PDR 71-5942

GENERAL ELECTRIC

NUCLEAR ENERGY

ENGINEERING

DIVISION

GENERAL ELECTRIC COMPANY, P.O. BOX 460, PLEASANTON, CALIFORNIA 94566

March 18, 1980

Mr. Charles E. MacDonald, Chief
Transportation Branch
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Ref: Certificate of Compliance No. 5942

Dear Mr. MacDonald:

General Electric has for several years shipped large quantities of radioactive materials in the G.E. Model 700 shipping container. General Electric hereby requests that Certificate of Compliance No. 5942 for that container be renewed.

In support of this request a consolidated application for certification is enclosed with this letter. Some minor changes, e.g. editorial or reflecting current cask drawings, have been made and are designated by vertical lines.

A check for the $150.00 renewal fee is enclosed.

As this application is being submitted at least thirty days prior to the expiration date of the certificate, it is our understanding that the extension provisions of 10CFR2.109 are applicable.

Sincerely,

G. E. Cunningham

G. E. Cunningham
Sr. Licensing Engineer

/11

enclosures

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POOR QUALITY PAGES

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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GENERAL ELECTRIC SHIELDED CONTAINER - MODEL 700

1.0 Package Description - Packaging

(a) General

All containers of this model, for purposes of constructing additional containers of this model, will have dimensions of plus or minus 5% of the container dimensions specified in this application, and all lifting and/or tie-down devices for additional containers of this model if different from the lifting and/or tiedown devices described in this application will satisfy the requirements of 10CFR71.31(c)(d). This container will be used with and without the extension. The same protective jacket is used for both situations. This container is detailed in G.E. Drawings 289E642, Rev. 2, 289E646, Rev. 3, 195F127, Rev. 0, 237E325, Rev. 2, 129D4059,Rev. 1, 106D4150, Rev. 0, 106D4331, Rev. 0 and 289E647, Rev. 1, attached.

Shape

An upright circular cylinder shielded cask and an upright ciruclar cylinder protective jacket with a rectangular base which bolts to the jacket.

Size

The shielded cask is 36-13/16 inches diameter by 64-3/4 inches high. With the extension, the cask is 78-7/8 inches high. The protective jacket is 81 inches high by 66-1/2 inches across the box section.

Construction

The cask is a lead-filled carbon and stainless steel weldment. The protective jacket is a double walled structure of 5/8 inch carbon steel plate and surrounds the cask during transport.

1.0 (continued)

(a) (continued

Weight	The cask weights 23,000 pounds. The cask with extension weights 27,900 pounds. The protective jacket and base weigh 6000 pounds.
(b) Cask Body-Outer Shell	3/8 inch steel plate, 63-1/2 inches high by 36-13/16 inches diameter with 3/4 inch top and bottom plates. The extension is 1/2 inch thick steel plate 36-13/16 inches diameter and 14-1/8 inches high in the exposed portion, 21 inches diameter and 10-1/4 inches high for the portion which extends into the cask. The top plate is 1/2 inch thick and the bottom plate is 1/4 inch thick.
Cavity	1/4 inch stainless steel wall and bottom plate, 15 inches diameter by 40-1/4 inches deep. With the extension, the cavity is 15 inches diameter by 54-1/4 inches deep.
Shielding Thickness	10-9/32 inches of lead on sides, 9-29/32 inches of lead beneath cavity and 9-7/8 inches of lead above cavity, both with and without the extension.
Penetrations	(1) A 1/2 inch, schedule-40 stainless steel siphon drain from the cask cavity bottom terminating in a valve on the upper surface of the cask. The valve is guarded by steel channel attached to the adjacent lifting structure. (2) A 1/2 inch, schedule-40 stainless steel liquid fill line from the side of the cavity to the side of the outer cask shell terminating in a valve guarded by a surrounding pipe sleeve and covered by the protective jacket during transport.

1.0 (continued)

(b) (continued)

Filters	None.
Lifting Devices	Two diametrically opposed, vertical 12 inch structural tees, 3-1/2 feet long welded to the cask shell with reinforced lifting slots located in the web. Covered by protective jacket during transport.
Pressure Rating	Tested to 100 psig; normally unpressurized.
Primary Coolant	Water or air.
Means for Sampling	Vent and drain lines; both closed by valves and covered by protective jacket during transport.
Closure Seal	A minimum 1/4 inch thick flat silicone rubber or equivalent gasket between extension and cask body when extension is used.
(c) Lid-Shape	Flat plates and a cylindrical plug.
Size	Top plate is 30-1/2 inches diameter by 3/4 inch thick, thickened to 1 inch at the flange. The bottom plate is 21 inches diameter by 1/4 inch thick. The right cylinder is 10-1/4 inches high.
Construction	Steel weldment, lead filled.
Closure	Eight 3/4 inch - 10-UNC-2A by 2-1/4 inches long stainless steel bolts equally spaced 45^{o} apart on a 28 inch bolt circle. The bolts are 14-3/4 inches long when the extension is used.

1.0 (continued)

(c) (continued)

Closure Seal	A minimum 1/4 inch thick flat gasket between body and lid.
Penetrations	A 1/2 inch schedule-40 stainless steel pressure-vent line through the lid, terminating in a relief valve assembly guarded by a surrounding pipe sleeve and covered by the protective jacket during transport.
Pressure Relief Device	100 psi rating
Shielding Expansion Void	None.
Lifting Device	3/4 inch thick by 8 inch high by 13 inch long vertical plate welded to the lid with a 1-1/2 inch diameter hole centered 2-1/2 inches from the top edge to accommodate lifting hook or cable. Covered by protective jacket during transport.

(d)

Protective Jacket Body Shape	Basically a right circular cylinder with open bottom and with a protruding box section diametrically across top and vertically down sides with a smaller box section extending from only one portion of the cylinder.
Size	81 inches high by 66-1/2 inches across the main box section. Outer cylindrical diameter is 51-1/4 inches. Inner diameter is 46 inches.
Construction	Carbon steel throughout. Double walled construction. The walls are 5/8 inches thick with a 4-1/2 inch air gap between outer cask wall and inner jacket wall and 1-1/2 inch air gap between inner and outer jacket walls.

1.0 (continued)

(d) (continued)

Attachments	Eight 2-inch hex head bolts connecting the jacket to the cask base at the bottom edge of the jacket.
Lifting and Tiedown Devices	Two 10 by 7 by 6 inch steel blocks located on the sides of the main box section. A 4 inch diameter hole is cut through each block to accept cables or clevis. Eight 1-1/4 inch diameter by 1-3/8 inch steel studs welded to the main box section at the level of the center of gravity of the assembly. These are designed to allow the use of a basket hitch tiedown for the assembly.
Penetrations	Air passage through a 4 inch diameter hole in the top of the inner protective jacket and out through two 1 inch by 6 inch horizontal slots on top of box section of outer protective jacket.

(e)

Cask Base - Shape	3/4-inch top and bottom plates separated by 1/2-inch steel ribs with center well for cask. Four hollow rectangular members underneath to provide strength and guides for lift forks.
Size	The base is 66-1/2 inches by 51-1/2 inches by 18-1/2 inches.
Construction	Carbon steel weldment.
Attachment	Eight 2-inch hex head bolts connecting the base to the jacket at the bottom edge of the jacket.

2.0 Package Description - Contents

(a) General

By-product material, source material and special nuclear material, with or without cask extension.

(b) Form

Cladding, encapsulated or contained in a metal encasement of such material as to withstand the combined effects of the internal heat load and the 1475^{o} fire with the closure pre-tested for leak tightness; or in special form.

(c) Fissile Content

(i) 740 grams U-235, provided that the maximum U-235 enrichment does not exceed 6 weight percent; or

(ii) 1200 grams U-235, provided that the fuel material is in the form of MTR-type fuel elements with a minimum active fuel length of 23 inches; or

(iii) 220 grams fissile; or

(iv) 1650 grams U-235, provided that the maximum 235 enrichment does not exceed 3.5 weight percent; the fuel material is in the form of 88 rods loaded with 0.376 inch diameter pellets; and the fuel column length is at least 37 inches; or

(v) Not to exceed those values as presented in Figure 1, UO_2 weight limits for the model 700 shipping container, Exhibit A to this application; or

(vi) Not more than 10 ETR type fuel elements (GETR fuel) containing not more than 510 grams U-235 per element; loaded and spaced in the stainless steel shipping basket as described in Drawing No. 106D4150, Rev. 0.

2.0 (continued)

(d) Radioactivity	That quantity of any radioactive material which does not spontaneously generate more than 6500 thermal watts by radioactive decay with the package contents dry; or 1500 thermal watts, provided that the cavity shall contain at least a 1000 cubic-inch air void (at STP) at the time of delivery to a carrier for transport.
(e) Heat	Total maximum internally generated heat load not to exceed 6500 watts. An analytical determination, described in Exhibit B to this application, of the container temperature profile and heat load resulted in the following:

Cask Surface	$300^{o}F$
Inner Shield	$101^{o}F$
Outer Shield	$87^{o}F$
Ambient	$80^{o}F$
Heat Load	6566 Watts

General Electric will analyze by test or other assessment each container heat loading prior to shipment to verify that the requirements of 10CFR71.35 will be satisfied. Reference is made to GE-Model 100 Application, Exhibit B, for a method of internal heat load analysis and heat dissipation.

3.0 <u>Package Evaluation</u>

(a) General

There are no components of the packaging or its contents which are subject to chemical or galvanic reaction; no coolant is used during transport. The protective jacket is bolted closed during transport. A lock wire and seal of a type that must be broken if the package

3.0 (continued)

(a) Genera' (continued)

is opened is affixed to the cask closure device. If that portion of the protective jacket which is used in the tie-down system or that portion which constitutes the principal lifting device failed in such a manner to allow the protective jacket to separate from the tiedown and/or lifting devices, the basic protective features of the protective jacket and the enclosed cask would be retained. The package (contents, cask and protective jacket) regarded as a simple beam supported at its ends along its major axis, is capable of withstanding a static load, normal to and distributed along its entire length equal to five times its fully loaded weight, without generating stress in any material of the packaging in excess of its yield strength. The packaging is adequate to retain all contents when subjected to an external pressure of 25 pounds per square inch gauge. Reference is made to the GE - Model 100 Application. Exhibit C, for a method of determining static loads.

The calculative methods employed in the design of the protective jacket are based on strain rate studies and calculations and on a literature search* of the effects on materials under impact conditions. The intent was to design a protective jacket that would not only satisfy the requirements of the U.S. Nuclear Regulatory Commission and the Department of Transportation prescribing the procedures and standards of packaging and shipping and the requirements governing such

*TID-7651, SE-RR-65-98

3.0 (continued)

(a) General (continued)

packaging and shipping but would protect the shielded cask from significant deformation in the event of an accident. In the event that the package was involved in an accident, a new protective jacket could be readily supplied and the shipment continued with minimal time delay.

The effectiveness of the strain rate calculations and engineering intuitiveness in the design and construction of protective jackets was demonstrated with the General Electric Shielded Container - Model 100 (Ref: Section 3.0). The protective jacket design for the General Electric Shielded Container - Model 700 will be scaled from the design of the Model 100 in accordance with the cask weight and dimensions, maintaining static load safety factors greater than or equal to unity, and in accordance with the intent to protect the shielded cask from any deformation in the event of an accident.

(b) Normal Transport Conditions

Thermal: Packaging components, i.e., steel shells and lead, uranium and/or tungsten shielding, are unaffected by temperature extremes of -40^{O}F and 130^{O}F. Package contents, at least singly-encapsulated or contained in inner containers, but not limited to special form, will not be affected by these temperature extremes.

Pressure: The package will withstand an external pressure of 0.5 times standard atmospheric pressure.

3.0 (continued)

(b) (continued)

Vibration:	Inspection of the Model 700 casks used since 1958 reveals no evidence of damage of significance to transport safety.
Water Spray and Free Drop:	Since the container is constructed of metal, there is no damage to containment resulting from dropping the container through the standard drop heights after being subjected to water spray.
Penetration:	There is no effect on containment or overall spacing from dropping a thirteen pound by 1-1/4 inch diameter bar from four feet onto the most vulnerable exposed surface of the packaging.
Compression:	The loaded container is capable of withstanding a compressive load equal to five times its weight with no change in spacing.
Summary and Conclusions:	The tests or assessments set forth above provide assurance that the product contents are contained in the Shielded Container - Model 700 during transport and there is no reduction in effectiveness of the package.

(c) Hypothetical Accident Conditions

General:	The effectiveness of the strain rate calculations and engineering intuitiveness in the design and construction of protective jackets was demonstrated with the GE Shielded Container - Model 100 (Ref.: Section 3.0 of the

3.0 (continued)

(c) (continued)

General (continued)	Model 100 Application). Extrapolations of the Model 100 data were used in the design and construction of the GE Model 700 protective jacket. The increased weight and dimensions of the Model 700 container over the Model 100 container necessitated a protective jacket wall of 5/8 inch steel compared to a 1/4 inch wall for the Model 100.
Drop Test	The design and construction of the GE Model 700 protective jacket was based on an extrapolation of the proven data generated during the design and construction of the GE Model 100 and on the results of cask drop experiments by - C. B. Clifford[1][2] and H. G. Clarke, Jr.[3] The laws of similitude were used in an analytical evaluation[3][4] to determine the protective jacket wall thickness that would withstand the test conditions of 49CFR173.398(c) and 10CFR71.36 without breaching the integrity of the Model 700 cask. The evaluation, described

(1) C.B. Clifford, The Design, Fabrication and Testing of a Quarter Scale of the Demonstration Uranium Fuel Element Shipping Cask, KY-546(June 10, 1968).

(2) C.B. Clifford, Demonstration Fuel Element Shipping Cask from Laminated Uranium Metal-Testing Program, Proceedings of the Second International Symposium on Packaging and Transportation of Radioactive Materials, Oct. 14-18, 1968, pp. 521-556.

(3) H.G. Clarke, Jr., Some Studies of Structural Response of Casks to Impact, Proceedings of the Second International Symposium of Packaging and Transportation of Radioactive Materials, Oct. 14-18, 1968, pp. 373-398.

(4) J.K. Vennard, Elementary Fluid Mechanics, Wiley and Sons, New York, 1962, pp. 256-259.

3.0 (continued)

(c) (continued)

Drop Test (continued)	in GE-Model 1000 Application, Exhibit A, indicated a protective jacket wall thickness of 5/8 inch. The intent of the design for the GE Model 700 is, during accident conditions, to sustain damage to the packaging not greater than the damage sustained by the GE Model 100 during its accident condition tests (Ref.: Section 3.0 of the Model 100 Application). It is expected that damage not exceeding that suffered by the GE Model 100 will result if the GE Model 700 is subjected to the 30 foot drop test.
Puncture Test	The intent of the design for the GE Model 700 is to sustain less or equal damage to the packaging during accident conditions than the deformation suffered by the GE Model 100. It is expected that deformation not greater than that sustained by the GE Model 100 will be received by the GE Model 700 in the event that the package is subjected to the puncture test.
Thermal Test	Since it is expected that the GE Model 700 cask will sustain negligible damage and only minor damage will occur to the protective jacket in the drop and puncture tests, it is reasonable to consider the resultant package, for purposes of thermal resistance, as essentially undamaged. Accordingly, the package was assessed using the General Electric Transient Heat Transfer Computer Program, Version D (THTD), which allows the

3.0 (continued)

(c) (continued)

Thermal Test (continued) analysis of the general transient problems involving conduction, convection and radiation. The program allows the thermal properties of the materials to be entered as a function of temperature and the boundary conditions to be entered as a function of time.

The significant assumptions, approximations, and boundary conditions used for the analysis are listed below:

1. Fire temperature — 1472^{o}F
2. Effective fire Emissivity — 0.9
3. Fire shield surface Emissivity — 0.8 and constant with temperature
4. Emissivity of other Surfaces — 0.8 and constant with temperature.
5. There is intimate contact between the lead shielding and the stainless steel shell of the cask.
6. There is negligible heat transfer by conduction through the pipes used as spacers between the cask and the first shield and between the two shields of the protective jacket.
7. There is negligible heat transfer by convection between the two shields of the protective jacket and between the cask and first shield of the protective jacket.

3.0 (continued)

(c) (continued)

Thermal Test (cont.)	8. There is an internal heat load of 6500 watts with assessed temperatures as outlined in Section 2.0 of this application.
	The computer program calculations were run for a 30 minute fire. The calculations indicate a maximum temperature rise to less than 473^{o}F for the lead after 30 minutes and no lead melting could be expected. A coast up analysis (Ref. the Model 100 Application) indicated that a temperature of 464^{o}F could be expected at the innermost lead node after 34 minutes. The Model 100 Application further describes the computer code THTD.
Water Immersion	Since optimum moderation of product material is assumed in evaluations of criticality - safety under accident conditions, the water immersion test was not necessary.
Summary and Conclusions	The accident tests or assessments described above demonstrated that the package is adequate to retain the product contents and that there is no change in spacing. Therefore, it is concluded that the General Electric Shielded Container - Model 700 is adequate as packaging for the contents specified in 2.0 of this section.

4.0 Procedural Controls

Vallecitos Site Safety Standards have been established and impelemented to assure that shipments leaving the Vallecitos Nuclear Center (VNC)

4.0 Procedural Controls (continued)

comply with the certificates issued for the various shipping container models utilized by the VNC in the normal conduct of its business.

Each cask is inspected and radiographed prior to first use to ascertain that there are no cracks, pinholes, uncontrolled voids or other defects which could significantly reduce the effectiveness of the packaging.

After appropriate U.S. Nuclear Regulatory Commission approval, each package will be identified with a welded on steel plate in accordance with the labeling requirements of 10CFR71 and any other information as required by the Department of Transportation.

5.0 Fissile Class - Class III

The Density Analog Method as described in the SNM-960 License Application for VNC, Docket 70-754, was used for calculations. Although this method is normally used to calculate the number of units for transport under Fissile Class II, it was used in this case to demonstrate that one shipment of two casks would be subcritical.

No credit was taken in the calculations for Pu-240 or other poisons present. The cask cavity was filled with water, and the fuel was homogenized with the water in the volume of the 5.0 inch liner. This water filling was done to represent the accident case and to allow for cask wet loading. The calculations were based on the cavity volume without the extension resulting in the greatest homogenized concentration.

The full results of the calculations are shown below:

Fissile Material	Quantity	Safe Number
Pu-239	2.0 Kg	11
U-233	2.0 Kg	8
U-235	2.0 Kg	63

In all cases, at least two containers each containing 2.0 Kg of fissile material were subcritical.

EXHIBIT A

Supportive Information for Fissile Loadings

APPLICATION AMENDMENT

FOR GENERAL ELECTRIC SHIELDED CONTAINER --

MODEL 700

DATED FEBRUARY 25, 1970

SUPPORTIVE INFORMATION

Byproduct Material and special nuclear material in solid metal or metal oxide form:

A. Maximum amount of fissile material prior to irradiation:

(5) Not to exceed those values as presented in Figure 1, <u>UO_2 Weight Limits for the Model 700 Shipping Container</u>, of General Electric Company's application dated February 25, 1970;

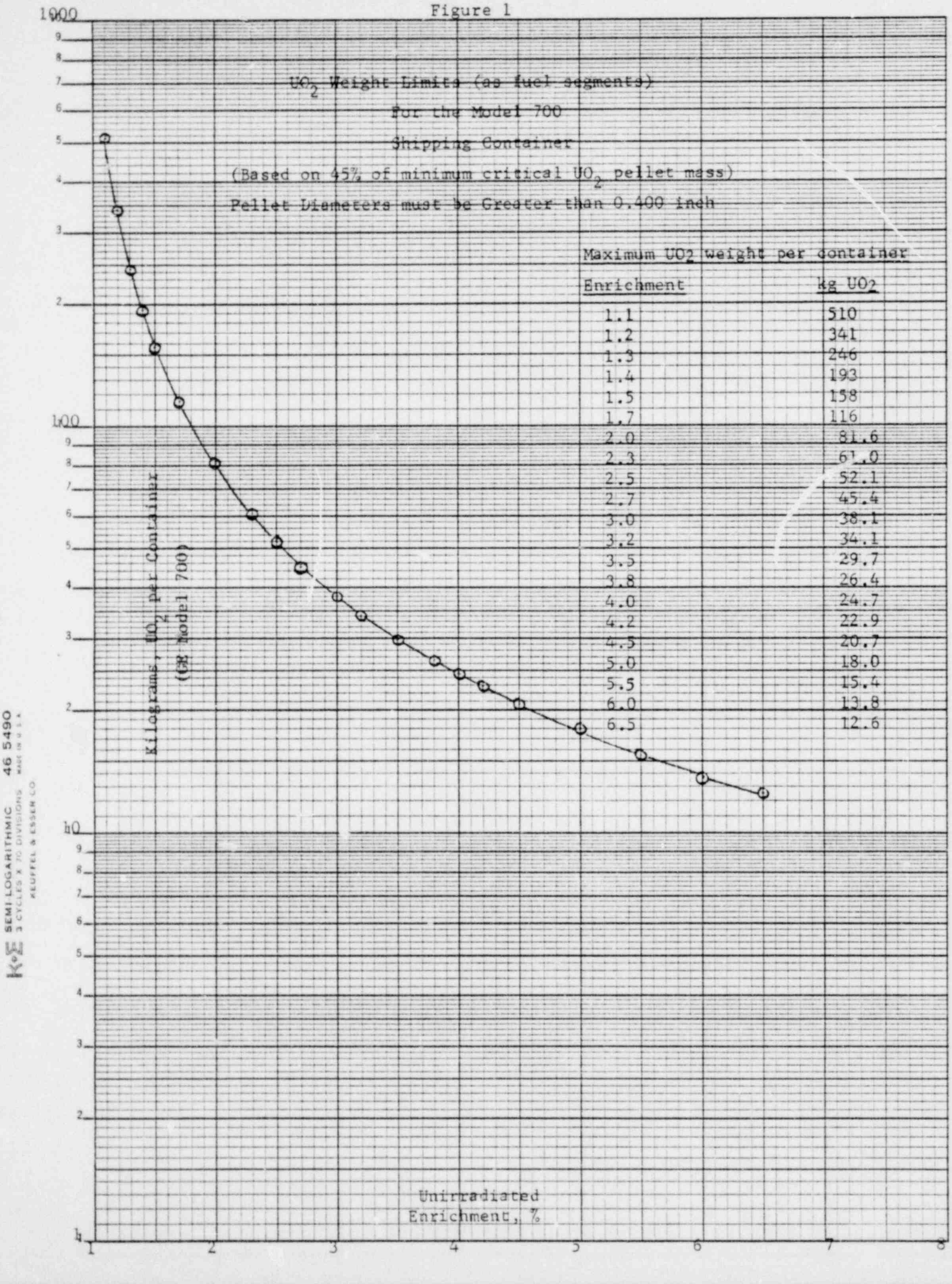
Figure I, calculated with the use of GERM and GETHRM codes, gives fully moderated and reflected UO_2 weight limits for shipment of fuel segments in the Model 700 container. These values are based on 45% of the minimum critical UO_2 pellet mass for pellet diameters greater than 0.400 inch. The weight limit selected for a given container is based on the maximum unirradiated enrichment to be shipped.

(6) Not more than 10 ETR-type elements (GETR Fuel) containing not more than 510 grams of U-235 per element loaded and spaced in the stainless steel fuel shipping basket as described in General Electric Company's application dated February 25, 1970 and GE Drawing No. 106D4150.

<u>Fuel Flement Description</u>

The fuel elements are ETR-type, flat-plate, uranium-aluminum assemblies. The nominal net overall dimensions of each complete fuel element are 3.00 inches by 3.00 inches by 54.35 inches. This length is reduced to approximately 40 inches for shipment.

Figure 1



Maximum UO_2 weight per container

Enrichment	kg UO_2
1.1	510
1.2	341
1.3	246
1.4	193
1.5	158
1.7	116
2.0	81.6
2.3	61.0
2.5	52.1
2.7	45.4
3.0	38.1
3.2	34.1
3.5	29.7
3.8	26.4
4.0	24.7
4.2	22.9
4.5	20.7
5.0	18.0
5.5	15.4
6.0	13.8
6.5	12.6

Each fuel element consists of 19 fuel plates each 0.050 inch thick, 2.80 inches wide and 37.25 inches long. The fuel plates are roll-swaged into 6061-T6 aluminum alloy side pieces which hold and space the fuel plates 0.110 inch apart. An aluminum "comb" spacer plate, inserted at the upper end of the assembly, maintains the nominal 110-mil spacing between the fuel plates.

Each fuel plate is composed of a 20-mil-thick uranium-aluminum central core sandwiched between two layers of 15-mil aluminum cladding. The central core region or "meat" is 36 inches long and starts 0.625 inch from each end of the plate. A 1060 alloy aluminum "picture frame" surrounds the meat in each plate with 15-mil 1060 aluminum cladding covering the meat and picture frame. Nominal finished net dimensions of each fuel plate are 0.050 inch by 2.80 inches by 37.25 inches.

The fuel meat alloy is a uranium-aluminum alloy containing 30.5 wt% uranium, 2% silicon, and the balance aluminum. Fully enriched (93.5% U-235) uranium and pure aluminum are melted together to form the fuel alloy billets. Up to 2% silicon is added to promote homogeneity in the alloy. After rolling the alloy billet to shape, individual fuel plate cores are cut. These cores, inside aluminum picture frames, are then metallurgically bonded to the cladding by hot-rolling in a series of passes followed by cold-rolling. Between hot and cold-rolling, the plates are heated to 1000° F for 1 hour and inspected to ensure freedom from blisters or laminations. After cold-rolling, the plates are assembled and swaged into finished fuel elements.

Each plate contains 26.9 ± 1.0 gm U-235, and each fuel element assembly contains 510 ± 6.0 gm U-235.

Fuel Element Summary

Fuel type	ETR flat plate
U-235 concentration in meat, wt%	30.5
Meat thickness, inch	0.020
Cladding thickness, inch	0.015
Fuel plate thickness, inch	0.050
Plates per element	19
Uranium enrichment, %	93.5
U-235 per element, gm	510
Element length, inches	54.35
Element cross section, inches	3.00 x 3.00
Number of elements per shipment	
Normal	10
Maximum	10
Active element length, inches	36

Poison Basket Description

The shipping container Model 700 poison basket is comparable to the boral fuel magazine shown in the "Irradiated Fuel Shipping Cask Design Guide", L. B. Shappert, ORNL-TM-2410, (cask BMI-1, issued AEC License SNM-807, Amendment No. 4, dated March 31, 1967 and DOT Special Permit No. 5957, dated April 23, 1969). For the Model 700 basket, 304 stainless steel is used in place of boral, resulting in the advantages of improved material properties at room and elevated temperature and permitting the use of conventional fabrication techniques.

The Model 700 poison basket is fully described in General Electric Drawing No. 106D4150, attached hereto.

Nuclear Considerations

A criticality analysis was performed for the loading and shipment of 10 GETR fuel elements in a Model 700 container. The elements are contained in a stainless steel basket (GE Dwg. No. 106D4150) with 0.25 inch of steel between each element forming a stainless steel cell around each element. No burnup was assumed.

Two basic conditions were evaluated: (1) fuel in the steel basket contained in the 10.5 inches thick lead cask with all void spaces in and around the cask filled with water and (2) fuel in the steel basket surrounded with water. The second case will be encountered during loading of the basket. No dry case was considered as the assembled fuel elements in the poison basket are already undermoderated in the flooded case, and the further removal of water would only reduce the keff. of the system.

In each of the above cases, cross-sections were calculated using the GERM and GETHRM computer codes. GERM and GETHRM are General Electric Company proprietary versions of THERMOS - a Thermalization Transport Theory Code for Reactor Lattice Calculations, H. C. Honeck, Brookhaven National Laboratory. The calculated cross-sections were in turn input to the TWOD code.

TWOD is a General Electric Company proprietary version of PDQ, reported in WAPD-TM-230. The following results were obtained:

Case	Keff.
(1) Flooded fuel array in Pb cask	0.81
(2) Flooded fuel array in water	0.75

In evaluating case (1) against the accident criteria of 10CFR71, reference is made to TID-7028, Critical Dimensions of Systems Containing U-235, Pu-239, and U-233, Figure 8, page 14. As the H/U-235 ratio is approximately 225 and the amount of U-235 per element is fixed, any accident which increases fuel density will make the system less reactive. The only credible accident in the Model 700 container would involve the fuel breaking into pieces (itself highly suspect, as tests on the irradiated fuel indicate little or no embrittlement) and settling, resulting in a more dense and consequently less reactive system.

B. Maximum amount of radioactive decay heat:

(2) Package contents wet - 1500 thermal watts, provided that the cavity shall contain at least a 1000-cubic-inch air void (at standard-temperature-pressure) at the time of delivery to a carrier for transport.

The calculations for the 1500 watt load in the Model 700 container with or without the extension were performed in the same manner as the calculations for the 500 watt load, submitted as Exhibit C to the Model 700 application dated August 4, 1969 and resulting in License Amendment 71-43, dated August 19, 1969. The results of the calculations including the FRECON and THTD computer code runs indicate that a 100 psi wet load will not be exceeded under either normal or accident conditions provided that 700 cubic-inches of water are removed from the cavity, without the extension, and 940 cubic-inches of water are removed from the cavity when the extension is used. In performing the calculations, the volume of the payload was assumed to be zero which makes the results a bit conservative but allows for an unlimited number of payload configurations up to 1500 watts.

EXHIBIT B

An Analytical Method for Determining Container Temperature Profiles and Heat Loads.

EXHIBIT B

An analytical method for the determination of container temperature profile and heat load when the geometry and cask surface temperature conditions are known.

1. Scope

The analytical method described in Exhibit B provides a means for determining the container heat load and temperature profile used in evaluating the package when subjected to the conditions normally incident to transport and for obtaining information necessary to the application of THTD in the evaluation of the container when subjected to the 1475° F fire for 30 minutes, including a coast-up analysis.

2. Assumptions, Approximations, and Boundary Conditions

2.1 Emissivities of all surfaces are constant with temperature, all surfaces painted white.

2.2 Intimate contact between the lead shielding and the cask shell.

2.3 Negligible heat transfer by conduction through the pipes used as spacers between the cask and the first shield and between the two shields.

2.4 Maximum cask surface temperature allowed under normal transport conditions, 300° F.

2.5 Convective surface film coefficients obtained by using correlations found in "GE Heat Transfer and Design Data", Section G504.3, page 5, figures 8B and 9B.

2.6 Surface film coefficient for outside of outer fire shield obtained from "Heat Transmission", page 172, Equation 7-4A, McGraw-Hill.

2.7 Turbulent flow only.

2.8 Uniform heat flux.

2.9 Forced flow and drafts negligible.

2.10 All surfaces of cask and fire shields, except bottom, are available for heat transfer.

3. Description

FRECON

A BASIC language time sharing program to calculate container fire shield temperatures and heat load knowing the container geometry and cask surface temperature was developed. Using data obtained from the thermal testing of the GE Models 100 and 1500 shipping containers, an analytical correlation was developed to calculate a temperature distribution from the cask surface to the ambient air. This method also permits calculation of the container maximum allowable heat load. A BASIC language computer program was written for the GE 235 computer employing the aforementioned analytical correlation. Specifically, the program was written to calculate the equilibrium temperatures and heat load for containers employing a GE double wall steel protective jacket. It could, however, be modified to calculate temperatures and heat load for other fire shield configurations.

The program user specifies the outside surface areas for the cask and fire shields and their emissivities. He also inputs an arbitrarily selected cask surface temperature, T_1, an ambient air temperature, T_4, and a first guess for outer shield temperature, T_3. For the given T_1 and T_4, the program will iterate to explicit values for T_3, inner fire shield temperature, T_2, and the container heat load. The temperatures between the cask surface and the cavity surface are then hand calculated using the equation for heat conduction through a composite cylinder wall:

$$Q\ (\text{BTU-HR}^{-1}) = \frac{2\pi K_{12}\ L\ (t_1 - t_2)}{\ln\ (r_2/r_1)}$$

where:

K_{12} = Thermal conductivity in BTU/Hr-Ft-° F
L = Length of cylinder in feet
r_1 = Inside radius
r_2 = Outside radius

The standard fire transient is then run using the THTD computer code and the total temperature distribution just obtained. If the post fire temperatures are too high (lead melting occurs) a new value for T_1 is selected and the entire process is repeated.

Data comparing the measured values with computed values for the GE Models 100 and 1500 containers are indicative of the success of the program.

Container Model	Heat Load, Measured	Heat Load, Calculated
100	1310 $BTU\text{-}Hr^{-1}$	1101 $BTU\text{-}Hr^{-1}$
1500	10317 $BTU\text{-}Hr^{-1}$	8190 $BTU\text{-}Hr^{-1}$

EXHIBIT C

Lifting Devices

CABLE ANALYSIS

700 SERIES

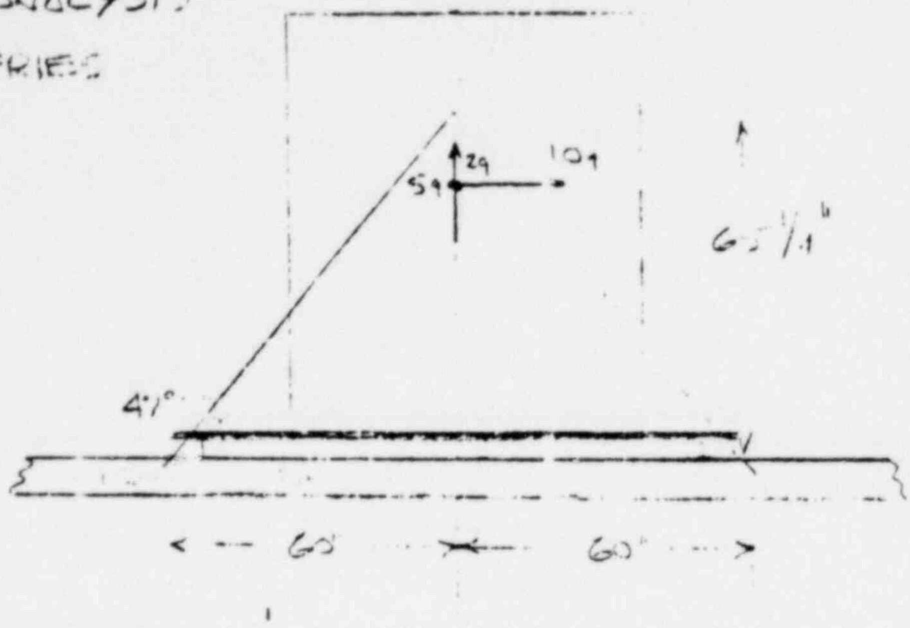


FIG. 1 ELEVATION VIEW PACKAGE ON TRUCK BED

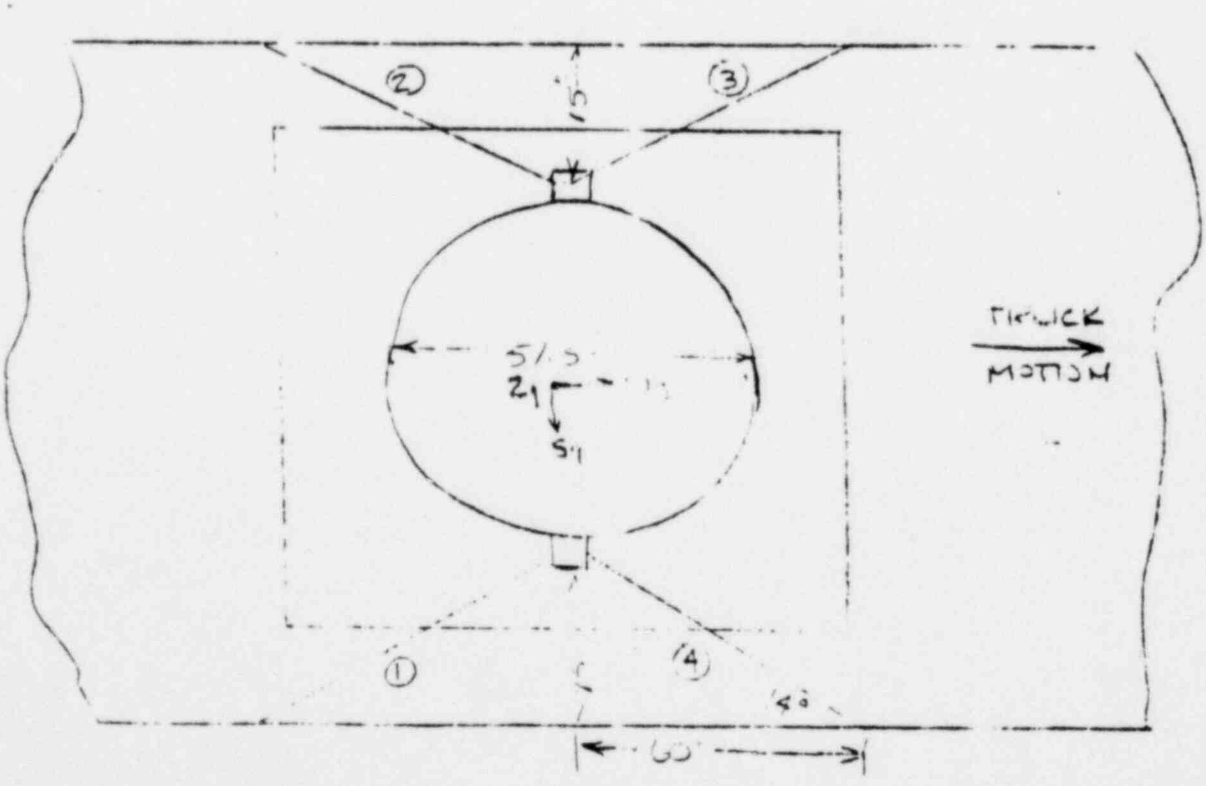


FIG 2 PLAN VIEW PACKAGE ON TRUCK BED

SIN 47 = 0.733   SIN 14° = 0.242
COS 47 = 0.680   COS 14° = 0.971
TAN 47 = 1.08   TAN 14° = 0.25

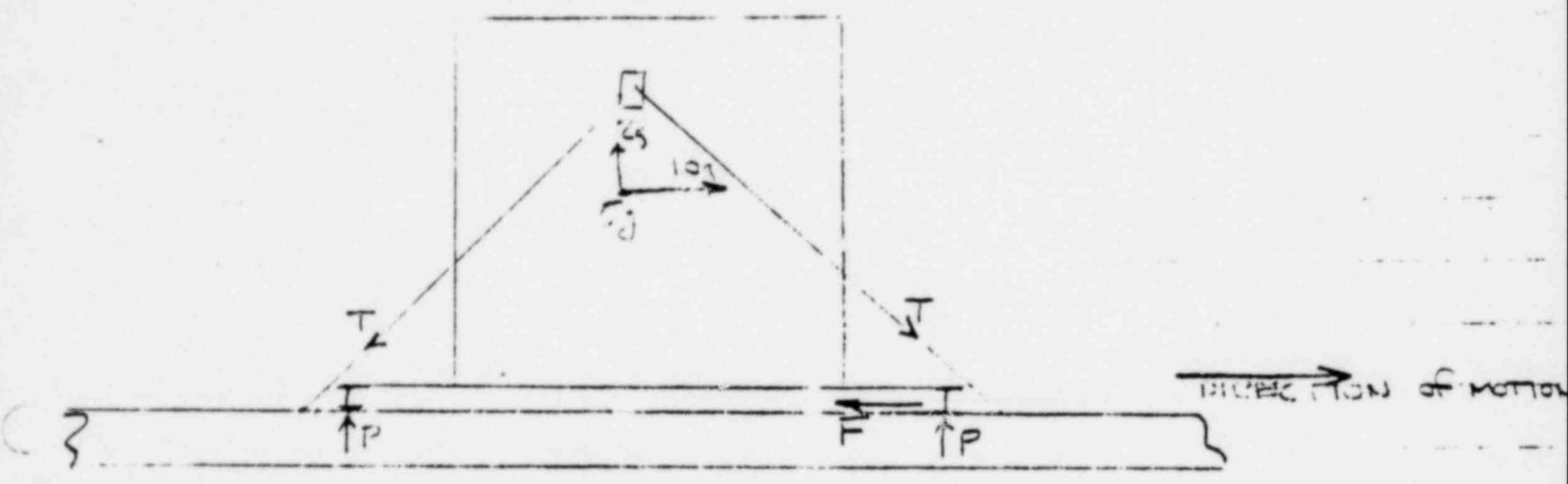


FIGURE 3 LOADING DIAG.

IF THE PACKAGE IS NOW LOADED WITH 10G, 5G, & 2G FORCES ACTING AT THE C.G. OF THE PACKAGE, THE ACTIONS AND REACTIONS ARE AS SHOWN IN FIG 3.

THE 10G FORCE ACTS IN THE DIRECTION OF MOTION.

THE 5G FORCE IS ASSUMED TO ACT TO THE RIGHT AND WOULD RESULT IN THE SAME SOLUTION REGARDLESS OF ITS DIRECTION.

THE 2G FORCE IS ASSUMED TO ACT UPWARDS

THE CABLE LOADINGS DUE TO THE 10G LOAD ARE DISTRIBUTED AS FOLLOWS. (SEE FIG. 2)

IN CABLES 3&4 THERE IS A COMPRESSIVE FORCE WHICH MAKES THE CABLES ASSUME A SLACK POSITION. THEREFORE THE WHOLE 10G LOAD IS TAKEN IN THE CABLES 1&2. DUE TO SYMMETRY EACH CABLE WILL TAKE 5G's, IN THE DIRECTION OF THE 10G LOAD.

THE CABLE LOADINGS DUE TO THE 5G LOAD ARE DISTRIBUTED AS FOLLOWS. (SEE FIG. 2)

IN CABLES 1&4 THERE IS A COMPRESSIVE FORCE WHICH MAKES THE CABLES ASSUME A SLACK POSITION. CABLE 1 IS UNDER SOME TENSION DUE TO 10G LOADING, H. EVER THIS IS REDUCED BY THE 5G LOAD. SO 2 & 3 TAKE THE 5G LOADING. THE FULL 5G LOAD CAN CONSERVATIVELY BE PUT ON CABLE 2 BY ASSUMING THAT CABLE 3 IS STILL SLACK BECAUSE THE LARGEST FORCE (10G) TENDS TO COMPENSATE ANY TENSION DUE TO 5G LOAD AND KEEP CABLE 3 SLACK. FULL 5G LOAD ON CABLE 2 IS ASSUMED TO BE WORST CASE CONDITION.

THE CABLE LOADING DUE TO THE 2G LOAD ARE DISTRIBUTED AS FOLLOWS (SEE FIG 2)

CABLE 4 IS SLACK SO IT CAN TAKE NONE OF THE VERTICAL LOAD, CABLES 1 AND 3 CAN TAKE SOME OF THE LOAD, HOWEVER SINCE EACH HAS AT LEAST 1 COMPRESSIVE FORCE, THE EFFECT OF THE 2G FORCE WILL HAVE THE WORST EFFECT ON CABLE 2. WE ASSUME ALL 2G'S ARE TAKEN BY CABLE 2 FOR WORST CASE CONDITIONS

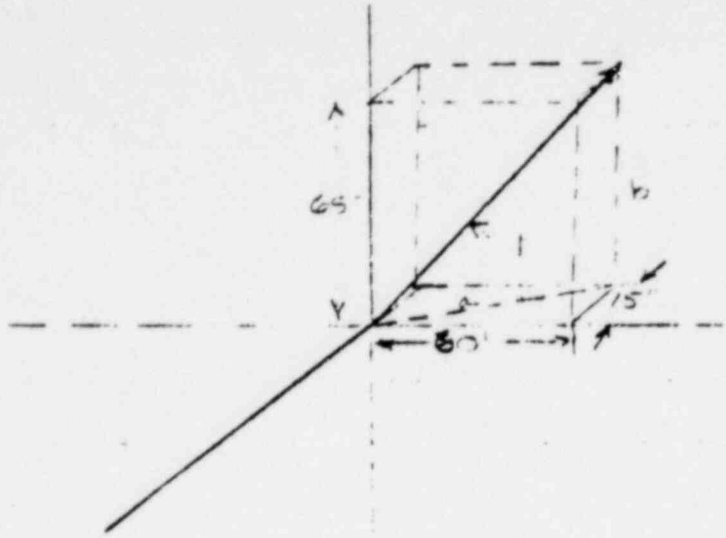


FIG. 4 CABLE GEOMETRY

FROM FIG 4, THE ANGLE THAT THE CABLE MAKES WITH RESPECT TO THE TRUCK BED CAN BE DETERMINED.

$$\tan\phi = \frac{b}{a} = b/\sqrt{60^2+15^2} = b/62 = 65/62 = 1.048$$

$$\phi = \tan^{-1} 1.048$$

$$\phi = 46.4^\circ$$

SINCE CABLE 2 IS WORST CASE WE WILL INVESTIGATE THE LOAD IT TAKES

FORCE VECTOR SYSTEM IS TRANSFERRED SO ORIGIN COINCIDES WITH CABLE ORIGIN

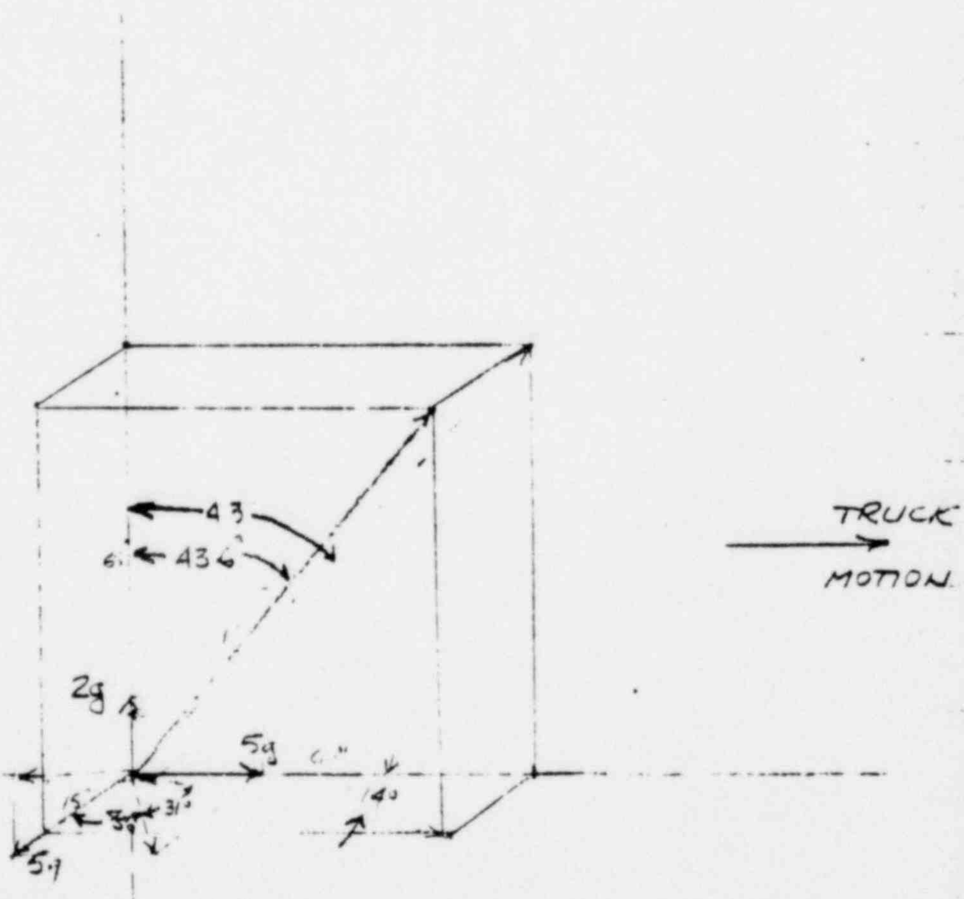


FIG 5 CABLE AND LOAD GEOMETRY

THE VECTOR SUM OF THE FORCES IS ADDED AND FOUND TO BE

$$F = \sqrt{5^2 + 5^2 + 2^2}\ G = 7.34G$$

TRANSFERING THIS TO THE CABLE IS DONE BY S - D GEOMETRY IN FOLLOWING MANNER:

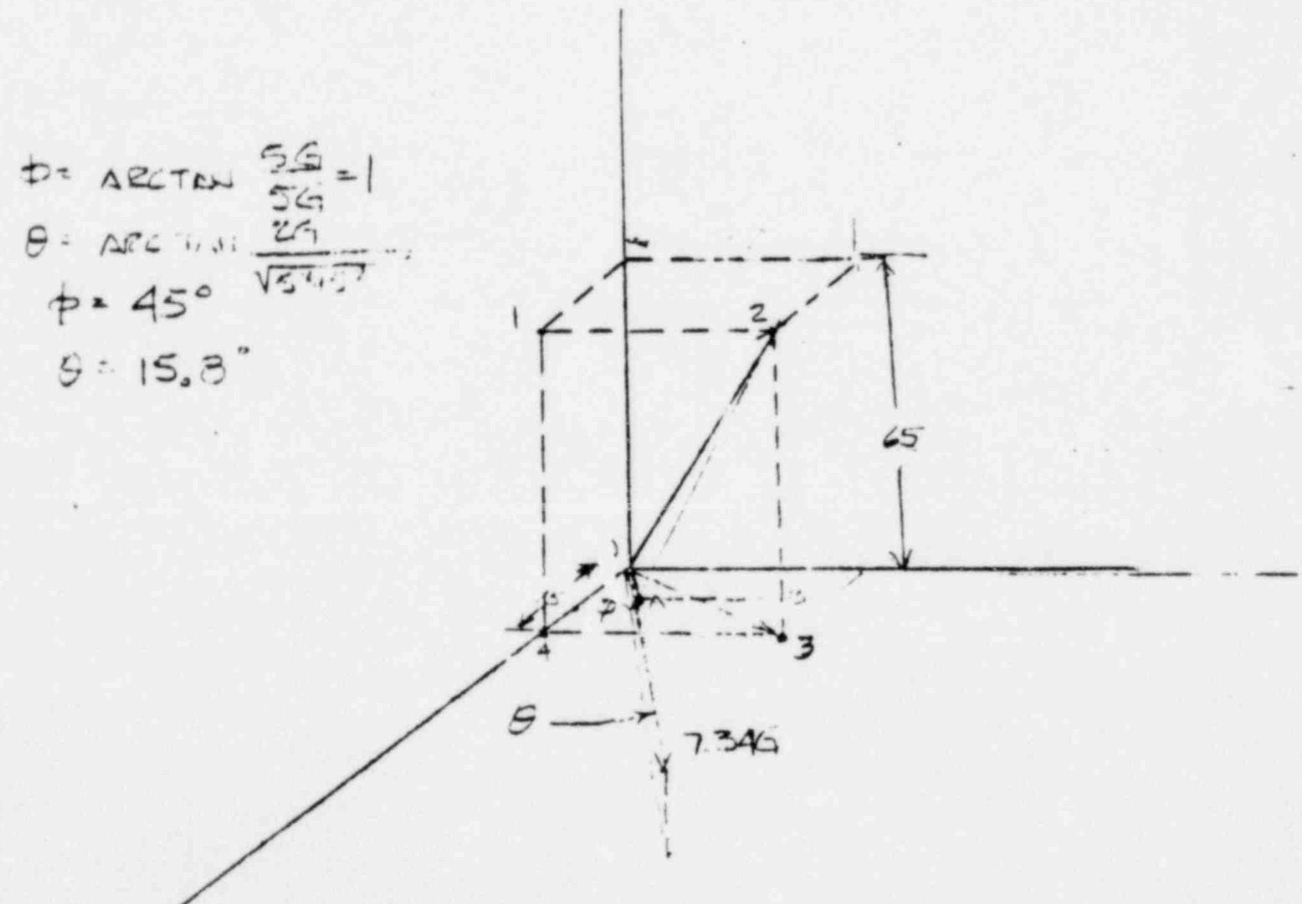


FIG. #6

THE FORCE VECTOR SUM IS PROJECTED UNTIL IT INTERSECTS PLANE 1,2,3,4. ITS LENGTH TO THIS PLANE - 22 IN

$$L = 15/\cos 45° (\cos 15.8°) = 22 \text{ in}$$

NOW LOOKING AT PLANE 2,3,4 IN FIG #6
WE SEE TRIANGLE A,B,2

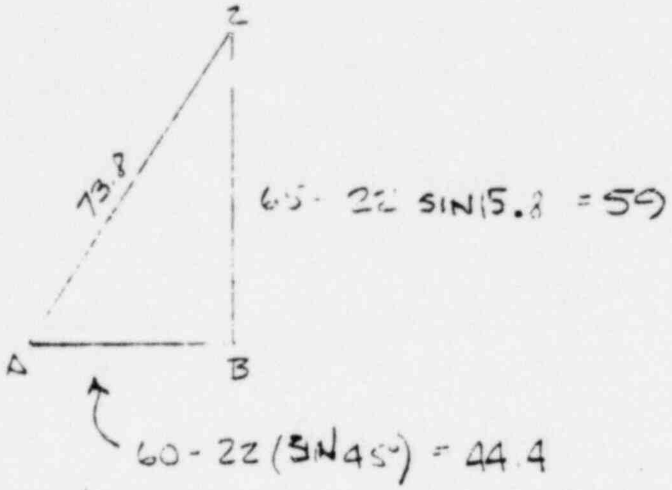


FIG. 7

THE LENGTH OF VECTOR O-2 IS

$$60/\cos 14°(\cos 47°) = 89.1 \text{ inches}$$

NOW FOR TRIANGLE OA2 WE HAVE FIG. 8, USING THE LAW OF COSINES TO FIND θ

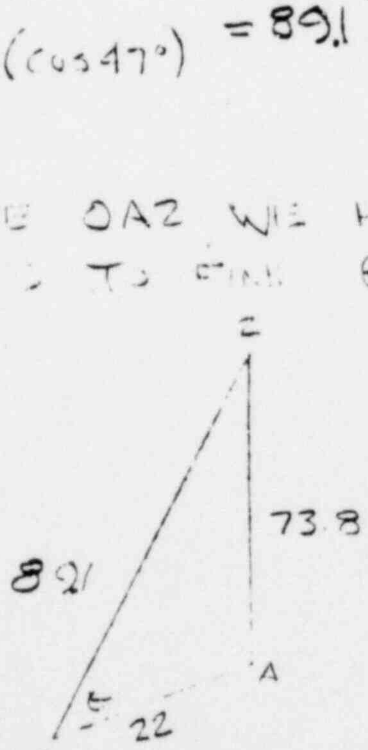


FIG 8

Δ^2

$(73.8)^2 = (91)^2 + (22)^2 - 2(91)(22)(\cos\theta)$

$5446 = 8281 + 484 - 4004 \cos\theta$

$5446 - 8765 = -4004 \cos\theta$

$\cos\theta = \frac{3319}{4004} = 0.8289$

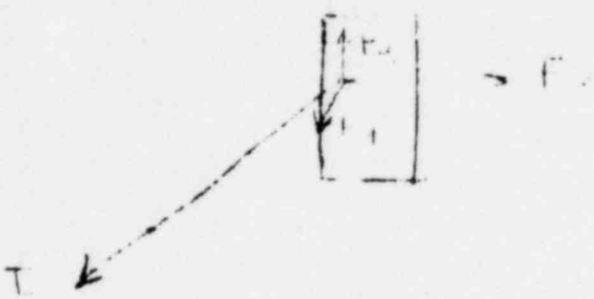
$\theta = 34°$

TRANSFERRING THE FORCE TO THE CABLE WE [illegible]
THE COS OF THE ANGLE

$T = 7.346 / \cos 34° = \underline{8.96}$

[illegible]

700 [illegible]

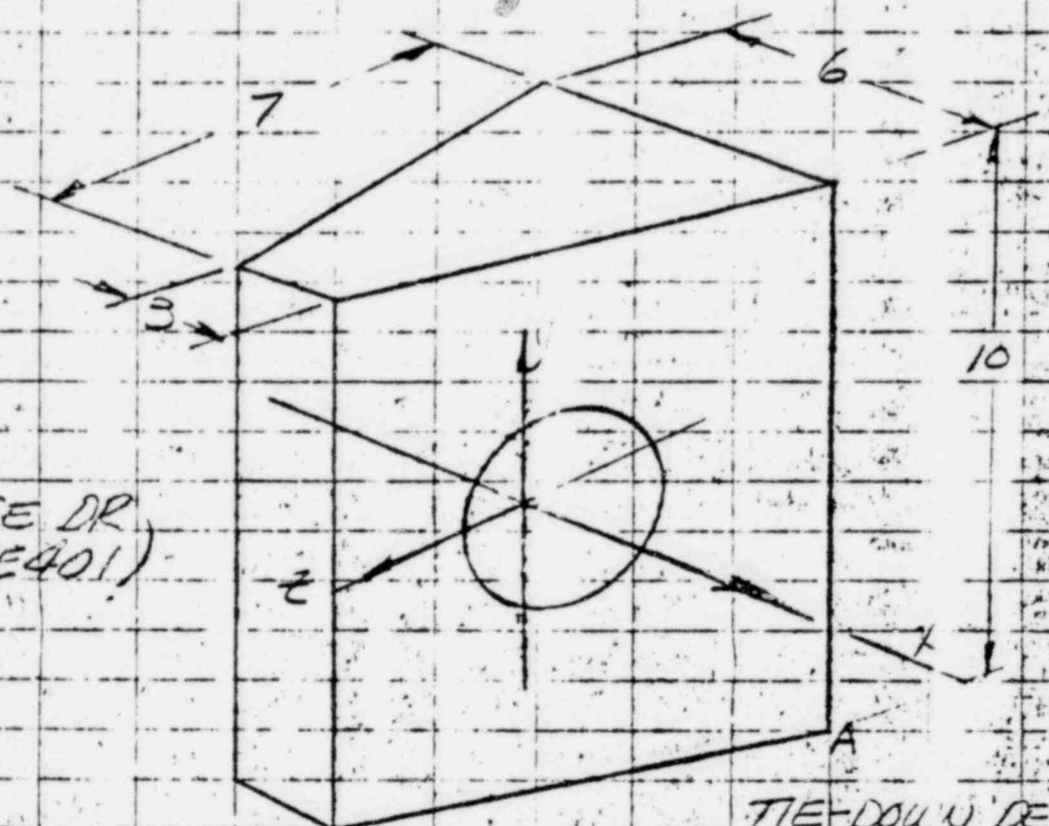


$F_x = 8.9(\cos 46.4)(\cos 14^\circ) = 5.$[illegible] G

$F_y = 8.9(\cos 46.4)(\sin 14^\circ) = 1.49\,G$

$F_z = 8.9(\sin 46.4) = 6.45\,G$

700 SERIES TIE-DOWN SYSTEM ANALYSIS 1/8



(SEE GE DR 277E401)

TIE-DOWN DEVICE

FIGURE 1

THE WORST CASE CONDITION FOR LOADING THE TIE-DOWN DEVICE UNDER THE STIPULATION OF 10CFR 71.31(d)(1) OCCURS WHEN THE CABLE TENSION IS 8.9 G'S (SEE CABLE ANALYSIS). THE FORCES ACTING ON THE TIE-DOWN WHEN BROKEN DOWN INTO THEIR RESPECTIVE COMPONENTS ARE:

$$F_x = 5.95\,G$$
$$F_y = 6.45\,G$$
$$F_z = 1.49\,G$$

THE LOAD WAS CONSIDERED TO ACT THROUGH THE CENTER OF THE DRILLED HOLE OF THE TIE-DOWN DEVICE (FIG. 1).

FOR ANALYZING PURPOSES, ASSUME THAT THE TIE-DOWN DEVICE IS A BLOCK. REFER TO FIGURE 2 (PAGE 3) FOR LOADING CONDITIONS.

a) BENDING STRESS DUE TO LONGITUDINAL FORCE

$$S_B = \frac{4.24\ PL}{h[b^2 + 3l(b+h)]}$$

REFER TO FIG. 2a (REF. SHIGLEY, MACHINE DESIGN PG 210)

$P = 5.95G \times 35{,}000 = 208{,}000$ LB
$L = 3.5$ IN
$h = 1.0$ IN
$b = 6.0$ IN
$l = 10.0$ IN

$$S_B = \frac{4.24(208{,}000)(3.5)}{(1)[36 + 3(10)(6+1)]}$$

$S_B = 12{,}500$ LB/IN^2 ①

b) SHEAR STRESS DUE TO LONGITUDINAL FORCE

$$S_S = \frac{P}{2hl}$$

REFER TO FIG. 2.2

$l = 16.0$ IN

$$S_S = \frac{208{,}000}{2(1)(16)}$$

$S_S = 6{,}500$ LB/IN^2 ②

2/8

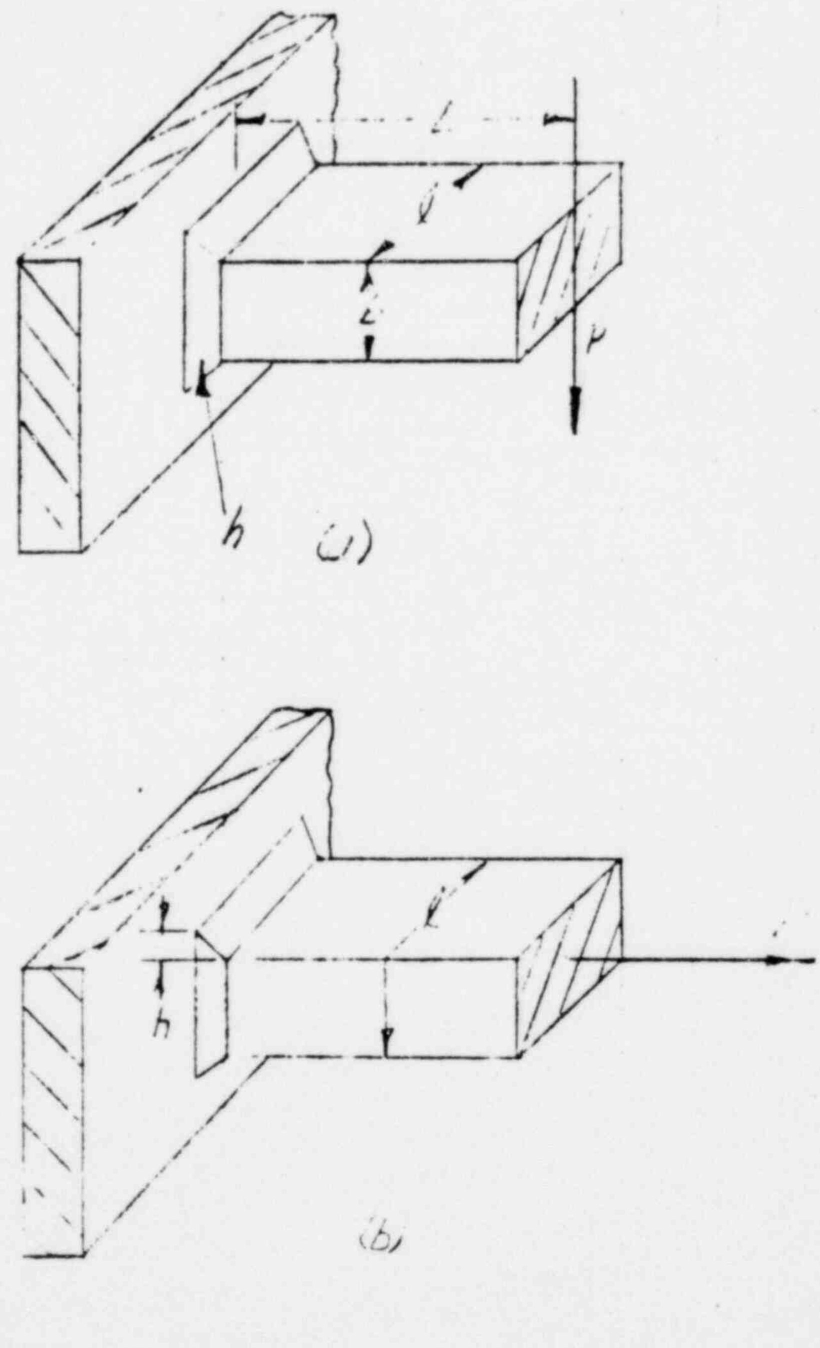


FIG. 2

c) TENSILE STRESS DUE TO TRANSVERSE FORCE

$$S_T = \frac{0.707 P}{h \ell}$$ REFER TO FIG. 2b

$\ell = 16$ IN.
$P = 1.496 \times 35{,}000 \quad 52{,}000$ LB

$$S_T = \frac{0.707 (52{,}000)}{(1)(16)}$$

$$S_T = 2{,}300 \text{ LB/IN}^2 \quad (3)$$

d) BENDING STRESS DUE TO VERTICAL FORCE

$$S_B = \frac{4.24 PL}{h[b^2 + 3\ell(b+h)]}$$ REFER TO FIG. 2a

$P = 6.456 \times 35{,}000 = 226{,}000$ LB
$b = 10.0$ IN
$\ell = 6.0$ IN

$$S_B = \frac{4.24 (226{,}000)(3.5)}{1[100 + 18(11)]}$$

$$S_B = 11{,}240 \text{ LB/IN}^2 \quad (4)$$

c) SHEAR STRESS DUE TO VERTICAL FORCE

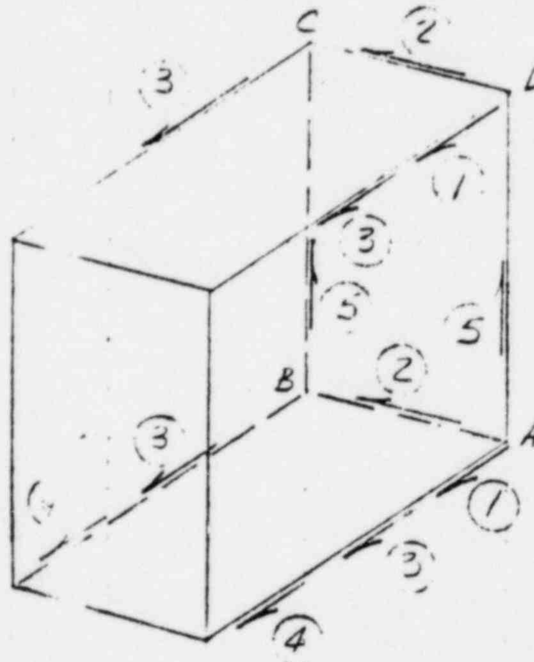
$S_s = \frac{P}{2tl}$ REFER TO FIG. 2.0 [illegible]

$l = 16.0 IN$

$S_s = \frac{[illegible]}{2(1)(16)}$

$S_s =$ [illegible] LB/IN^2 (C)

A FREE BODY ISOMETRIC DIAGRAM OF THE TIE-DOWN DEVICE SHOWS THE FOLLOWING STRESSES



TOTAL STRESSES

(1) 12,500 LB/IN²
(2) 6,500 LB/IN²
(3) [illegible],300 LB/IN²
(4) 11,240 LB/IN²
(5) 1,080 LB/IN²

FIGURE 3

A UNIT CUBE AT THE POINT A*, THE POINT OF HIGHEST STRESS, SHOWS THE TOTAL STRESSES AND THEIR DIRECTIONS.

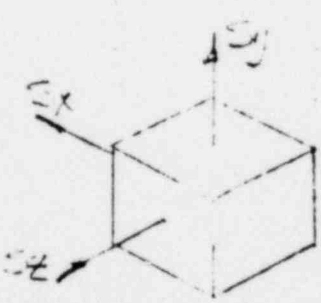


FIGURE 4

* SEE FIGURES 1 AND 3.

THE STRESSES FROM FIGURE 3 ARE:

S_x = ② = 6,500 LB/IN^2

S_y = ⑤ = 7,080 LB/IN^2

S_z = ① + ③ + ④ 12,500 + 2,300 + 11,240

S_z = 26,040 LB/IN^2

THE CUBE IS LOADED WITH A NORMAL STRESS AND A SHEARING STRESS IN ONE PLANE AND A SHEARING STRESS ONLY IN A PLANE AT RIGHT ANGLES TO THE FIRST.

NORMAL STRESS = S_z
CO-SHEARING STRESS = S_y
OP SHEARING STRESS = S_x

THE RESULTING SHEARING STRESS IS

$S_x + S_y$ = 13,580 LB/IN^2

MAXIMUM AND MINIMUM PRINCIPAL STRESSES IN TIE DOWN DEVICE

$$S_1 = \frac{S_x}{2} + \left[\left(\frac{S_x}{2}\right)^2 + (S_s)^2\right]^{1/2}$$ (REF. SHIGLEY, MACHINE DESIGN, PG. 210).

S_x = 26,040 LB/IN²
S_s = 12,580 LB/IN²

$$S_1 = 13{,}020 + \left[(13{,}020)^2 + (12{,}580)^2\right]^{1/2}$$

$$= 13{,}020 + \left[169.2 \times 10^6 + 184.5 \times 10^6\right]^{1/2}$$

$$S_1 = 13{,}020 + 18{,}820$$

S_1 = 31,840 LB/IN²

$$S_2 = \frac{S_x}{2} - \left[\left(\frac{S_x}{2}\right)^2 + (S_s)^2\right]^{1/2}$$

13,020 − 18,820

S_2 = −5,800 LB/IN²

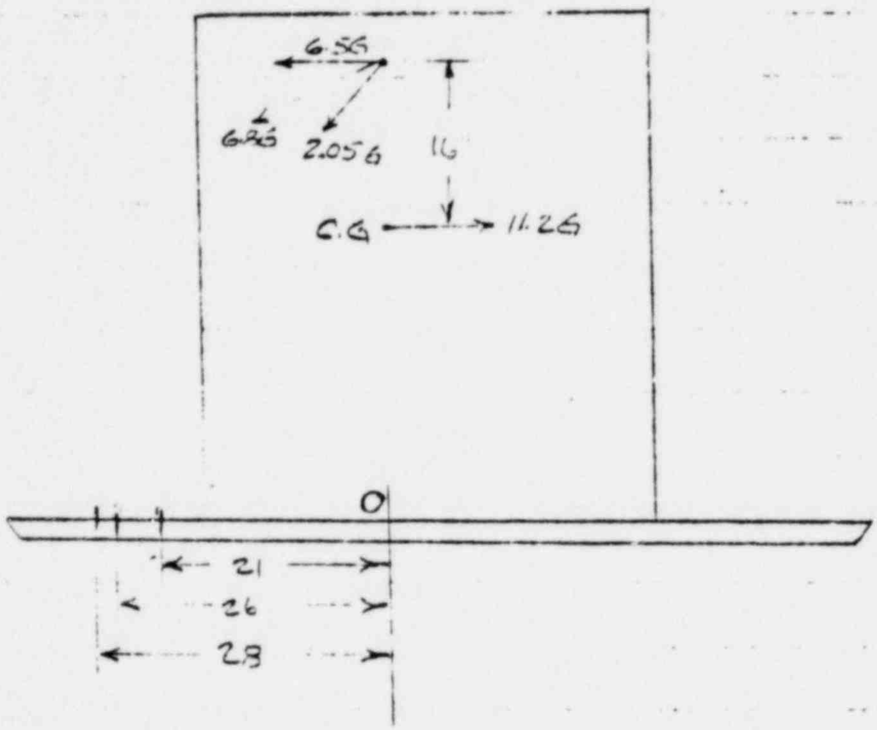
MIN. FACTOR OF SAFETY (WELD)

$$F.S. = \frac{42{,}000\,(.85)^*}{31{,}840}$$

F.S. = 1.14

* (.85 = WELD JOINT EFFICIENCY)

BOLT ANALYSIS 700 SERIES

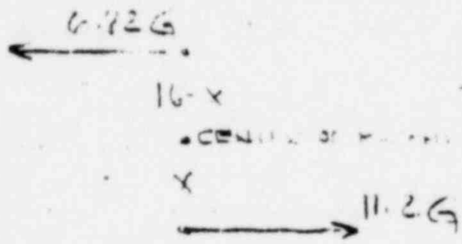


G = 35,000 LBS.

TO ANALYZE THE LOADINGS ON THE C.G. OF THE PACKAGE, THE 2G FORCE IS LEFT OUT BECAUSE IT WOULD NOT CONTRIBUTE TO THE MOMENT. THE RESULTANT VECTOR IS 11.2G. THE DIRECTION IS SHOWN TO THE RIGHT BECAUSE IN THIS DIRECTION IT WILL GIVE THE MAXIMUM COUPLE WHEN COMBINED WITH LOADING ON EARS. FOR WORST CASE CONDITION IT CAN BE ASSUMED THAT THE RESULTANT 6.8G FORCE ON THE EARS ACTS PARALLEL TO 11.2G FORCE. THIS WILL GIVE THE MAXIMUM COUPLE. THIS LOADING DIRECTION ALSO ELIMINATES 2 BOLTS FROM STRESS EQUATIONS

IF PALLET IS FIXED THEN ALL OF FORCE WILL BE TRANSMITTED BY THE BOLTS

THE RESULTING MOMENT CAUSED BY THIS FORCE COUPLE CAN BE CALCULATED FROM THE DATA IN FIG #1



LET X BE THE DISTANCE FROM 11.2G FORCE TO CENTER OF MOMENT, THEN DISTANCE FROM 6.82G FORCE TO CENTER IS 16-X X EQUALS

$$\frac{11.2}{(16-x)} = \frac{6.8}{x}$$

$$11.2x = 109 - 6.8x$$

$$18x = 109$$

$$x = 6.05 \text{ in}$$

MOMENT CAUSED BY THIS COUPLE IS TWICE ONE FORCE TIMES ITS DISTANCE FROM CENTER

$$M = 2(11.2)6.05\,G = 135.4G$$

SINCE PALLET IS FIXED THE PACKAGE SEES THE SAME MOMENT OVER ITS FULL LENGTH

THEREFORE THE RESISTING MOMENT IS 135.4G
SUMMING MOMENTS (RECALL THERE ARE 11 - 1 IN BOLTS)

$$\Sigma M_o = 135.4G - 2(2)F(21) + 2(2)\left(\frac{26}{21}\right)F(26) + 3\left(\frac{28}{21}\right)F(28)$$ *

135.4G = 84F + 128F + 112 F
G = 35,000
F = 14,600 lbs   F = $\frac{28}{21}$(14,600) 19,500 - load [illegible]

TENSILE STRESS

A = 0.606 IN

$$S = \frac{P}{A} = \frac{19,500}{0.606} = 32,100 psi$$

THE SHEAR FORCE CAN NOW BE DETERMINED
USING $\Sigma F_x = 0$

11.2 - 6.82 = 4.38G lbs SHEAR FORCE

THE AREA SEEING SHEAR FORCE IS

A = 11(.606) = 6.66 IN^2

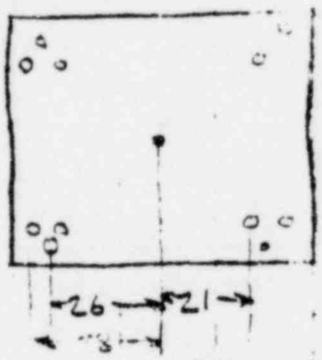
$$S = \frac{P}{A} = \frac{4.38(35000)}{6.66} = 23,800 \text{ p.s.i.}$$

* SEE PAGE 21-A

MOMENT EXPLANATION

$$\Sigma M_o = 155.4\,G = 2(2)F(21) + 2(2)\left(\frac{26}{21}\right)F(26) - 3\left(\frac{2}{2}\right)F(28)$$

IN THIS EQUATION REFER TO FOLLOWING FIGURE



① FIRST TERM $2(2)F(21)$
A B C D

C FORCE ON ONE BOLT AT 21"
D 21 = DISTANCE TO BOLT WITH FORCE F
B NO. OF BOLTS AT 21 INCHES
A NO. OF SIDES WITH B NO. BOLTS AT DIST. D

② SECOND TERM $2(2)\left(\frac{26}{21}\right)F(26)$
A B C D E

A SAME AS IN ① A
B SAME AS IN ① B
C FORCE RATIO FOR BOLTS AT 26 IN
F FORCE ON BOLT AT 21 IN
E MOMENT ARM FOR FORCE IN A B C D

③ THIRD TERM SEE #2

THE STRESS IN THE BOLTS IN COMPRESSION IS NOT CALCULATED BECAUSE SOME COMPRESSIVE FORCE IS TAKEN BY THE FLANGES EVEN IN THE WORST CASE CONDITION THE STRESS WILL BE NO GREATER THAN FOR THOSE IN TENSION

THE MAXIMUM COMPRESSIVE STRESS IS CALCULATED AS FOLLOWS,

$$S_{MAX} = \frac{S_x + S_y}{2} \pm \sqrt{\left(\frac{S_x - S_y}{2}\right)^2 + S_{xy}^2}$$

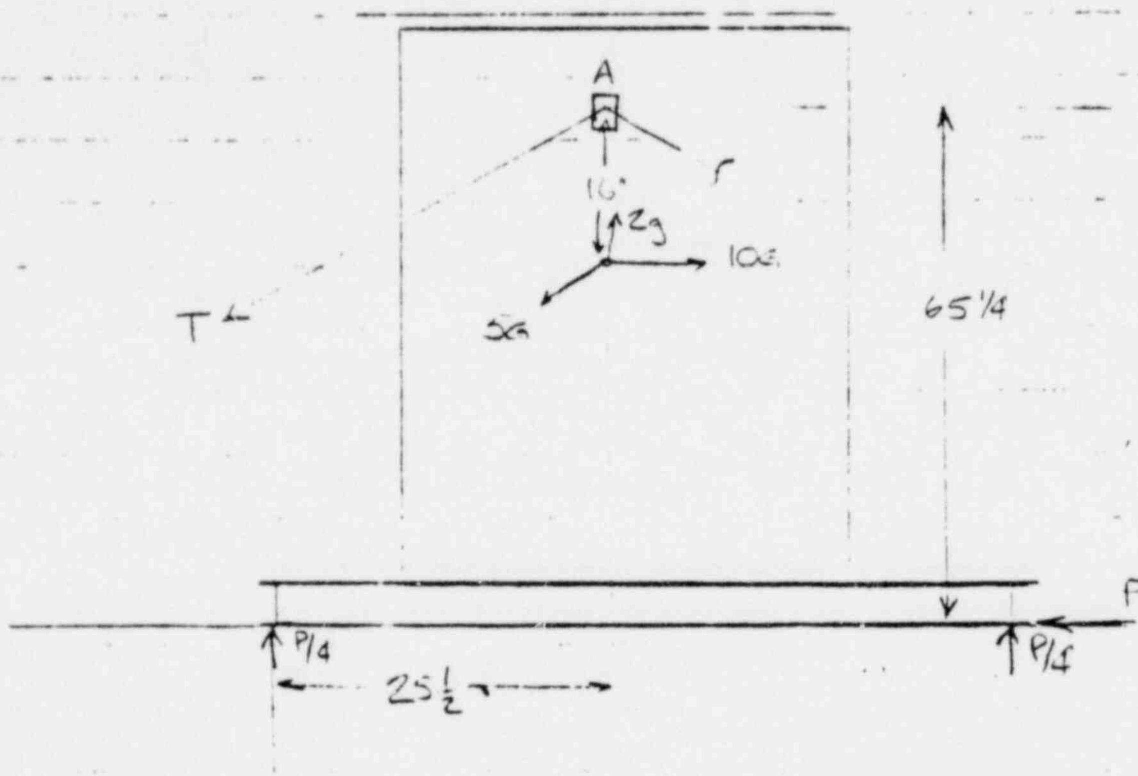
PAGE 330 STRENGTH OF MATERIALS by Singer

$$S = \frac{32,100}{2} + \sqrt{16,050^2 + 23,800^2}$$

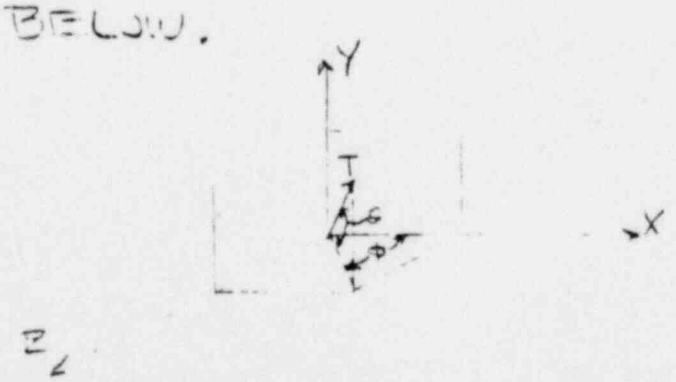
$$S = 16,050 + 28,700$$

$$S = 44,750 \text{ psi}$$ — MAX STRESS IN HOLD DOWN BOLTS 700 SERIES

700 SERIES PALLET LOADING



THE FORCES ON THE PACKAGE ARE AS SHOWN. THE CABLE TENSION SHOWN IS 3 DIMENSIONAL.* θ IS THE ANGLE T MAKES WITH THE HORIZONTAL PLANE AND ϕ IS ANGLE $T\cos\theta$ MAKES WITH X-AXIS AS SHOWN BELOW.



* (SEE PAGE 5, CABLE ANALYSIS)

$\theta = 47^\circ \quad \phi = 14^\circ$

$\Sigma F_x = 0$

EQ ① $F = (T\sin\theta - 2G)\mu$

FROM 3 DIMENSIONAL ANALYSIS OF FIG #2

$T = (11.2G - F)/\cos\theta\cos\phi$

$T = [11.2G - (T\sin\theta - 2G)\mu]/\cos\theta\cos\phi$

$T = (11.2G + 1.48G - 0.74(.71)T)/0.665$

$T = \frac{12.68G}{0.665} - \frac{0.525}{0.665}T$

$1.79T = 19G$

$T = 10.6G$

SUBSTITUTING INTO EQU. ①

$F = (10.6G \sin 47^\circ - 2G)0.74$

$F = 5.77G - 1.48G$

$F = 4.29G = 150,000 \text{ lbs}$

IF THE CABLE BREAKS OR STRETCHES A GREAT DEAL, THE PACKAGE WILL TIP. TO FIND THE P* FORCE WHICH WILL BE ACTING ON ONE EDGE USE $\Sigma M = 0$

$$11.2G(1.6) - F(65\tfrac{1}{4}) - P(25.5) = 0$$

$$179G = 65.25(150,000) + 25.5P$$

$$179G = 9,800,000 + 25.5P \qquad G = 35,000 \text{ LBS.}$$

P = 137,000 lbs ← DISTRIBUTED EVENLY ACROSS BASE OF 1 I-BEAM. THIS LOADING WILL NOT YIELD THE I-BEAM!

* (SEE PAGE 23)

IF THE CABLE BREAKS OR STRETCHES A GREAT DEAL, THE PACKAGE WILL TIP. TO FIND THE P* FORCE WHICH WILL BE ACTING ON ONE EDGE USE $\Sigma M = 0$

$$11.2G(16) - F(65\tfrac{1}{4}) - P(25.5) = 0$$

$$1796 = 65.25\,(150,000) + 25.5P$$

$$1796 = 9,800,000 + 25.5P \qquad G = 35,000 \text{ LBS.}$$

P = 137,000 lbs ← DISTRIBUTED EVENLY ACROSS BASE OF 1 I-BEAM. THIS LOADING WILL NOT YIELD THE I-BEAM!

* (SEE PAGE 23)