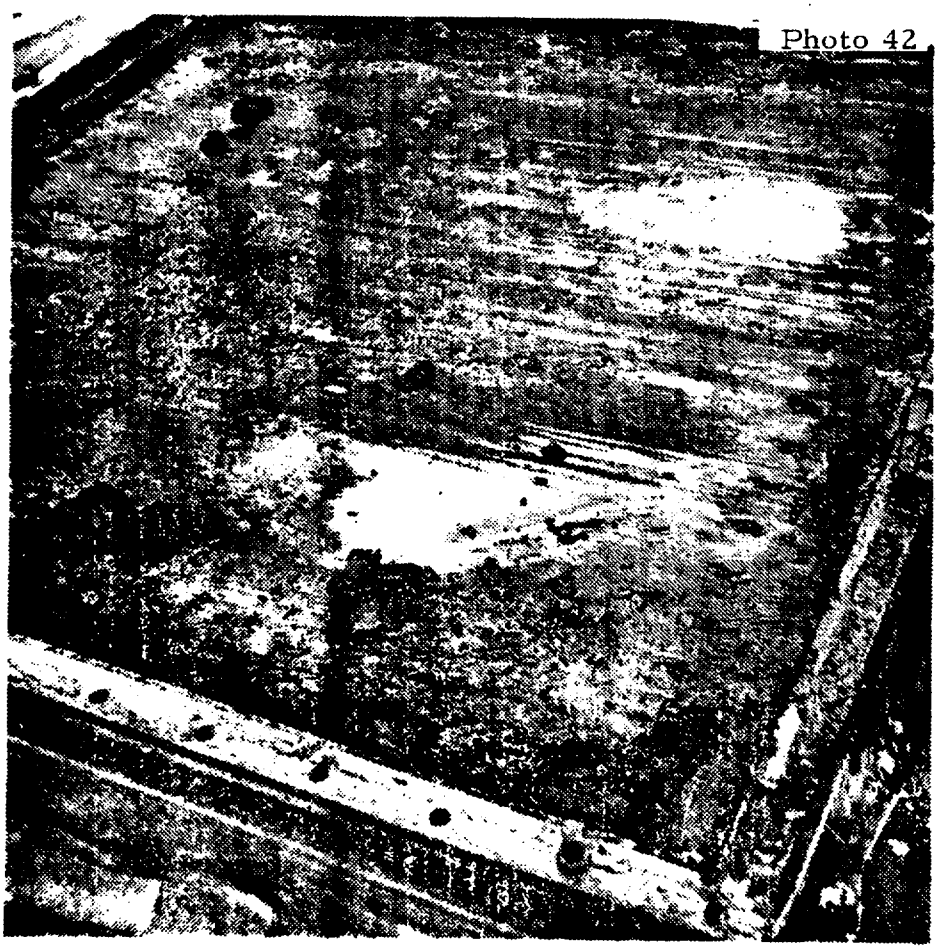


Photo 42

PATENT PENDING

Photo 42a

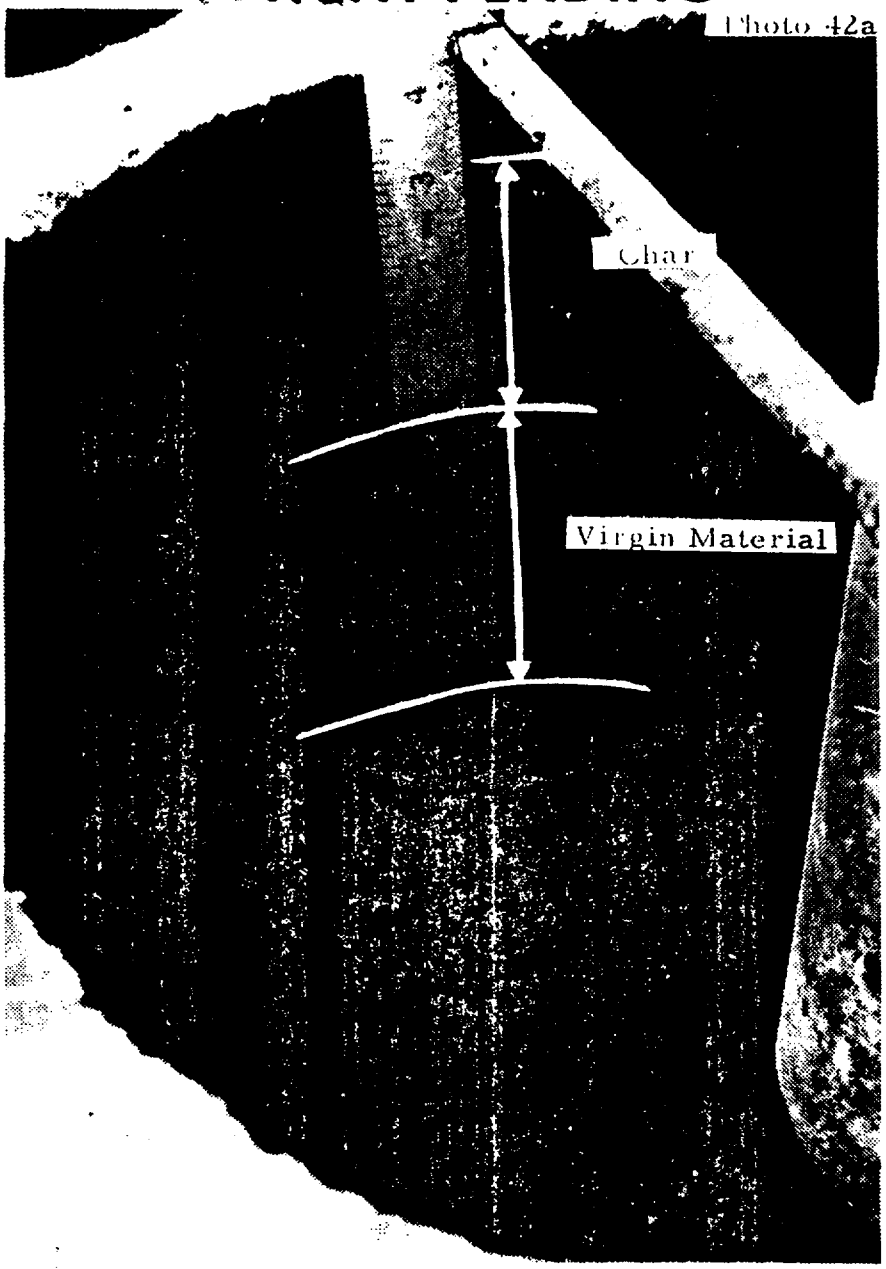


Photo 43

PATENT PENDING

Lack of degradation of the seal material indicated that only low temperatures (less than 200°F) had been experienced. It possessed its original color and elastic properties.

Examination of those drums located adjacent to the container wall indicated no thermal effects whatsoever, (see photo 44). Since the minimum temperature indicator used was 150° and it had not been triggered, it could be concluded that the cargo did at all times remain below 150°. The paper foldout previously taped to the wall evidenced were no thermal effects.

Photo 44

PATENT PENDING

During impact the compressive force on the bottom drums produced considerable flattening. These were used 22 gage oil drums filled with wet sand. In some cases seams were ruptured allowing water to drain, (see photo 45). In contrast, two of the drums were standard 16 gage 17H with removeable covers. These experienced little or no deformation as evidenced in photo 45a. It is felt that had thicker walled drums been used exclusively, no liquid would have been lost. Also the presence of a plastic drum liner would have provided added assurance. In any event the innercontainment shell is capable of containing any released liquid negating reliance on a secondary system.

Photo 45

PATENT PENDING

Photo 45a

PATENT PENDING

Contained within one of the 17H drums was a carton of eggs, a drinking glass, a few dishes, a bottle, etc. There was no damage to any of these items, (see photo 46).

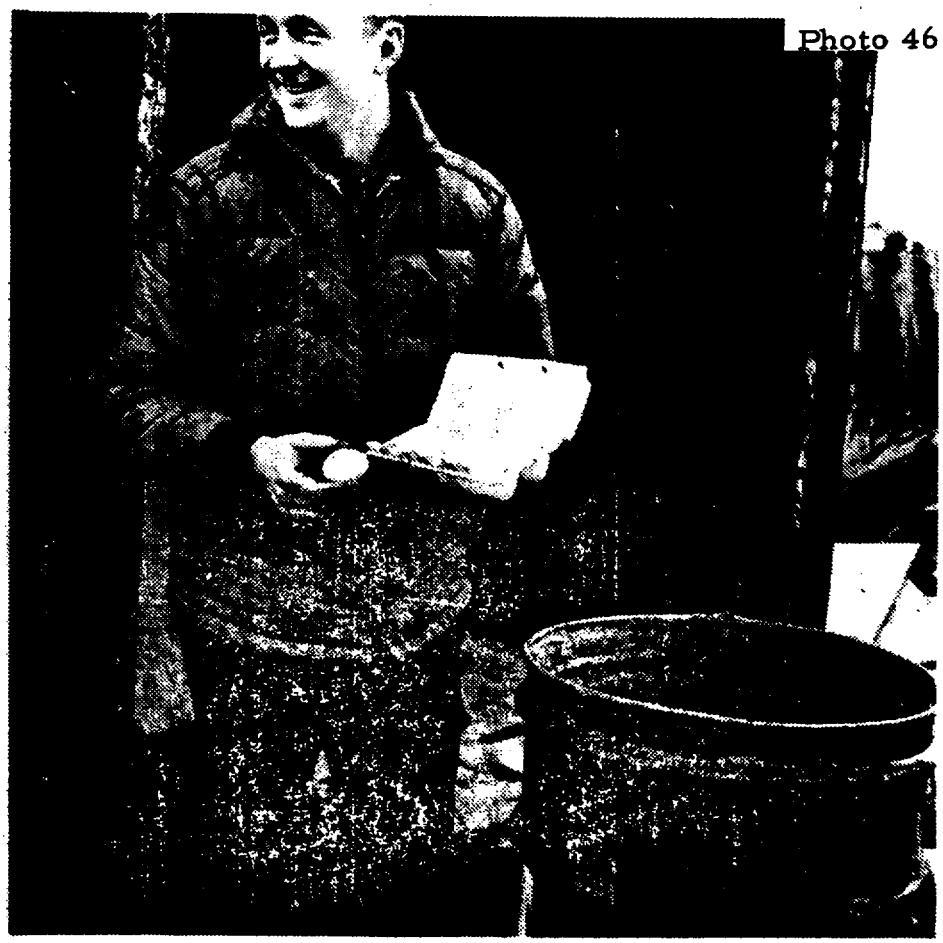


Photo 46

Photo 47

REFERENCES

PATENT PENDING

1. Code of Federal Regulations, Title 49, Part 171, Department of Transportation, Hazardous Material Regulation Board, Radioactive Materials and Other Miscellaneous Materials.

2. Code of Federal Regulations, Title 10, Part 71, Atomic Energy Commission, Packaging of Radioactive Material for Transport.

3. Thermal Analyzer Program (THAN), Mark K, Honeywell, Radiation Center, 1400 Soldiers Field Road, Boston 35, Mass., September 1964.

4. S. Timoshenko, "Theory of Plates and Shells", McGraw Hill Book Company, 1940.

5. Specification of Corner Fitting for Series 1 Freight Container, International Organization for Standardization #1019.

6. Engineering Evaluation of ANL Type B Waste Shipping Container Designed per 49 CFR 170-173. C2333-TR-2, March 4, 1970 For Nuclear Engineering Company by MRI.

APPENDIX A

PATENT PENDING

Free Drop Impact Analysis Program

Introduction

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

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

Equation of Motion

The second order differential equation is:

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

Initial conditions are:

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

Where:

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

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

x_o = initial displacement

M_x = the displacement varying mass

= initial total mass - mass of crushed media at rest

= $M_o - m_x$

M_o = W/g

W = Weight (lbs)

g = 386.4 in/sec^2, gravitational constant

F_x = the displacement varying crush force

= $\sigma_{cr} \cdot A_x$

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

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

m_x = mass of crushed material

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

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

Vol_x = Volume of crushed media (in^3)

h = drop height of package (in)

Evaluation of Equation Coefficients

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

1. Flat drop

$$A_x = \ell \cdot w$$

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

Where: ℓ = length

w = width

x = crush depth

2. Edge Drop

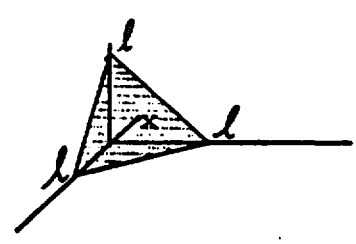
$$A_x = 2x\ell$$

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

3. Corner Drop

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

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



Note: x = crush depth

= $\perp$ distance from corner to plane passing through coordinate axis at

APPENDIX B

PATENT PENDING

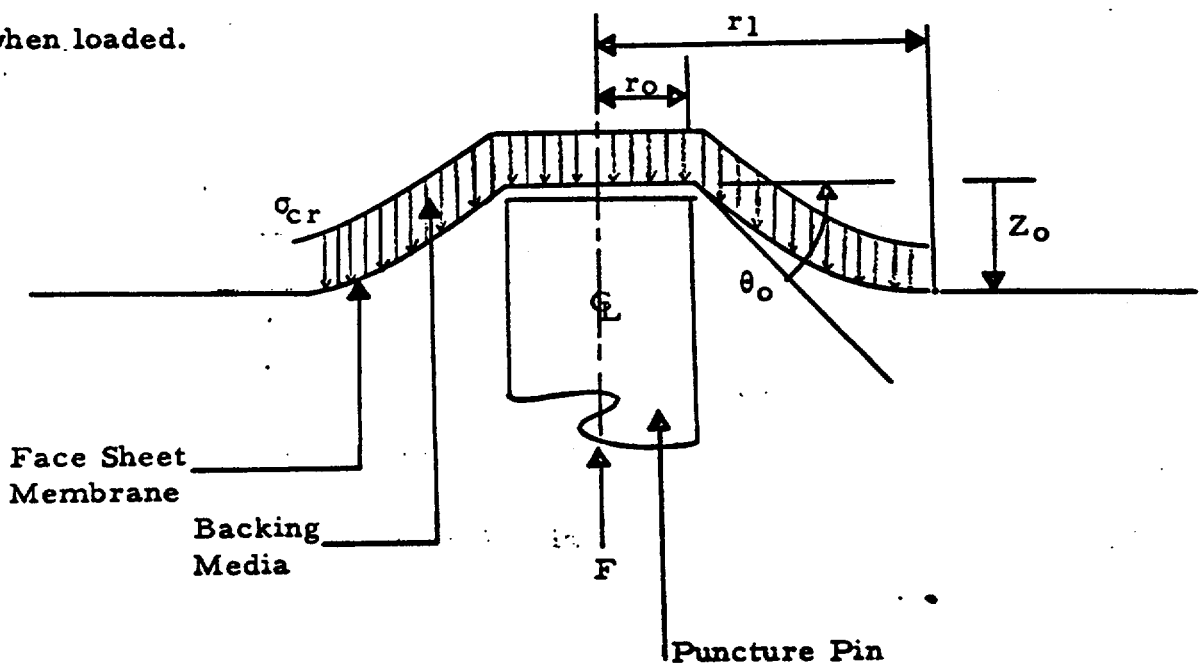
Introduction

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

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

Membrane Failure Criterion and Basic Total Energy Relations

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

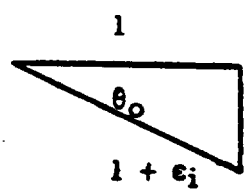


Where:

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

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

The strain due to general inclination, θ_o is:

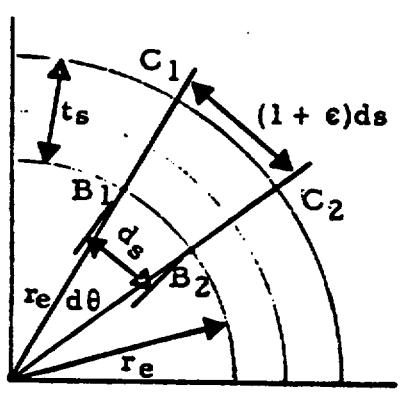


$$\cos\theta_o = \frac{1}{1+\epsilon_i}$$

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

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

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



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

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

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

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

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

$$\frac{\text{Allowable Elongation \%}}{100} \leq \frac{\int_{o}^{\theta_o + 3t_s} (\epsilon_i + \epsilon_r)\, d\ell}{\int_{o}^{\theta_o + 3t_s} d\ell} \qquad (1C)$$

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

The total force applied by the pin is

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

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

The total energy absorbed by the crushing media is:

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

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

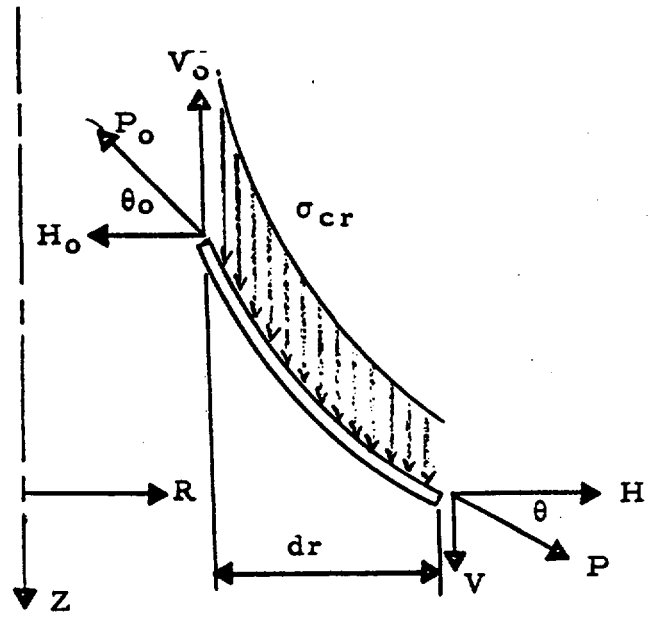
The radius of the deformed area of the backing media is obtained from basic equilibruim principles as follows:

$$F_Z = \pi r_1^2 \sigma_{cr}$$

$$r_1 = \sqrt{\frac{F_Z}{\pi \sigma_{cr}}} \qquad (4)$$

Membrane Equilibrium Equations

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



Equilibrium in the horizontal and vertical directions gives:

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

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

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

$P = H/\cos\theta$

Then (6) becomes:

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

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

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

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

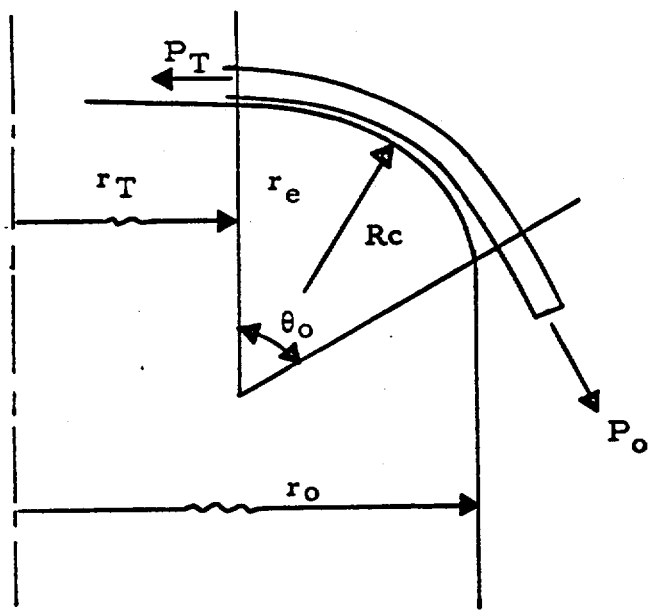
Now, from membrane ultimate strength characteristics we may derive a relation for H in terms of applied force F_Z.

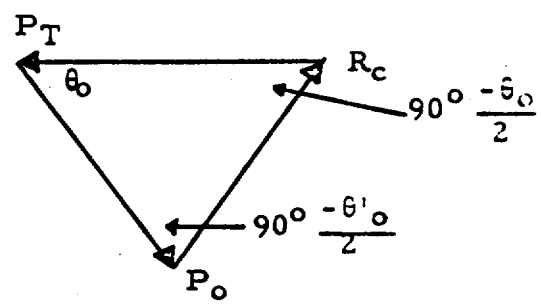
$$H = P_o \cos \theta_o \tag{9A}$$

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

$$P = 2\pi r t \sigma_{su} \tag{9B}$$

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





$$P_T = P_o$$

$$r_T = r_o - r_e \tag{9C}$$

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

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

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

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

And from (2):

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

$$\cos\theta_o = [1 - \sin^2\theta_o]^{1/2} \tag{9G}$$

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

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

$$Z = \frac{-\omega r^3}{6} + c_1 r + c_2 \tag{11}$$

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

$$\underline{r = r_o}: \quad Z = 0 \tag{12A}$$

$$\frac{dZ}{dr} = \tan\theta_o \tag{12B}$$

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

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

$$c_1 = \tan\theta_o + \frac{\omega r_o^2}{2} \tag{13}$$

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

$$c_1 = \frac{+\omega r_1^2}{2} \tag{14}$$

Equating (13) and (14) requires that:

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

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

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

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

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

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

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

Where ω is given by Equation (9E).

Computer Program, PUNCH

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

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

Basically the program performs the following steps:

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

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

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

Comparison and Conclusion

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

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

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

PATENT PENDING

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

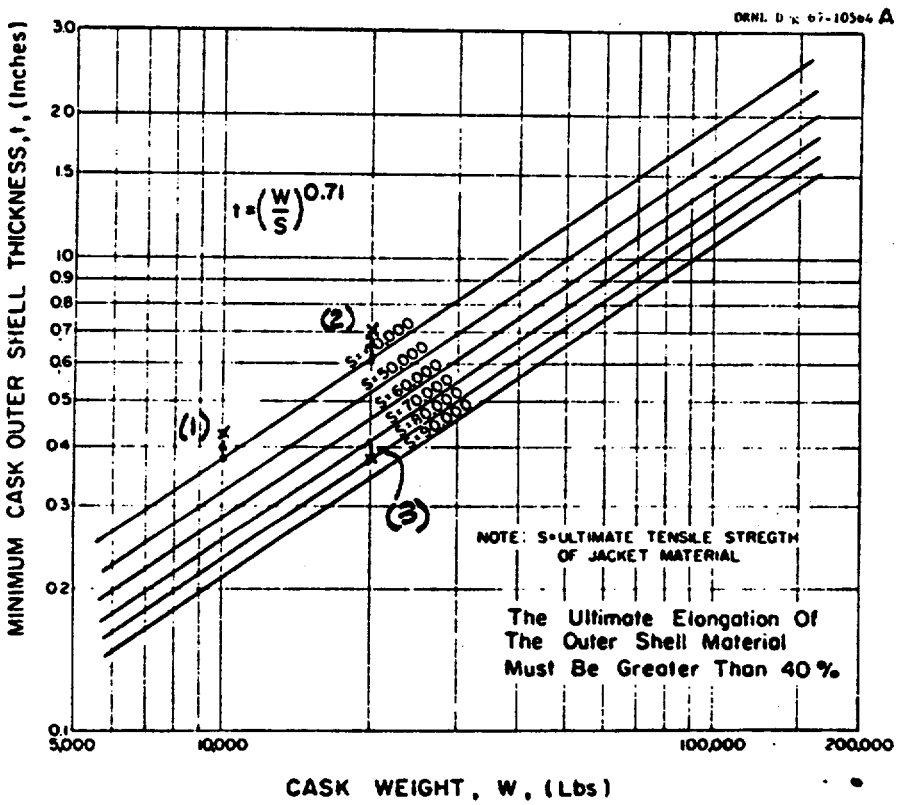


Fig. 2.2. Graph to Estimate Minimum Outer Shell Thickness. From ORNL TM-2410, January 1969

PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS (1) See Fig [illegible]

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 10000.

DROP HEIGHT (IN) = 40.

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

ULTIMATE STRESS OF MEMBRANE (PSI) = 40000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 40.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 2300.

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

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

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

PATENT PENDING

STATIC INFLASTIC MEMBRANE PUNCTURE ANALYSIS (2) See Fig 22 [illegible]

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 20000.

DROP HEIGHT (IN) = 40.

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

ULTIMATE STRESS OF MEMBRANE (PSI) = 40000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 40.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 2300.

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

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

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

PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS (8) SEE FIG 2.2 ORIGINAL TM-2010

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 20000.

DROP HEIGHT (IN) = 40.

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

ULTIMATE STRESS OF MEMBRANE (PSI) = 70000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 40.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 2300.

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

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

	********** VALUES AT MEMBRANE FAILURE **********						
SHEET THICK (IN)	CRUSH RADIUS (IN)	TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.3000	6.680	342062.	2.35	50265.	17.1	44.4	
0.3200	7.064	360530.	2.46	55407.	18.0	44.4	
0.3400	7.242	378999.	2.58	60735.	18.9	44.4	
0.3600	7.417	397468.	2.69	66247.	19.9	44.4	
0.3800	7.587	415937.	2.81	71937.	20.8	44.4	*DESIGN VALUE*

PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS, PARTIAL, DOT CP [illegible]

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 660.

DROP HEIGHT (IN) = 40.

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

ULTIMATE STRESS OF MEMBRANE (PSI) = 40000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 40.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 30.

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

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

	********** VALUES AT MEMBRANE FAILURE **********						
SHEET THICK (IN)	CRUSH RADIUS (IN)	TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.0050	6.082	3487.	1.83	410.	5.3	44.4	
0.0075	7.141	4806.	2.51	752.	7.3	44.4	
0.0100	8.062	6125.	3.12	1167.	9.3	44.4	
0.0125	8.887	7444.	3.67	1646.	11.3	44.4	
0.0150	9.643	8763.	4.17	2184.	13.3	44.4	
0.0175	10.343	10083.	4.64	2778.	15.3	44.4	*DESIGN VALUE*

0.0350 ACTUAL - NO PUNCTURE

PATENT PENDING

STATIC INELASTIC MEMBRANE PUNCTURE ANALYSIS , Supplemental

*** BASIC ENGINEERING DATA

PACKAGE WEIGHT (LB) = 45000.

DROP HEIGHT (IN) = 40.

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

ULTIMATE STRESS OF MEMBRANE (PSI) = 55000.

ULTIMATE ELONGATION OF MEMBRANE (%) = 30.

RADIUS OF PUNCTURE PIN (IN) = 3.

EDGE RADIUS OF PUNCTURE PIN (IN) = .25

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 100.

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

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

	********** VALUES AT MEMBRANE FAILURE **********						
SHEET THICK (IN)	CRUSH RADIUS (IN)	TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.1500	18.036	102193.	8.44	48367.	2.3	39.7	
0.1750	19.442	118754.	9.27	61545.	2.6	39.7	
0.2000	20.754	135315.	10.05	75813.	3.0	39.7	
0.2250	21.987	151876.	10.78	91102.	3.4	39.7	
0.2500	23.155	168437.	11.48	107356.	3.7	39.7	
0.2750	24.267	184998.	12.14	124526.	4.1	39.7	
0.3000	25.329	201559.	12.78	142570.	4.5	39.7	
0.3250	26.350	218120.	13.38	161452.	4.8	39.7	
0.3500	27.332	234681.	13.97	181140.	5.2	39.7	
0.3750	28.279	251242.	14.54	201606.	5.6	39.7	
0.4000	29.197	267802.	15.09	222822.	6.0	39.7	*DESIGN VALUES

PATENT PENDING

*** TRIAL CASE DATA

CRUSH STRENGTH OF BACKING MEDIA (PSI) = 200. Surfcrtiger

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

NUMBER OF MEMBRANE SHEETS = 1

*** PUNCTURE DESIGN TRIAL CASES

SHEET THICK (IN)	********** VALUES AT MEMBRANE FAILURE ********** CRUSH RADIUS (IN)	TOTAL FORCE (LB)	CRUSH DEPTH (IN)	TOTAL ENERGY (FT-LB)	PEAK ACCEL (G)	SHEET ANGLE (DEG)	
0.3000	18.036	204386.	8.44	96733.	4.5	39.7	
0.3250	18.752	220947.	8.66	109630.	4.9	39.7	
0.3500	19.442	237508.	9.27	123091.	5.3	39.7	
0.3750	20.109	254069.	9.66	137095.	5.6	39.7	
0.4000	20.754	270630.	10.05	151627.	6.0	39.7	
0.4250	21.379	287191.	10.42	166668.	6.4	39.7	
0.4500	21.987	303752.	10.78	182205.	6.8	39.7	
0.4750	22.579	320313.	11.13	198224.	7.1	39.7	*DESIGN VALUE

APPENDIX C

THAN Thermal Analysis From Reference 6

3.3 Fire Test

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

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

Heat Source: $\epsilon = .9$

Outer Container Walls: $\epsilon = .8$

Inner Box Walls: $\epsilon = .8$

Payload: $\epsilon = .8$

Figure 2

PATENT PENDING

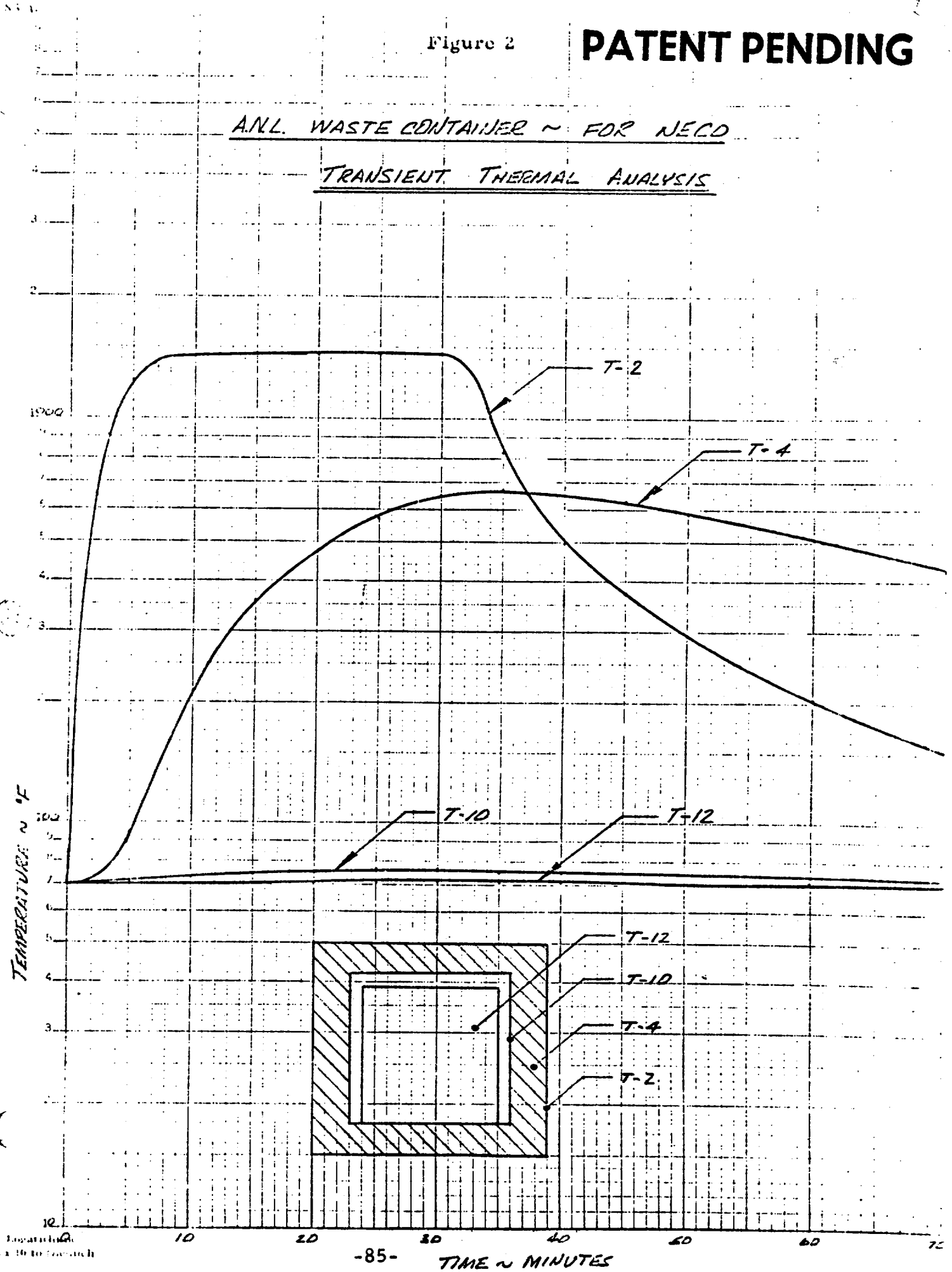
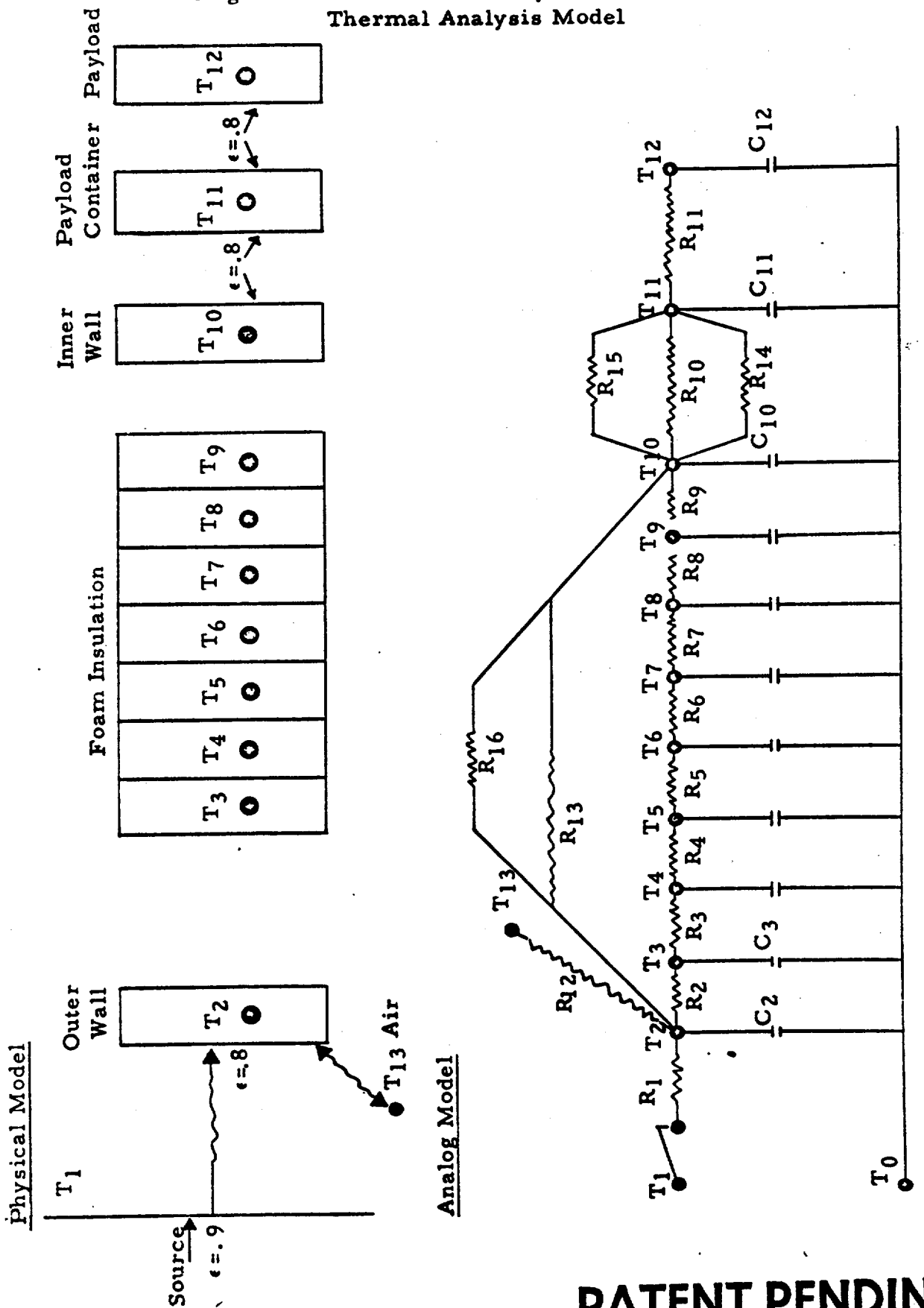


Figure 3

Argonne National Laboratory Waste Container
Thermal Analysis Model



PATENT PENDING

The model includes the following special features:

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

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

3.3.1 Nodal Capacitances

1. Outer Wall

Weight = 1872 + 300 = 2172 lb.

c = .11 for mild steel

c_2 = (2172)(.11) = 238.92 Btu/°R

2. Foam

Weight = 579 + 260 = 839 lbs

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

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

3. Inner Wall

Weight = 248.1 lb

$c = .11$

$c_{10} = (248.1)(.11) = 27.29$ Btu/°R

4. Payload Container

Weight = 700 lb

$c = .11$

$c_{11} = (700)(.11) = 77.$ Btu/°R

5. Payload

Weight = 2300 lb

$c = .33$ (assumed)

$c_{12} = (2300)(.33) = 759$ Btu/°R

3.3.2 Conduction Resistors

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

1. Outer Wall to Foam, R_2

R_2 = outer wall + 1/2" foam

$k_{ij} = 25$ Btu/hr-ft-°F (carbon steel)

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

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

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

$R_2 = 30.048 + .009014 = 30.057$ °R/Btu/sec

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

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

3. Foam to Inner Wall, R_9

PATENT PENDING

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

4. Foam Char Adjustment, R_2 to R_9

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

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

$\ell = 1/12$ ft.

$A = 249.6\ ft^2$

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

5. Payload Container to Payload, R_{11}

Assuming Payload is damp sand or similar material

$$\left.\begin{array}{l} k_{ij} = .6\ Btu/hr\text{-}ft\text{-}^{\circ}F \\ \ell_{ij} = 2'' \end{array}\right] \quad \text{assume}$$

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

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

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

$A_i = 150.78\ ft^2$

$A_j = 165.4\ ft^2$

$F_{ij} = 1$

$\epsilon_i \quad \epsilon_j = .8$

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

PATENT PENDING

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

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

2. Interface Conductive Coupling, R_{14}

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

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

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

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

$= 20.52\ ft^2$

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

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

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

3. Radiant Source to Outer Wall, R_1

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

PATENT PENDING

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

4. Lug Pocket Radiation Coupling, R_{16}

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

$\epsilon_i = \epsilon_j = .8$

$F_{ij} = 1$

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

5. Temperature Dependent Air Conduction Resistance

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

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

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

For Air: $k_{32} = 0.155$

$C = 225$

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

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

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

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

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

The above are coefficients for parallel resistors

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

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

b. Lifting Lug Pockets, R_{13}

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

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

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

There are two of these:

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

6. Combined External Air Convection and Radiation

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

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

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

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

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

$$= 6.01\ ^\circ F/Btu/sec$$

This resistor switches in @.5 hr.

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

3.4 Closing Device

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

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

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

PATENT PENDING

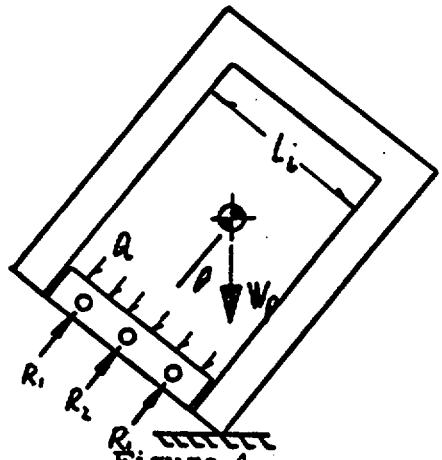


Figure 4

ARGONNE LABORATORY NUCLEAR WASTE CONTAINER, OWNERSHIP CONDITIONS PRIMARY.

PRINT CODES

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

THERMAL RESISTANCE DATA

RESISTOR	ATTACHING NODES		RESISTANCE DEG.R/BTU/SEC	
1	1	2	.10000+01	RESISTOR DATA ** OUTER RAD. COUPLING
2	2	3	.10000+01	FOAM CONDUCTION
3	3	4	.10000+01	FOAM CONDUCTION
4	4	5	.10000+01	FOAM CONDUCTION
5	5	6	.10000+01	FOAM CONDUCTION
6	6	7	.10000+01	FOAM CONDUCTION
7	7	8	.10000+01	FOAM CONDUCTION
8	8	9	.10000+01	FOAM CONDUCTION
9	9	10	.10000+01	FOAM CONDUCTION
10	10	11	.10000+01	PAYLOAD RAD. COUPLING
11	11	12	.60450+01	PAYLOAD CONDUCTION
12	2	13	.10000+01	EXTERNAL AIR CONV.
13	2	10	.10000+01	LUG POCKET AIR CONDUC
14	10	11	.10200+00	CONTACT RESISTANCE
15	10	11	.10000+01	PAYLOAD AIR CONDUCTIO
16	2	10	.10000+01	LUG POCKET RADIATION

INITIAL TEMPERATURE DATA

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

NODE CAPACITANCE DATA

NODE	CAPACITANCE BTU/DEG.R	
1	-.10000+01	NODE CAPACITANCE
2	.23892+03	
3	.23970+02	
4	.23970+02	
5	.23970+02	
6	.23970+02	
7	.23970+02	
8	.23970+02	
9	.23970+02	
10	.27230+02	
11	.77000+02	
12	.75000+01	

PATENT PENDING

PATENT PENDING

MODEL DATA SUMMARY

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

CONNECTING RESISTORS - 1 TOTAL

ID	NODE	RESISTANCE	ID	NODE	RESISTANCE	ID	NODE	RESISTANCE
1	2	.10000+01						

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

CONNECTING RESISTORS - 6 TOTAL

ID	NODE	RESISTANCE	ID	NODE	RESISTANCE	ID	NODE	RESISTANCE
1	1	.10000+01	2	3	.10000+01	12	13	.10000+01
13	10	.10000+01	16	10	.10000+01			

NODE NO. 3 NODE ID 3
CAPACITANCE = .2387000+02 BTU/DEG.R
INITIAL TEMPERATURE = .5296900+03 DEG.R

CONNECTING RESISTORS - 2 TOTAL

ID	NODE	RESISTANCE	ID	NODE	RESISTANCE	ID	NODE	RESISTANCE
2	2	.10000+01	3	4	.10000+01			

NODE NO. 4 NODE ID 4
CAPACITANCE = .2387000+02 BTU/DEG.R
INITIAL TEMPERATURE = .5296900+03 DEG.R

CONNECTING RESISTORS - 2 TOTAL

ID	NODE	RESISTANCE	ID	NODE	RESISTANCE	ID	NODE	RESISTANCE
3	3	.10000+01	4	5	.10000+01			

NODE NO. 5 NODE ID 5
CAPACITANCE = [illegible] BTU/DEG.R
INITIAL TEMPERATURE = .5296900+03 DEG.R

CONNECTING RESISTORS - 2 TOTAL

ID	NODE	RESISTANCE	ID	NODE	RESISTANCE	ID	NODE	RESISTANCE
4	[illegible]	.10000+01	[illegible]	[illegible]	[illegible]			

PATENT PENDING

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

                CONNECTING RESISTORS -     2  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    5     5  .1000D+01    6     7  .1000D+01

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

                CONNECTING RESISTORS -     2  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    6     6  .1000D+01    7     8  .1000D+01

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

                CONNECTING RESISTORS -     2  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    7     7  .1000D+01    8     9  .1000D+01

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

                CONNECTING RESISTORS -     2  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    8     8  .1000D+01    9    10  .1000D+01

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

                CONNECTING RESISTORS -     6  TOTAL

   ID  NODE RESISTANCE    ID  NODE RESISTANCE    ID  NODE RESISTANCE

    9     9  .1000D+01   10    11  .1000D+01   13     2  .1000D+01
   14    11  .1020D+00   15    11  .1000D+01   16     2  .1000D+01

NODE NO.   11      NODE ID    11
```

CONNECTING RESISTORS - 4 TOTAL

ID	NODE	RESISTANCE	ID	NODE	RESISTANCE	ID	NODE	RESISTANCE
10	10	.10000+01	11	12	.60450+01	14	10	.10000+00
15	10	.10000+01						

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

CONNECTING RESISTORS - 1 TOTAL

ID	NODE	RESISTANCE	ID	NODE	RESISTANCE	ID	NODE	RESISTANCE
11	11	.60450+01						

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

CONNECTING RESISTORS - 1 TOTAL

ID	NODE	RESISTANCE	ID	NODE	RESISTANCE	ID	NODE	RESISTANCE
12	2	.10000+01						

PATENT PENDING

PATENT PENDING

SPECIAL FUNCTION SPECIFICATIONS

RADIATION RESISTOR DATA - FUNCTION 2

RESISTOR	RESISTANCE DEG.F/BTU/SEC	
1	.97317-10	RADIATION RESISTOR # VALUE.
10	.48600-10	
16	.8916F-13	

TABULAR FUNCTION DATA - FUNCTION 7

DEP.ID.	INDEP. ID	TABLE ID	FACTOR	
1	0	1	.10000+01	TABLE 1** SOURCE TEMP. [illegible]
11	2	2	.2980[illegible]+01	TABLE 2** AIR DIFFUSIONAL [illegible]
15	17	2	.57312-03	[illegible]
12	0	3	.1[illegible]00+01	TABLE 3** [illegible]
2	2	4	.5[illegible]00-02	TABLE 4 ** FLOW CHA[illegible]
3	2	4	.1[illegible]00+01	TABLE 4 ** FLOW CHA[illegible]
4	2	4	.1[illegible]00+01	TABLE 4 ** FLOW CHA[illegible]
5	2	4	.1[illegible]00+01	TABLE 4 ** FLOW CHA[illegible]
6	2	4	.1[illegible]00+01	TABLE 4 ** FLOW CHA[illegible]
7	2	4	.1[illegible]00+01	TABLE 4 ** FLOW CHA[illegible]
8	2	4	.1[illegible]00+01	TABLE 4 ** FLOW CHA[illegible]
9	2	4	.5[illegible]00-02	TABLE 4 ** FLOW CHA[illegible]

PRINT SPECIFICATION - FUNCTION 8

CLASS	VARIABLE NO.	PLOTTING FACTOR	
2	1	-.5	OUTPUT SPECIFICATION

ALL TEMPERATURES TO BE PRINTED OUT

PROBLEM CONSTANTS

1 OUTPUT TIME INTERVAL : .[illegible]+02

2 TIME INCREMENT BASED ON MINIMUM OF PRODUCT

3 POINTER MULTIPLIER : .[illegible]-[illegible]

4 PROBLEM CUT OFF TIME : .1[illegible]+[illegible]

5 INTEGRATION METHOD

6 INITIAL TIME : .[illegible]

OUTPUT VARIABLES BY CLASS

TR[illegible]IENT PROBLEM

PATENT PENDING

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

NO. OF INCREMENTS = -0

CLASS 2 - TEMPERATURE, T

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

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

NO[illegible]F INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	371.1051500	3	81.8531650	4	70.155922
5	70.0013610	6	70.0000000	7	70.0000000	8	70.000000
9	70.0001140	10	70.0094140	11	70.0068820	12	70.000000
13	70.0000000						

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

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	1446.6909000	3	757.6222200	4	214.99070
5	92.2961720	6	72.6970590	7	70.2801740	8	70.13786
9	70.8472440	10	72.7132260	11	72.6228020	12	70.11219
13	70.0000000						

PATENT PENDING

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

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	1465.3011000	3	1063.5010000	4	477.7071900
5	199.8394600	6	103.4821540	7	77.4085540	8	72.4202919
9	73.1343760	10	75.3324050	11	75.2305900	12	70.5002870
13	70.0000000						

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

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	1467.8425000	3	1162.7200000	4	647.1059700
5	322.4916700	6	163.1246700	7	99.9451440	8	79.8441540
9	76.0808250	10	76.9080650	11	76.7961420	12	71.2681040
13	70.0000000						

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

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.3100050	2	498.9976100	3	819.9088000	4	665.5044300
5	391.1502100	6	211.2430900	7	124.0288890	8	89.7212830
9	78.3522950	10	74.7223050	11	74.6954490	12	71.8195870
13	70.0000000						

TIME = .4799966+04SEC.
MINIMUM RC PRODUCT = .2763683+01SEC. ----- FOR NODE 10

NO. OF INCREMENTS = 43

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.3100050	2	126.1048960	3	244.4630100	4	364.8884400
5	355.3303600	6	278.0673700	7	194.5890100	8	132.3696200
9	91.7849040	10	75.2621690	11	75.2114330	12	72.9199460
13	70.0000000						

ENCLOSURE

USAEC - Mr. Donald Nussbaumer
August 28, 1970

PATENT PENDING

1. Description of Cask Contents

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

(1) Radioactive Constituents - Identification and Maximum Radioactivity

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

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

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

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

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

(2) Identification and Maximum Quantities of Fissile Constituents

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

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

(3) Chemical and Physical Form

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

(4) Maximum Amount of Decay Heat

(a) For Solids:

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

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

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

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

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

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

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

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

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

PATENT PENDING

(b) For Liquids:

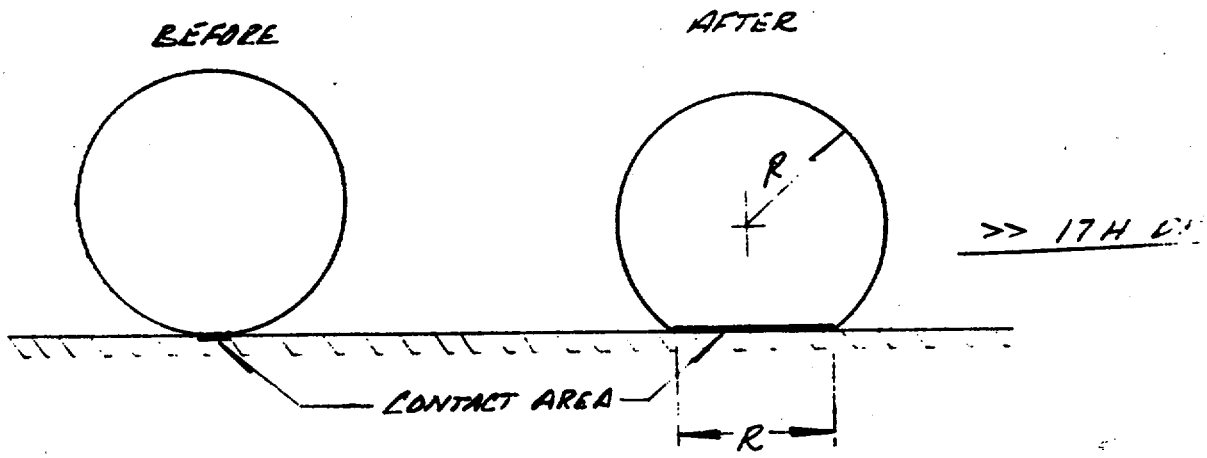
For liquids, the maximum internal temperature conditions shall be limited to 200 degrees, and possibly some unstable natural organic polymirs that may be found in nuclear waste. (Normal paper and rags made of natural fiber would not be in this category). Since the temperature difference is reduced to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

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

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

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

PATENT PENDING



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

We therefore propose the secondary container to be used in:

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

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

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

PATENT PENDING

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

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

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

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

PATENT PENDING

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

Cable Tie down

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

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

"A"

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

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

Allowable load in double shear/fitting.

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

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

"B"

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

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

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

(2 g's Vertical)

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

$$\text{Load} = (2 \text{ g's})(45,000 \text{ lbs.}) = 90,000 \text{ lbs.}$$

Since one fitting will react:

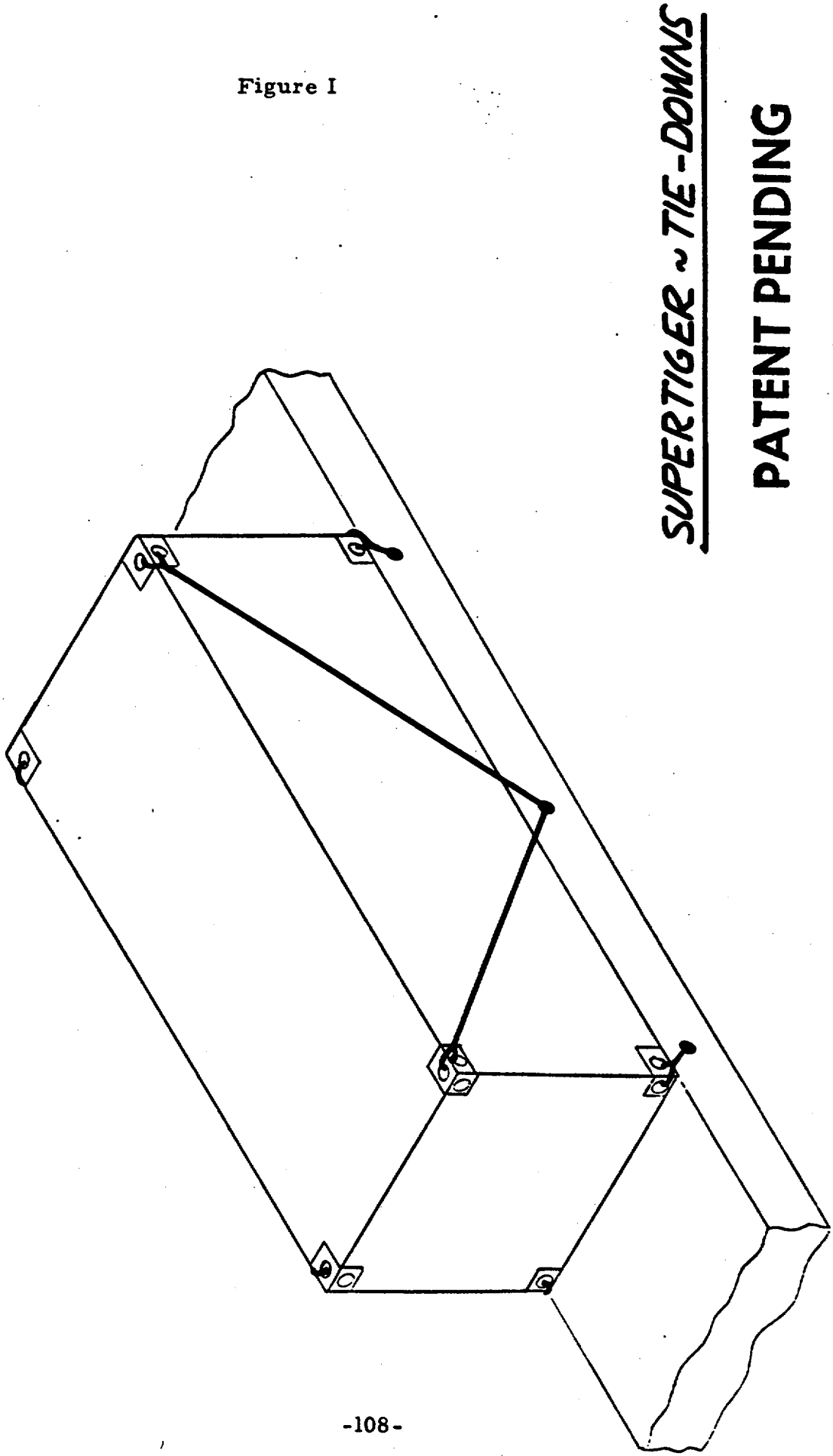
$$\cos 45^\circ (182,200) \text{ or } 128,800 \text{ lbs.}$$

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

M.S. = + Large

PATENT PENDING

Figure I



SPECIFICATION #1 - .30% MAXIMUM CARBON STEEL

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

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

3.0 HEAT TREATMENT

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

4.0 WELDING

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

5.0 APPROXIMATE EQUIVALENT SPECIFICATIONS

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

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

PATENT PENDING

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

(5 g's Lateral)

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

$$\text{Load} = (5\ g's)\ (45,000\ \text{lbs.}) = 225,000\ \text{lbs.}$$

$$\text{Capability} = 4\ (182,200)\ \cos 45^{\circ} = 515,200\ \text{lbs.}$$

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

$$\underline{\underline{\text{M.S.} = +1.29}}$$

(10 g's Fore and Aft)

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

$$\text{Load} = 10\ (45,000) = 450,000\ \text{lbs.}$$

$$\text{Capability} = \cos 45^{\circ}\ \left[2\ (182,200) + 2\ (215,000)\right.$$

$$= 561,600\ \text{lbs.}$$

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

$$\text{M.S.} = +.25$$

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

(Lifting Loads):

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

$$\therefore\ \text{Capability} = 4\ (182,200) = 728,800\ \text{lbs.}$$

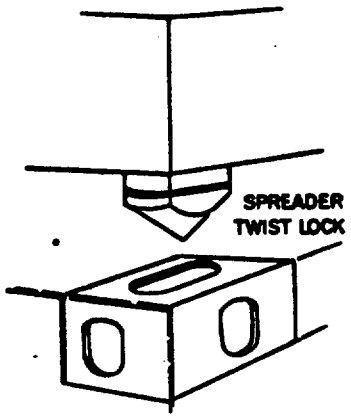
Conservatively, assume a 30° sling.

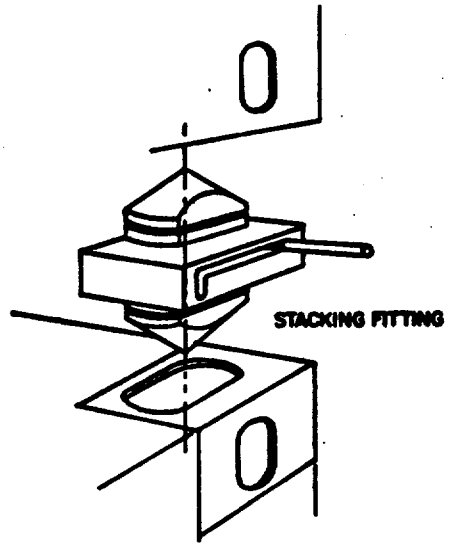
PATENT PENDIN

PATENT PENDING

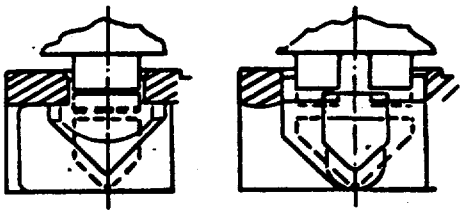
ANNEX A

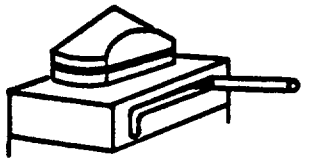
EXAMPLES OF CORNER FITTING ENGAGING, LIFTING, AND SECURING DEVICES



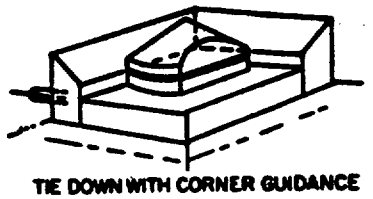


TWIST LOCK APPLICATION

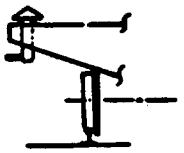




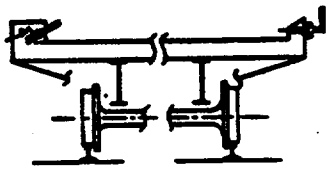
TIE DOWN FITTING



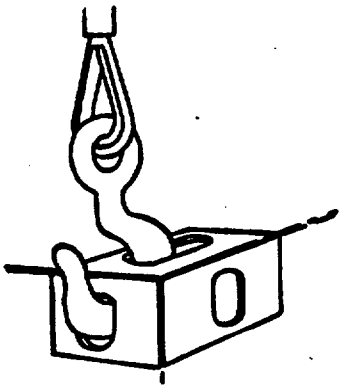
TIE DOWN WITH CORNER GUIDANCE



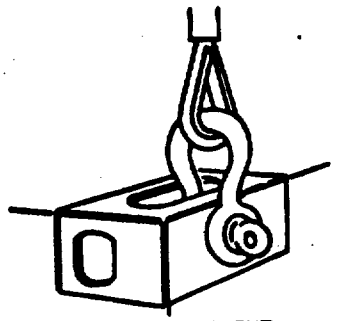
FLUSH TIE DOWN MOUNTING



BOLSTER-WITH THROW-BOLT LOCK
FROM FRONT OR SIDE



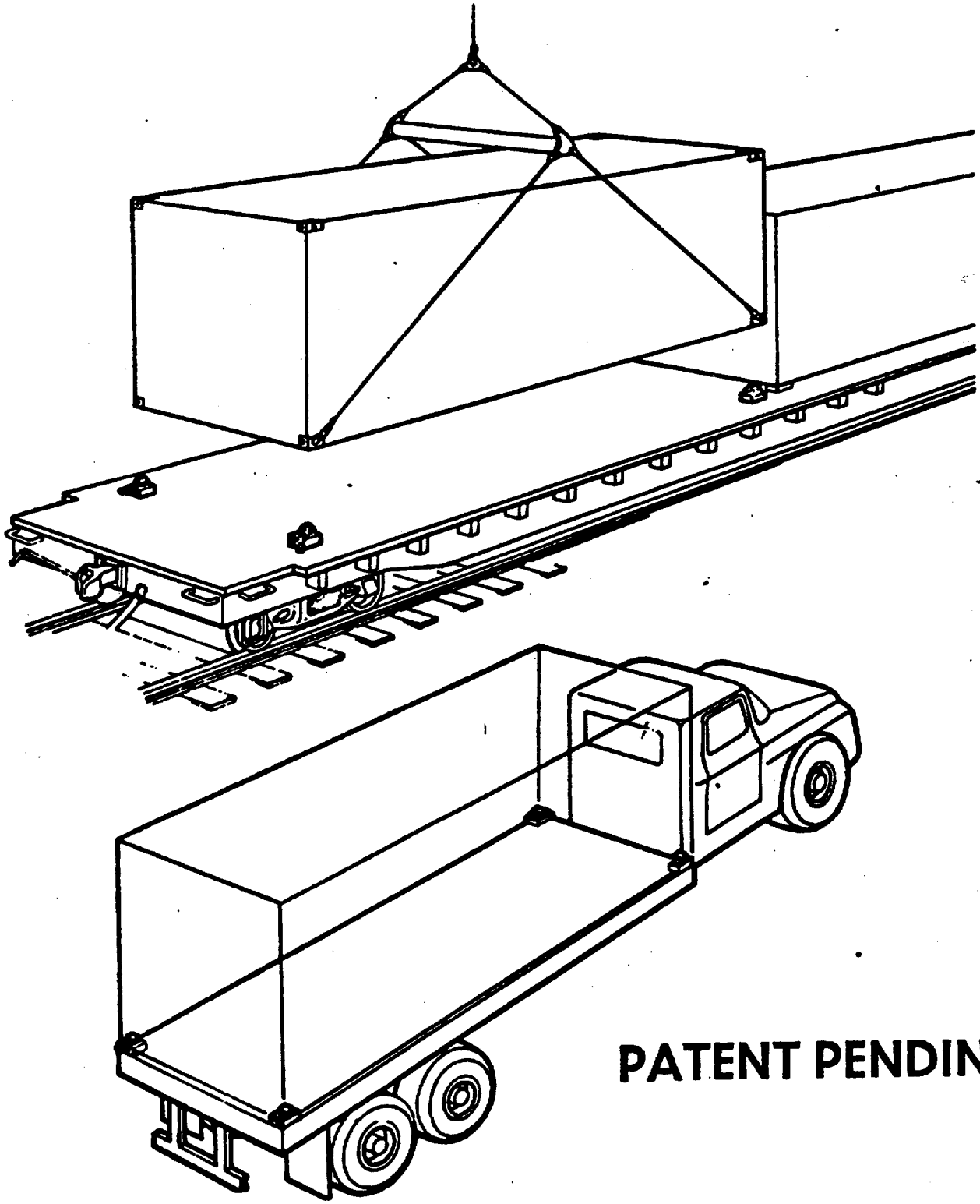
HOOK ENGAGEMENT



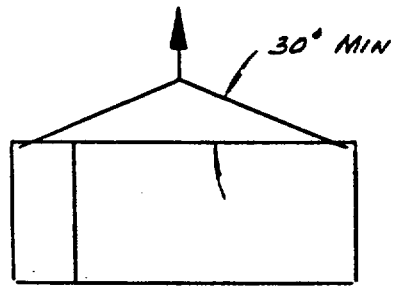
CLEVIS ENGAGEMENT

ANNEX B

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



PATENT PENDING



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

M. S. = +Large

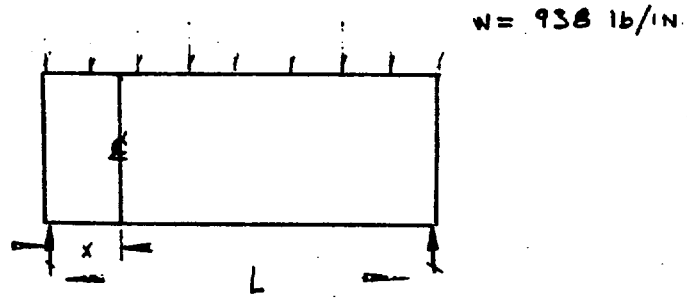
∴ Lifting capability meets requirements listed in Chapter 0529, Page 18,033 II, A, 3.

Standard ISO Tie Downs:

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

PATENT PENDING

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



A) Bending moment at bolt centerline:

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

$x = 35$

$L = 240$

$M_{\mathfrak{L}} = wx(L - x)/2$

$M_{\mathfrak{L}} = (938)(35)(240 - 35)/2$

$M_{\mathfrak{L}} = 3,365,000$ in.-lb.

Conservatively assume only the bottom two bolts react this load:

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

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

Allowable Bolt Load = 80,700 at 125 ksi

∴ Margin of Safety (Bolts)

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

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

PATENT PENDING

B) Max. Shell Bending Moment:

PATENT PENDING

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

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

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

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

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

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

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

$$f_c = M/2hA$$

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

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

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

Margin of Safety:

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

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

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

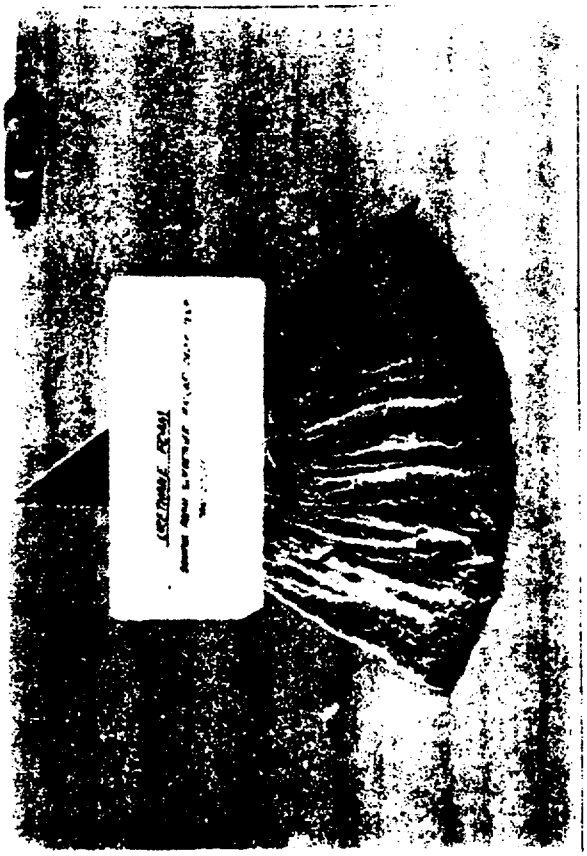
PATENT PENDING

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

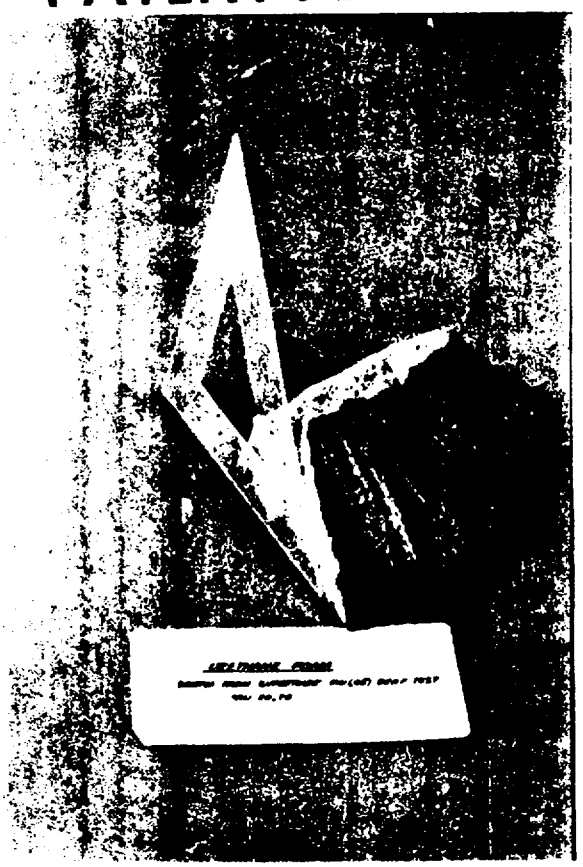
Chuck, as a point of interest to me, was the 25 psi requirement established to protect against submersion to a depth that will produce 25 psi? If so, it is interesting to note that it would require over 17 tons of additional weight to overcome the positive buoyancy of a fully loaded Super Tiger.

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

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



PATENT PENDING



PROTECTIVE PACKAGING, INC.

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

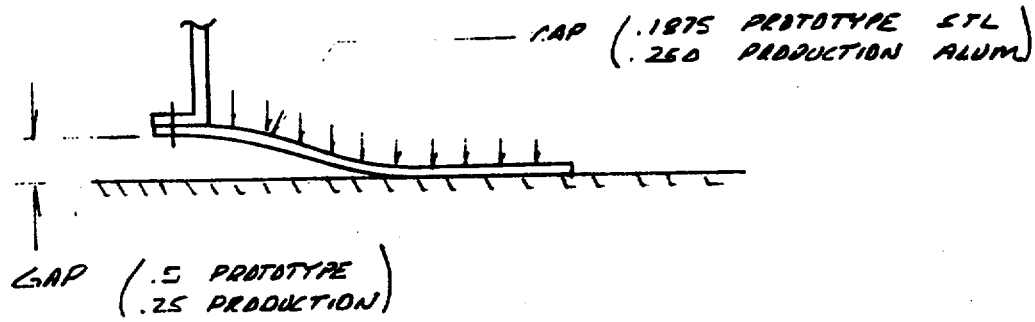
This can easily be reacted by the five container inner walls in the same manner that the 25 psi is reacted externally. Loads on the inner container cover must be treated differently.

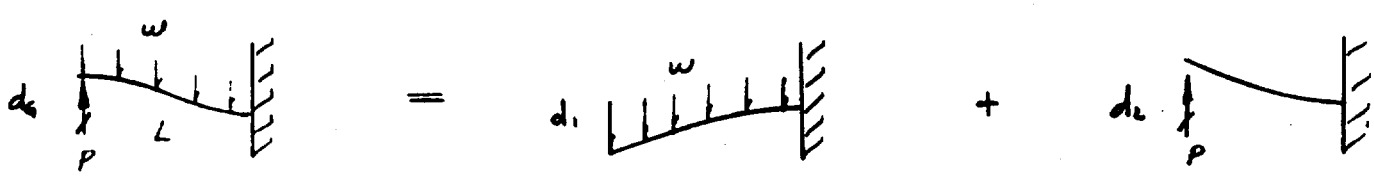
Pressure loads on the cover will cause it to deflect until it contacts the inside of the removable end cap. At this point, the pressure is reacted directly by the end cap.

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

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

Prototype:





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

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

$$d_G = \text{Gap}$$

Where:

$w = 7.1$ psi

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

$E = 3 \times 10^7$ psi

$G = .5$ in.

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

Solving for P as a function of L:

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

Differentiating and set to 0:

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

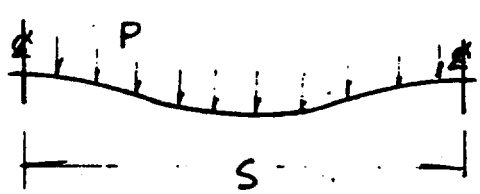
$$L = \sqrt[4]{\frac{72EI\, d_G}{3w}}$$

Solving for L:

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

Solving Eq. 1 for P:

P = 46 lb./in.



Seal deflection can be calculated by:

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

PATENT PENDING

Where:

$P = 46$ lb./in.

$S = 5$ in.

$E = 3 \times 10^7$ psi

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

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

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

Therefore, the seal area will be opened by approximately:

$d_s = .00227$ in.

Bolt load:

$P_b = (46 \text{ lb./in.})(5 \text{ in.}) = 230$ lbs.

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

Production:

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

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

Where:

$E = 10^7$ psi

$d_b = .5$ in.

$w = 7.1$ psi

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

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

PATENT PENDING

$$L = 19.7 \text{ in.}$$

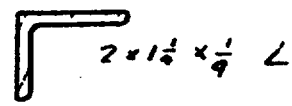
Solving for P:

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

$$P \doteq 55 \text{ lbs./in.}$$

Seal Deflection:

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



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

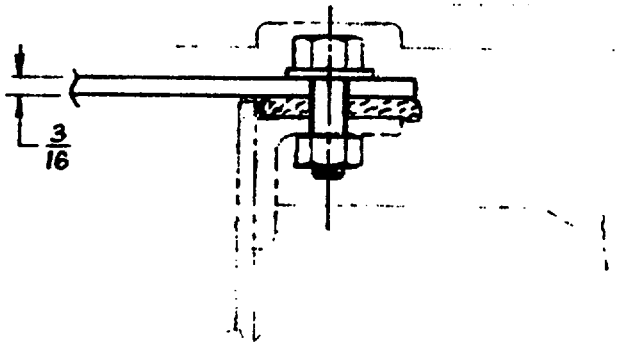
$$d_s = .00161 \text{ in.}$$

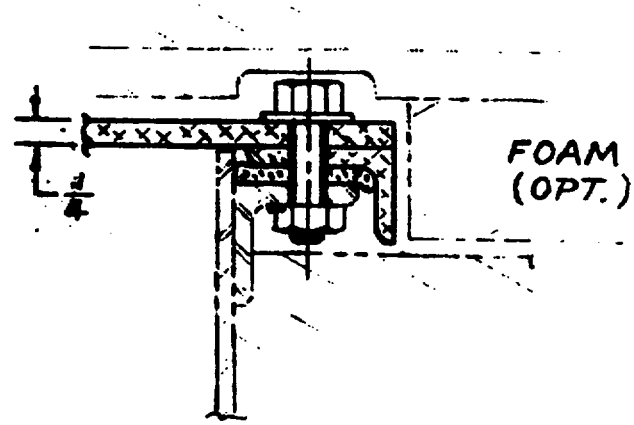
Bolt Load:

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

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

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





PATENT PENDING

B) External End Cap Attachment

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

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

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

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

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

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

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

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

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

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

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

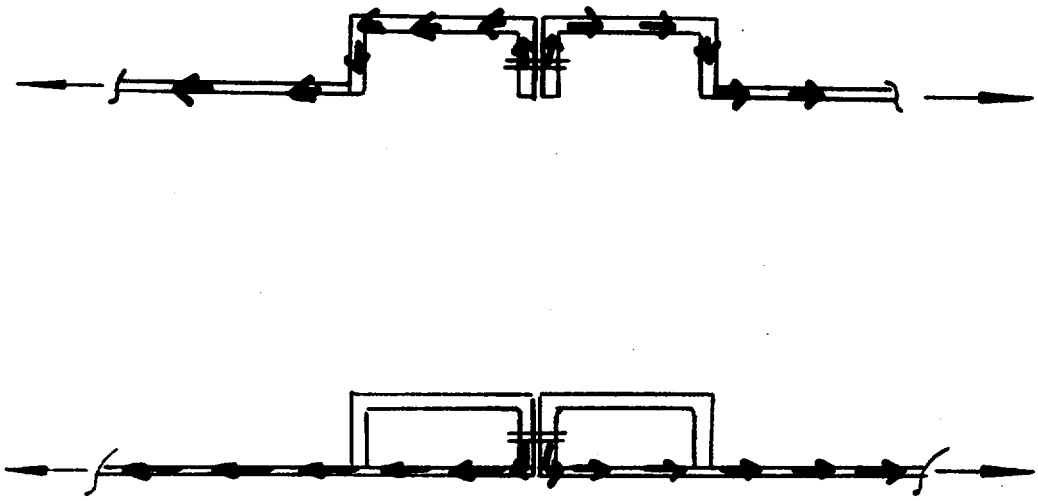
The production design differs from that which was tested in the manner in which the bolt load path was directed across the joint. As shown in the sketch below, the two channels forming the joint were bolted through the mating legs. Loads were required to pass from the skin to the outside leg, then in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

PATENT PENDING

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

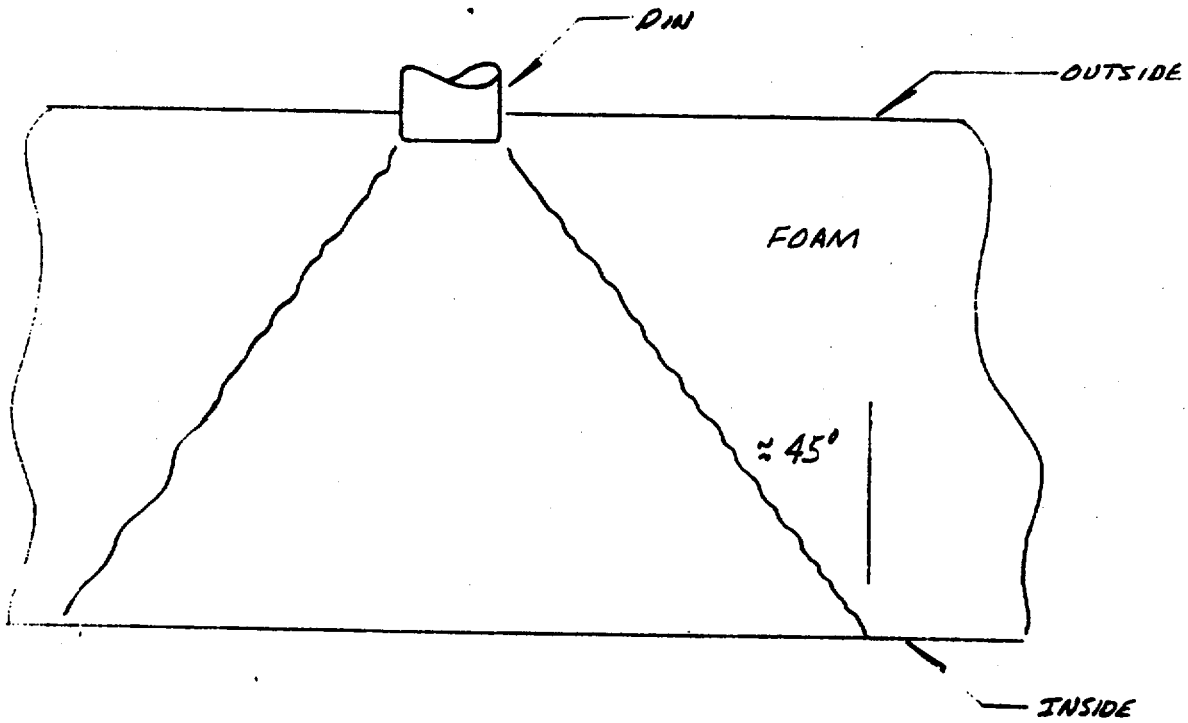
From the comparative EI values and the seal deflection calculations, it is concluded that the production design will provide higher compressive seal pressure than that of the prototype design test. It will provide a pressure tight seal.

PATENT PENDING



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

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



In actuality, it compresses a cone of foam.

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

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

$$KE = ws$$

∴ Solving for h:

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

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

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

Where:

$w = 45,000$ lbs.

$s = 40$ in.

$F_c = 200$ psi

PATENT PENDING

PATENT PENDING

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

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

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

PATENT PENDING

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

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

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

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

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

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

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

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

3. Bleed full contents of can into cavity.

4. Disconnect hose from fitting and install cap.

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

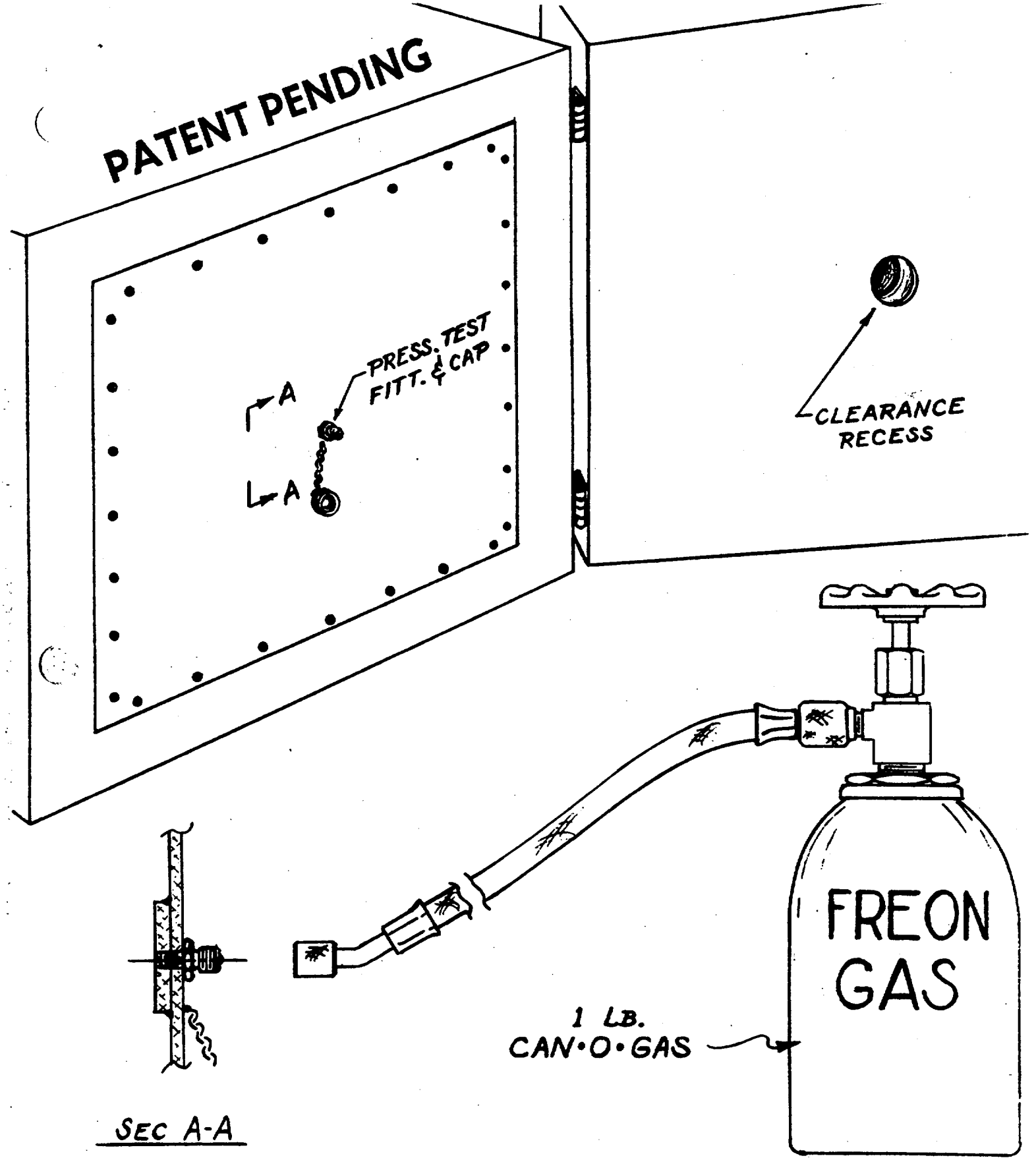
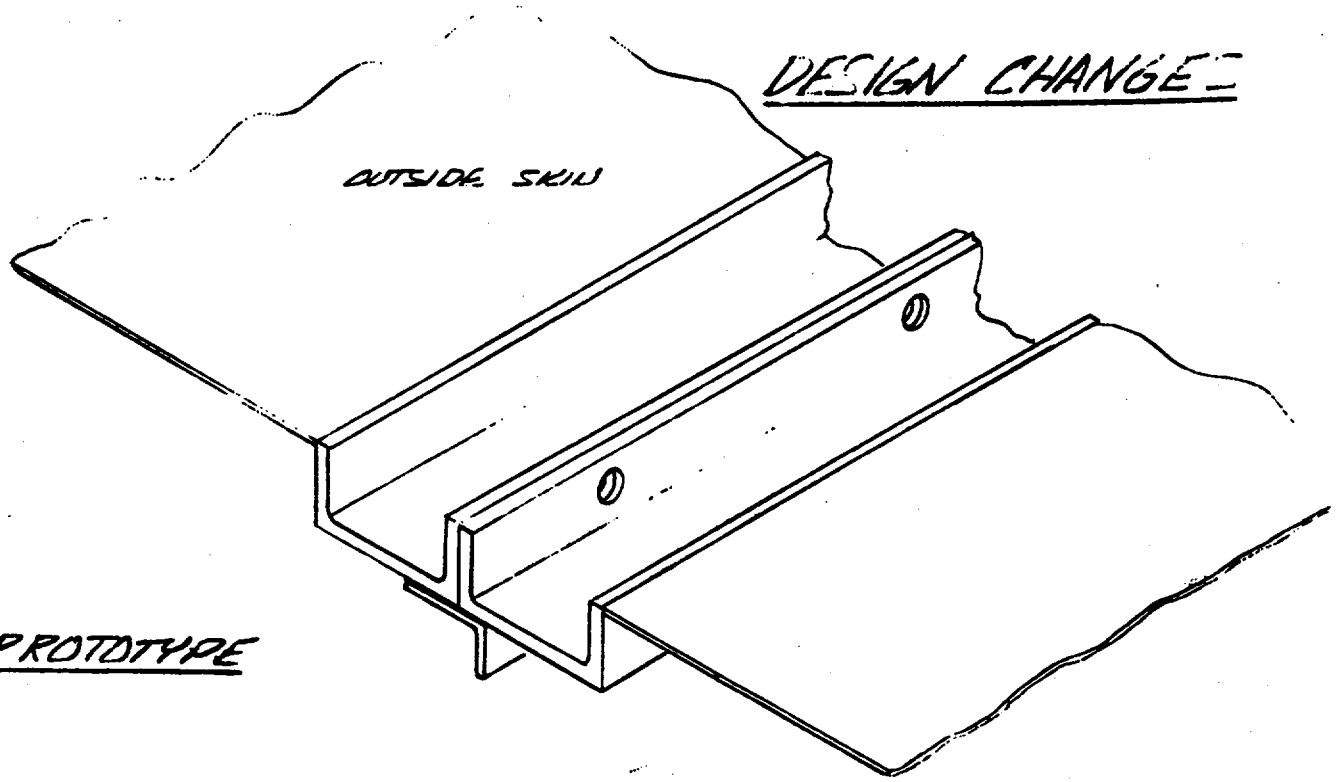

PATENT PENDING
PRESS. TEST FITT. & CAP
A
A
CLEARANCE RECESS
FREON GAS
1 LB. CAN•O•GAS
SEC A-A

FIGURE NO. 2

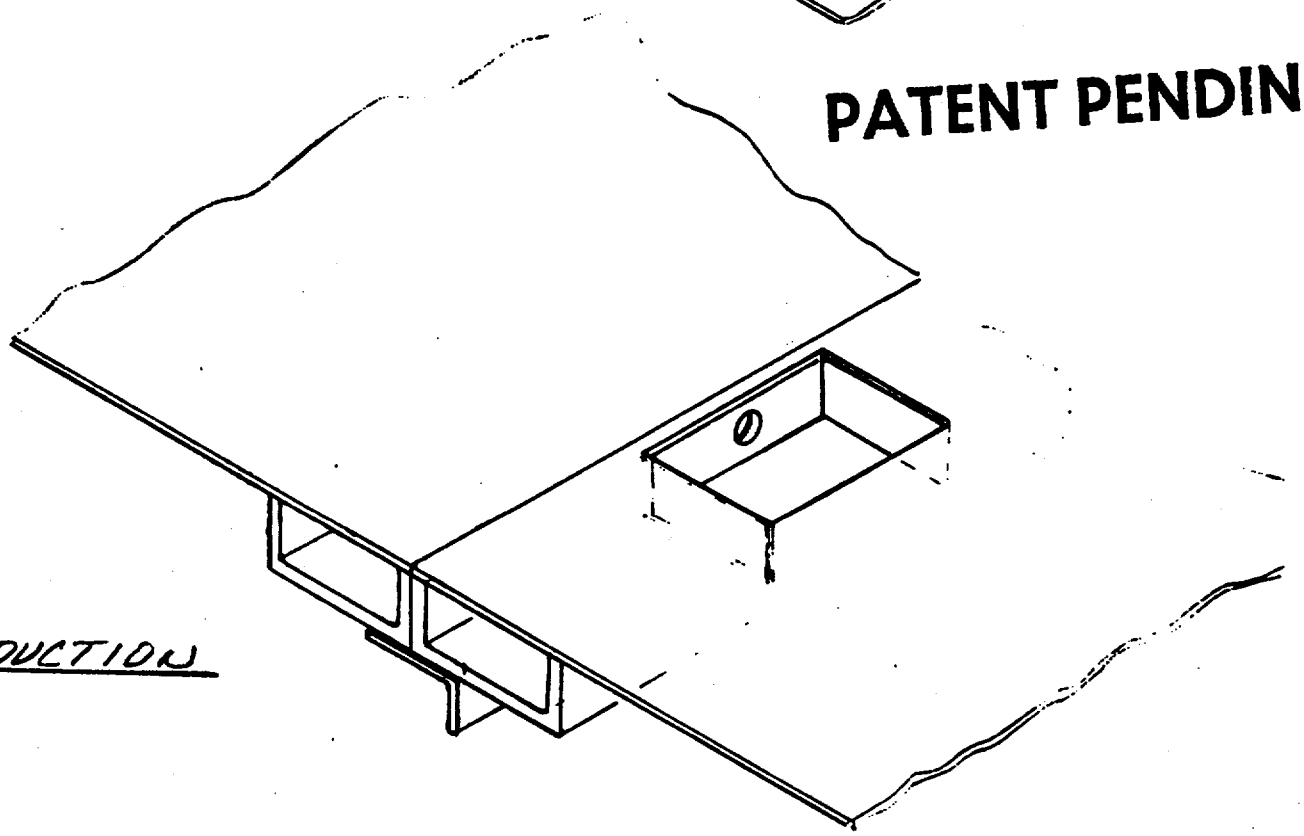
A.

DESIGN CHANGES



PROTOTYPE

PATENT PENDING



PRODUCTION

FIGURE 3

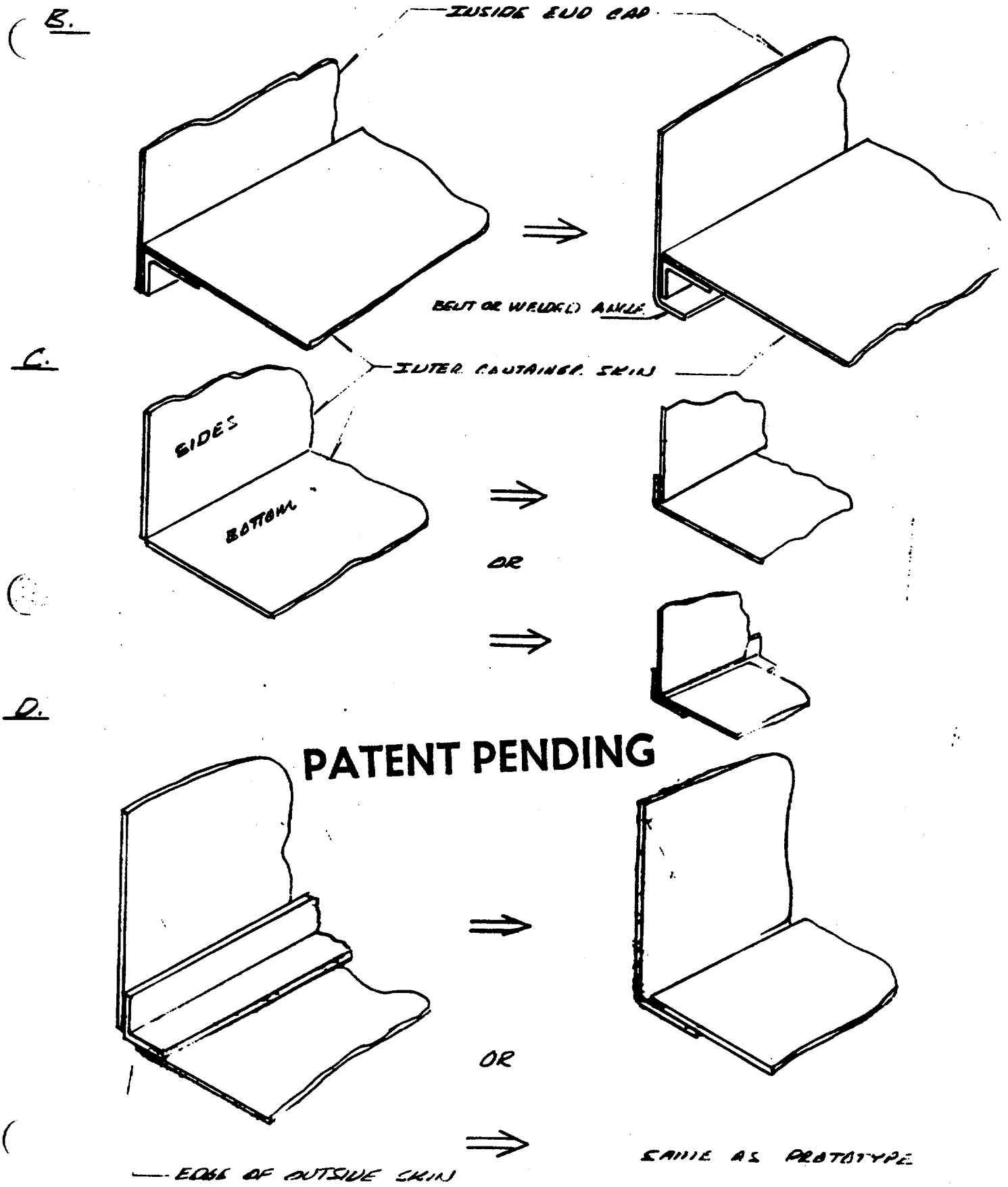

B.
INSIDE END CAP
BOLT OR WELDED ANGLE
C.
INTER. CONTAINER SKIN
SIDES
BOTTOM
OR
D.
PATENT PENDING
OR
EDGE OF OUTSIDE SKIN
SAME AS PROTOTYPE

 FIGURE 4

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

7. Repeat steps 2 through 5.

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

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

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

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

TORNADO DESIGN CONSIDERATIONS

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

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

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

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

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

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

PATENT PENDING

THERMAL STRESS CONSIDERATIONS

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

PATENT PENDING

QUALITY ASSURANCE PROGRAM FOR THE SUPER TIGER

1.0 FOAM PRODUCTION

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

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

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

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

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

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

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

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

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

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

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

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

1.1 FOAM QUALITY CONTROL DURING INSTALLATION

Refer to PPI Quality Control Document F17, attached.

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2.0 WELDING PROCEDURES

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

2.1 GENERAL WELDING REQUIREMENTS OF THE SUPER TIGER

Refer to PPI Quality Control Document W13 attached.

3.0 METAL QUALITY CONTROL

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

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

4.0 OVERALL CONSIDERATIONS

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

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

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

FOAMING REQUIREMENTS FOR SUPER TIGER CONTAINER

1.0 SCOPE

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

2.0 GENERAL DISCUSSION

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

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

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

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

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

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

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3.0 CONTROL CONDITIONS AND METHOD OF INSTALLATION

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

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

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

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

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

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

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

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

4.0 FOAM SPECIFICATION

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

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

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

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

PATENT PENDING

WELDING AND STEEL REQUIREMENTS FOR SUPER TIGER CONTAINER

1.0 SCOPE

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

2.0 GENERAL DISCUSSION

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

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

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

3.0 STEEL SPECIFICATION

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

The pertinent portion of specification is attached.

4.0 WELDING ROD AND WIRE SPECIFICATION

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

5.0 WELDING

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

6.0 FABRICATION

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

EXTERNAL PRESSURE

PATENT PENDING

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

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

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

1. Procedural inspection prior to end cap assembly.

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

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

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

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

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

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

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

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

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

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

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

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

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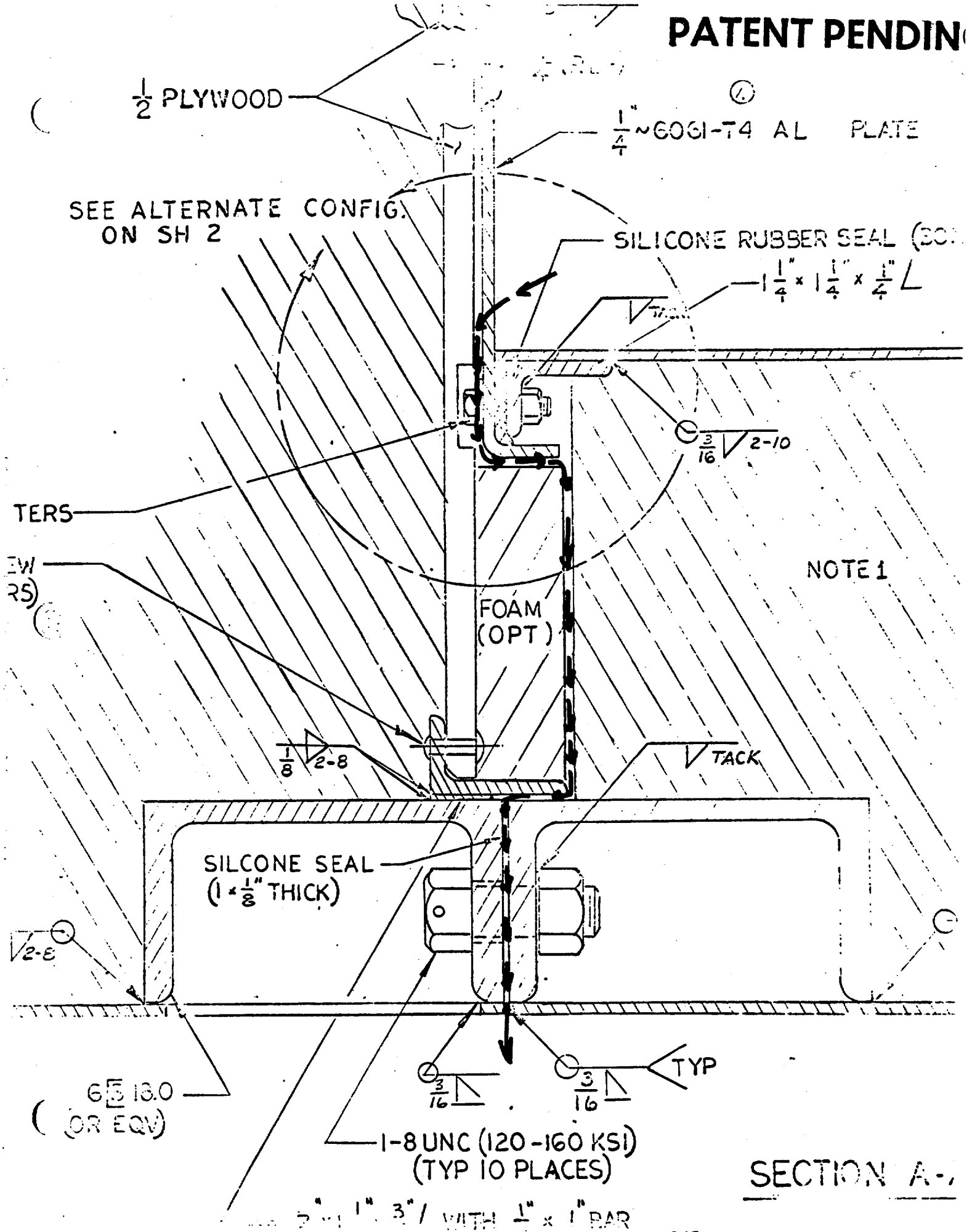

PATENT PENDIN
1/2 PLYWOOD
1/4" ~ 6061-T4 AL PLATE
SEE ALTERNATE CONFIG. ON SH 2
SILICONE RUBBER SEAL
1 1/4" x 1 1/4" x 1/4" L
3/16 2-10
TERS
NOTE 1
FOAM (OPT)
1/8 2-8
TACK
SILCONE SEAL (1 x 1/8" THICK)
2-E
6 13.0 (OR EQV)
3/16
3/16
TYP
1-8 UNC (120-160 KSI) (TYP 10 PLACES)
SECTION A-
WITH 1" x 1" BAR

SUPERTIGER CORNER COLUMN STABILITY

PATENT PENDING

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

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

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

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

$A = 7.686$ inch^2

$L = 205$ inches

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

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

The allowable compressive load based on yield strength is:

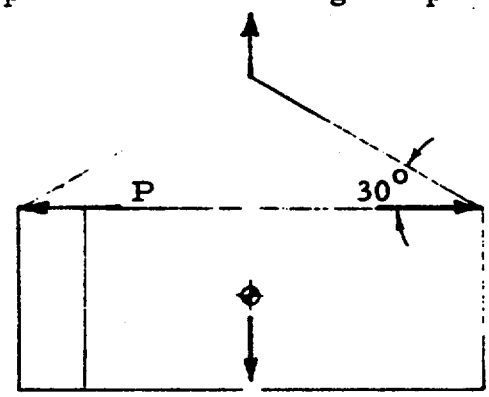
$$P_y = (46,000 \text{ psi})(7.686 \text{ inch}^2)$$

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

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

Compressive Loads:

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



(45,000) (3g's)

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

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

Margin of Safety:

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

M. S. = + Large

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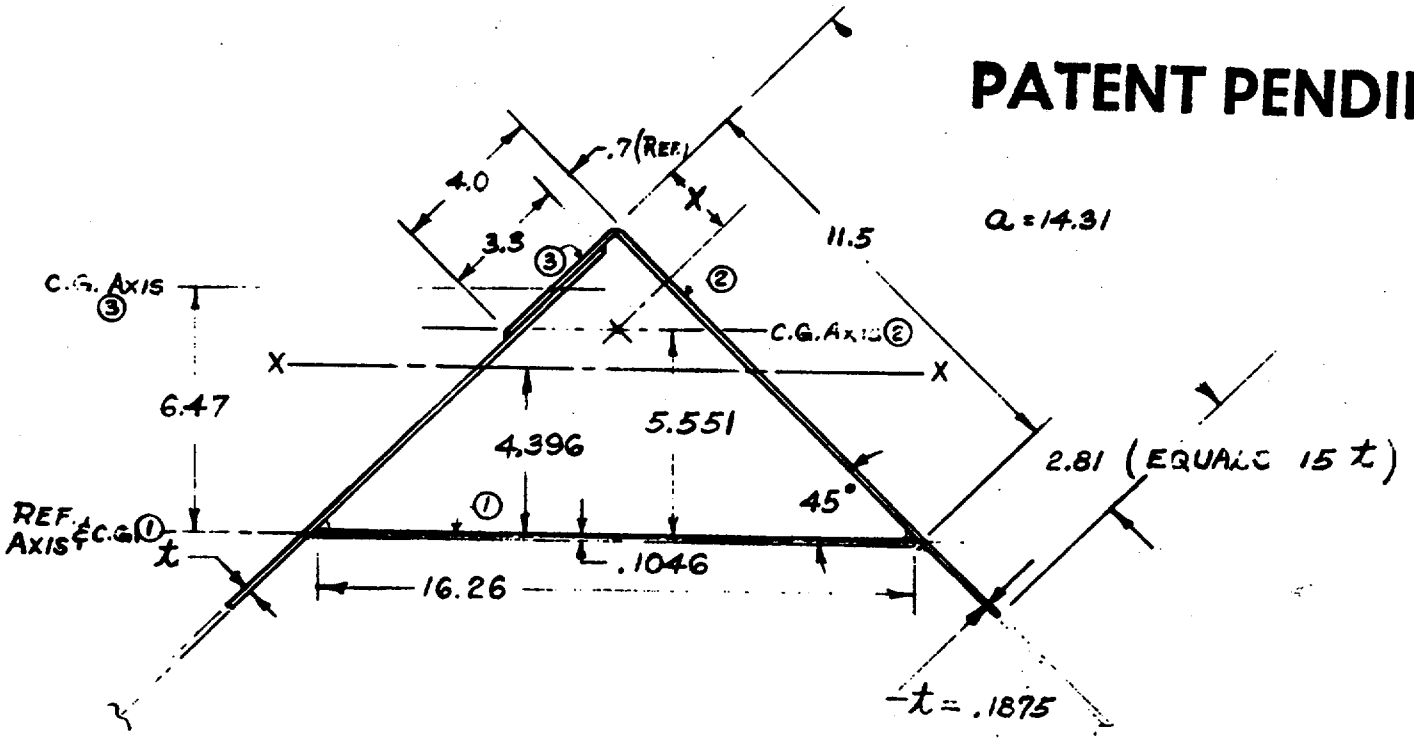
Conclusion:

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

PATENT PENDING



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

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

PART ①

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

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

PART ②

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

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

$$I_{C.G.} = \frac{bt^3+b^3t+3bt\,(a-4X+2t)^2+t^4+6t^2(2X-t)^2}{12}$$

} FORMULA FROM HUDSON'S ENG. MAN. A

$$= \frac{14.123(.1875)^3+(14.123)^3.1875+3(14.123).1875\left[14.31-4(3.649)+2(.1875)\right]+(.1875)^4+6(.1875)^2\left[2(3.649)-.1875\right]}{12}$$

$$= 45.072 \text{ IN.}^4$$

PART ③

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

$$I_{C.G.} = \frac{b\,h(t^2\sin^2\alpha + h^2\cos^2\alpha)}{12}$$ } FOR [illegible]

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

$$= .2922 \text{ IN.}^4$$

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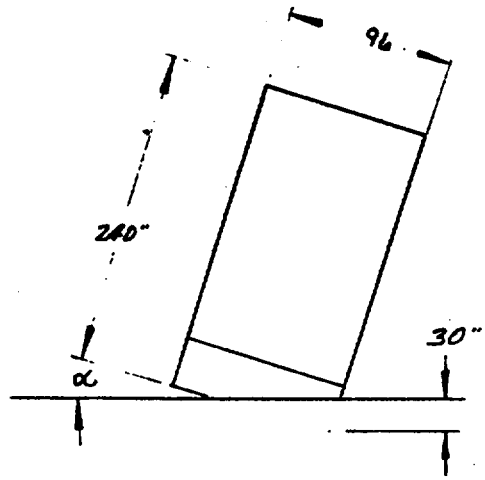
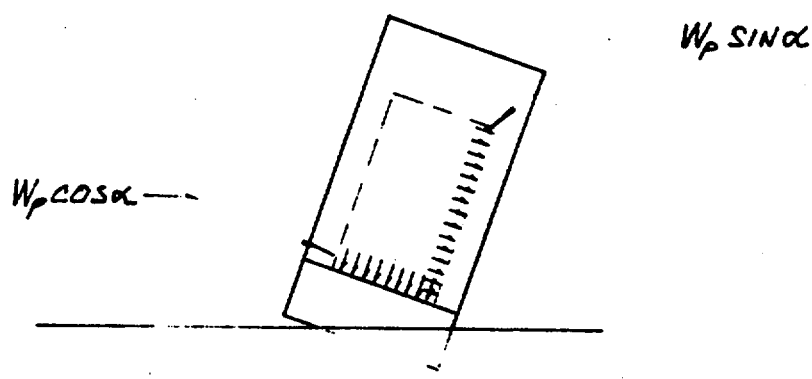
Maximum bolt loads will be generated during an edge drop onto the container end. From page 16 of the report the maximum expected crush depth of 30 inches will produce an acceleration of 24.9 g's.



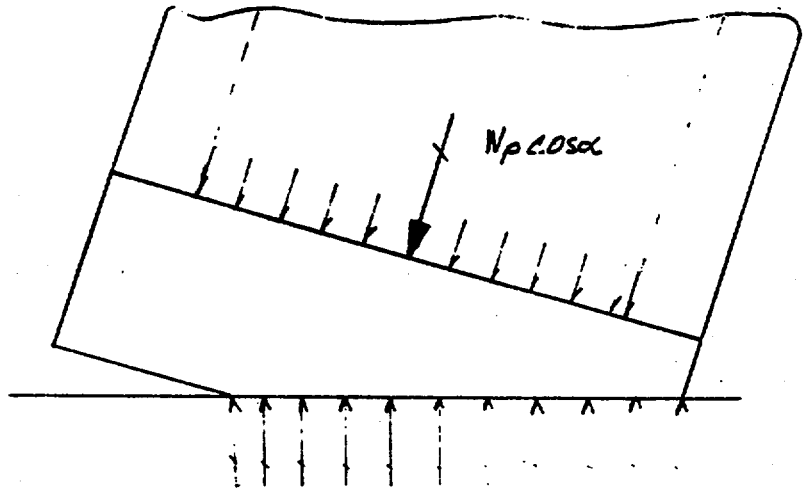
$$\tan \alpha = 96/240 = .40$$

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

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



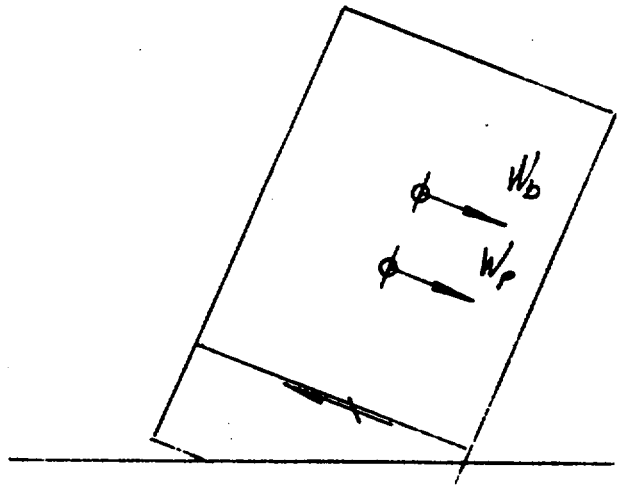
Since the non linear acceleration assures the maximum load is experienced at the end of the compression stroke all the payload component load will be reacted in direct compression through the cap. This can be seen graphically from the sketch below that shows the center of pressure of the payload to fall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



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

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

A. Shear Loads:



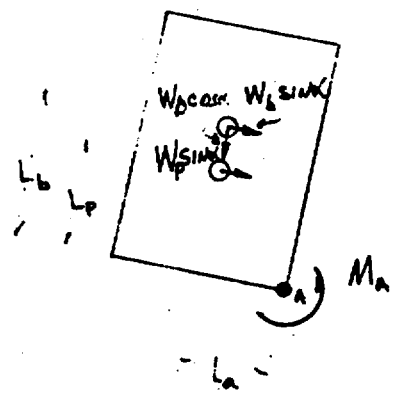
$$P_s = (W_p + W_b) \sin \alpha \text{ (g's)}$$

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

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

B. Tension Loads: **PATENT PENDING**

Interface bending moment is given by:



$M_a = 0$

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

Where: $W_p = 30,000$

$W_b = 12,000$ lbs.

$L_p = 88$ inches

$L_b = 115$ inches

$L_a = 48$ inches

$\alpha = 22^o$

$g = 24.9$

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

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

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

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

1. Dowels:

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

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

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

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

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

3. Friction:

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

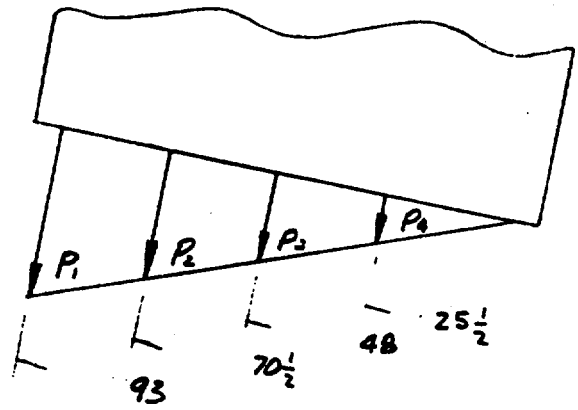
$$P_f = (10)(40,000)(1/3)$$

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

Total of: 433,000 lbs.

PATENT PENDING

Assuming a triangular bolt load distribution:



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

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

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

$$P_1 = 68,012 \text{ lbs.}$$

<u>Margin of Safety:</u>

Bolt Stresses:

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

$$f_t = .86612 \text{ psi}$$

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

$$f_s = 49920 \text{ psi}$$

Combined Stress:

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

$$S = 109,406 \text{ psi}$$

Margin of Safety:

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

$$M.S. = +.095$$

PATENT PENDING

PATENT PENDING

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

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

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

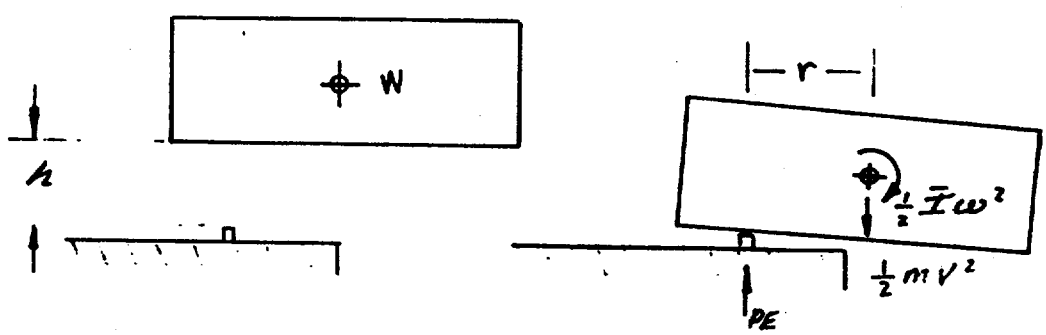
Using conservation of momentum and energy principles, impact energies can be calculated. We shall define the impact energy at an arbitrary pin location as:

Energy absorbed at pin,

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

and using:

Conservation of Energy



Σ Energy = 0

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

$$v_1 = r\omega$$

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

Conservation of Momentum

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

(+ | Components

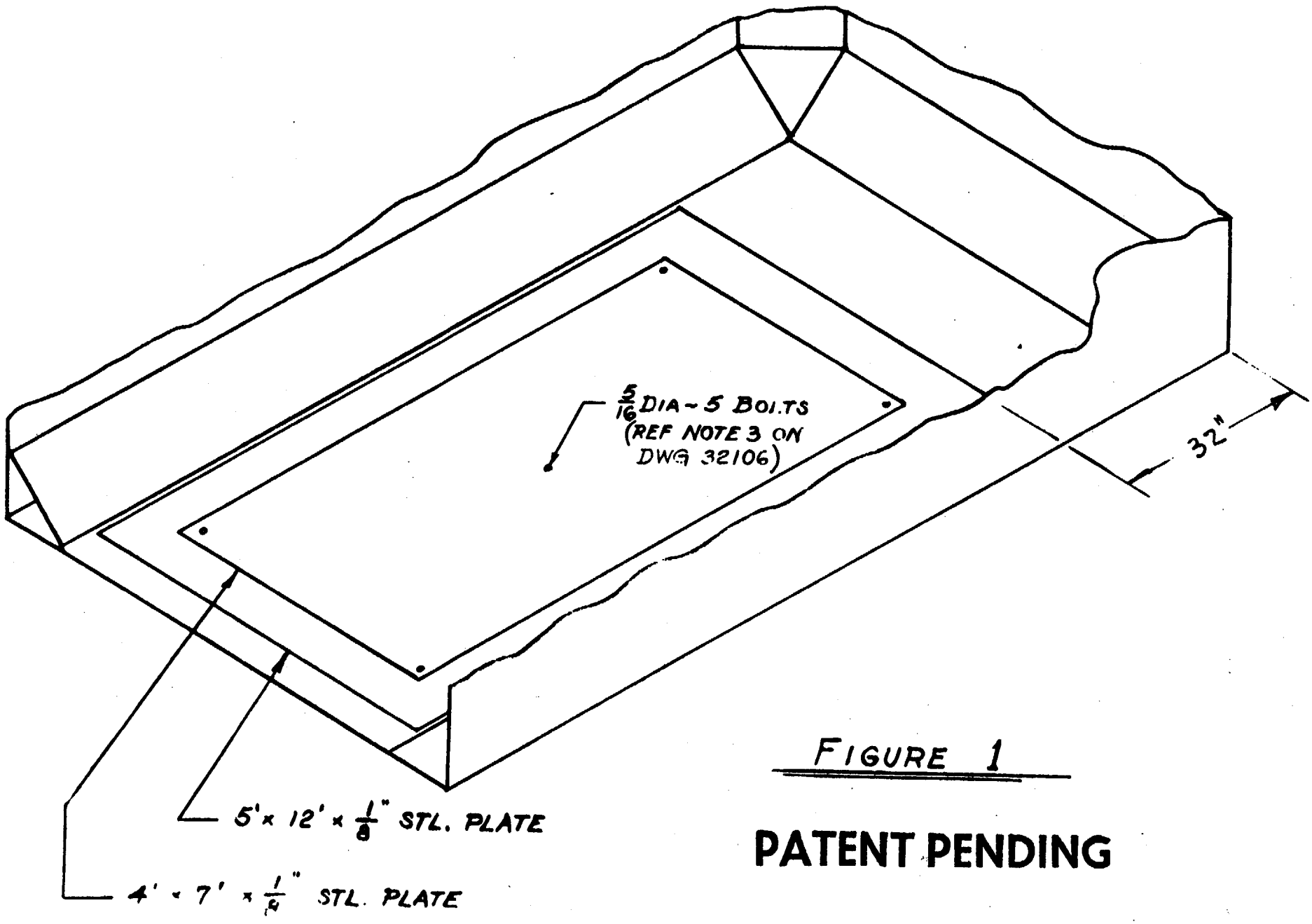
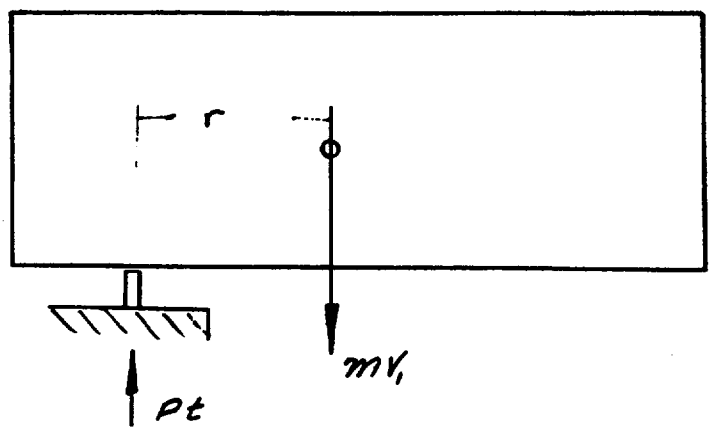


FIGURE 1

PATENT PENDING



$$mv_o = Pt + mv_1$$

Where: $t = 2E/v_o$

$v_1 = r\omega$

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

Solving for ω^2

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

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

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

Solving simultaneous equations Eq 1 and 2:

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

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

Where: $m = 45000 / 32.2 = 1400$

$v = 14.62$ fps

$h = 40$ inches

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

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

$I = 38198$

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

$W = 45000$ lbs.

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

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

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

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

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

<u>PE = 64115 ft. - lbs.</u>

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

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

Where: $m = 45000 / 32.2 = 1400$

$v = 14.62$ fps

$h = 40$ inches

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

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

$I = 38198$

$r = 3.5$ (End of Breakaway Plates)

$W = 45000$ lbs.

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

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

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

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

$\underline{PE = 102317.5 \text{ ft. - lbs.}}$

PATENT PENDING

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

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

$$t_c^2 = .066$$

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

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

$$t_5^2 = .0282$$

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

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

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

$$\underline{\underline{M.S. = +.116}}$$

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

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

$$t_5^2 = .0450$$

$$t_5 = .2122$$

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

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

$$\underline{\underline{M.S. = +.473}}$$

PATENT PENDING

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

Conclusion:

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

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

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

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