APPLICATION FOR APPROVAL OF A CONTAINER

FOR TRANSPORTATION OF 600,000 CURIES

OF ENCAPSULATED ^{60}Co

June, 1967

NEUTRON PRODUCTS, INC.

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Encapsulated ^{60}Co pins will be shipped from the Big Rock Point Reactor (BRP) facility in Charlevoix, Michigan, to other licensed facilities by utilizing equipment and personnel under full Neutron Products, Inc., control. All aspects of the shipment will be under the general supervision of a Neutron Products representative.

A cask, trailer, and tractor specifically designed for these shipments will be provided by Neutron Products. The cask will accomodate 600,000 Ci of ^{60}Co and has been designed to meet all the requirements specified in 10 CFR 71 for shipment of a large quantity of radioactive material. This equipment is described in other sections of this document. A typical shipment will consist of the following sequence of events.

The cask and trailer will arrive at Big Rock Point Reactor and the empty cask will be unloaded from the trailer and transferred to the fuel storage pool area. The tractor and trailer will proceed to a garage for preventative maintenance and repair, if required. The cask head bolts, cask head, pressure gauge, and pressure relief valve will be removed and the cask will be lowered to the bottom of the pool.

The irradiated ^{60}Co pins are removed from one fuel element at a time and placed in a storage rack on the pool wall. After all 60 of the ^{60}Co pins have been removed from the fuel elements, they are placed, one at a

time, in a radiation scanning device to determine their individual activities. The actual unloading of the ^{60}Co pins from the fuel elements and subsequent cask loading be performed in accordance with the shipping requirements established by Neutron Products Inc., and in accordance with existing Big Rock Point operating procedures.

After the cask has been completely loaded, the cask lid is then lowered into position on the cask on the bottom of the pool. The overhead crane is used to raise the cask out of the water. As the cask is raised out of the water, radiation dose rate measurements from all surfaces of the cask are made by Big Rock Point Health Physics personnel. With the cask in the suspended position over the pool, flushing water lines are connected to the cask. The flushing water inlet and outlet lines are connected to the bottom and top of the cask, respectively, by means of quick disconnects. Demineralized water is flushed through the cask and sampled for activity content. Flushing continues until the activity level of the water is at an acceptable level as determined by sampling and analyses. At the same time the cask is flushed internally, the outside surface of the cask is cleaned with steam to remove residual external contamination. When the internal flushing water has reached an acceptable level, the flushing water inlet is disconnected so as to permit the internal surfaces of the cask to air dry. After air drying, the cask is purged with helium.

The cask is then lowered onto the decontamination pad adjacent to the pool. Smear surveys of the external surfaces of the cask are made by BRP Health Physics personnel to insure that no significant contamination is present. Dose rate measurements are again taken. If the internal and external contamination levels are acceptable, the cask lid is bolted to the cask. During the interim between removal of the cask from the

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and loading the cask on the trailer, the internal temperature of the cask is monitored by means of thermocouples which are an integral part of the cask. The temperature at the surface of the ^{60}Co pin zircaloy cladding will be substantially below 580^{o}F, which is its normal operating temperature while in the BRP core. The cask will be allowed to come to the thermal equilibrium before the cask is shipped off-site.

A qualified driver, along with an NPI escort will ride in the tractor which is radiation monitored and each individual will be provided personnel radiation monitoring devices. Both the driver and the escort will have been trained in the fundamentals of radiological control and will have detailed instructions as to the action they have to take in any conceivable emergency situation. The pre-determined shipment route will avoid populated areas, and in general, will employ routes through rural areas. Routine inspections of the cask at periodic intervals will include radiation, temperature and pressure measurements in addition to inspection of the cask, cask tie down devices and trailer for possible mechanical failures. The shipments will be made in compliance with all applicable AEC and ICC regulations.

Upon arrival at its destination, the cask will be surveyed to insure that it meets the criteria for loaded cask acceptance. After receipt of the cask, the cask will be transferred to the pool for unloading. Prior to lowering the cask into the pool, the head bolts will be loosened and the cask vented. As the cask is lowered into the pool, lines will be connected to the top and bottom of the cask by means of the quick disconnects. The cask will be gradually cooled to prevent thermal shocking by incrementally lowering the cask into the canal pool. Any steam generated in the cask during the cooling process as previously stated, will

be vented underwater into the pool in order to avoid an airborne contamination problem. After the cask has cooled sufficiently, it will be lowered to the bottom of the pool and the head removed.

Approximately ten ^{60}Co pins will be removed from the cask and placed in a special rack on the wall of the pool. An open top tank will be placed around the ten ^{60}Co pins located in the rack. The purpose of the tank is to provide a water environment, separate from the canal water, while the pins are in the pool in the unlikely event that the encapsulation integrity of one or more ^{60}Co has been violated. The water inside the tank will be continuously recirculated through a filter by means of a small auxiliary pump. The filter will be monitored periodically to determine whether or not activity is building up in the system.

In any event, shipments will be made only to duly authorized licensees and in compliance with all applicable AEC and ICC regulations.

II. DESCRIPTION OF EQUIPMENT

A. CASK AND ASSOCIATED EQUIPMENT

The equipment used for transporting the ^{60}Co consists of three units:

1. Cask
2. Trailer
3. Shock Protection Frame

The trailer serves simultaneously as a shipping skid and as part of the tie down device designed for increased stability of the whole unit during transportation.

1. Cask

The cask, which is graphically described in O.G. Kelley prints number 67-0442-1, 67-0442-2, 67-0442-3, and 67-0442-4, has a gross weight of 30,000 pounds

and is Model No. 67-0442. The cask is a right circular cylinder closed at one end and haying the overall dimensions of 113.75 in length by 37.75 in. in outside diameter (including cooling fins). There is a 5.0 in. O.D. x 4.5 in. I.D. type 304 stainless steel inner cavity approximately 74.25 in. in length. The sides are shielded by approximately 8.9 in. of lead, which in turn is surrounded by the outside wall of the cask, the latter being an ASTM A7 carbon steel vessel approximately 7/8 in. thick. The top and bottom of the cask are shielded with approximately 10.6 in. and 9 in. of lead, respectively.

The inner cavity is surrounded by sixty 3/4 in. O.D. and forty-eight 1/2 in. O.D., type 304 stainless steel tubes equally spaced on circles of 3 in., 3.75 in., 4.5 in., 5.25., and 6 in., radii from the center of the cask. These tubes are open at both ends and are approximately 74.25 in. long. The tubes are positioned and supported by four 15 in. diameter tube sheets. The spaces between the tubes are filled with lead bonded to the stainless steel tubes which serve as receptacles for the ^{60}Co pins. Expansion voids are provided at both ends of the cask.

The cask cover, which is also lead clad with ASTM A7 carbon steel, is attached to the top of the cask by means

of a bolted closure, consisting of two matched flanges sealed with an "O" ring (Drawing 67-0442-4). When closed and bolted, the cask is designed to operate at 45 psig internal pressure and is built to withstand 75 psig test pressure. The cask cover is provided with a 0.5 in. expansion void. The pressurized unit will meet the requirements of the 1965 ASME Boiler Code, Section VIII, including latest addenda. The cask is lifted by means of trunions located 180° apart on the cask wall, and the cover is lifted by means of a removeable lifting lug located at its top. The lifting lug will be bolted to the lid only during cask loading and unloading. At all other times, it will be left off to prevent the entire cask from being lifted by the lug only. The cask proper rests in a horizontal position on the 0.5 in. thick steel pad welded to both ends of the cask which not only serves as a support for the cask but also as a tie down for the cask when it is on the trailer. Twenty-seven equally spaced cooling fins each 0.50 in. thich x 4.0 in. deep are welded to the outside shell of the cask.

There are ten pipe penetrations into the cask. Two of these, located at the bottom and top of the cask, are used to flush, dry and purge the cask internals. A stainless steel relief valve in series with a 10 to 13 micron absolute filter is connected to the other bottom penetration by means of a quick disconnect for overpressure protection. Another line located at the top of the cask leads

to the cask cavity plenum and is connected to a pressure gauge by means of a quick disconnect. The relief valve is designed to open at 45 psig and the removeable pressure gauge enables the internal pressure to be monitored directly. Six thermocouple wells are provided for monitoring the surface temperature of selected 0.75 and 0.50 in. stainless steel tubes.

The cask is sectioned approximately 53.9 in. from the bottom by means of matched bolted flanges sealed with an "O" ring (Drawing 67-0442-3). The purpose for sectioning the cask in this manner is to permit the smaller cask thus formed to be used for the transportation of shorter length (<75 in. long) ^{60}Co pins. The normal transportation mode, however, will utilize the large cask. During transportation of either cask, selected bolts connecting these flanges are provided with wire safety seals. A separate cask cover as described in O. G. Print Number 67-0442-4, is provided for use with the smaller cask. This cover is also provided with a 0.5 in. expansion void.

The yoke for lifting the cask and the cask trunions are described in Drawing 67-0442-5.

Summaries of the thermal, pressure and structural considerations in the design of the cask are given in Appendix A of this document.

2. Trailer

The ^{60}Co cask will be transported on a modified depressed platform, heavy duty trailer originally designed for the trans-

portation of heavy construction equipment (Drawing 67-0442-6). The trailer is of heavy steel underframe construction having a depressed flat bed center section intended to lower the center of gravity of the load and thereby increase the stability of the system. The overall length of the trailer is 25 ft. - 1-1/2 in. This size and load placement is in compliance with all state size and weight distribution restrictions. The power unit to perform the transportation will be a lightweight, gasoline powered, newly reconditioned and overhauled 1960 International tractor, Model 222.

The trailer is also equipped with an aluminum cage which surrounds the cask and is fabricated from expanded metal supported by structural extrusions bolted to the trailer and trailer receptacle. The cage (see Drawing 67-0442-6) is covered with a roof of corrugated aluminum. The cage is intended to prevent persons from coming into contact with the thermally hot surfaces when the cask is on the trailer.

3. <u>Shock Frame</u>

The shock protection frame (see Drawing 67-0442-1) is the protective structure surrounding the cask to assure that in the event of an accident the impact forces on the cask proper are reduced to the point where the cask wall can absorb them without causing penetration of the cask shielding, dislocation of the cask cover, or separation of the cask from the trailer.

The shock frame consists of two 0.5 in. thick steel plates welded to the bottom and end of the cask at each end of the cask. The shock frame also serves as a tie-down to the trailer. The frame is bolted to the trailer cask receptacle and the trailer frame as shown in Drawing 67-0442-6. The trailer cask receptacle consists of four vertical I beams which are supported and braced by additional I beams. One cask receptacle on the trailer is also adjustable to accommodate the smaller cask previously described.

The structural analysis of this tie-down device is presented in Appendix I of this document.

4. Miscellaneous

Equipment will be provided for the use of the driver and the escort in determining the condition of the vehicle and cargo, making minor repairs and adjustments, and coping with emergency conditions.

Inspection equipment, in addition to that already described, and that which is required under Interstate Commerce Commission regulations, will include temperature and pressure gauges and instrumentation for determining the condition of the cask, as well as receptacles for film badges which will monitor the radiation levels in the tractor cab. Portable instrumentation including radiation survey instruments, will be provided as required for performing the prescribed tests and inspections.

The vehicle will carry emergency radiation warning signs and equipment as well as the standard flares and markers required by the ICC.

III. SAFEGUARDS AND DESIGN CONSIDERATIONS

A. DESCRIPTION OF ^{60}Co CAPSULES

NPI ^{60}Co sources are available in two basic types, hollow and solid sources. These sources are shown in Figure 1. All sources are singly encapsulated in type 304 stainless steel capsules having an outside diameter of 0.271 ± 0.0015 in., a nominal wall thickness of 0.010 in. and overall lengths of 5-3/8 in., 10 in., and 12 in. Each capsule has been sealed with a 1/8 in. plug by high integrity tungsten inert gas welding.

All targets have passed dye penetrant and x-ray inspections. In addition, the hollow targets, which are filled with helium to prevent oxidation of the cobalt metal, have passed helium mass spectrograph leak testing as described in Appendix II. The small void space at either end of the solid targets contains argon, and accordingly, the solid targets cannot be helium leak tested.

The central metallic cobalt core in the solid sources is in intimate physical contact with the inner stainless steel cladding and weighs 83.7, 69.5, and 35.7 grams per 12, 10 and 5-3/8 in. solid source, respectively. The tolerance in cobalt weights is ± 1.7 grams per source.

The cobalt in the hollow sources is in the form of a uniform pitch coil made from wires having diameters of 0.046 and 0.060 in. The nominal metallic cobalt weights are 35 ± 0.5 grams for the 12 inch hollow sources and 29 ± 0.5 grams for the ten inch sources.

The average source activity per 12 inch source will range between 500 and 1700 curies per source although higher activity sources may be prepared.

In order to provide a material environment compatible with the Big Rock Point reactor core the stainless steel clad ^{60}Co sources are encapsulated in a zircaloy tube having an O.D. of 0.344 in., a wall thickness of 0.031 in. and a length of 75 in. prior to insertion into the BRP fuel elements. Three loading arrangements for the ^{60}Co sources in the zircaloy tube are possible: five 12 inch sources and one 10 inch source; thirteen 5-3/8 inch sources; or seven 10 inch sources. The sources are held rigidly in position in the zircaloy tube by means of a spring inserted between the capsules and the zircaloy tube and plug. Each zircaloy tube is sealed with an end plug adaptable to a remote handling tool by means of high integrity tungsten inert gas welding.

With due regard for the protection afforded by the shipping cask and in view of the fact that the ^{60}Co is doubly encapsulated in stainless steel and zircaloy, release of ^{60}Co under the hypothetical accident conditions specified in Appendix B of 10 CFR 71 is not considered credible.

B. DECAY HEAT REMOVAL

The heat transfer criteria of Appendix A and Appendix B of 10 CFR 71 are met by the cask design. Under conditions of maximum ambient temperature (130^{o}F) in still air, the cask will dissipate the maximum decay heat of 9 kw to the inner cask wall, through the lead shielding, and to air through external cooling fins, even when assuming 30% of the gamma energy released from the most active

conceivable source to be absorbed by the source. Taking no credit for convection or conduction heat transfer from the source to the inner cask wall, the maximum temperature of the sources is calculated to be no greater than 580°F which is their normal operating temperature while in the BRP reactor. The calculation showing the heat transfer capability of the cask is presented in Appendix I of this document. Heat transfer calculations under hypothetical accident conditions are also presented in Appendix I and indicate that the specified thermal criteria are met.

C. STRUCTURAL INTEGRITY

Safeguards aspects of the cask structural design under normal conditions of transport and hypothetical accident conditions are verified by the calculations in Appendix I. It is, therefore, contended that the present design affords adequate structural integrity.

D. EXTERNAL RADIATION LEVELS

The regulations set forth in Order No. 70 to 49 CFR, Parts 71-79 require that the external gamma radiation will not exceed 200 milliroentgens per hour at any readily accessible surface; 10 milliroentgens per hour at six feet from the external surface of the vehicle; or, 2 milliroentgens per hour in any normally occupied position (tractor cap) in the vehicle. The shield design meets these criteria. As described in other sections of this document, radiation measurements prior to shipment and enroute will verify that the radiation levels of the cask are within specified limits.

The driver and escort who will accompany shipments will be shielded such that their constant occupancy of the tractor cab (approximately 8 ft. from the cask) will not subject them to doses

approaching the occupational radiation exposure limits specified by 10CFR20.

E. PRESSURE INTEGRITY

In order to provide adequate integrity with respect to containment of the pressurized helium, the cask has been designed according to ASME Boiler and Pressure Vessel Code, Section VIII, 1965 Edition including latest addenda. Appendix I of this document contains verification of conformance with Code requirements and standards for normal conditions of transport specified in Appendix A of 10CFR71. The maximum expected operating pressure of the cask is 45 psig and the designed pressure is 75 psig. A pressure relief valve will prevent the pressure from exceeding a pre-set value of 45 psig. The vessel will be acceptance tested by hydrostatic testing at 75 psig, and a full pressure hydrostatic test will be repeated approximately once per year thereafter. The pressure relief valve will also be tested every time a shipment is made.

IV. ACCEPTANCE TESTS

Prior to accepting the cask, NPI will determine and assure that the cask has been fabricated in accordance with the design approved by the Commission. Additional acceptance tests, as described below, will also be required.

A. HEAT REMOVAL TESTS

Prior to acceptance of the cask and its appurtenances from the vendor, proof tests simulating the heat input of the ^{60}Co pins will be performed to demonstrate that the heat removal capability of the cask is adequate to meet the design limitations.

B. PRESSURE TESTS

Prior to acceptance from the vendor, the cask must pass a 75 psig hydrostatic pressure test. This test will be repeated at regular intervals during use of the cask, at approximately twelve month intervals. Prior to each shipment, the cask will be pressure tested at not less than 40 psig but below 75 psig. The relief valve will be tested prior to each shipment.

V. OPERATIONS

A. CASK LOADING

Loading and unloading of the cask will be conducted under the direct supervision of NPI. These procedures will conform to the cask manufacturer's recommendations and the requirements of the facility license as it pertains to the handling of by-product materials. Identification of individual ^{60}Co pins transferred will be carefully checked and recorded prior to loading.

B. INSPECTION PRIOR TO SHIPMENT

After the cask is loaded and the cover is installed, it will be lifted out of the fuel storage pool, decontaminated and pressurized. The cask will then be loaded on the trailer and permitted to come to thermal equilibrium. During this time, pressure and temperature readings will be taken at regular intervals. Examination of the lid gasket will be made prior to each shipment, and whenever the cask is separated to allow use of the small sections the "O" ring gasket and surface will be examined.

External radiation levels will be measured by conventional survey meters to ascertain compliance with the limits established by 49 CFR, Parts 71-79. In the event that maximum permissible

limits are exceeded, the cask will be returned to the pool and the ^{60}Co loading altered as required. A final check of the cask external contamination levels will be made by conventional smear survey techniques. Any external surfaces showing significant contamination levels will be decontaminated as required.

The tractor, trailer and cask will be inspected for conformance with ICC regulations prior to departure from either site. If the cask contains ^{60}Co, the shipment will be placarded in compliance with ICC regulations.

C. ENROUTE INSPECTIONS

At periodic intervals enroute, the driver or escort will conduct a safety inspection of the vehicle and cask to determine their general condition. At the same time the inspector will observe and record in a permanent log the cask pressure and the temperature at various points. Radiation levels will also be measured and recorded. The inspector will also check the cask support structure for loose or missing bolts, and will tighten or replace such bolts before proceeding. These inspections will be conducted in accordance with consistent procedures and a written log will be maintained.

D. CASK UNLOADING

Cask unloading will be performed under the direct supervision of NPI.

E. RECORDS AND REPORTS

Pursuant to Section 71.62 of 10CFR71, NPI will maintain those records which are applicable to the shipment of ^{60}Co. A copy

of the records will accompany the shipment and a file copy will be maintained by NPI for at least two years after the records are generated. These records will include the results of pre and enroute shipment inspections. In addition, all records required by ICC regulations will be maintained by NPI.

Any instance in which there is substantial reduction in the effectiveness of the cask during use will be reported to the Division of Material Licensing, U. S. Atomic Energy Commission, Washington, D. C. within 30 days.

VI. EMERGENCY PROCEDURES

A. INSTRUCTIONS

The driver and escort will be properly trained and of sound judgement, and shall be provided with written instructions covering emergency procedures to be followed in the event of an accident or malfunction.

B. ACCIDENTS

In the event of a vehicular accident of any kind, the driver or escort will notify local civil authorities as quickly as possible. In the case of a major accident, or one in which damage to the cask is suspected, or in any case where there is suspicion or evidence of release of radioactive material, the driver or escort will notify the Manager of the nearest AEC Operations Office immediately. Either the driver or escort shall be in attendance and maintain security in the event of any accident. Such notification will also be given in the event of theft or loss of the material.

APPENDIX I

^{60}CO PACKAGE EVALUATION

COBALT 60 SHIPPING CONTAINER

NEUTRON PRODUCTS INCORPORATED

ANALYSIS
AND
COMPLIANCE
WITH
TITLE 10 CODE OF
FEDERAL REGULATIONS
10 CFR 71
AND
IAEA STANDARDS

By [signature]
George S. Scruton
Engineering Dept.

May 28, 1967

TITLE 10
CODE OF FEDERAL REGULATIONS
10CFR 71 and IAEA STANDARDS

Para 71.4 (f) Cobalt 60 is not a fissile material. Cobalt 60 is a Group III radionuclide per Appendix C. Since the amount of Cobalt 60 exceeds 200 curies, it is classified as a large quantity and therefore falls under the scope of these regulations.

Para 71.5 Does not apply since the material being shipped is not covered by the category defined by this Paragraph.

Para 71.6 Does not apply since the package contains a large quantity of licensed material.

Para 71.7 The contents of this Paragraph do not apply at this time since the design proposed is an entirely new container which has not been approved by the ICC.

Para 71.8 It is understood that all communications concerning this regulation are to be processed through AEC per this Paragraph.

Para 71.9 To be complied with.

Para 71.10 To be complied with

Para 71.11 There is a possibility that specific exemptions may be requested as permitted by this paragraph.

Para 71.12 Does not apply since the material being shipped is not special nuclear material.

Para 71.13 Since a new license must be issued, the contents of this paragraph are not applicable.

Para 71.21 (a) Package description per Paragraph 71.22 by O. G. Kelley & Company, Inc.

(b) Package evaluation per Paragraph 71.23 by O. G. Kelley & Company, Inc.

(c) Procedural controls per Paragraph 71.24 by Neutron Products, Inc.

Para 71.22 Description of Packaging

(a) Package (See O. G. Kelley & Company, Inc. Drawing 67-0442)

(1) Gross weight of package will not exceed 30,000 lbs.

(2) Model No. 67-0442

(3) See O. G. Kelley & Company, Inc. Drawing 67-0442

(i) See O. G. Kelley & Company, Inc. Drawing 67-0442

(ii) Not Applicable

(iii) See O. G. Kelley & Company, Inc. Drawing 67-0442

(iv) See O. G. Kelley & Company, Inc. Drawing 67-0442

(v) See O. G. Kelley & Company, Inc. Drawing 67-0442 and heat transfer calculations.

(4) No coolants are used and there are no receptacles for coolants.

(b) Contents of the Package

(1) Maximum of 600,000 curies of Cobalt 60.

(2) Does not apply

(3) Cobalt 60 is in a cylindrical metallic form. There will be shipped a maximum of (60) such cylinders either 0.344" dia. or 0.564" dia. (may be a combination of both with a maximum limit of 60 pieces) by 75" long. (Each cylinder is doubly encapsulated in a sealed Zircaloy tube and an interior sealed stainless steel tube.)

(5) Maximum weight of contents is 31.5 kilograms (14.3 lbs.)

(6) Maximum amount of decay heat is 9 K W.

Para 71.23 Package Evaluation

(a) See subpart (c) review

(b) Not applicable

(c) Not applicable

Para 71.24 Procedural Controls to be prepared by Neutron Products, Inc.

Para 71.25 Will be complied with

Para 71.31 Subpart (c) Packaging Standards

(a) Because of the material selected and the proposed method of construction there will be no significant chemical, galvanic or other reactions between packaging components or packaging components and the contents.

(b) Refer to O. G. Kelley & Company, Inc. Drawing 67-0442

(c) (1), (2), (3), and (4) See O. G. Kelley & Company, Inc. Drawing 67-0442 and calculations.

(d) (1), (2), and (3) See O. G. Kelley & Company, Inc. Drawing 67-0442 and calculations.

Para 71.32 (a) & (b) See calculations.

Para 71.33 This paragraph does not apply since no fissile materials are being shipped.

Para 71.34 (1) The ability of the package to withstand conditions likely to occur in normal transport will not, in this case, be determined by subjecting a sample package or scale model to a test, but by other assessment. Such assessment to be either a mathematical investigation of conditions specified in Paragraph 71.35 or by referring to previously approved design details.

(2) The effect on a package of conditions likely to occur in an accident shall be assessed mathematically.

(b) & (c) The controls proposed by Neutron Products under Paragraph 71.34 may permit the AEC to approve different conditions of transport and hypothetical accident conditions than those specified in Paragraph 71.35 and 71.36.

Para 71.35 (a) (1) Under normal conditions of transport as specified in Appendix A, there will be no release of radioactive material from the Containment Vessel.

(2) There will be no reduction in the effectiveness of the packaging on the shielding.

(3) The Cobalt 60 material being shipped will not release any gasses or vapors. The helium blanket gas could increase in pressure due to internal heat generation. Any increase in pressure will be decreased through the relief valve which is a part of the cask.

(4) There will be no radioactive contamination of the helium gas since the Cobalt 60 does not release any gas. The helium is used to prevent oxidization and provide an inert blanket during shipment and is not used as a coolant.

(5) Loss of the helium through the relief valve will not effect the cooling capability of the cask.

Para 71.35 (b) Not Applicable

Para 71.35 (c) Under normal conditions of transport as specified in Appendix A, the Containment Vessel will vent through a relief valve in series with a micron filter thus there will be no direct venting of helium gas to the atmosphere. Once the cask has stabilized insofar as heat transfer is concerned, shipment will be made. Only in remote instances could the helium gas increase in pressure to vent through the relief valve.

WT. OF CASK △

VOLUME OF LEAD

CYL $\frac{\pi}{4}(28^2 - 5^2)(80\frac{1}{2})$	48,000 IN^3
BOTT $\frac{\pi}{4}(28)^2 \times 9$	5544
END CYL $\frac{\pi}{4}(28^2 - 15^2)\,7\frac{7}{8}$	3470
PLUG $\frac{\pi}{4}(15)^2 \times 10$	1770
	58784

VOLUME OF TUBES

3/4 OD - 60 TUBES x 80½ x .443 = 2120 IN^3
1/2 OD - 48 TUBES x 80½ x .176 = 755
2875

	−2875
	55,907 IN^3

WT OF LEAD = 55707 x 0.41 = 22,900 LBS.

WT OF STEEL

2 - 28" - 150 LB FLGS @ 125	250 LBS
7/8" PL SHELL 36# (113.5 x [illegible])/144	2560
1" PL ENDS 2 x 40.8# $(28)^2 \frac{\pi}{4}$	345
1/2 PIPE [illegible] $\frac{\pi}{4}$ [illegible] $\frac{220}{144}$	1620
5/8 PL TUBE SHT $4\frac{\pi}{4}(\frac{15}{12})^2 \times 25.5$	1375
VALVES, [illegible] TUBES	30
LIFT BRACKET $4(22\#)\left(\frac{6\times10 - 3\times7}{144}\right)$	102
BOLTS	50
5" OD TUBE x 4" ID. 4.31# (7')	30
MISC	500
	6462 LBS

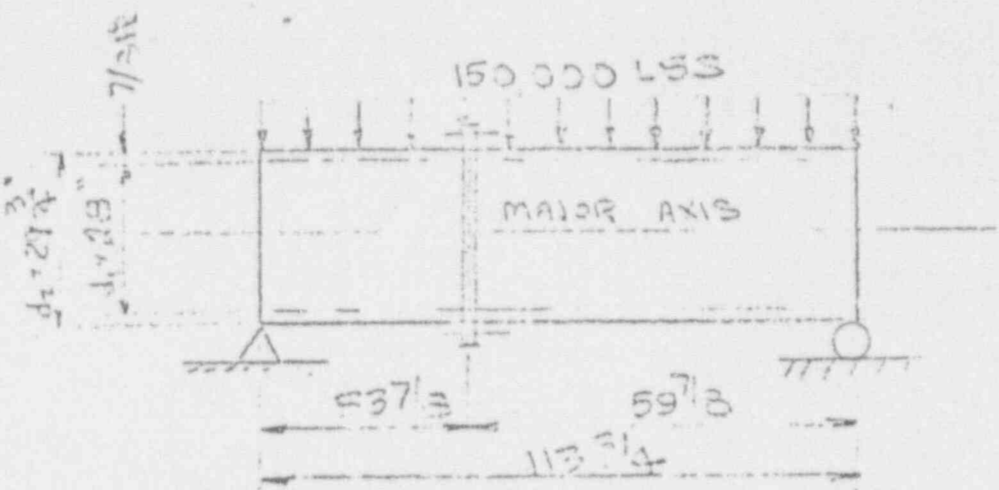
SHIPPING WT

LEAD	22,900
STEEL	6462
CONTENTS	150
	29,512

CALL 30,000 LBS

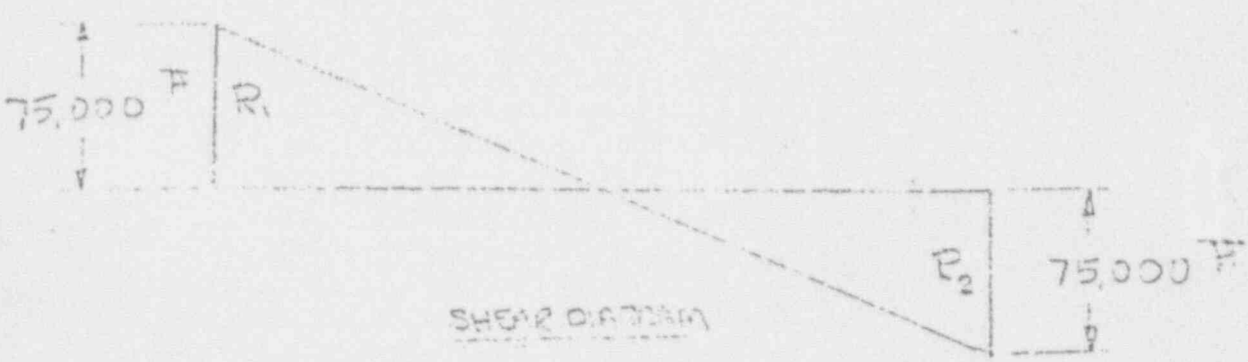
△1

PARA 71.32 (2)



CONSIDERED AS A SIMPLE BEAM

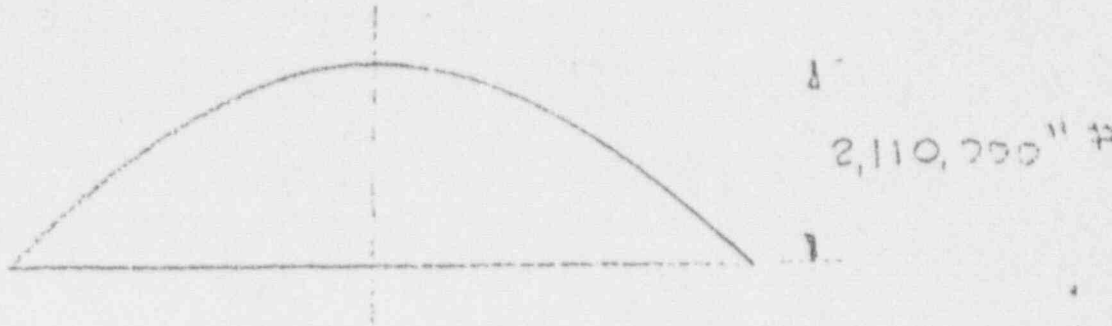
5 X FULLY LOADED WT = 5 X 30,000 LBS = 150,000 LBS



$$\frac{150,000}{113.75} = 1305\ \#/\text{IN}$$

$$R_1 = \frac{150,000}{2} = 75,000\ \text{LBS}$$

△1



MOMENT DIAGRAM

$$I_{SHELL} = \frac{\pi}{4}\frac{(d_2^4 - d_1^4)}{16} = 0.0491\left[(29.75)^4 - (28.0)^4\right]$$

$I = 4.91 \times 1720 = 8500''^4$ (CONSERVATIVE SINCE NO ALLOWANCE MADE FOR 4 1/2 ID TUBE OR 1/2" AND 3/4" TUBE BUNDLE, AND LEAD SHIELDING)

$$M_{max} = \frac{Wl^2}{8} = \frac{1305\,(113\tfrac{3}{4})^2}{8}$$

$$= 2,110,000 \text{ ''\#}$$

$$S = \frac{My}{I} = \frac{2,110,000\left(\frac{29.75}{2}\right)}{8500}$$

$S = 3700$ LBS/IN² < 33,000 LBS/IN²

(YIELD POINT OF A7 STEEL)

PARA 71.32 (b)

EXTERNAL PRESSURE ON CONTAINMENT VESSEL OF 25 LBS/IN² GAUGE.

PER ROARK 5TH EDITION "FORMULAS FOR STRESS & STRAIN"

P 503 CASE 1

ASSUME NON-ELASTIC FAILURE. DETERMINE EXTERNAL PRESSURE BASED ON EXCEEDING PROPORTIONAL LIMIT OF MATERIAL. IN ADDITION THE CONTAINMENT VESSEL IS TO BE [illegible] INTERNALLY

AT 75PSIG HYDROSTATICALLY (ASME CODE) △

$$\frac{p'R}{t} = 33,000 \text{ LBS/IN}^2 \text{ (YIELD POINT)}$$

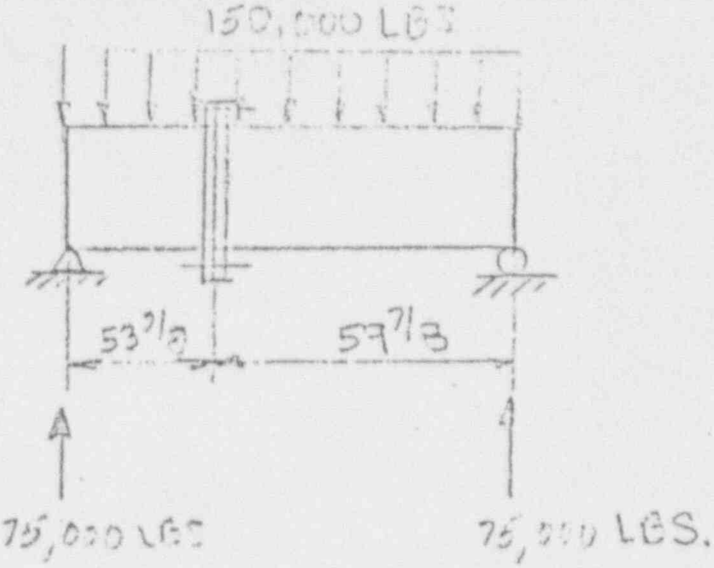
$$\frac{p' \times 14.875}{.875} = 33,000$$

$$p' = 1930 \text{ LBS/IN}^2 > 25 \text{ LBS/IN}^2$$

SATISFACTORY!

FURTHER PROOF OF ADEQUACY TO WITHSTAND 25 LBS/IN² EXTERNAL PRESSURE IS THE PRESSURE EXERTED ON THE CONTAINMENT VESSEL DURING LEAD POUR. A MINIMUM OF $\frac{720 \text{ LBS/FT}^3}{144 \text{ IN}^2/\text{FT}^2} \times 8$ FT (HT OF LEAD POUR) EQUALS 40 LBS/IN² IS APPLIED TO THE VESSEL. THE THERMAL SHOCK ALSO EXERTED IS FURTHER PROOF OF THE INTEGRITY OF THE WELDS

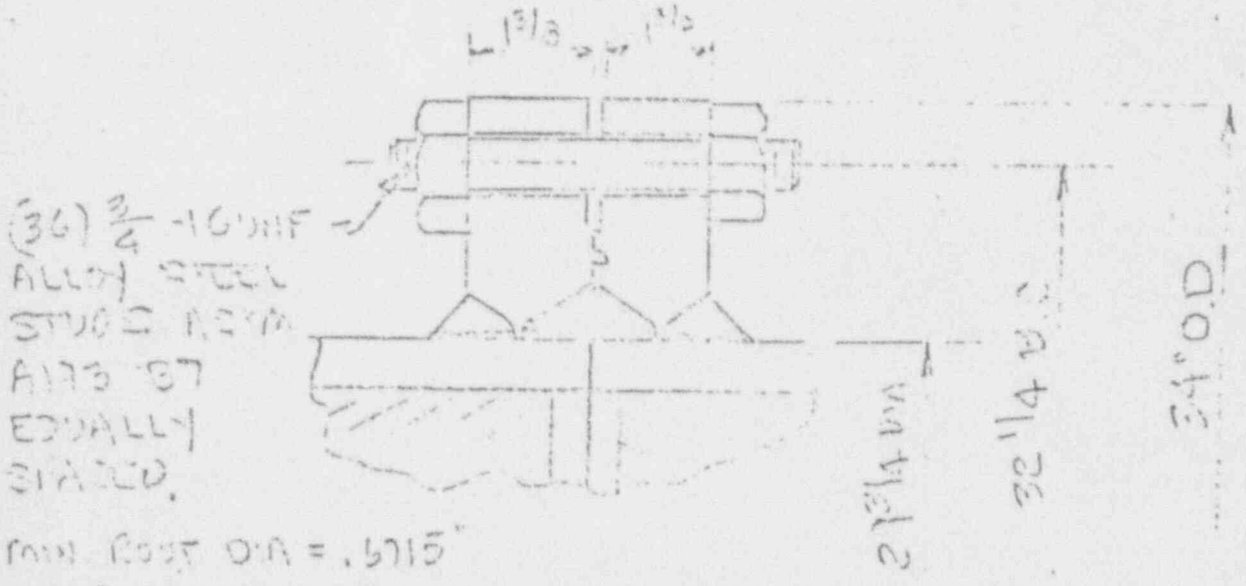
BOLT LOADING AT FLANGE FOR 5G CONDITION



MOMENT AT FLANGE = 75,000 X 53 7/8" $\left(1 - \frac{53\,7/8}{113\,3/4}\right)$

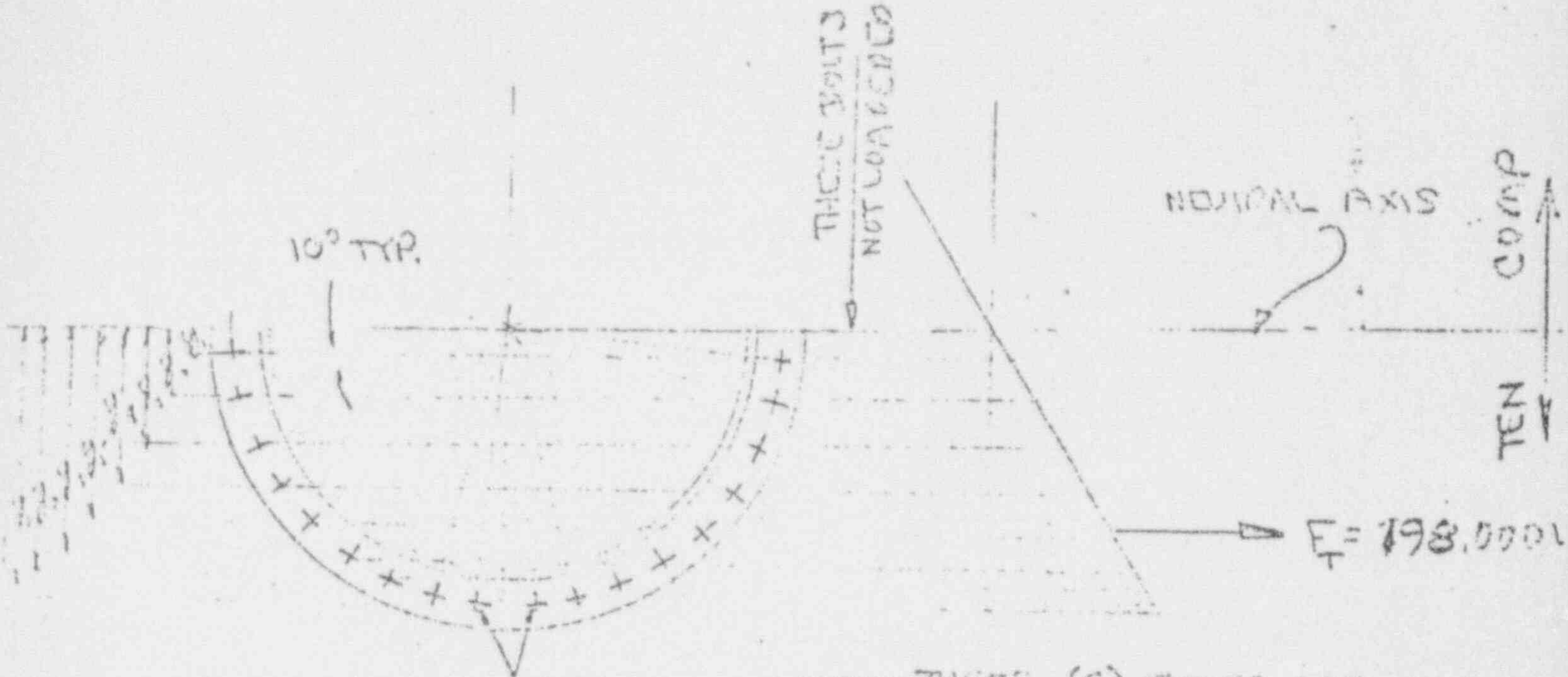
= 2.13 X 10^6 in

FLANGE CHARACTERISTICS



MIN. ROOT DIA = .6715"

$A = \frac{\pi}{4}(.6715)^2 = .353 \text{ IN}^2$



$y_1 = 16\frac{1}{8} \sin 5° = 16.13 \times .0872 = 1.41"$

$y_2 = 16\frac{1}{8} \sin 15° = 16.13 \times .259 = 4.18"$

$y_3 = 16\frac{1}{8} \sin 25° = 16.13 \times .423 = 6.81"$

$y_4 = 16\frac{1}{8} \sin 35° = 16.13 \times .574 = 9.25"$

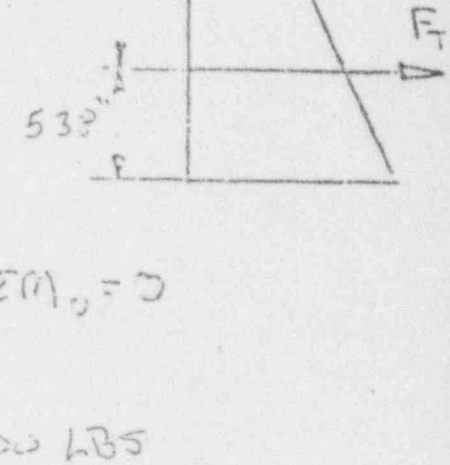
$y_5 = 16\frac{1}{8} \sin 45° = 16.13 \times .707 = 11.45"$

$y_6 = 16\frac{1}{8} \sin 55° = 16.13 \times .819 = 13.21"$

$y_7 = 16\frac{1}{8} \sin 65° = 16.13 \times .906 = 14.60"$

$y_8 = 16\frac{1}{8} \sin 75° = 16.13 \times .966 = 15.61"$

$y_9 = 16\frac{1}{8} \sin 85° = 16.13 \times .996 = 16.10"$

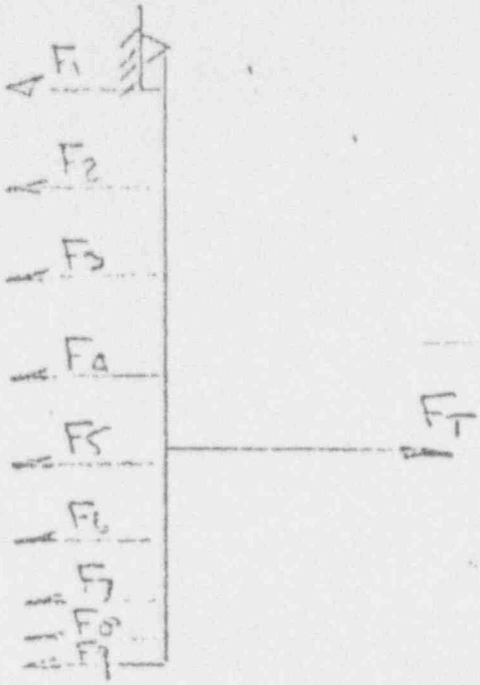


$\frac{2}{3} \times 16.13 = 10.75"$ $\Sigma M_0 = 0$

$\frac{1}{3} \times 16.13 = 5.38"$

$$F_T = \frac{M}{10.75} = \frac{2.13 \times 10^6}{10.75} = 198,000 \text{ LBS}$$

BOLT RESISTANCE



$\Sigma F = 0 \qquad F_T = F_1 + F_2 + \cdots F_9$

$198{,}000 = (0.088)F_9 + (0.259)F_9 + \cdots F_9$

$198{,}000 = 5.75 F_9$

$F_9 = 34{,}500$ LBS

F_9 IS THE TOTAL TENSILE LOAD IMPOSED ON TWO BOLTS (WORSE CONDITION)

$$S = \frac{34{,}500}{2 \text{ BOLTS} \times .353}$$

ROOT AREA OF 3/4 ST

$S = 48{,}900$ LBS/IN^2 < Y.P. OF A193 B7 OF 105,000 LBS/IN^2

$F_1 = \frac{y_1}{y_9} F_9 = \frac{1.41}{16.1} F_9 = 0.088 F_9$

$F_2 = \frac{4.18}{16.1} F_9 = 0.259 F_9$

$F_3 = \frac{6.91}{16.1} F_9 = 0.428 F_9$

$F_4 = \frac{9.35}{16.1} F_9 = 0.575 F_9$

$F_5 = \frac{11.45}{16.1} F_9 = 0.710 F_9$

$F_6 = \frac{13.21}{16.1} F_9 = 0.821 F_9$

$F_7 = \frac{14.6}{16.1} F_9 = 0.905 F_9$

$F_8 = \frac{15.61}{16.1} F_9 = 0.969 F_9$

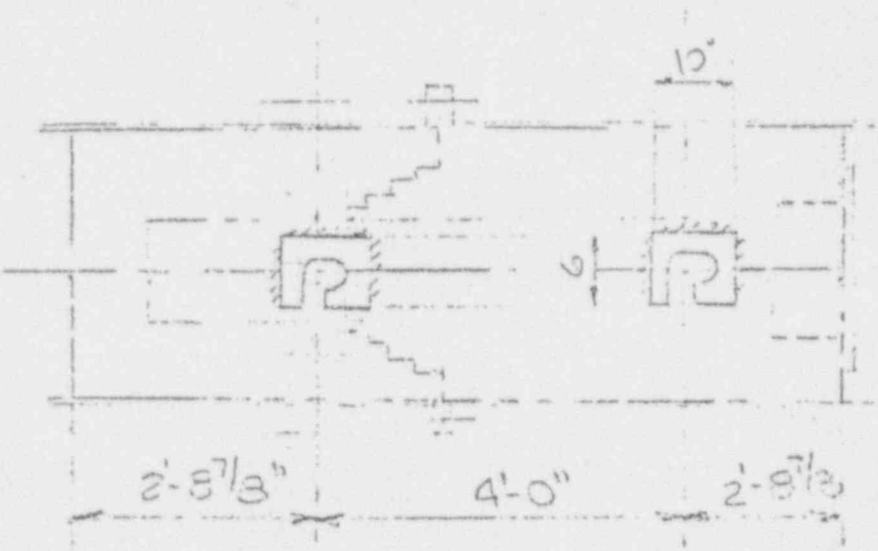
$F_9 = 1.00 F_9$

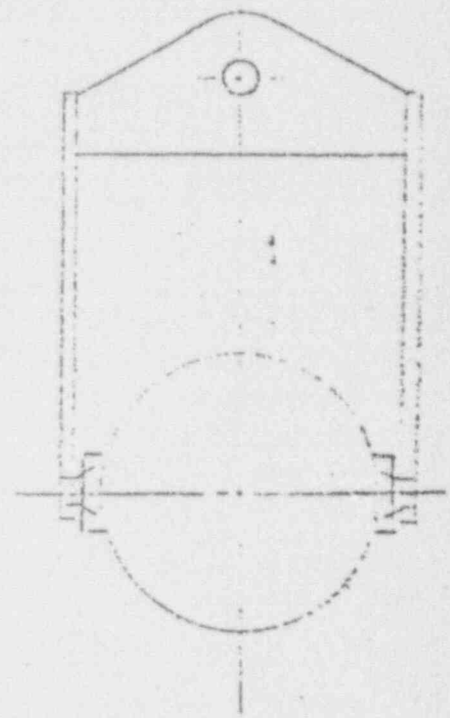
TOTAL $5.75 F_9$

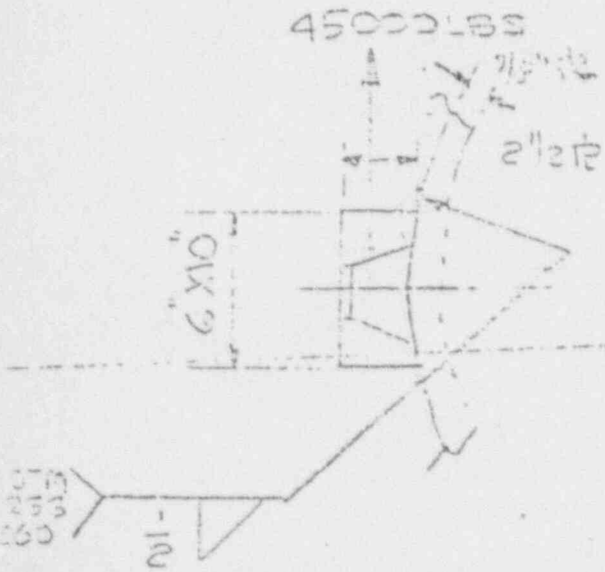
⚠ 1

PARA 71.31 (C)(1)

LIFTING DEVICE TO BE CAPABLE OF SUPPORTING 3 TIMES WT OF LOADED PACKAGE







LOAD FOR SET OF LIFT DEVICE $= \frac{30,000}{2} = 15,000$ LBS

$3 \times 15000 = 45,000$ LBS.

WELD AREA $= 0.707\left(\tfrac{1}{2}\right)[6+10+6]$

$= 7.77$ SQ.IN.

STRESS $= \frac{45,000}{7.77} = 5800$ #/□

5800 #/□ < SHEAR STRESS YP OF 16,000 #/□ (FOR WELD METAL)

STRENGTH OF WELD $= 33,000 \times 7.77 = 256,000$ LBS

STRENGTH OF CASK SHELL UNDER LIFT PAD TO RESIST PUNCTURE $= 33,000 \times .875\,(6+10)\times 2 = 925,000$ LBS

LIFT DEVICE WOULD FAIL <u>BEFORE</u> SHELL IS PENETRATED.

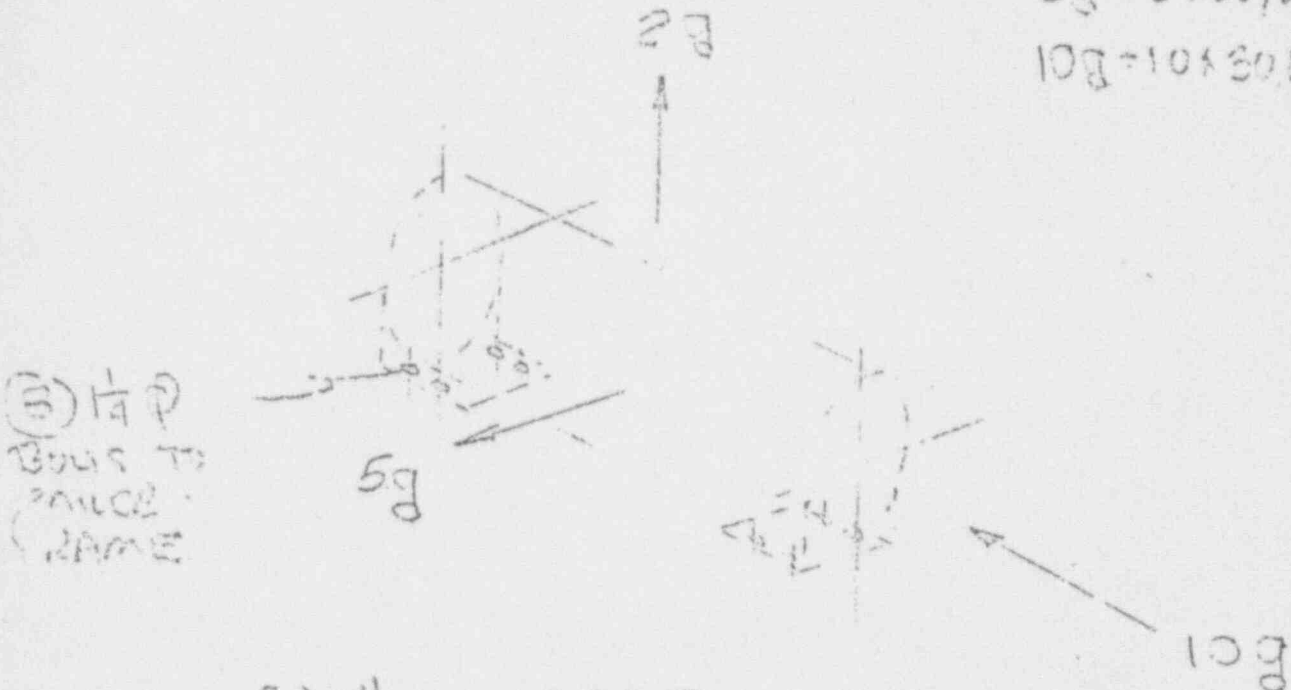
PARA 71.31 (d)

PACKAGE IS BOLTED TO TRAILER AS SHOWN ON OGK DWG 67-0442-6

2g = 2 × 30,000# = 60,000#

5g = 5 × 30,000# = 150,000#

10g = 10 × 30,000# = 300,000#



(8) 1¼ DIA A193 B7 BOLTS

ROOT AREA = 0.890 IN²

FOR 10g CONDITION $S_{BOLTS} = \dfrac{300,000}{8 \times .890}$

S_{BOLTS} = 41,900 LBS/IN² < 105,000 LBS/IN² Y.P OF A193 B7

SINCE SATISFACTORY FOR 10G, NO NEED TO EXAMINE LESSER LOADS OF 5G AND 2G

NO CREDIT TAKEN FOR ADDITIONAL BOLTING TO CRASH FRAME.

APPENDIX A 10 CFR 71

SURFACE TEMP OF CASK DURING NORMAL TRANSPOR

NORMAL CASK SURFACE AREA

$A_{cyl} \simeq 2.5\pi(8) = 20\pi = 63\ ft^2$ considering cylinder only

subtract finned contact area

$2.5\pi(27 \times \frac{1}{24}) = 8.85$, so normal $A = 54\ ft^2$

$A_f = 27 \times 2 \times \frac{1}{144}\left(\frac{\pi}{4}\right)(37.75^2 - 29.75^2)$

$= 54\pi(1430 - 890)\left(\frac{1}{576}\right) = 159\ ft^2$

fin efficiency = .92, so $A_{f_{eff}} = 146\ ft^2$

from DP-357, empirically, at $T_A = 75°F$, $T_S = 165°F$,

$h_c = 0.8$, $h_r = 1.3$

from Perry's Handbook, 3rd Edit, pg 475,

effect of Δt in range of interest is positive, but small, so neglect, and use $h_c = 0.8$

however, for $t_r = 130$ and same Δt and emissivity,

$h_r = 1.3\ (6.8^4 - 5.9^4) / (6.25^4 - 5.35^4)$

$= 1.3\ (960/710) = 1.76$

thus, for air temp of 130°F and surface temp of 2..

heat removal capability of cask by natural convection is

[illegible]

$$q = \left[54\ (2.56) + 146\ (0.8)\right] 90$$

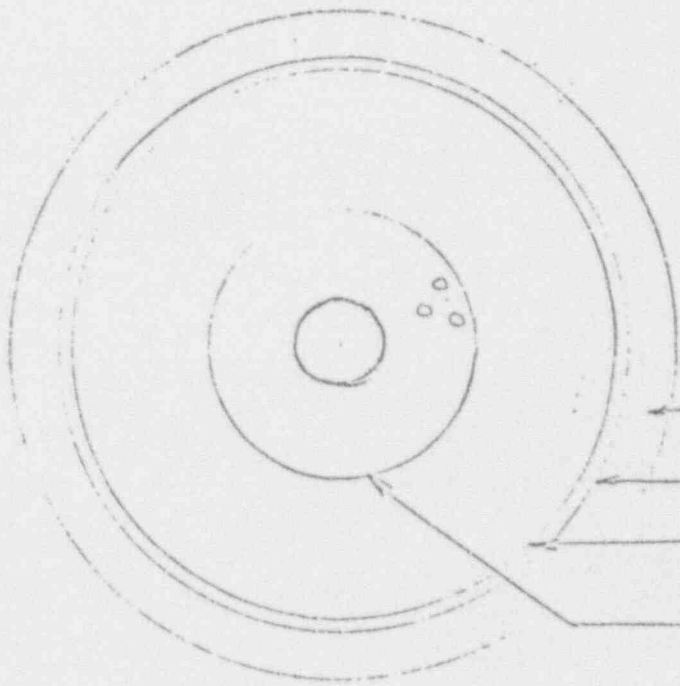
$$= 90\ (138 + 117) = 23{,}000\ BTU/hr.$$

for design load of 600,000 Ci, or 31,500 BTU/hr, neglecting increase in h_r,

$$\Delta t = \frac{31{,}500}{23{,}000}\ (90) = 123°F$$

$$T_s = 253°F$$

HEAT TRANSFER WITHIN CASK (ASSUME PERFECT BONDING)



$$T_{Pb\text{-}Fe} = 253 + \frac{31{,}500\ \Delta x}{A\ k_{stl.}}$$

$$= 253 + \frac{3.15 \times 10^4 \times 7/32}{63 \times 26} \sim 253 + 1.4 = 255°F$$

$$T_{Pb_{13''}} = 255 + \frac{31{,}500\ \Delta x}{A_{mean}\ k_{Pb}}$$

$$T_{Pb_{12''}} = 255 + \frac{3.15 \times 10^4 \, (7/3)}{18 \, \frac{A_{27} - A_{12}}{\ln \frac{A_{27}}{A_{12}}}} = 255 + \frac{1.17 \times 10^3}{\frac{59 - 25}{\ln 2.4}} = 255 + \frac{1.17 \times 10^3}{39}$$

$$= 285\,°F$$

Thus, the temperature of the lead heat sink into which heat from the sources must be passed is 285°F at the locus of the outer row of source tubes.

SOURCE TEMPERATURE

Calculation of source temperature is complex. In general except when numerous sources of low activity are to be shipped, the sources will be placed in the cask beginning with the outer row and working inward. The bulk of the energy emitted will be absorbed in the steel tubes and the surrounding lead, and in any event the sources will be placed in such a manner that fractional of self and mutual attenuation in the source tubes themselves is less than 30%.

The maximum activity contemplated, [illegible], is 3000 curies per foot; thus at 30% self attenuation, the maximum heat flux from source tube to tube wall would be 16 watts per foot;

$$q = \frac{16 \times 3.41 \, BTU/hr\text{-}watt}{\pi D_{in}} = \frac{54.5}{\pi \, .344/12} = 610 \, BTU/hr$$

Using the source pin area only (the zirc tubes are 0.344" in diameter) with emissivities of 0.4 for both the zirc and stainless,

the temperature of the zirc tube wall is calculated neglecting heat transfer by either conduction or convection. Thus, by radiation alone,

$$q = 0.173\,\epsilon \left[\left(\frac{T_2}{100}\right)^4 - \left(\frac{T_1}{100}\right)^4\right]$$

$$610 = 0.173(0.4)\left[\left(\frac{T_2}{100}\right)^4 - 7.45^4\right].$$

$$\left(\frac{T_2}{100}\right)^4 = \frac{610}{.069} + 3110$$

$$= 12{,}000$$

$$T_2 = 1040\,^\circ R$$

$$= 580\,^\circ F$$

Since the zirc clad experiences this temperature in the normal course of operation of the Big Rock Point reactor, and since the probable amount of Helium is so very small, and since the assumptions herein are conservative, the present analysis is deemed adequate pending the results of actual experience.

A summary of performance information under normal transport conditions required by 10CFR71 follows:

1. The surface temperature of the fully loaded cask for ambient air at 130°F is 253°F. Under these conditions it is calculated that, neglecting heat transfer by contact conduction and by conduction and convestion through helium, the maximum temperature of the most active sources contemplated will be no greater than that encountered in normal use during the course of exposure in the Big Rock Point Reactor. Thus on a conservative basis the cask has satisfactory heat transfer characteristics for disposal of the decay heat generated by its contents.

2. The cask is constructed of materials which will perform satisfactorily for their intended purpose at a temperature of -40°F.

3. The cask is designed for 50 psig per ASME Code Section VIII. Hydrostatic testing at 75 psig will be performed. Cask will therefore withstand 0.5 times standard atmospheric pressure.

4. Prior to being placed in service, the cask shall be transported over rough roads at speeds which will exceed those in normal transport. The cask will also be roughly handled during lifting and tie down operations. Examination of the cask shall be made following the vibration test.

5. Before being placed in service, the cask shall be wetted with a heavy spray of water for a minimum of 30 minutes. Entire cask except bottom shall be continuously wetted during the test. After testing the cask shall be examined.

6. Free drop within 2-1/2 hours of water spray test. Allow cask to fall vertically on end from a distance of 2 feet on a concrete surface (shop floor). Examine after this test.

7. Corner drop not required since:

   a) No wood is used in the cask construction;

   b) The cask weighs more than 10,000 pounds.

8. Penetration of any cask surface by a 1-1/4 inch diameter steel pin weighing 13 pounds dropped from a 4 foot height. This test will be performed on the cask after construction and the cask examined. It is to be noted that during fabrication greater loads which could cause puncture occur (i.e., crane hooks, sledge hammers, chipping guns).

9. Compression not required since cask weight exceed 10,000 pounds.

APPENDIX B — HYPOTHETICAL ACCIDENT CONDITIONS

Even with the aid of simplifying assumptions, the series of hypothetical accidents does not readily admit of mathematical analysis. Complicating all this further is the fact that the mode of shipment of this cask is as an integral part of a trailer, thus making the plausibility of either a clean end drop, a clean side drop, or a corner drop so remote as to be incredible. The end result of all this is a conviction that the assumptions are somewhat more important than the analyses. Nevertheless for the purpose of securing a license, we have sought to comply with the requirements for the drop and fire test performing an analysis of the modes which admit of credible analysis.

We believe that the most serious potential accident is an end drop of a fully loaded cask as a result of which the lead in the cask might shear away from the outer wall and the tube bundle in the center of the cask and fall onto the end plate, transmitting its load to the weld. We have analyzed for this hypothetical condition and found the lead to hold, although without much margin. In any event, although the lead might conceivably deform somewhat, the possibility of it breaking loose and becoming a missile within the cask did not prove to be credible.

In evaluating the fire hazard, we found that the lead melts, but not completely. We have no basis for assuming a cask integrity failure and have provided enough void space to limit the buildup of pressure due to the compression of air within the shielding space to a few hundred pounds per square inch, which is above the code rating of the cask but well within its design capability, even for complete melting.

In view of the fact that the cask is made an integral part of the trailer, and further, because the cask is surrounded by a substantial crash frame, also made an integral part of the trailer, we believe that the "package" to be analyzed for the sequence of events defining the hypothetical accident is the cask as an integral part of the trailer. However, the analysis of the consequences to this "package" is even more complex than the analysis of consequences to the cask alone; and in view of the fact that the cask alone appears to survive the accident without loss of integrity, we elected to spare ourselves the rather speculative exercise of analyzing what we consider to be the true "package."

△

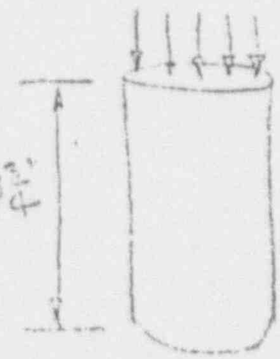
APPENDIX B

a) End Drop

30 FT. DROP ONTO A FLAT UNYIELDING SURFACE. ENERGY INVOLVED IS APPROXIMATELY A 60 G FORCE APPLIED FOR A MIN PERIOD OF 16 MILLISECONDS (CRITERIA FROM PROPOSED 10CFR72)

60 × WT OF CASK = 60 × 30,000 LBS = 1,800,000 LBS

a) End Impact



$S_c = \frac{Load}{Area} = \frac{1,800,000}{\frac{\pi}{4}[27.75^2 - 28^2]} = 62,700$ LBS/□"

$S_c = 29,700$ #/□" < 55,000 #/□" U.T.S OF A7 STL

ANALYSIS FOR COLUMN ACTION

RADIUS OF GYRATION $(K) = \frac{\sqrt{D_1^2 + D_2^2}}{4} = 10.2"$

RATIO OF SLENDERNESS $= \frac{l}{K} = \frac{113.75}{10.2} = 11.15$

SINCE 11.15 < 80 CONSIDER AS SHORT COLUMN

RANKINE'S (MODIFIED GORDON RANKINE) FORMULA

S_c = STRESS INDUCED ; F = AXIAL LOAD

S_e = ELASTIC LIMIT (YIELD POINT) OF MATERIAL

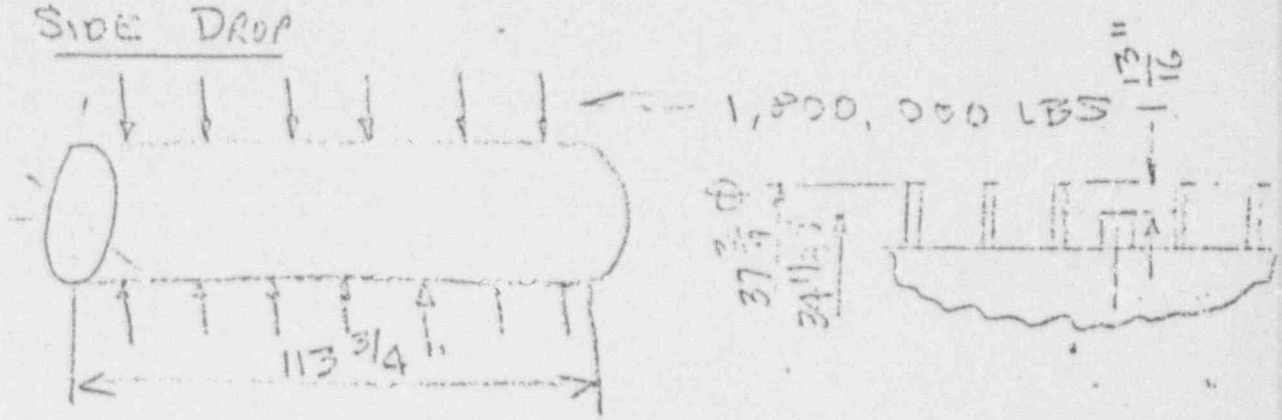
$\frac{l}{K}$ = RATIO OF SLENDERNESS ; A = AREA

n = [illegible] RATIO ; E = MODULUS OF ELASTICITY

$$S_c = \frac{F\left[1 + \left(\frac{l}{K}\right)^2 \frac{S_e}{n\pi^2 E}\right]}{A} = \frac{1,800,000\left[1 + (11.15)^2 \frac{30,000}{\pi^2 \times 1.30 \times [illegible]}\right]}{\frac{\pi}{4}\left[(27.75)^2 - (28.0)^2\right]}$$

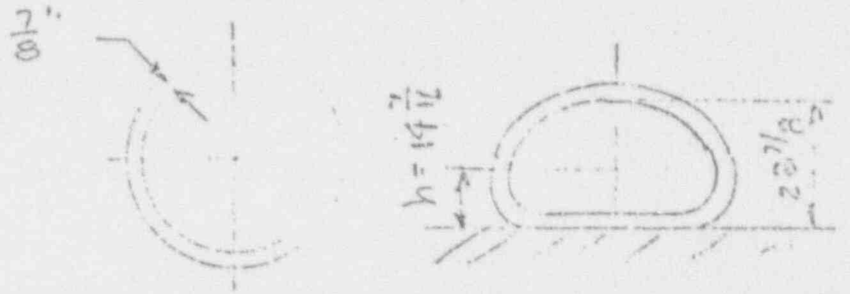
$S_c = 26,000$ #/□" < 55,000 #/□" UTS OF A7 STEEL

b) SIDE DROP



THE KINETIC ENERGY GENERATED BY THE 30 FT DROP IS ABSORBED BY YIELDING (DEFORMING) THE OUTER SHELL OF THE CASK. THE SHAPE ASSUMED WOULD BE THAT OF A SHELL OF CONSTANT STRENGTH. ENERGY ABSORBED WOULD BE THE RESULT OF STRETCHING THE RADIAL PERIPHERY OF THE SHELL. THE FINS ABSORB ENERGY THEREBY PROTECT THE FLANGED JOINT

REF.: THEORY OF PLATES & SHELLS - TIMOSHENKO



L = 113 3/4"

ε = DEFORMATION IN/IN

KINETIC ENERGY = KE = WT × HEIGHT = 30,000 × 30 × 12

= 10,800,000 IN LBS

STRAIN ENERGY - LOAD DEFORMATION AND ∂ TO YIELD STRESS, AS WELL AS INITIAL CONFIGURATION CHANGE HAS BEEN OMITTED, THUS ANALYSIS IS CONSERVATIVE

STRAIN ENERGY = SE = F e

F = FORCE @ YIELD STRESS = 33,000 LB/IN² FOR A7 STEEL

SE = Fe = (σ)(AREA)(LENGTH)(2π h_{AVE})(ε)

= 33,000 (7/8 × 1)(113 3/4)(2π × 28 7/8 / 2) ε

= 6.15 × 10^? ε IN LBS

$KE = SE$

$\epsilon = 1.08 \times 10^7 / 2.93 \times 10^8$

$= .0363 = 3.63\%$ (within the 21% elongation allowable)

END DROP

CONSIDER A LEAD CYLINDER 54" LONG, 28 OD X 12" ID, 12" BEING THE DIAMETER OF THE OUTER ROW OF SOURCE TUB.

THERE IS A 3 IN AIR GAP BETWEEN THE LEAD AND THE END PLATE WHICH WOULD OFFER A DEGREE OF RESISTANCE SHOULD THE LEAD BREAK FREE. THE PRINCIPLE QUESTION THEN IS OVER THE ABILITY OF THE LEAD TO WITHSTAND THE IMPACT.

BASED UPON AN AVERAGE LEAD TEMPERATURE OF 285°F, THE SHEAR STRENGTH IS ESTIMATED TO BE 800 psi. THUS, THE FORCE REQUIRED TO SHEAR WOULD BE

$$F = \sigma_s A_s = 800 (54) \pi (28 + 12)$$

$$= 5.4 \times 10^6 \#$$

THE MASS OF LEAD AFFECTED IS

$$M = 54 \left(\frac{\pi}{4}\right) (28^2 - 12^2) (.41) = 11,100 \#$$

THUS A LOADING OF 486 g IS REQUIRED TO SHEAR THE LEAD FROM THE WALLS.

ASSUMING A UNIFORM DECREASE IN VELOCITY AFTER IMPACT, THE DEFORMATION WHICH WOULD COINCIDE WITH A 486 g DECELERATION WOULD BE

$$S = \frac{1}{2} a t^2$$

THE VELOCITY OF THE CASK UPON IMPACT WOULD BE

$$V = at = a\sqrt{\frac{2S}{a}} = 32\sqrt{1.86} = 44 \text{ ft/sec}$$

so the average velocity would be 22 ft/sec during deceleration; and $S = 22t$. Thus

$$22t = \frac{1}{2}(1.86)(32)t^2$$

$$t = .00283 \text{ sec}$$

$$S = 22t = .062' = 0.75''$$

this appears to be a reasonable degree of deformation to anticipate without failure since it represents a crushing deformation of about 10% to the point where the steel is bonded to the lead.

2. <u>PUNCTURE</u>

$$t = 1.22 \times 10^{-3} W^{0.613}$$

W = TOTAL CASK WEIGHT

FORMULA IS FOR A MINIMUM WALL THICKNESS BASED ON A 40" DROP, DEVELOPED BY LB SHAPPERT OF ORNL. FULL SCALE CASK PUNCTURE TESTS WERE CONDUCTED AT ORNL. *

THIS CASK W = 30,000 LBS

$$t_r \text{(OUTER SHELL)} = 1.22 \times 10^{-3} (30,000)^{0.613}$$

.613 log 3.0 + .613 log 10,000

.613(.475) = 0.296

.613 × 4 = 2.452

2.748 antilog = 585

$$t_1 = 1.22 \times 10^{-3} \times .585 = 0.714" \quad \text{(USE 7/8" PL)}$$

TO RESIST WALL PUNCTURE A MINIMUM OF 0.714" IS REQUIRED.

* A RECENT TEST AT ORNL OF AN 36000 LB CASK WITH A 1 3/8" WALL THICKNESS SHOWED THAT NO PUNCTURE OCCURRED DURING A 37" DROP. PUNCTURE DID OCCUR DURING A 46" DROP. THESE RESULTS ARE IN AGREEMENT WITH THE ABOVE EQUATION. REF P 66 OF "HNPF [illegible] ELEMENT [illegible] SHIPPING [illegible]" ATOMICS INTERNATIONAL DIV. OF NAA REPORT NO 13374.

3. <u>THERMAL</u>

A 30 MINUTE EXPOSURE TO RADIANT HEAT HAVING A TEMPERATURE OF 1475°F, AND AN EMISSIVITY COEFFICIENT OF 0.9

a) ASSUME ALL LEAD MELTS

TOTAL VOLUME OF LEAD = 66,055 IN³ (FROM P.4)

UNIT VOLUMES

1. 25" CASK SECT. 5544 + 1/3(48,000 − 5875) = 20,580

2 55½" CASK SECT. 3470 + 2/3(48,000 − 5875) = 33,560

3 TOP PLUG SECT 1770

55,910

SOLIDIFICATION SHRINKAGE OF LEAD (99% Pb) = 3.72% *

1.) 25" CASK SECT. 20,580 × .0372 = 760 in³

$$Vol = DEPTH\ \frac{\pi}{4}(d)^2 = 760$$

$$DEPTH = \frac{760}{\frac{\pi}{4}(28)^2} = 1.23''\ DEEP$$

2.) 55½" CASK SECT. 33,560 × .0372 = 1250 in³

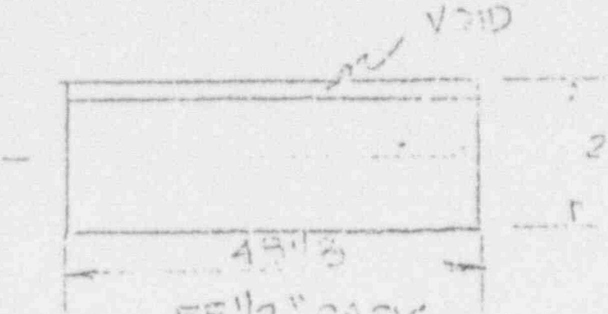
$$DEPTH = \frac{1250}{[28^2 - 15.5^2]\ \pi/4} = 2.85''$$

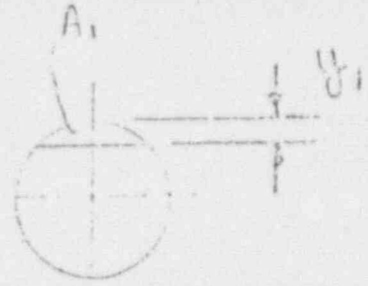
3) TOP PLUG SECT 1770 × .0372 = 66 IN³

$$DEPTH = \frac{66}{\frac{\pi}{4}(14.125)^2} = 0.4[illegible]''\ DEEP$$

ASSUME LEAD SOLIDIFIES IN MOST UNFAVORABLE SHIELDING GEOMETRY.

* SEE METALS HANDBOOK 1948 EDITION P. 7[illegible]





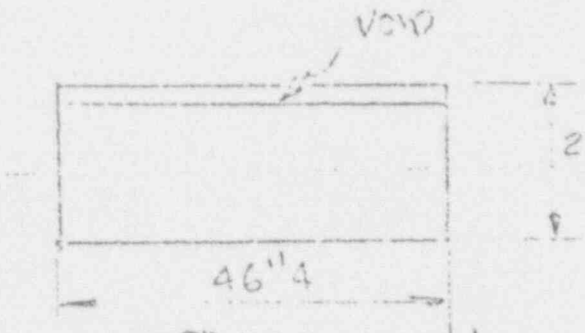
55 1/2" CASK

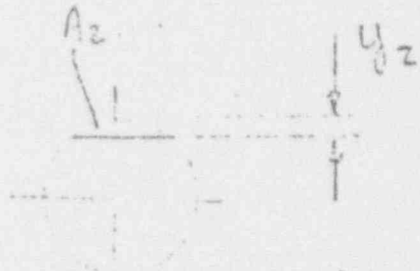
VOID = 1430 IN^3

$1430 = A_1 (49\,3/8)$ $\qquad A_1 = 31.7\ \text{IN}^2$

TOTAL AREA = $\frac{\pi}{4}(28)^2$ * $\frac{31.7}{616} = .0513$, $\frac{h}{D} = .0967$, $h = y_1 = .0967 \times 28$

$y_1 = 2.71''$





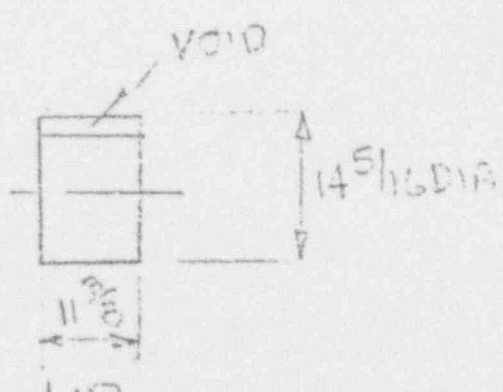
25" CASK

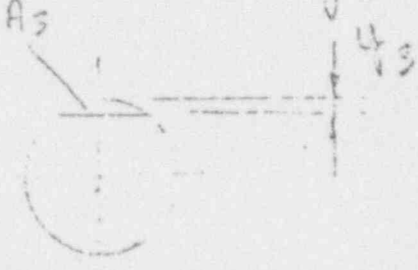
VOID = 910 IN^3

$910 = A_2 (46\,1/4)$ $\qquad A_2 = 19.7\ \text{IN}^2$

TOTAL AREA = $\frac{\pi}{4}(28)^2$ $\quad \frac{19.7}{616} = .0319$, $\frac{h}{D} = .0756$, $h = y_2 = .0756 \times 28$

$y_2 = 2.12''$





LID

VOID = 66 IN^3

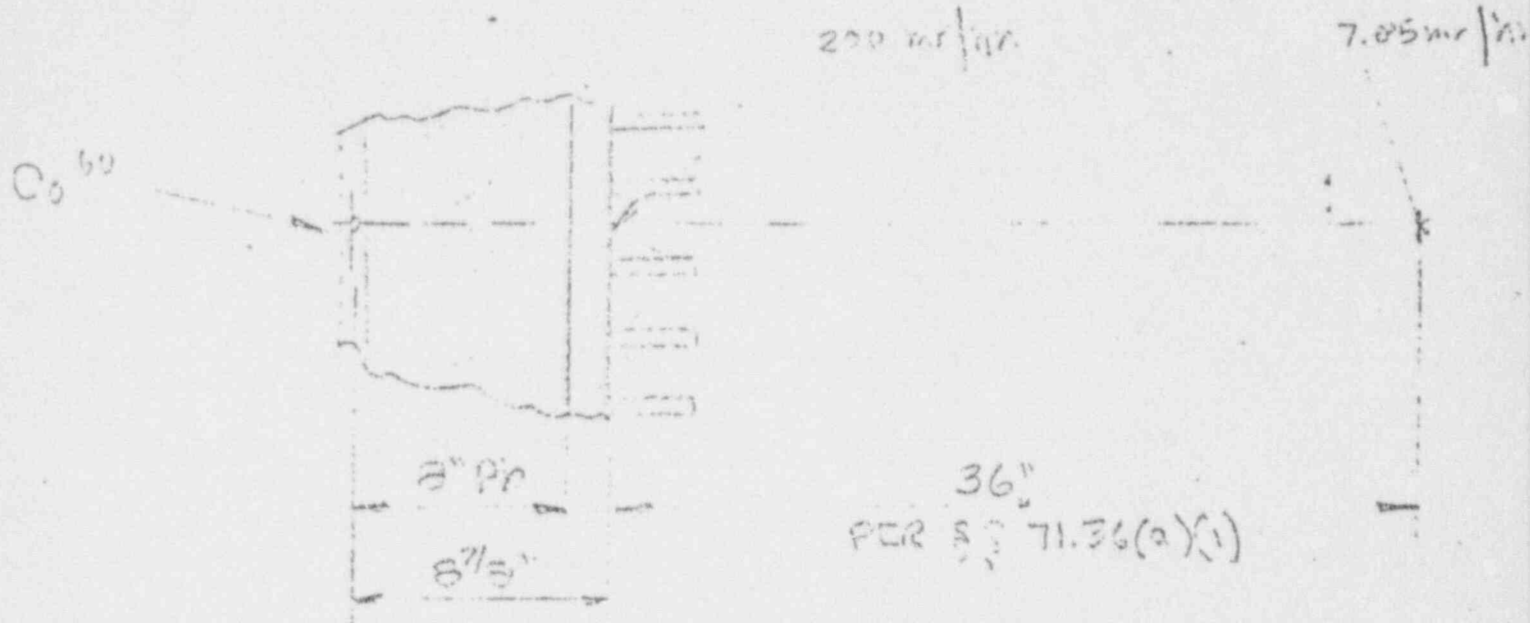
$66 = A_3 (11\,3/8)$ $\qquad A_3 = 5.82\ \text{IN}^2$

TOTAL AREA = $\frac{\pi}{4}(14.31)^2 = 161.2$ $\quad \frac{5.82}{161.2} = .0361$, $\frac{h}{D} = .0753$, $h = y_3 = .0753 \times 14.31$

$y_3 = 1.08''$

* REF. MARKS HANDBOOK, 4TH EDITION p 35 SEGMENTS OF CIRCLE

CASK DESIGNED FOR 200 mr/hr AT SURFACE PER ICC REGULATION §§ 73.393(?) OF 49 CFR PART ?



$$\text{DOSE AT 3FT} = \frac{(200\,\text{mr/hr})}{\left(\frac{44.875''}{8.875}\right)^2} = 7.85\,\text{mr/hr}$$

DETERMINE LOSS OF SHIELDING NECESSARY TO INCREASE DOSE AT 3FT TO 1000 mr/hr (§§ 71.36 (a)(1))

$$\frac{1000\,\text{mr/hr}}{7.85\,\text{mr/hr}} = 127.5$$

$$2^x = 127.5$$

$$x \log 2 = \log 127.5 = x(.301) = 2.106$$

$$x = 7.00$$

FOR LEAD AND Co^{60} HALF VALUE LAYER .51" Pb

7.00 × .51 = 3.57" Pb > ACTUAL OF 2.11" Pb MAX.

DETERMINATION OF [illegible] TO WHICH [illegible] MELTS

HEAT IS [illegible] FROM 2 SOURCES:

[illegible] ([illegible] [illegible]) from [illegible]; and [illegible] [illegible] [illegible]

$$Q_{1} = \epsilon_{12} A_{1} (.173)\left(1955 - \frac{T_c}{100}\right)$$

$\epsilon_{1,2}$ is [illegible] as [illegible] 0.72

Again [illegible] the [illegible] area, so

$A = 54 \text{ ft}^2$

[illegible] T_c, the [illegible] temperature at the surface

$$Q_R = 0.173\,(54)(.72)(1.3 \times 10^5) = 870,000 \text{ BTU}$$

$$Q_T = Q_1 + Q_2 = 900,000 \text{ BTU/HR}$$

To [illegible] THE [illegible] TO THE MELTING POINT OF P_c, [illegible] [illegible] the temperature to 121°F.

$$Q_{Pc} = Wc_p\Delta t = 22,000\,(.051)(121 - 271)$$

$$= 250,000 \text{ BTU sensible heat } P_c$$

$$Q_{SHELL} = 2500\,(.07)(400) = 72,000 \text{ BTU [illegible]}$$

[illegible], heat [illegible] is [illegible] [illegible] [illegible]

$$Q_{[illegible]} = \tfrac{1}{2}([illegible]) - 250,000 - 72,000 \text{ BTU}$$

$$= 128,000 \text{ BTU}$$

λ_f - 11.3 BTU/# Pb

Lead melted

$$M = \frac{Q}{\lambda_f} = \frac{128,000}{11.3} = 11,300\#$$

So, approximately 1/2 the lead melts during accident and the space provided for expansion is adequate, and an internal pressure of no more than 4 atmospheres is anticipated.

4. Subsequent water immersion presents no problems we can visualize at this time, and it is noted that the cask will periodically undergo a water immersion from operating temperature in any event.

APPENDIX II

NPI HELIUM MASS SPECTROGRAPH TEST PROCEDURE

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NPI HELIUM MASS SPECTROGRAPH

LEAK TEST PROCEDURE*

General Test Method

Each finished source assembly shall be subjected to a pressure of 300 psig minimum with helium for a period of one-half hour. The assembly shall then be removed to an evacuation chamber. The chamber shall be evacuated to the specified pressure and monitored with a leak detector.

Detailed Procedure

Pressurizing

Place the finished source assembly in a pressure tube.

Using helium bottle pressure, purge the pressure tube of air.

Pressurize the tube to 300 psig minimum with helium and maintain for a period of one-half hour.

Depressurize the pressure tube and remove the source assembly to the evacuation chamber.

Helium Leak Detector

Operation of the leak detector shall be strictly in accordance with the manufacturer's instructions.

The leak detector and vacuum system shall be calibrated by using a calibrated standard leak before and after leak testing of each source capsule. When checking the leak detector the regulated power supply shall be turned on for a least ten minutes before any readings are taken and the internal pressure of the leak tester shall not exceed 0.1 micron for at least five minutes with the throttle valve wide open. The leak detectors

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* This procedure is in accordance with the United States of America Standards Institute leak test guide included in the proposed standard entitled "Classification of Sealed Radioactive Sources".

shall be adjusted to a reading of at least 8-10 leak rate meter full scale deflections when a 1.4×10^{-6} std cc/sec glass standard leak is used.

In calibrating the vacuum system, the roughing pumps shall be isolated from the system, and the standard leak placed at the furthest point from the leak detectors. After calibration, valve off the leak. The system calibration readings shall be 10% or less of the leak calibration level in five minutes.

Leak testing shall be performed in well ventilated areas to minimize the possibility of detecting helium contaminated air.

The vacuum system, exclusive of the vacuum chamber, shall be kept under a continuous dynamic vacuum.

Testing of Source

Before each finished source assembly is tested, the following blank tests shall be performed:

Source assembly background shall be determined by testing a solid bar of the same dimensions and material, and with approximately the same configuration as the source assembly. The bar is to be subjected to the pressurization previously described prior to being leak tested.

Place the lower plug weld section of the finished source assembly inside the vacuum chamber.

Evacuate the chamber and begin monitoring when the system pressure falls within the range of the leak detector. This shall be done with a maximum leak detector internal pressure of 0.1 microns and with the instrument set for maximum sensitivity. The required procedure is to crack open the throttling valve on the leak tester when the system vacuum reaches 5 microns or less. A full open throttle is made only if the leak tester vacuum can be maintained below 0.1 microns.

If no helium signals are given after continuously pumping and testing with an open throttle valve for one minute, isolate the chamber from the vacuum pumps and accumulate any helium leakage for 30 minutes. Monitor chamber following the procedure described in preceding step.

Data Required

Record the magnitude of leak indication for each of the following:

a. Chamber background.
b. Solid background.
c. Each of the finished source assemblies.

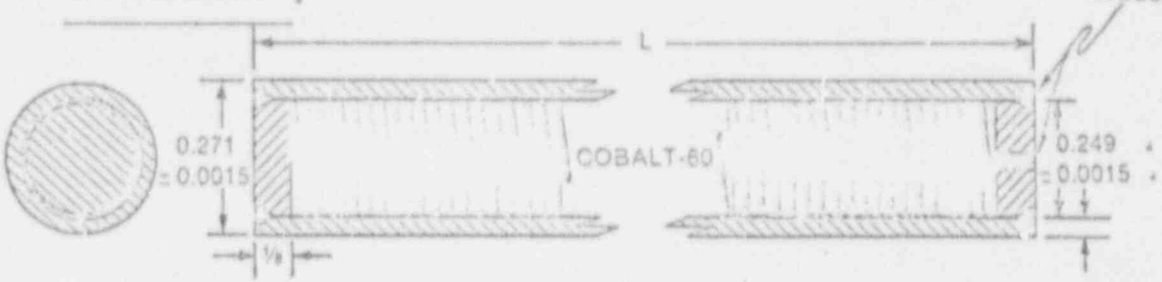
Acceptance Criteria

If c is less than or equal to b, or equal to or less than 1×10^{-8} std cc/sec, the source shall be considered leak free.

FIGURE 1

DIMENSIONS OF SINGLY ENCAPSULATED CO-60 SOURCES

NPI-HOLLOW*

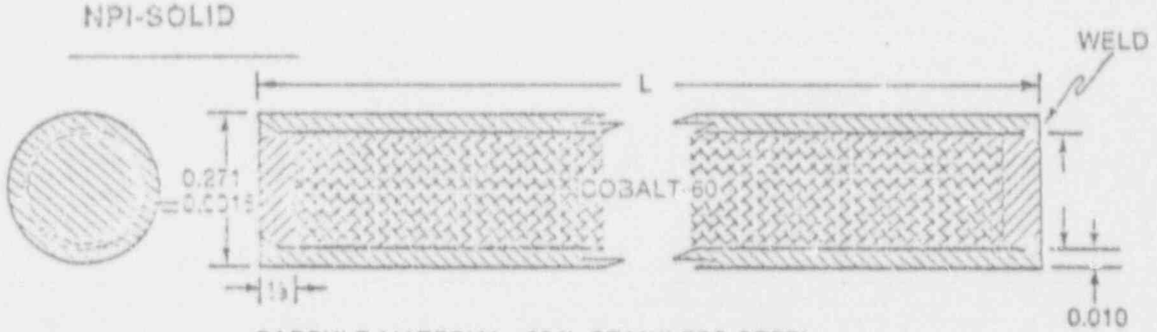


CAPSULE MATERIAL: 304L STAINLESS STEEL

COBALT: REACTOR GRADE, WOUND SPRING

CATALOG	OVERALL LENGTH (L) (INCHES)	COBALT WEIGHT (GRAMS)
NPI-12 C 3	12 ± 3/32	35 ± ½
NPI-10 C 3	10 ± 3/32	29 ± ½

NPI-SOLID



CAPSULE MATERIAL: 304L STAINLESS STEEL

COBALT: REACTOR GRADE, SOLID ROD—INTIMATE CONTACT WITH CLADDING

CATALOG	OVERALL LENGTH (L) (INCHES)	COBALT WEIGHT (GRAMS)
NPI-12 S 3	.12 ± 3/32	83.7 ± 1.7
NPI-10 S 3	10 ± 3/32	69.5 ± 1.7
NPI-6 S 3	5-1/3 ± 3/32	35.7 ± 1.7

ALL DIMENSIONS IN INCHES

* Patents Applied For