71-9102

August 31, 1977

Mr. Charles MacDonald
Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. MacDonald:

Approval is hereby requested for authorization of a package design consisting of:

- a lead filled steel cask meeting the requirements of NPI Specification E1, dated August 1972,

in a:

- wood and steel overpack meeting the requirements of a 20WC6 overpack (Title 49-178.194),

under the following conditions:

- The radioactive material is cobalt-60 in sealed sources meeting the requirements of Special Form.

- The activity limit is 9500 curies.

- All current requirements, including radiation limits, labeling, and documentation, of the Nuclear Regulatory Commission and Department of Transportation will be met.

- The overpack will be opened only by NPI personnel who will always allow the external temperature of the cask to cool so that it can be readily handled with bare hands.

- Transport will be limited to land and sea.

This request for approval is based on the following:

- The 20WC6 overpack has been evaluated, approved, and used for many years within its specified limits when loaded with a Specification 55 inner cask,

07607

- NPI has used the 20WC6 overpack with its Specification E1 inner cask for over 500 times without incident or problem.

- The existing NPI Specification E1 inner cask meets all requirements for a Specification 55 cask and all the requirements of Title 10, 71.31 except for the fire test as shown by the attached evaluation, which was performed in 1972.

- The calculated temperature of the inner cask steel shell without the overpack based on the conservative assumption that all the decay heat is conducted from the source, is 164°F when the package is loaded with 7000 curies of cobalt-60 with solar heat of 0.29 watts/in.^{2} and 130°F ambient temperature; the temperature of the cask outer steel shell was measured as 145°F when the package was loaded with 6750 curies and subjected to simulated sunshine of 0.5 watts on the top and 0.25 watts/in.^{2} on the sides, 55°F ambient outside the overpack and the inside between the overpack and cask of 130 and 145°F; and when the cask was loaded with 9360 curies, and subjected to the same simulated sunshine, 72°F ambient outside the overpack and the air inside the overpack was between 143 and 163°F.

- There was no appreciable weight loss of the wooden portion of the overpack during a nine day test with 9360 curies and simulated sunshine; the actual weight loss was 1 pound of 1172 pounds.

Since the integrated average value of the heat input from the simulated sunshine was approximately 2000 watts and the decay heat of 9360 curies of cobalt-60 is approximately 135 watts, it is not surprising that the observed temperature rise between the two tests was essentially equal to the difference in the ambient temperature and independent of the approximately 35 watts contributed by the increased cobalt-60 activity. Accordingly, we see no reason why the requested increase in the activity limit should not be granted. Further, we foresee no problems in having the limit extended to 15,000 curies but will perform the test before requesting approval to that limit.

In support of the above, enclosed is a copy of:

- NPI Specification E1, dated August 1972;

- An analysis of the shipping container which was performed in 1972; and,

Mr. Charles MacDonald
Nuclear Regulatory Commission
Page Three

- A report of the tests with 6750 and 9360 curies of cobalt-60.

If you have any questions, please call me.

Sincerely,

NEUTRON PRODUCTS, INC.

Marvin M. Turkanis
Vice President

Enclosures
MMT/dls

07607

FROM: Neutron Products, Inc

DATE OF DOCUMENT: 09/31/77

DATE RECEIVED: 09/08/77

NO.: 07607

LTR.: X

MEMO:

REPORT:

OTHER:

TO: Charles MacDonald

ORIG.: X

CC:

OTHER:

ACTION NECESSARY ☐

NO ACTION NECESSARY ☐

CONCURRENCE ☐

COMMENT ☐

DATE ANSWERED:

BY:

CLASSIF.: U

POST OFFICE

REG. NO.:

FILE CODE: ~~XXXX~~ 071-09102

DESCRIPTION: (Must Be Unclassified) Request for authorization of a package design consisting of a lead filled steel cask meeting the ~~xxx~~ requirements of NPI Specification E1, dtd 8/72.

ENCLOSURES:

REMARKS:

REFERRED TO	DATE	RECEIVED BY	DATE
Odegarden (adv. cy)	9/14/77		
Reg file cy			
PDR			
I&E (3)			
MacDonald (1 cy)		07607	het

U. S. NUCLEAR REGULATORY COMMISSION

MAIL CONTROL FORM

FORM NRC-326 (1-75)

1.0 SCOPE

This specification establishes the requirements for materials, fabrication, testing, inspection, product quality, and preparation for and delivery of a lead shielded shipping cask as shown on NPI Drawing D240010.

1.1 Applicable Documents

1.1.1 ASTM Specifications

B29, A516, A519, A36, A193, D-2000

1.1.2 ASME Boiler and Pressure Vessel Code, Sections VIII and IX

1.1.3 AWS Specifications

5.5

1.1.4 ANSI Standards

1.1.5 NPI Drawing D240010

1.1.6 NPI Cask Fabrication Quality Assurance Program (Appendix I)

1.2 NPI

Where the term NPI is used in this specification, it refers to Neutron Products, Inc., Dickerson, Maryland.

1.3 Contractor

Where the term Contractor is used in this specification, it refers to the organization selected to supply the equipment specified herein.

1.4 Exceptions

Bidder shall include in his proposal a separate sheet(s) titled "Exceptions" listing any such exceptions taken. In the absence of stated exceptions, it is understood that Bidder's proposal is in complete accord with these specifications and drawings herein described.

NPI Specification E-1

August 1972

Equipment Specification for a Lead Shielded Shipping Cask (Refer NPI Drawing D240010)

TABLE OF CONTENTS

2.0 MATERIALS AND PURCHASED COMPONENTS

The Contractor is to furnish all materials required for the construction, inspection, test and shipment of the cask. The Contractor shall also furnish spare parts as listed on NPI drawing 240010. All raw material and purchased components shall be certified to the requirements of this specification and/or the applicable drawing requirements.

2.1 Mill Test Reports

Certified mill test reports shall be included for all steel used in the construction of the shell assembly NPI Part Number E 240010-2. Mill test reports shall also be furnished for all lead used in the cask. The mill test reports shall include the ASTM specification number, the Contractor's name, the heat or batch number and the results of the chemical analyses and mechanical properties tests.

The material shall be marked in accordance with the applicable ASTM specification. The marking shall be retained until fabrication is complete.

2.2 Repair of Defects

Minor defects in materials as defined by the appropriate ASTM specification may be repaired, provided that NPI approves the method and extent of repairs. Defective material that cannot be satisfactorily repaired shall be rejected.

2.3 Forming Materials

Materials may be formed to the required shape by any process that will not degrade the physical properties of the material below that required by the applicable ASTM standard.

2.4 Material Specifications

2.4.1 Lead

Lead utilized shall be in accordance with ASTM Standards B29, pig lead - chemical grade.

2.4.2 Standards

Outer shell - ASTM A516 Grade 55

Cavity Liner - ASTM Seamless Tube A519 (1018)

Miscellaneous Plate - ASTM A36

2.4.3 Bolts

Cask lid bolts are to be in accordance with ASTM Standard A193 grade B7.

2.4.4 Welding Electrodes and Filler Wire or Rod

All weld material to be in accordance with AWS Standard 5.5. The filler metal shall be within the limits of chemical composition and physical properties specified for the materials to be joined.

2.4.5 Ring Gaskets

Ring gasket material to be in accordance with ASTM Standard D-2000-70. Silicone rubber, Parker Seal Company, Number S604-7, or equal.

3.0 WELDS

3.1 General

All welds on the shell portion of the cask are to be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII Division I.

Butt welds shall be slightly convex, of uniform height, and have full penetration, unless otherwise approved. Fillet welds shall be of a specified size with full throat and the legs of uniform length. Repair, chipping, or grinding of welds shall be done in such a manner as not to gouge, groove, or reduce the base metal thickness. All exposed welds, on the finished cask, shall be ground smooth or polished to at least 125 RMS finish.

3.2 Welder Qualification

All welds on the cask shall be performed by qualified welders who meet the requirements of (have passed the test as required by) the ASME Boiler and Pressure Vessel Code, Section IX.

3.3 Welding Process

All welds on the shell portion of the cask are to be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

3.4 Preheat

Preheat for pressure vessels shall be as recommended in the applicable portions of Section VIII, Division I of the ASME Boiler and Pressure Vessel Code.

3.5 Nondestructive Testing

Nondestructive testing of welds when required shall be in accordance with the applicable portions of Section VIII, Division I of the ASME Boiler and Pressure Vessel Code.

3.6 Repair of Weld Defects

Visible defects such as cracks, pinholes, and incomplete fusion, as well as defects that can only be detected by prescribed examinations or tests, shall be removed; then the joint shall be rewelded.

Repair welding shall be done in accordance with the applicable portions of Section VIII of the ASME Boiler and Pressure Vessel Code. The repaired weld shall meet the quality requirements for the original weld.

Removal of undercutting by reduction of the base metal section adjacent to the welded seam is not permitted.

4.0 LEAD SHIELD

The lead shall be poured in such a manner that the entire cask is filled with lead at room temperature and at $500^{\circ}F$ with no voids or cracks in the lead that could cause radiation streaming. Also, the lead must be poured in such a manner that volumetric expansion of the lead during a temperature increase from room temperature to $500^{\circ}F$ will not yield the steel shells.

4.1 Lead Casting

4.1.1 Pour Hole

Lead may be poured through one or more holes in the steel structure of the cask. An acceptable method is through a hole in the bottom of the cask. After the pour, the hole shall be sealed by welding and the closure welds shall be made and inspected in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I.

4.1.2 Open Cavity Pour

Lead may be poured in the cask shield cavity by leaving one flange off the cask and pouring into the open cavity. If this method of lead pouring is selected, the cavity shall be leak checked both before the lead is poured and after the cavity flange has been welded to the inner and outer shells.

4.2 Lead/Steel Interfaces

Lead/steel interfaces must exhibit a minimum resistance to heat flow. Pour bonding of the lead to the steel is acceptable providing the requirements of 4.2.1 are met.

4.2.1 Lead Bonding

There shall be a minimum of 60 percent bond between the lead and the shell with a minimum of 40 percent bond over any one foot square segment of the outer shell.

Any unbonded region shall not exceed 20 square inches or a maximum dimension in excess of 6 inches.

5.0 QUALITY ASSURANCE

After award of contract NPI shall notify the Contractor as to the names of persons who shall function as NPI representatives prior to start of fabrication, the Contractor shall submit to NPI for review and approval two copies of manufacturing and test procedures. NPI shall complete review within two weeks of receipt of documents. NPI shall be notified three days in advance of any testing.

5.1 Quality Assurance Requirements

5.1.1 Compliance

The Contractor shall be responsible for inspection, examination and testing of all materials and workmanship to insure compliance with applicable codes and the final specifications.

5.1.2 Contractors Quality Assurance Program

It is the Contractor's responsibility to establish and conduct a Quality Assurance Program for all procurement, fabrication and testing operations. A specific Quality Assurance Program shall be proposed by the Contractor. The program should be patterned after Appendix I. Prior to the start of procurement of equipment materials the Contractor shall submit detailed quality control procedures to NPI for review and approval.

5.1.3 Evidence of Compliance

Physical evidence of the compliance with codes and specifications shall be turned over to NPI prior to or concurrent with delivery of equipment.

5.1.4 Inspection

Test and inspection shall be made at the place of manufacture in the presence of an NPI representative, unless previously waived. The Contractor shall afford the NPI representative all reasonable facilities to satisfy himself that the material furnished is in accordance with this specification and NPI drawing 240010. Material accepted by the NPI representative at the place of manufacture which subsequently reveals imperfections not detected at the place of manufacture, or which subsequent similar tests or analyses show not to be in accordance

- Detailed description of method of application.
- Method of testing bond integrity including minimum acceptable percentage of bond.

(e) Miscellaneous manufacturing and cleaning procedures.

(f) Witness and sign-off procedures for all tests.

5.2.3 Contractor Responsibility

Drawing, specification and procedure approval by NPI does not relieve the Contractor of the responsibility to meet the requirements as outlined by this specification and drawing.

5.3 Deviations

Wherever, in this specification, components and equipment are specified by NPI and in the Contractor's opinion the use of such components and equipment might interfere with the Contractor's ability to meet required standards, the Contractor shall immediately advise NPI. If the Contractor desires to substitute equipment, change components, or deviate from this specification, NPI shall require proof that such action will result in a system equal to or better than that specified. NPI reserves the right to disapprove the substitution, changes, or deviations after reviewing each case.

5.4 Welds

5.4.1 Weld Inspection

All welds shall have 100% weld penetration. All exterior welds shall be liquid penetrant checked (root and final pass).

5.4.2 Defects

Unacceptable defects as defined in the applicable portions of

Section VIII of the ASME Boiler and Pressure Vessel Code may be repaired by the methods defined in same.

5.5 Leak Testing

5.5.1 Lead Shield Containment Chamber

The lead shield containment chamber shall be leak checked before the shield chamber is filled with lead. The chamber shall be pressurized to 20 psig with a gaseous mixture which contains at least 10% of a gas to which the leak detector is sensitive.

Leak tests may be performed by any procedure that can be demonstrated to have a sensitivity of $1X10^{-5}$ cm^3 (STP) of helium per second. Acceptable test methods are mass spectrometry or helium leak detection. If leakage is indicated, the leaks shall be located and repaired and the test repeated.

5.6 Shielding Integrity

5.6.1 Shield Inspection

On final assembly, the cask shall be tested and inspected by nondestructive means and evidence submitted to show that the required homogeneity of shielding is provided to meet this specification. Insofar as possible, the entire outer surface shall be surveyed to determine the absence of voids or imperfections in the poured lead or steel shell.

5.6.2 Shield Radiation Survey

The entire outer surface of the cask shall be surveyed with a cobalt-60 radiation source in the central chamber. Any area showing surface radiation more than 10% above the average for that position at the surface of the lead shield shall be repaired and retested.

5.7 Equipment Weight

The finished cask assembly shall be weighed at the completion of assembly and the actual weight shall be plainly and durably marked on the name plate (see drawing 240010).

6.0 CLEANLINESS AND SURFACE FINISH

6.1 Surface Finish

All exposed surfaces shall be ground or polished to 125 RMS finish or better with no nicks or gouges.

6.2 Cleanliness

All surfaces shall be free from grease, oil, dirt, weld slag, machining chips, etc. prior to painting of the cask. All surfaces shall be cleaned by a solvent that is not detrimental to the cask base material.

6.3 Paint

7.0 FABRICATION RECORDS

7.1 General Requirements

The Contractor, during the construction period, shall maintain current Fabrication Records containing the documentation necessary to demonstrate compliance with this specification. The Fabrication Record shall include, but is not limited to, the following items:

(a) A material record specifying (1) product form and heat number, (2) correlation of part and test report, and (3) cask component name or part number. Marked drawings or annotated bills of material may be necessary to satisfy this requirement.

(b) Material test reports or other evidence of acceptability of material, in compliance with the stipulations listed in Section 2.0.

(c) Welding procedure, procedure qualification, welder performance records, and lead pouring procedure.

(d) Reports of all inspections and tests, including weld examinations; dimensional inspections; pressure tests; shielding and lead bonding integrity tests. Radiographs used in shielding tests shall be included.

(e) Reports of any required check analyses, clearly identified with the material they represent.

(f) Any deviation from this specification and the resolution of same, showing NPI approval.

(g) Reproducible "as-built" drawings showing all changes, additions and deletions that occurred after initial NPI approval of manufacturing drawings. These drawings shall show a clear and correct description of the construction details of the cask at delivery.

7.2 Access to Records

The Fabrication Record shall be assembled by the Contractor and shall be kept current at all times. NPI shall have access to the Record and shall be assured that it is complete and correct. Any deficiencies found shall promptly be rectified by the Contractor

7.3 Conformity

On completion of fabrication and testing, the Fabrication Record shall be reviewed by the manufacturer and then by NPI. The Contractor shall certify to NPI, in writing, that the fabrication is (with noted exceptions) in complete conformity with the contract.

7.4 Copies of Records

The Contractor shall furnish two copies of the Fabrication Records to NPI. These reports shall be submitted to NPI within two weeks following the date of the shipment of the shipping cask. All test specimens and weld samples shall be submitted with the copies of the Fabrication Records.

7.5 Ownership of Drawings

All manufacturing drawings shall become the property of NPI upon the completion of cask fabrication.

8.0 SHIPMENT

The Contractor shall deliver the cask and equipment F.O.B. to the Dickerson, Maryland plant of NPI.

It is the Contractor's responsibility to protect the equipment against damage during manufacture and transit.

COBALT-60 SHIPPING CONTAINER*

NEUTRON PRODUCTS, INC.

ANALYSIS

AND

COMPLIANCE

WITH

TITLE 10 CODE OF

FEDERAL REGULATIONS

10 CFR 71

AND

IAEA STANDARDS

*Description of package updated on August 29, 1977

SUBPART B - License Application

71.22 Package Description

This package consists of an assembly of a single D.O.T. Specification 55 container designed for transporting a large quantity of licensed material, as defined in Paragraph 10 CFR 71.4 (f). The container is a 24" diameter spherical shell of 3/8" steel plate filled with lead except for a central horizontal cavity formed by a 8-1/4" inside diameter by 3/8" thick wall steel tube. The cavity houses an interchangeable source positioning and transferring cylinder. This package cask is used to mate with and recharge commercial radiotherapy devices with Cobalt-60 sources. The variations in the source, shape, and machine design of these irradiators are reason for the interchangeable cask central cylinder. A typical central cylinder will have two or three through holes spaced radially from the center of rotation. One or two holes will contain the new source, a second hole is used to preposition the cask to the irradiator and receive the expended source. The interchangeable central cylinders all use inserted end plugs to position and shield the contained sources. During shipping, both ends of the cask are covered and sealed with bolted end covers. The protective jacket is a right cylinder fabricated from single pieces of 3/4" exterior plywood glued together and reinforced with steel through bolts. The lower base of the jacket forms the skid to support the cask during transport, and the top section fits snugly over the cask, and when firmly joined with base, provides auxiliary fire and impact protection in the event of an accident during transit. The package assembly is firmly lashed to the bed of a transport vehicle during shipment.

The details of the Spec 55 cask are shown in NPI Drawing D-240010.

71.22 (a) 1. Gross weight - Cask 3,070 pounds.

2. Model number - OPX where X is a digit representing the serial number.

3. Specific materials of construction, weights, dimensions, and fabrication methods are shown on NPI Drawings D-240010 and Specifications E1.

4. There are no coolants in this package. Cooling is provided by external air convection.

71.22 (b) 1. Maximum source 7000 curies of cobalt-60.

2. No fissile constituents.

3. Sources are solid metallic cobalt-60 double encapsulated in stainless steel.

4. No fissile material.

5. Maximum weight of a source is

6. Maximum amount of decay heat is 100 watts.

71.23 <u>Package Evaluation</u>

71.23 (a) Compliance to Subpart C is evaluated under Subpart C.

71.23 (b) No fissile material involved.

71.23 (c) No fissile material involved.

71.24 <u>Procedural Controls</u>

The cask is two overpacks used with a 20WC6 and both are to be visually inspected by the licensed source handlers prior to each use and by the Manager Field Service at irregular intervals, in compliance with Paragraph 71.51 (b).

SUBPART C - Package Standards

71.31 General Standards

71.31 (a) The materials specified for the construction of this package system and its contents can form no significant chemical or galvanic couple under any normal wet or dry condition.

71.31 (b) The cask end closures are bolted in place and the cask placed in this. The 700 pound protective jacket which is in turn bolted shut and wire sealed. The deliberate opening of the cask therefore requires special handling facilities not normally available during transit.

71.31 (c) 1. The cask lifting eyes are capable of supporting more than 3 g as shown by calculation.

2. The shield lid only weights 58 pounds and is manually moved.

3. There is no exposed structure that could be employed for lifting during transport. The protective jacket completely encloses the cask.

4. The lifting eyes of the cask are designed to deform and break before impairing the integrity of the shield containment.

71.31 (d) 1. The cask is firmly bolted to its base, the cask is snugly contained in protection, and the jacket is lashed to the frame of the transport vehicle. Calculations show that the proposed tie-down system is adequate to withstand the 10 g forward and 5 g sideways force without failure.

2. There is no exposed structure that could otherwise be used for tie-down purposes.

3. The shield cask is snugly contained in the wood protective jacket and it is the jacket that is directly tied to the vehicle. The failure of

the tie-down system could not directly impose damaging loads on the cask.

71.32 (a) The shape of this cask is a sphere so beam analysis is not meaningful. However calculations are provided as required.

71.32 (b) The containment vessel will be fabricated and tested under the provisions of A.S.M.E. Code Section VIII. Calculations show 25 psi external pressure is within the design limits.

71.33 No fissile material involved.

71.23 (a) 1. The only source material packaged in this cask will be cobalt-60 encapsulated in stainless steel. Decay heat generated in the source and shield will be dissipated by conduction through the lead and outer steel shell to the atmosphere. Since no fissile material is involved and no auxiliary cooling medium is required, the integrity of the package will always be assured during normal transportation if the cask is found capable of remaining functional after hypothetical accident conditions as evaluated in Paragraph 71.35.

2. An analytical assessment of the effects of a hypothetical accident as defined in Paragraph 71.36 shows that the cask is not ruptured by either a 30 foot free fall to an unyielding surface or a free drop of 40 inches into a 6 inch diameter bar. The deformation of the shield caused by these events could result in a maximum radiation exposure rate of 260 mR/hr at three feet for the 7000 curies. This is well below the limit of 1000 mR/hr set in Paragraph 71.36 (1). The effects of a 30 minute fire on the shield would be a melting of 27% of the total lead. This represents a layer of 0.81 inches of the outer shell of shielding.

The drop damage analysis showed that the lead container would not be ruptured but even the loss of this melted lead in addition to shield deformation would result in an exposure rate of 730 mR/hr. Maximum in a very limited direction.

71.34 (b) Shipment evaluated without the transporting vehicle.

71.34 (c) Specified normal and accident conditions are used here for package evaluation.

71.35 (a) 1. The cobalt-60 source material is sealed in stainless steel and leak tested prior to packaging. Inside of the package cask the source is fixed in the center of the shield between solid inserted plugs. The plugs are locked in place by bolted and sealed end covers that provide an additional leak tight seal between the source and the environment.

2. The package is structurally strong enough to withstand any normal transporting condition as evidenced by the accident analyses. The decay heat rate is not high enough to cause the lead to melt and flow. No shielding or containment failure is therefore possible under normal circumstances.

3. The only pressurizing mechanism possible, would be the thermal expansion of air in the sealed cask due to the decay heat load. The maximum internal cask temperature is calculated to by 170°F. This corresponds to a maximum vapor pressure of 18 psi which is well below the design pressure of the container.

4. The source is encapsulated in stainless steel and helium leak tested to ANSI Specs. The surfaces of the encapsulated sources are cleaned and wipe tested to assure surface contamination levels below .005 microcuries.

5. Cooling is by conduction through the metallic structure of the cask.

71.35 (b) No fissile material involved.

71.36 (a) 1. Calculations show a maximum reduction of shielding would be caused by the hypothetical 30 foot free fall drop of the cask without the protective jacket. This loss of shielding would result in a very localized radiation level 26 times the normal at 3 feet and well below the limits set by this paragraph, of a factor of 100.

2. Calculations show that the cask remains assembled after the accident, therefore, no radioactive material could be released.

71.36 (b) No fissile material involved.

SUBPART D - Operating Procedures

71.51 (a) Operation procedures are contained in NPI document.

71.51 (b) Procedures for opening and closing packages are detailed in the above NPI document.

71.51 (c) Regular and periodic inspections are described in the above NPI document.

71.52 No fissile material will be packaged in this cask.

71.53 (a) Prior to use, the cask will be radiation tested by gamma scanning the exterior surface and three foot exclusion distance with a calibrated cobalt-60 source of at least 200 curies set centrally in the shield.

71.53 (b) The containment section of the cask will be pressure tested at 125 psi.

71.53 (c) NPI will witness all specified acceptance tests on the cask and assure the compliance of the cask with the AEC approved design prior to labeling the cask as per this application.

71.54 (a) NPI operating procedures include a check list for cask preparation for shipping. This checklist includes visual and mechanical inspection of all

71.54 (b) No fissile material involved.

71.54 (c) The closures and seals are to be inspected as per (a) above.

71.54 (d) No valves involved.

71.54 (e) No pressure gauge involved.

71.54 (f) No liquid coolant involved.

71.61 NPI will report to the Division of Materials Licensing. AEC within 30 days any instance in which there is substantial reduction in the effectiveness of this package during use.

71.62 (a) A record of all shipments of large quantities of licensed material as defined in 71.4 (f) in a single package will be maintained in the office of NPI, Dickerson, Maryland, for a period of at least two years from date of shipment. These records will include all information required by the provisions of this paragraph. AEC access to company records will be allowed under Section (b) of this paragraph.

71.63 (a) NPI will permit the AEC to inspect the licensed material, packaging, and facilities under company control as provided in this paragraph.

71.63 (b) NPI will perform and allow the Commission to perform appropriate tests as provided in this paragraph.

71.64 NPI accepts the responsibility for compliance with 10 CFR 71 as written in this application.

Weight of Cask

I. BODY

(a) Steel

1. Outer shell 24" O.D. x 3/8" wall sphere 24 3/4"

Mean surface of sphere πd^2 = $\underline{23.625^2 \times 3.14}$ = 1753 $"^2$ 24.375 1789

less 2 segment surfaces $2\pi rh$ = 2 x 6.28 x 11.8 x 2 = $\underline{-296}$

1457 $"^2$ 1493

1457 x 3/8 = 546 Cu.In. 560

2. Flanges (2) 13" O.D. x 9" I.D. x 1.5"

(132.7 - 63.6) 1.5 x 2 = 207 Cu.In.

3. Inner cylinder 8 5/8 D x 3/8 W. x 21 5/8 L.

$3/8\pi dL$ = .375 x 3.14 x 8.63 x 21.63 = 220 Cu.In.

4. Stand 22 x 21.5 x 0.5 = 236.5

22 x 12 x 0.5 = 132

368 Cu.In.

5. Lugs 2 x 6 x 4 x 1/2 = 24 Cu.In.

Total volume of steel 1365 — 1379

(b) Lead

1. 23 1/4 D. Sphere less 9 D Cylinder

$.524 \times 23.25^3$ = 6586 — 7244

less 63.6 x 22 = 1399

Volume of lead = 5187 Cu.In. 5845

(c) Weight of steel 1365 x .283 = 386 — 390

Weight of lead 5187 x .410 = 2127 — 2396

Weight of body = 2513 lbs. 2786

II. COVERS (2)

(a) Steel

1. 13 Dia x 3/8 = 133 x .375 = 49.9

9 1/2 Dia x 1/4 = 70.9 x .25 = 17.7

3.14 x 9.25 x .25 x 1.375 = 10.0

77.6 Cu.In.

(b) Lead

9 Dia x 1.375 = 63.62 x 1.375 = 87.5 Cu.In.

(c) Weight of steel 77.6 x .283 = 22

Weight of lead 87.5 x .410 = 36

Weight of cover = 58 lbs. each

III. 8" DRUM

(a) Steel

3.14 x 8 x .188 x 21.5 = 101.5

3 x 3.14 x 2.68 x .12 x 21.5 = 65.1

2 x .375 x 48 -21 = 20.3

186.9 Cu.In.

(b) Lead

7 13/16 Dia x 20.75 = 47.9 x 20.75 = 994

less 3 x 5.16 x 20.75 = 321

673 Cu.In.

(c) Weight of steel 186.9 x .283 = 52.9

Weight of lead 673 x .410 = 275.9

Weight of drum = 328.8 lbs.

IV. SOURCE HOLDER

Average weight used Vol. x Av. Dens. of .35

3 x 5.16 x 21.5 x .35 = 111 lbs.

V. TOTAL CASK WEIGHT

Body	2513
2 Covers	116
Drum	329
Holder	111
	3069 lbs.

Normal Shipping Conditions

Maximum Surface Temperature

The maximum surface temperature is the result of internal source decay heat conducted to the surface and incident solar radiant heat absorbed on the surface. The ambient air temperature is required to be $130^{o}F$ by 10 CFR 71 App. A. Solar heat load is based on normal maximum radiation averaged over a summer day in latitude 42^{o}.

Procedure for calculating surface temperature is taken from O.R.N.L. N.S.I.C. 68 "Cask Designers Guide". Values for h_r, h_c, Q_s are taken from this document.

Basic formula

$$Q_t = h_t A (T_s - T_A)$$

WHERE

$$Q_t = Q_s + Q_d$$

AND

$$h_t = h_c + h_r$$

$$A = \pi d^2 \text{ (SPHERE)}$$

Q_t = Total heat flow

Q_s = Solar heat flow

Q_d = Decay heat

h_t = Total Coef.

h_c = Conduction Coef.

h_r = Radiant Coef.

T_s = Surface Temp.

T_a = Air Temp.

d = Cask Dia.

Source heat f n 7000 Curies CO 60

Decay energies gamma 1.33, 1.17, beta .15 (av)

$$E = 2.65 \text{ MEV}/d$$

$$\text{curie} = 3.7 \times 10^{10}\ {}^{d}/\text{sec}$$

$$2.65 \times 3.7 \times 10^{10} \times 7 \times 10^{3} = 68.6 \times 10^{13}\ {}^{\text{MEV}}/\text{SEC}$$

$$68.6 \times 10^{13} \times 1.52 \times 10^{16} \times 3.6 \times 10^{3} = 374\ {}^{\text{BTU}}/\text{HR}$$

$$374 \times .293 = 110 \text{ Watts}$$

Solar heat $Q_s = 144\ {}^{\text{BTU}}/\text{HR Ft}^2 \times \text{Projected Area}$

$$= 144 \times .785 \times 4 = 452\ {}^{\text{BTU}}/\text{HR}$$

Total heat $Q_t = Q_s + Q_d = 374 + 452 = 826\ {}^{\text{BTU}}/\text{HR}$

Heat transfer coeficients $h_c = .18\ \Delta T^{1/3}$ assume $\Delta T = 30^{o}$

$h_c = .18 \times 3.12 = .56$

$h_r = \underline{1.35}$ (from NSIC 68)

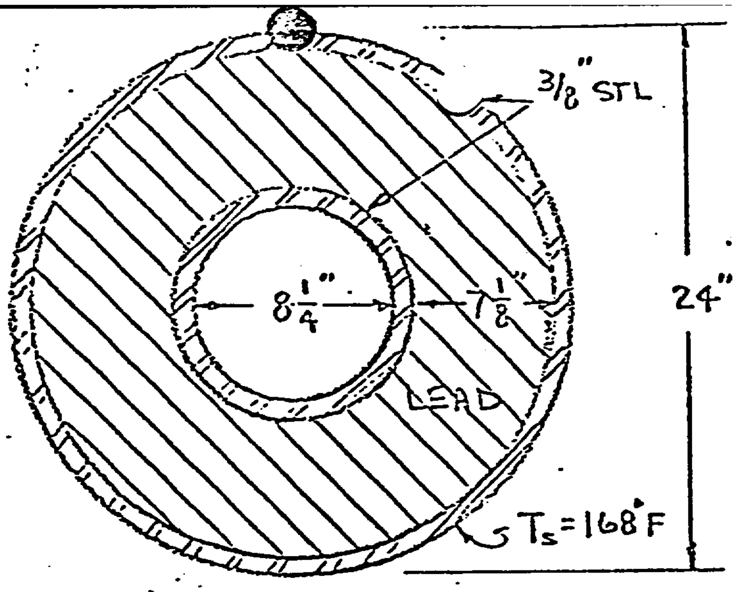
$h_t = 1.91$

$$T_s - T_A = \frac{Q_t}{Ah_E} = \frac{826}{12.56 \times 1.91} = 34.5$$

Maximum surface temperature = 130 + 34 = 164°F

Normal surface temperature will be about

20° above ambient air temperature.



$$q = \frac{kA}{E} \Delta T$$

$q = 374$ BTU/HR Source decay

k = 25 steel

k = 18.6 lead

INSIDE OUTER STEEL SHELL

$$\Delta T = \frac{374 \times 3/8 \times 1/12}{25 \times 12.56} \cong \frac{1}{26}\ °F$$

$$T_{S-Pb} = 168° + \frac{1}{26}° = 168°F$$

INNER SURFACE OF LEAD

$$\Delta T = \frac{374 \times 7.13/12}{18.6 \times 5.33} = 2.24°$$

$$T_{Pb-S} = 168 + 2\tfrac{1}{4} = 170°\ F$$

$A_1 = \pi d^2 = 3.14 \times 1$

$A_1 = 11.8$ 'S.F.

$A_2 = \frac{1.8 \text{ S.F.}}{10}$

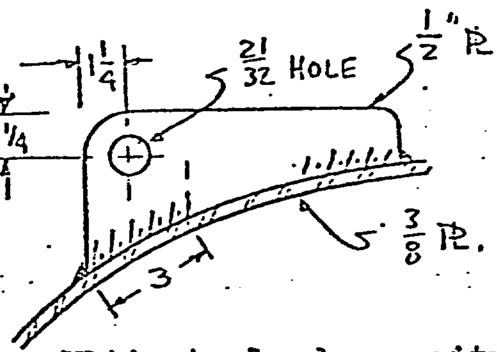
$\frac{10}{\ln 6.55} = \frac{10}{1.88} = 5.3$

INNER SURFACE OF CASK

$$\Delta T = \frac{374 \times 3/8 \times 1/12}{25 \times 2} = \frac{1}{4}°$$

Maximum air temperature inside cask is 170°F. This assumes all decay heat conducted from source and is therefore conservative.

Strength of Lifting Eyes



Shear stress of weld = 45,000 PSI (ULT.)

Area of weld = $6 \times 3/8 = 2.25''^2$

Ultimate load capacity of weld

$$P = AS = 2.25 \times 45{,}000 = 100{,}000^{\#}$$

Tear out of eye

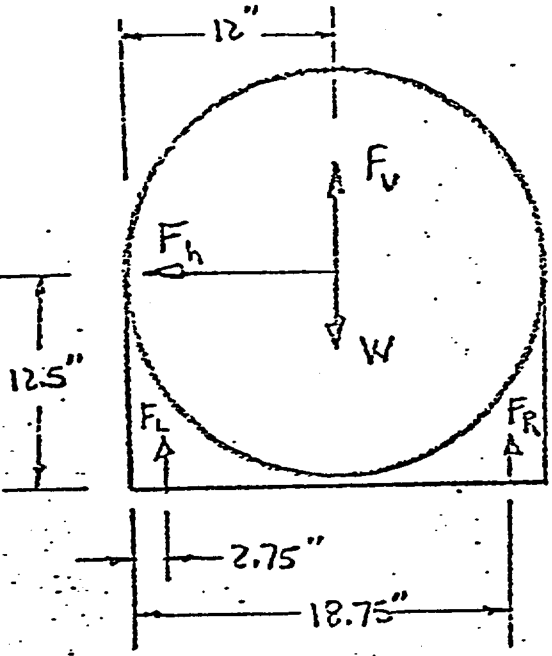
$$P = 2 \left[1/2 \times 1\ 1/4\right] \times 45{,}000 = 56{,}200^{\#}$$

Shear of Shackle pin (5/8" Dia pin) $S_s = 97{,}500$ PSI

$$P = 2\ (.307)\ 97{,}500 = 60{,}000^{\#}$$

Failure would be tear out of eye at $56{,}000^{\#}$ on any <u>one</u> eye. This is $\frac{56}{3} = 18.7$ times the weight of the cask.

Loading on tie-down bolts due to deceleration:



$$W = 3070^{\#}$$

$$F_v = 2g = 6140^{\#}$$

$$F_h = 10g = 30{,}700^{\#}$$

Moments

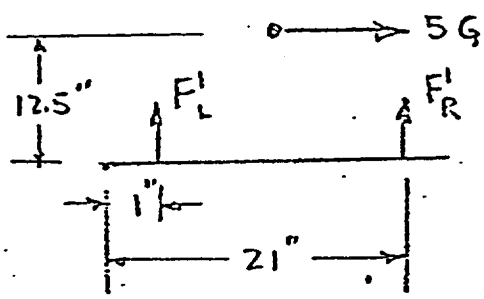
$$2.75\ F_L + 18.75\ F_R = 12.5\ F_h + 12\ (F_v - W)$$

$$F_R = \frac{1875}{275} F_L = 6.82\ F_L$$

$$F_L = \frac{12.5(30{,}700) + 12(3070)}{2.75 + 128} = \frac{420{,}800}{131}$$

$$F_L = 3210^{\#} \qquad F_R = 21{,}900^{\#}$$

For lateral load of 5 G



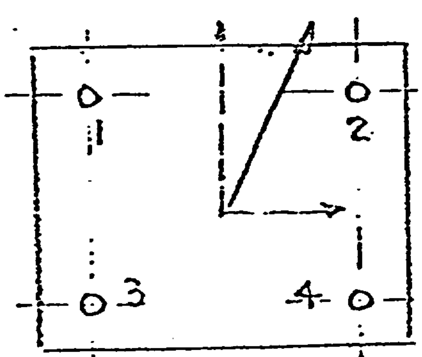
Moments

$$12.5 \times 5 \times 3070 = F'_L + 21\ F'_R$$

$$F'_R = 21\ F'_L$$

$$F'_L = \frac{192{,}000}{442} = 435''^{\#}$$

$$F'_R = 9140''^{\#}$$



BASE PLAN

Loads

Bolt 1 $\quad 1/2\ (F_L + F'_R) = 6{,}175^{\#}$

Bolt 2 $\quad 1/2\ (F_L + F'_L) = 1{,}822^{\#}$

Bolt 3 $\quad 1/2\ (F_R + F'_R) = 15{,}520^{\#}$

Bolt 4 $\quad 1/2\ (F_R + F'_L) = 11{,}170^{\#}$

Bolt 3 is most highly stressed

Tension on bolt 3 is 15,520#. Tensile area of 3/4 bolt is .334 Sq. In.

$$S_t = \frac{P}{A} = \frac{15,520}{.334} = 46,600 \text{ PSI}$$

$$\text{Shear load} = \sqrt{10g^2 + 5g^2} = 112 \text{ G} = 34,400^{\#}$$

$$\text{Shear per bolt} \doteq \frac{34,400}{4} = 8,300^{\#}$$

$$\text{Shear stress} \quad S_s = \frac{P}{A} = \frac{8300}{.334} = 24,800 \text{ PSI}$$

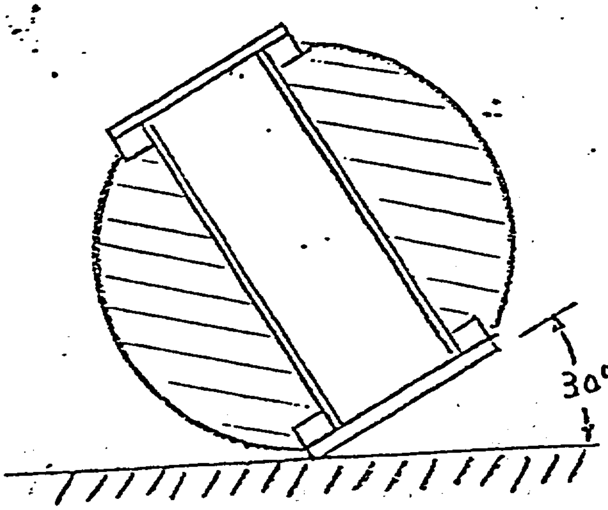
Total stress = 71,400 PSI max

$$\text{Factor of safety} = \frac{97,500}{71,400} = 1.37$$

This analysis assumes the cask is bolted to a perfectly rigid base, but this is not the case. The wood base is an impact absorber and the force crushing the wood relieves loading on the bolts. However, this analysis is conservative.

ANALYSIS OF THE RESULTS OF THE 30 FOOT DROP ONTO AN UNYIELDING SURFACE

The most damaging position of impact is assumed to be where the corner of the end closure contacts the impacted surface at a 30^{o} angle. The failures analyzed are failure of the closure hold-down bolts and failure of the cask closure flange to shell welds. It was shown that in a 30 foot free drop the kinetic energy is primarily absorbed in the deformation of the encased lead. The maximum deformation causes the spherical shell to flatten in a depth of 2.4". In the region of the closure flanges, the shell is substantially reinforced; but even using this displacement figure, it is not possible to bend the welds more than a few degrees; so failure of welds by bending is not considered here. The failure by shear is the predominant possibility.



Assume 60 G impact load

$F = 60\ (3070) = 184,000$

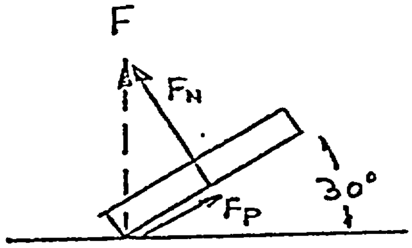
High strength alloy bolts (SA - 453) properties

Yield $S_y = 85,000$ PSI

Ult. $S_u = 130,000$ PSI

Shear $S_s = .75\ S_u = 97,500$ PSI

Bolt Analysis



$F_P = F \text{ Sin } 30^\circ = 1/2\ (184000) = 92{,}000^{\#}$

$F_N = F \text{ Cos. } 30^\circ = .866\ (184000) = 159{,}000^{\#}$

Shearing force = $92{,}000^{\#}$

Friction force opposing shear = $F_N \mu$ where μ = .2

$$159{,}000 \times .2 = 31{,}800^{\#}$$

No credit is taken for friction due to bolt pre-loading. This number is in question due to the imposition of the predominant impact load. This omission is however conservative.

Shear force - Friction force = Load on bolts.

$$92{,}000 - 31{,}800 = 60{,}200^{\#}$$

Force required to shear bolts

Area of 1/2" bolt at thread root = $0.126''^2$

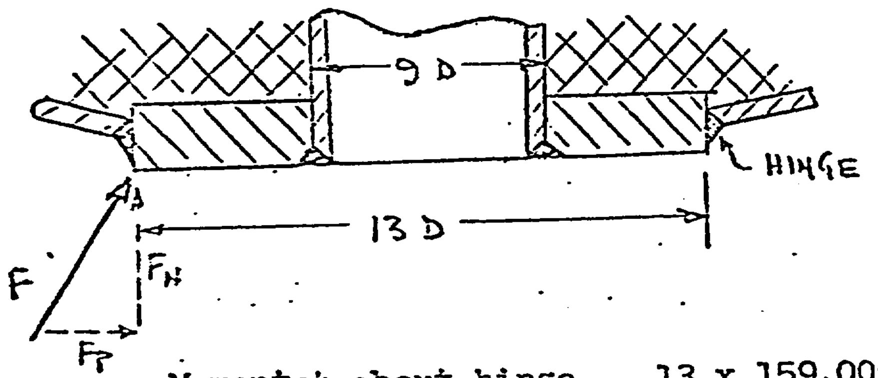
Area of 8 bolts = 8 (0.126) = $1.00''^2$

$$P = AS_s = 1 \times 97{,}500 = 97{,}500^{\#}$$

Safety Factor $\dfrac{97{,}500}{60{,}200} = 1.6$

(b) Weld Analysis

Assume closure flange to be a rigid beam hinged at one end and the imposed load acting at the opposite end.



$F_H = 159,000\#$

Moments about hinge $\quad 13 \times 159{,}000 = 2{,}070{,}000''\#$

Shear area of outer weld ring = $13\pi \times 3/8 = 15.1$ Sq.In.

Shear area of inner weld ring = $9\pi \times 3/8 = 10.6$ Sq.In.

Moments of welds $\quad \frac{13}{2}(15.1)\, S_s + \frac{9}{2}(10.6)\, S_s = (98+47.7)S_s$

$$146\ S_s = 2{,}070{,}000$$

$$S_s = 14{,}200 \text{ PSI}$$ Average shear stress

$$\text{Max } S'_s = 28{,}400 \text{ PSI}$$

The maximum imposed shear stress is 28,400 PSI and the ultimate shear stress for A7 steel is 45,000 PSI.

Factor of Safety $\frac{45}{28.4} = 1.6$

Deformation of shield due to a 30 ft. drop onto an unyielding surface. No protective jacket is considered for this calculation.

1. Energy absorbed in shield

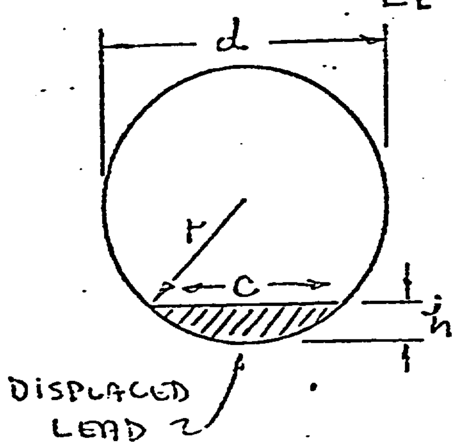
$$E_A = WH. \qquad \begin{array}{l} W = \text{weight of shield} \\ H = \text{height of drop} \end{array}$$

$$E_A = 3070 \times 30 \times 12 = 1{,}105{,}000'' \text{ lbs.}$$

2. According to ORNL - NSIC - 68 "Cask Designers Guide" the energy absorbed by bending of the steel shell may be insignificant compared to the energy absorbed in the plastic flow of the encased lead. This guide suggests a value of 5000 PSI as the flow stress of lead.

Energy absorbed in lead

$$E_L = \bar{\sigma} V \qquad \begin{array}{l} \bar{\sigma} = \text{flow stress} = 5000 \text{ PSI} \\ V = \text{flow volume} \end{array}$$



VOLUME OF SPHERICAL SEGMENT

$$V = \pi h^2 \left(r - \frac{h}{3}\right)$$

$$V = 3.14 \times 11.6 \times h^2 - \frac{3.14}{3} h^3$$

$$V = 36.4 h^2 - 1.05 h^3$$

$$E_L = \bar{\sigma} V = 182{,}000 h^2 - 5250 h$$

Energy absorbed in steel

Assume flat circular plate of diameter c supported around the edge and a concentrated load W in the center. The deflection is equal to h above.

$$\text{Defl.} = h = \frac{.55\ W\ r^2}{Et^3}$$

$r = 11.8"$

$t = 3/8"$ Plate

$E = 30 \times 10^6$

$$W = \frac{hEt^3}{.55\ r^2}$$

$$W = \frac{30 \times 10^6 \times .053\ h}{.55 \times 139} = 20{,}800\ h$$

Equating energies $\qquad E_A = E_L + E_S$

$$1{,}105{,}000 = 182{,}000\ h^2 - 5250\ h^3 + 20{,}800\ h^2$$

$$210 = 38.6\ h^2 - h^3$$

$$h = 2.4"$$

Percentage of energy absorbed by steel

$$\frac{120{,}000}{1{,}105{,}000} = 11\%$$

Absorbed by lead = 89%

3. Half layer value of lead shielding for CO_{60} is .51"

$$\frac{2.4}{.51} = 4.7 \text{ half layer}$$

$$2^{4.7} = 26 \text{ shielding factor}$$

Puncture Analysis

For hot rolled carbon steel outer shell, the minimum thickness required to withstand punching action is given by

$$t = \left(\frac{w}{s} \right)^{0.71}$$

t = inches

w = cask wt.

s = ult. stress

This formula is suggested in the ORNL - NSIC - 68 "Cask Designers Guide"

$$t = \left(\frac{3070}{60,000} \right)^{0.71} = (.051)^{0.71}$$

$$t = .107"$$

Shell is 3/8" and therefore conservative.

Fire Analysis

The method of determining the effects of the hypothetical fire on this cask is the "Energy Balance Method" proposed in O.R.N.L. N.S.I.C. 68 "Cask Designers Guide". This method is based on theoretical and emperical data developed at Oak Ridge Lab. Referenced figures are taken from this report.

The results of the calculations show that all the lead in the cask will melt in a little over one hour of exposure to the fire. The amount of lead melted after 1/2 hour exposure is 27% of the total weight.

W_{os} = weight of outer shell of cask in lbs.

W'_{os} = weight of outer shell in lbs/ft^2 of outer shell.

W_{is} = weight of inner shell in lbs.

W'_{is} = weight of inner shell in lbs/ft^2 of outer shell.

W_{l} = weight of lead in lbs.

W'_{l} = weight of lead in lbs/ft^2 of outer shell.

T_{o} = maximum normal temperature of outer shell.

Constants

k (steel) = 25 BTU/Hr Ft °F

k (solid lead) = 18.6 BTU/Hr Ft °F

k (liquid lead) = 9.3

Cp (steel) = .125 BTU/# °F

Cp (lead) = .0325

H_f heat of fusion of lead = 10.55 BTU/#

$W_{os} = 1753 \times 3/8 \times .283 = 186$ (from page C.S.1)

$W'_{os} = \frac{186}{12.2} = 15.3$ #/ft^2

$W_{is} = 220 \times .283 = 62.2$

$W'_{is} = \frac{62.2}{12.2} = 5.1$ #/ft^2

$W_1 = 5187 \times .410 = 2130$

$W'_1 = \frac{2130}{12.2} = 175$ #/ft^2

$T_o = 168^oF$ (from page C.S.10)

T_{mp} = melting point of lead = 621^oF

The time intervals expressed here are t_o - the start of the exposure, t_1 - the time when all outer lead begins to melt, and t_2 - the time all lead is melted.

From time t_o to t_1 the average surface temperature is T_{s-1}. From Figure 5.21 $T_{s-1} = 425^oF$ when $T_o = 168^oF$.

From time t_o to t_1 the average heat flux $\overline{Q}_1$ is 16,600 BTU/HR ft^2 for $T_{s-1} = 425^oF$ (Figure 5.22)

The average temperature in the lead at time t_1 is

$$T_{L-1} = 621 - \frac{\overline{Q}_1 D}{30\ k}$$ Where D = lead thickness in inches

$$T_{L-1} = 621 - \frac{16,600 \times 7.12}{30 \times 18.6}$$

$$T_{L-1} = 444^oF$$

(b) Inner Shell

$$H'_{is-1} = W'_{is} (T_{s-1} - T_o) .125$$

$$= 5.1 (424 - 168) .125$$

$$H'_{is-1} = 163$$

(c) Lead

$$H'_{L-1} = W'_L (T_{L-1} - T_o) .0325$$

$$= 175 (444 - 168) .0325$$

$$H'_{L-1} = 1570$$

$$H'_{t-1} = 1570 + 163 + 884 = 2617$$

$$t_1 = \frac{H_{t-1}}{Q} = \frac{2617}{16,600} = .158 \text{ Hours}$$

Total heat absorbed by cask after .158 hours

$$H^*_{t-1} = H'_{t-1} A = 12.56 (2617) = 32,900 \text{ BTU}$$

To determine the amount of lead melted in time t_1

$$H_{os-1} = W_{os} (T_{os-1} - T_o) .125$$

$$= (185) (463) .125 = 10,800 \text{ BTU}$$

$$H_{is-1} = W_{is} (T_{is-1} - T_o) .125$$

$$= 62 (256) .125 = 1,980 \text{ BTU}$$

$$H_{L-1} = W_L (T_{L-1} - T_o) .0325$$

$$= 2130 (276) .0325 = 19,100 \text{ BTU}$$

The average temperature in the inner shell at time t_1 is

$$T_{is-1} = 621 - \frac{\bar{Q}_1 D}{24\ k}$$

$$T_{is-1} = 621 - \frac{16{,}600 \times 7.21}{24 \times 25}$$

$$T_{is-1} = 424^\circ\ F$$

The average temperature in the outer shell at time t_1 is

$$T_{os-1} = 621 + \frac{\bar{Q}_1 X}{24k} \quad \text{where } X = \text{plate thickness}$$

$$T_{os-1} = 621 + \frac{16{,}600 \times 3/8}{24 \times 25}$$

$$T_{os-1} = 631^\circ\ F$$

The heat absorbed in the outer shell during time t_1 is

$$H'_{os-1} = W'_{os}\ (T_{os-1} - T_o)\ .125$$

$$H'_{os-1} = 15.3\ (631 - 168)\ .125$$

$$H'_{os-1} = 884\ \text{BTU}$$

$$H_{t-1} = 10,800 + 1,980 + 19,100 = 31,900 \text{ BTU}$$

$$\Delta H_{t-1} = H^*_{t-1} - H_{t-1} = 32,900 - 31,900 = 1000 \text{ BTU}$$

$$W_{ML-1} = \frac{\Delta H_{t-1}}{(621 - t_{L-1}).0325 + 10.55} = \frac{1000}{5.75 + 10.55} = \frac{1000}{16.30}$$

$$W_{ML-1} = 61.4^{\#}$$

After .158 hours 61.4 lbs. of lead is melted.

The super heat of molten lead is given by

$$T_{SUP} = (4.3°F)\frac{h}{2} \quad \text{WHERE } h = \text{CASK HEIGHT IN INS.}$$

$$T_{SUP} = 4.3 \times 12 = 52°$$

The average surface temperature of the cask at time t_2 is

$$T_{OS-2} = T_{OS-1} + T_{SUP} = 631 + 52 = 683°F$$

The net heat flux absorbed from time t_1 to t_2 is obtained from curve Fig. 5.29.

$$\bar{Q}_2 = 1506 \ \text{BTU/HR FT}^2$$

The total heat absorbed by the cask at time t_2 when the lead is completely melted is

$$H_{OS-2} = W_{OS}(T_{OS-2} - T_o).125$$

$$H_{OS-2} = 186 \times 515 \times .125 = 12,000 \text{ BTU}$$

$$H_{IS-2} = W_{IS}(621 + T_{SUP} - T_o).125$$

$$H_{IS-2} = 62 \times 505 \times .125 = 3,910 \text{ BTU}$$

$$H_{LM} = W_L\,(621 - T_0)\,.0325$$

$$H_{LM} = 2130\,(453)\,.0325 = 31{,}400 \text{ BTU}$$

$$H_{LS} = W_L\,(T_{SUP})\,.038$$

$$H_{LS} = 2130 \times 52 \times .038 = 4220 \text{ BTU}$$

$$H^{*}_{t-2} = 31{,}400 + 4220 + 3900 + 12{,}000 = 51{,}500 \text{ BTU}$$

$$t_2 - t_1 = \frac{H^{*}_{t-2} - H_{t-1}}{\bar{Q}_2\,A} = \frac{51{,}500 - 31{,}900}{1506 \times 12.56}$$

$$t_2 - t_1 = \frac{19{,}600}{18{,}900} = 1.037$$

$$t_2 = t_1 + (t_2 - t_1) = .158 + (1.037 - .158)$$

$$t_2 = 1.037 \text{ HOURS}$$

All the lead would melt in 1.04 hours.

At the end of 1/2 hour the amount of lead melted is

$$W_{ML-2} = W_{LM-1} + (W_L - W_{LM-1})\frac{(.500 - t_1)^{1.5}}{(t_2 - t_1)^{1.5}}$$

$$W_{ML-2} = 61.4 + (2130 - 61.4)\frac{(.500 - .158)^{1.5}}{(1.037 - .158)^{1.5}}$$

$$\therefore W_{ML-2} = 61.4 + 2069\,\frac{(.342)^{1.5}}{(.879)^{1.5}} = 61.4 + 504$$

$$W_{ML-2} = 565\ \#$$

$$\frac{565}{2130} = 26.5\,\%$$

REPORT ON TESTING

TELETHERAPY SHIPPING CASK TEST

I. Purpose

The purpose of the test program was to investigate the suitability of the present NPI teletherapy shipping casks and overpack for shipping up to 9500 curies of cobalt-60 sources.

The cask and overpack combination has been evaluated, licensed and used for shipping sources with cobalt-60 contents of not more than 7,000 curies and test program was designed to furnish information pertinent to the effect of the greater heat load.

II. Test Design

The heat loads imposed on the system were:

- the internal heat generated by the decay of the cobalt-60, and
- simulated sunshine of 800 $gcal/cm^2$ per 12 hours per day on the top of the metal overpack and 400 $gcal/cm^2$ per 12 hours per day on the sides of the metal overpack.

These values were taken from Table III, Paragraph 233 of IAEA Safety Series 6.

Iron-constantan thermocouples were placed in various positions throughout and connected to a multipoint recorder to record temperatures of interest. The location of these thermocouples and the equilibrium temperatures are shown in the attached "Schematic View of Teletherapy Casks with Temperature Profile, Sunshine Test Equilibrium."

III. Test Instrumentation

Before commencing each test:

a. The wooden overpack was visually inspected.

b. The wooden overpack was weighed and then placed into the metal overpack container.

c. The cask was loaded into the overpack.

d. The thermocouples were installed and connected to a multipoint recorder.

e. The metal overpack was bolted closed, as if for shipping.

f. The heat lamp array was installed.

The test was conducted by turning the heat lamps on for 12 hours and then off for 12 hours to simulate the cyclic variation of sun heating. This sequence was continued until no further temperature increases were noted in the cask and internal overpack temperatures. Temperatures from some of the thermocouples are plotted to show that equilibrium was obtained.

APPENDIX A

From Table III Top of the overpack requires insolation of 800 $gcal/cm^2/12$ hours which translates to 0.500 $watts/in^2$. The sides require 400 $gcal/cm^2/12$ hours or 0.250 $watts/in^2$.

To simulate sunshine conditions the outside the overpack should be irradiated at the above rates for 12 hours and should then receive no radiation for the ensuing 12 hours. To furnish the required heating GE R40 Infra Red lamps were selected:

Overpack top is 48.5" in diameter for total area:

$$= \frac{D^2}{4} = \frac{(48.5)^2}{4} = 1848 \text{ in}^2$$

Assuming 75% reflector efficiency then we need:

$$\frac{1848 \times .5}{.75} = 1231 \text{ watts}$$

Since six 250 watt lamps = 1500 watts, this will be sufficient. These lamps could be mounted on a circle enclosing half the area of the top of the overpack. This, then, calls for a mounting circle diameter $D = \frac{4A}{12} = \frac{4 \times 1848}{2} = 34.3"$

Mount the lights, equally spaced, around a circle whose diameter = 34.3". For good uniformity the lamps should be at least 1.6 times the lamps spacing away from the surface being irradiated. This, then, would call for a lamp height of $\frac{1.6 \times 34.3}{2} = 27.5"$ above surface.

From the above, one can see that included angle of irradiation = ton^{-1}

$$\frac{27.5 \times 2}{(48.5 - 34.3)} = 75.5^{o}$$

Since over 90% of the heat radiated from the lamps comes in a cone with an angle of 15^{o} to the axis of the lamp, the energy wasted over the side of the overpack will not result in reducing the total heat input below .90 X 1500 =

1350 watts which is comfortably above the 1231 watts required.

Similarly, for the side of the overpack:

Side area A = Dh where D = diameter = 48.5"

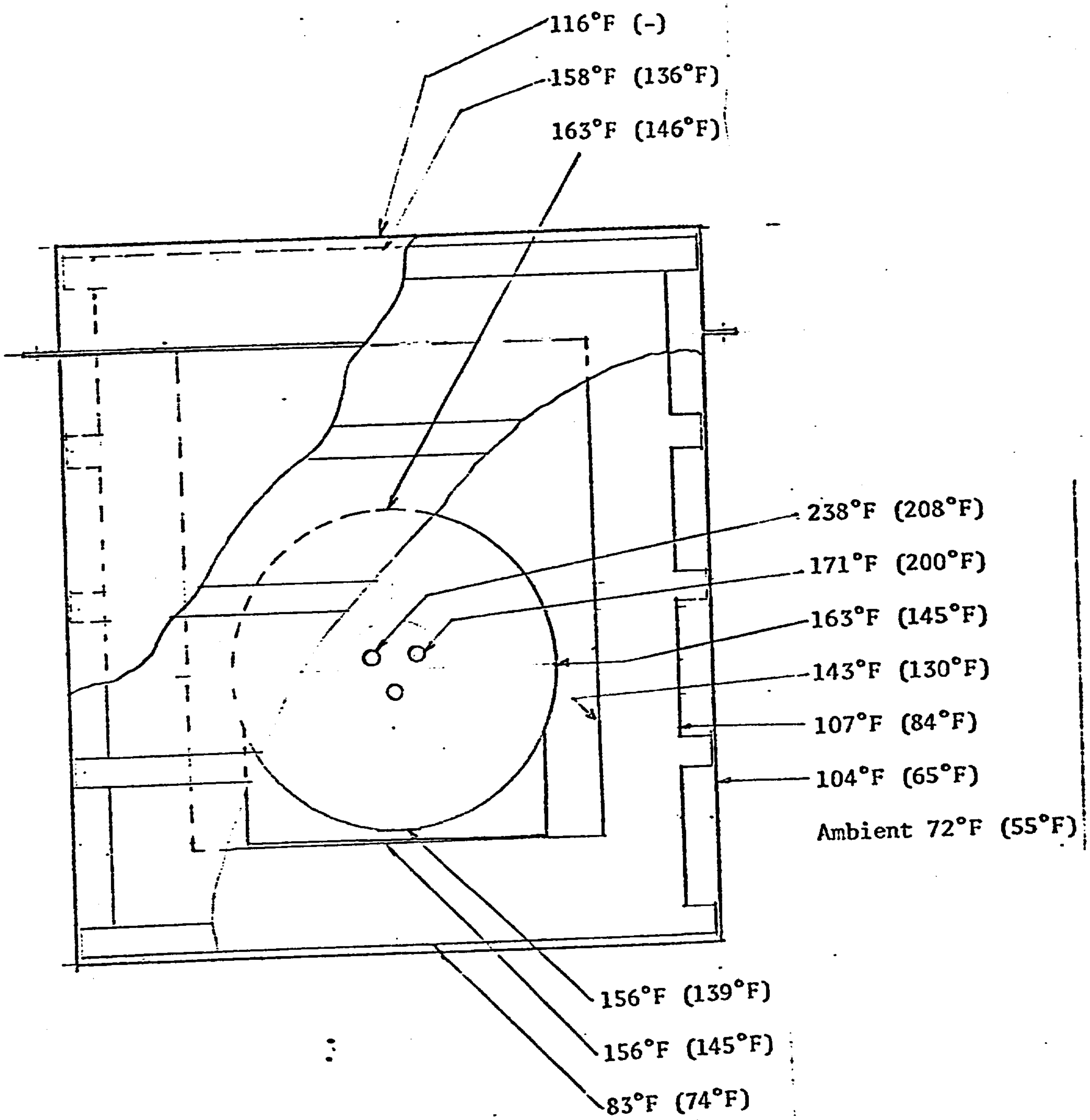
= 7313 in^2 where h = height = 48"

$$\text{Required heat} = \frac{7313 \times 0.250}{.75} = 2438 \text{ watts}$$

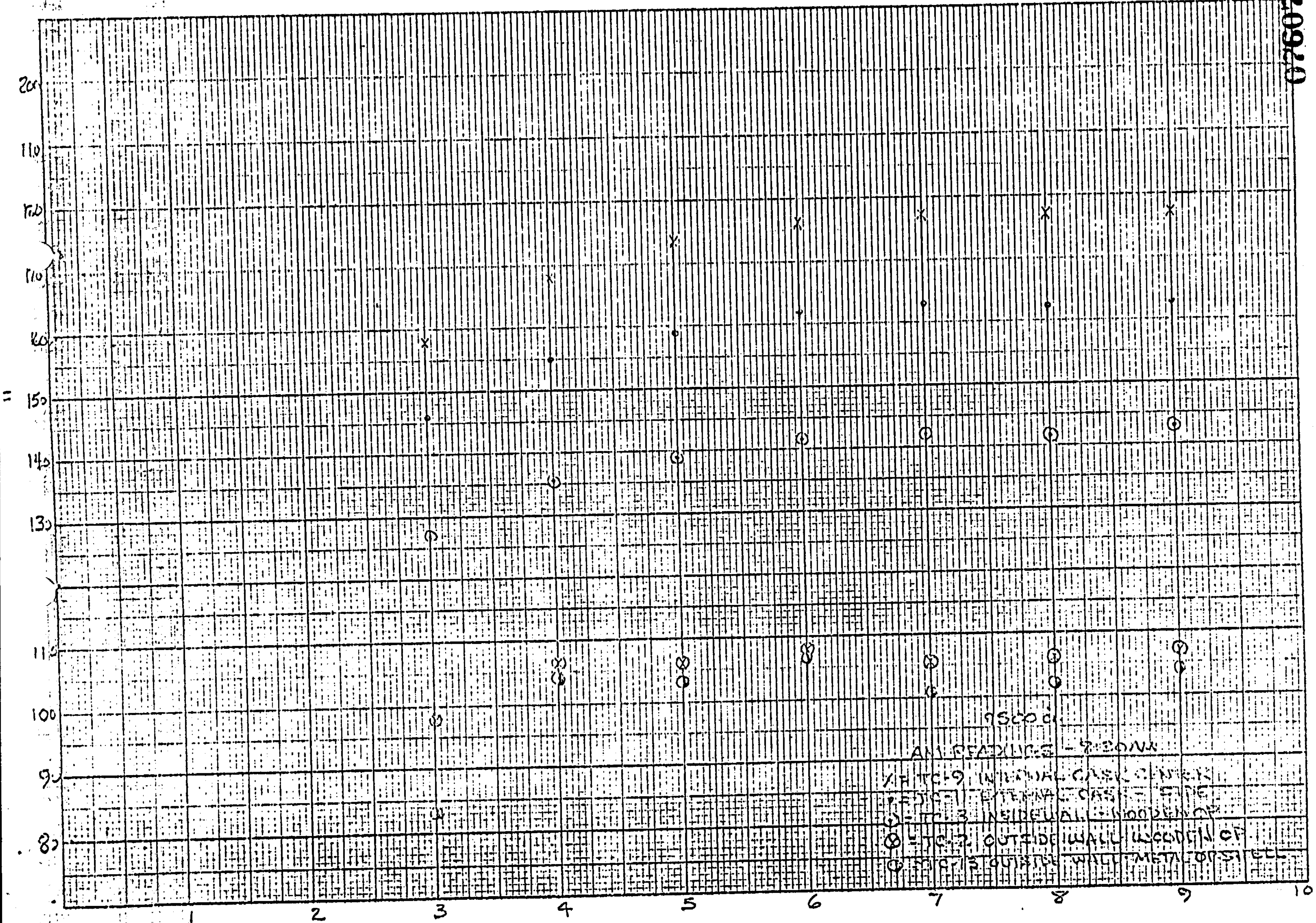
Since 24 125 watt lamps = 3000 watts, this will be sufficient. Once again, using the equal area principle, mount the lamps in two rings 12" and 36" from the floor.

Since the two rows are 24" apart, the lamps should be 24 X 1.6 = 38.4" from the surface for good heat uniformity. This can be done further improved by staggering the two rows. Once again more than 90% of the radiated energy will fall on the surface. This is .9 X 3000 = 2700 watts, comfortably above the 2438 watts needed.

First temperature measured with 9360 curies of cobalt-60
Temperature in parenthsis measured with 6750 curies of cobalt-60



REVISIONS	TITLE	NEUTRON PRODUCTS inc Dickerson, Maryland
APPROVED	SCHEMATIC VIEW TELETHERAPY CASK WITH TEMPERATURE PROFILE SUNSHINE TEST EQUILIBRIUM	SIZE A
DRAWN k...		SHEET 240026
SCALE ~ DATE 8-31-77		07807


07607
200
190
180
170
160
150
140
130
110
100
90
80
1
2
3
4
5
6
7
8
9
10
950°C
TC-9 INTERNAL CASK CENTER
TC-3 INSIDE WALL
TC-2 OUTSIDE WALL
TC-13 OUTSIDE WALL METAL