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SLBaggett

JUL 2 6 1983

MEMORANDUM FOR: Donald A. Nussbaumer
Assistant Director for State Agreements Program
Office of State Programs

FROM: Bernard Singer, Chief
Material Certification and Procedures Branch
Division of Fuel Cycle and Material Safety, NMSS

SUBJECT: REQUEST FOR TECHNICAL ASSISTANCE

Per your request dated June 28, 1983, we have reviewed the information submitted to the State of Maryland by Neutron Products, Inc. We understand that Neutron Products, Inc. proposes to manufacture and commercially distribute these Cobalt-60 sources.

We have had our engineering staff review the submittal, however, they did not have adequate information to permit a suitable analysis. We need Neutron Products, Inc. to provide additional information on the following items:

1. A more detailed description of the source, include procedures and standards required for fabrication and examination of the source.

2. Descriptions of the operating conditions intended for the source including any limitations (environment, temperature, cycles, etc.).

3. Maximum stress levels expected and maximum number of cycles in design life of source. How does the enclosed O'Donnell & Associates, Inc. report apply to the change?

4. Are any operating restrictions being recommended for the amended license by the applicant or being considered by the State that should be considered in an analysis?

5. Was ANSI N538 or DOT Special Form testing performed on the source? If not, please provide data that shows the source will meet these requirements. The source should be evaluated to the new, July 1983, DOT Special Form testing requirements.

2pp.

B/18

OFFICE							
SURNAME							
DATE							

We will continue our review upon receipt of the above information. If you have any questions, please contact Steve Baggett of my staff.

Original Signed By
Steven L. Baggett

Bernard Singer, Chief
Material Certification and
Procedures Branch
Division of Fuel Cycle and
Material Safety, NMSS

OFFICE	FCMC	FCMC	FCMC		
SURNAME	SLBaggett:rad	JMBrown	BSinger		
DATE	7/26/83	7/27/83	7/27/83		

Region I

71-9044

NEUTRON PRODUCTS inc

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 USA
301/349-5001 TWX: 710-828-0542

October 27, 1983

'83 NOV -2 A10:58

Mr. Charles E. McDonald, Chief
Transportation Certification Branch
Division of Fuel Cycle and Material Safety
Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. McDonald:

Please confirm that we are registered as a user of the Chem-Nuclear Systems, Inc. CNSI 1-13G radioactive materials shipping cask as stated in the attached correspondence. Package identification for this cask is USA/9044/B( )F.

We find that the Certificate of Compliance for this package was not included with others we received from your office on August 29, 1983.

Thank you.

Sincerely,

NEUTRON PRODUCTS, INC.

Teresa L. Snyder

Teresa L. Snyder
Traffic Department

Enclosure

TLS/kmw

8312070004

23045

October 28, 1980

Transportation Branch
Division of Fuel Cycle and
Material Safety
Nuclear Regulatory Commission
Washington, D. C. 20555

ATTN: Mr. C. E. MacDonald
Chief, Transportation Branch

Gentlemen:

Pursuant to the requirements of 10 CFR 71.12, Neutron Products, Inc., as holder of agreement state license number MD-31-025-01, wishes to register as a user of the Chem-Nuclear Systems, Inc. CNSI 1-13G radioactive materials shipping cask. Package identification number for this cask is USA/9044/B ( )F, NRC Docket No. 71-9044.

Sincerely,

NEUTRON PRODUCTS, INC.

Carmina Smedira
Quality Assurance Manager

cc: Mr. K. Krasner
C-E Power Systems

CS/dlm

bcc: Jeff Corum
Roger Gerbig
Marvin Turkanis

8011180503

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

DEC 12 1980

DEC 10 1980

FCTC:ZDM
71-9044

Neutron Products Inc.
Attn: Mr. Marvin Turkanis
22301 Mt. Ephraim Road
Dickerson, MD 20753

Gentlemen:

As requested in your letter, we have registered you in accordance with the provisions of Paragraph 71.12(b) of 10 CFR Part 71 or 49 CFR §173.393a as a user of the following:

Model	Package Identification Number
GE-1600	USA/9044/B( )F

Sincerely,

Charles E. MacDonald, Chief
Transportation Certification Branch
Division of Fuel Cycle and
Material Safety

cc: General Electric Co.
Attn: Mr. G. E. Cunningham
P.O. Box 460
Pleasanton, CA 94566

8101100104 1p

Reg. 1

FCTC:EPE
71-9081, 71-9044, 71-9152

NOV 18 1983

Neutron Products, Inc.
ATTN: Teresa L. Snyder
22301 Mt. Ephraim Road
Dickerson, MD 20842

Gentlemen:

As requested in your letter dated October 27, 1983, we have verified that you are registered in accordance with the provision of 49 CFR Part 173.471 as a user of the following certificates of compliance.

Model Number	Package Identification Number
CNSI 1-13C	USA/9081/B( )
GE-1600	USA/9044/B( )
CNSI 1-13CII	USA/9152/B( )

Sincerely,

Charles E. MacDonald

Charles E. MacDonald, Chief
Transportation Certification Branch
Division of Fuel Cycle and
Material Safety, NMSS

cc: Chem-Nuclear Systems, Inc.
ATTN: Ms. Robin Deal
240 Stoneridge Drive, Suite 100
Columbia, SC 29210

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71-5364

DOCKETED USNRC APR 10 1985 NMSS MAIL SECTION DOCKET CLERK

NEUTRON PRODUCTS inc

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 USA
301/349-5001 TWX: 710-828-0542

April 8, 1985

Mr. Charles E. McDonald
Chief, Transportation and Certification Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

'85 APR 10

Subject: Certificate of Compliance No. 5364

Dear Mr. McDonald:

During a discussion of several matters at NRC Transportation on March 29, 1985, we described a failure of the drain/vent line in Section B of the Model No. NPI-67-0442 cask system and discussed our plans for effecting its repair. NRC representatives recommended that we treat the matter as reportable under 10 CFR 71.95. This letter is in response to that recommendation. It also addresses related experiences of drain line failures in Section C of the cask system. Although we are willing to file such reports, we have not considered drain line failures to be reportable under 10 CFR 71.95, because actions and precautions taken by Neutron Products have precluded significant reduction in the safety and effectiveness of the packaging.

We have occasionally experienced failures of drain/vent lines, resulting in communication between the internal cavity (source chamber) and the internal volume containing lead shielding. In no case has the integrity of the boundary between the interior of the cask and the environment been affected. The consequences of internal leakage are radioactive contamination of the shielding cavity and, in a hypothetical accident condition, possible loss of some lead shielding by migration of lead into the shipping chamber. The potential loss of lead shielding is limited by our practice of filling the unused volume of the shipping chamber with stainless steel rods and/or brass disks.

Section C is the bottom section of cask Modes II and IV, as described in the Certificate of Compliance. On several occasions the drain/vent lines have failed where they are welded to the stainless steel lining of the source chamber. The problem was first identified in 1974 and the weld was repaired. The problem recurred and repairs were made in 1980, 1983, 1984, and 1985. The cause of the failures is thought to be differential thermal expansion between the lead shielding and the stainless steel lining and possibly also differential movement when the cask is set down, which events impose stresses on the drain line where it is welded to the lining of the source chamber. In the latest repair, recently completed, the old drain/vent tubes have been removed and replaced with heavier wall tubing. In addition, shims have been installed in the expansion void at the bottom of Section C to restrain movement of the lead. In our judgement, this repair is in accordance with the Certificate of Compliance and the basic design of the shipping container.

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Section B is the bottom section of cask Modes I and III, as described in the Certificate of Compliance. In 1980 Neutron Products identified an internal leak in a drain/vent line in a location not accessible for repair. An internal review of the safety significance was performed at that time and it was determined that the only potential concern was loss of some lead shielding, by migration into the source chamber, in a hypothetical accident condition. This possibility is mitigated by filling the unused volume of the source chamber as described above. Section B was removed from service in 1984 for the purpose of effecting repairs. The planned repair involves installing a stainless steel sleeve in the 4-1/2 inch diameter central hole and sealing the holes in the upper tube sheet, thereby isolating the source chamber from the cavity containing lead shielding, and providing for drainage through the top. Although we do not believe a structural review is required, our approach involves a change in the method of cask drainage and, prior to initiating these repairs, we will review with you the planned repairs and detailed drawings, with the hope that you will concur.

Very truly yours,

NEUTRON PRODUCTS, INC.

Frank Schwoerer

Frank Schwoerer, Vice President

FS:mbn

Region 1

NEUTRON PRODUCTS inc

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 USA
301/349-5001 TWX: 710-828-0542

'85 NOV -4 P3:33

November 1, 1985

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

Dear Mr. MacDonald:

Please register Neutron Products as a user of the Model No. 700 shipping cask. The cask identification number is USA/5942/B( )F.

Very truly yours,

NEUTRON PRODUCTS, INC.

Wayne J. Costley

Wayne J. Costley
Quality Assurance Manager

WJC:mbn

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Region I 71-5942

NEUTRON PRODUCTS inc

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 USA
301/349-5001 TWX: 710-828-0542

November 11, 1985

RECEIVED
NOV 1985
U.S. NUCLEAR REGULATORY COMMISSION

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

Ref: Certificate of Compliance No. 5942

Dear Mr. MacDonald:

This letter requests a modification to the subject Certificate of Compliance to allow Neutron Products to utilize the G.E. Model 700 shipping package to ship cobalt-60 from the Savannah River plant to Neutron Products' Dickerson, Maryland facility.

Most of the irradiated cobalt material is nickel plated and all of the material is encased in aluminum cladding. However, the material has been stored underwater for some time and the integrity of the nickel plating and aluminum cladding can not be assured. Therefore, the material can not be demonstrated to meet the requirements of "special form", stipulated in articles 5(b)(1) and 6 of the Certificate of Compliance. Neutron Products proposes to ship this material in a sealed, vacuum-dried, and helium-filled liner in the G.E. Model 700 shipping package. The liner, in combination with the shipping package, will retain its integrity throughout the normal conditions of transport prescribed by 10 CFR 71.71 and the hypothetical accident conditions prescribed by 10 CFR 71.73. Enclosed with this letter are (1) description of the liner, (2) a summary of the procedures for loading and drying the liner, (3) analyses of the performance of the liner/shipping package under normal conditions of transport and hypothetical aacident conditions, and (4) proposed wording of a modification to the Certificate of Compliance.

A check for the $150.00 application fee is enclosed.

Very truly yours,

NEUTRON PRODUCTS, INC.

Frank Schwoerer

Frank Schwoerer, Vice President

FS:mvc
Enclosures

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ENCLOSURE 1

DESCRIPTION OF SEALABLE LINER AND SLEEVE

Liner Design

The cask liner is shown in Neutron Products drawing 240139.

The lower portion is a 10 IPS Schedule 10 stainless steel pipe, with a flanged opening at the top and a flat-plate bottom. The underside of the bottom is grooved to allow water to drain from the cask cavity, outside the liner. A small diameter pipe for purging water from within the liner runs from the flanged opening to the bottom of the liner. Savannah River cobalt is in the form of aluminum rods of approximately 0.94 inch diameter and 8 inch length. These rods will be loaded into the liner, on basically a triangular pitch, with up to 64 rods per 8 inch high layer. Appropriate spacers/supports of stainless steel will be used to keep the rods in an upright position. There is room for four such layers. The actual number in any shipment will be established by the allowable curie loading or geometry, whichever is more limiting.

The lid of the liner contains a spiral-wound stainless steel and asbestos gasket, which seals the large opening in the liner. The mating flanges are machined with grooves that match the stainless steel chevrons of the seal. The lid is held in place and the gasket compressed by twelve 3/4 inch bolts. This design is close to that of a standard flange for 10 IPS piping. The differences are in the outer diameter of the flange (14-7/8 vs. 16 inch) and in the bolt diameter (3/4 vs. 7/8 inch), which are limited by the 15 inch cavity diameter.

The lid of the liner is penetrated by two openings: one to introduce gas, the other to purge water. Each opening has a stainless steel bellows valve, for sealing the opening, and a stainless steel hose connection. Enclosure 2 describes how these connections are utilized to purge water from within the liner, vacuum dry the contents, and fill with an inert gas. The valves and hose connections are protected against impacts, which can result from the normal conditions of transport and hypothetical accident conditions of 10 CFR 71.71 and 71.73 by a section of 10 IPS Schedule 10 stainless steel piping and two transverse plates of stainless steel. The transverse plates also support a lifting pin.

The liner will be assembled, sealed and leak-tested prior to use. The gap between the flanges (nominally 0.100 inch) will be measured after the lid bolts are fully torqued and the liner is demonstrated to be leak-tight. A shim ring will then be machined to the thickness of the gap between flanges and will be used, with a new gasket, when the liner is used to transport normal form radioactive material. This will ensure metal to metal contact at the flanges to transmit impact loads if the shipping package is dropped.

The weight of the liner is approximately 250 pounds. The maximum weight of the contents is 180 pounds. Thus, the loaded weight is a maximum of 430 pounds.

Sleeve Design

The sleeve design is shown in Neutron Products drawing 240138.

The sleeve is an annular cylinder of aluminum, that fills the space between the wall of the liner and wall of the cavity. Its purposes are to enhance radial heat transfer and to support the liner against lateral impacts.

The weight of the sleeve is approximately 240 pounds.

Total weight of Cask Contents

With a maximum weight of 430 pounds for the liner and its contents and a sleeve weight of 240 pounds, the maximum weight of the contents of the shipping package is 670 pounds, which conforms to the limit of 700 pounds specified in article 5(b)(2) of Certificate of Compliance No. 5942.

SUMMARY PROCEDURE FOR LOADING, DRYING AND SEALING LINER

1. Place the bottom portion of the liner in a holding fixture in a working platform, that is submerged at least ten (10) feet below the surface of the water in the storage pool (basin).

2. Transfer the cobalt-60 containing aluminum rods from storage buckets to the liner.

3. When the liner is filled, install the lid, with its integral seal and with hoses attached to the two hose connections on the lid. One hose shall connect to a source of helium; the other shall run to a water container. Install and tighten the lid bolts with a long-handled tool.

4. Supply helium with sufficient pressure (approximately 25 psia) to displace water from within the liner. Collect the discharged water in a container and measure its volume to ensure that essentially all of the water has been removed. During this step, observe the top of the liner for indication of helium leakage. If such indication exists, retorque the lid bolts and/or replace the gasket and repeat this step.

5. Connect a vacuum pump to the discharge line. Run the vacuum pump until a vacuum of at least 27" Hg can be maintained for 5 minutes with the pump turned off. (This is indication that all water has been removed from the liner.)

6. Close the discharge valve, using a long-handled tool.

7. Fill the liner with helium to 2 to 3 psi above the ambient hydrostatic pressure. (Minimum pressure in psia is given by: water depth in feet times 1/2 plus 17.)

8. Close the helium inlet valve with a long-handled tool. Observe the liner for indication of helium leakage. If leakage is indicated, make the necessary corrections and repeat steps as necessary to ensure that the liner is dry and filled with helium to the specified overpressure.

9. Pull the hoses off the hose connections.

10. Lower the GE 700 cask, with the sleeve inserted, into the pool.

11. Lift the sealed liner from the work platform and insert it into the GE 700 cask.

EVALUATION OF PACKAGE PERFORMANCE UNDER NORMAL CONDITIONS OF TRANSPORT (10 CFR 71.71) AND HYPOTHETICAL ACCIDENT CONDITIONS (10 CFR 71.73)

General

General Electric Company has demonstrated (in a consolidated application for certification, submitted to the NRC by letter dated March 18, 1980) that the GE Model 700 shipping package will survive normal conditions of transport and hypothetical accident conditions, except that the lid gasket may fail. A way to prevent any dispersal of radioactive material under normal conditions of transport and hypothetical accident conditions, since irradiated cobalt from the Savannah River plant can not be demonstrated to meet the clad integrity requirements for special form material, is to seal the cobalt within a cask liner. This enclosure demonstrates that the cask liner and seal described in Enclosure 1, when loaded and dried as described in Enclosure and contained within the GE Model 700 shipping package, will remain intact through normal conditions of transport and hypothetical accident conditions; and thus ensure containment of radioactive material.

The following evaluation builds upon General Electric's consolidated application for certification, referenced above.

Normal Conditions of Transport

Thermal: The liner components (stainless steel shell, and stainless steel, bellows-type shutoff valves, and stainless steel/asbestos gasket), the aluminum sleeve, and the contents of the liner are unaffected by ambient temperature extremes defined in 10 CFR 71.71. Calculated temperatures at an ambient temperature of 80°F and a limiting heat load of 6500 watts are:

Cask surface	300°F	(ref: GE application)
Sleeve I.D.	339°F	
Liner O.D.	380°F	
Gasket & valves	<400°F	
Contents @ centerline	505°F.	

These temperatures are sufficiently above and below limiting temperatures for the materials that ambient temperature extremes will have no effect on liner or seal integrity. The pressure within the liner will be approximately 15 psig, which is well within the capability of the seal and liner.

Pressure: The GE 700 package will withstand the range of external pressures defined in 10 CFR 71.71 (ref: GE application). The liner and its contents will therefore be unaffected by external pressure.

Vibration: The GE 700 package will withstand vibration normally incident to transport (ref: GE application). The liner fits closely within

the cask cavity and sleeve and will, therefore, be subjected to essentially no amplification of vibration. The close fits and the loose contents of the liner will tend to damp out vibration. The edge of the lid is of slightly smaller diameter than the flange on the liner, so there is no possibility of lateral impacts on the lid that might loosen the gasketed closure. The valves and bolts are protected from vibrational impacts.

Water spray: Water spray will not adversely affect the cask, including the lid gasket. Therefore the liner will be unaffected.

Free drop: There is no damage to the GE 700 cask from dropping the distance prescribed by 10 CFR 71.71 (ref: GE application). It will be shown that, even when subjected to the higher loads resulting from a postulated 30 foot drop, the liner will retain its integrity. Therefore, the liner, its seal, and its shut-off valves will retain their integrity for the one (1) foot free drop prescribed by 10 CFR 71.71.

Corner drop: Not applicable.

Compression: Not applicable.

Penetration: There is no damage to the GE 700 cask from the penetration impact prescribed by 10 CFR 71.71 (ref: GE application). Therefore the liner will be unaffected.

Summary and Conclusions: The assessments set forth above provide assurance that the Neutron Products liner, transported within the GE Model 700 shipping package, will not be adversely affected by Normal Conditions of Transport and will retain its sealing function.

Hypothetical Accident Conditions

Free drop: Based on analyses done by General Electric, damage to the GE 700 shipping package from a 30 foot drop would not exceed that suffered by the GE Model 100 package in a 30 foot drop test (ref: GE application). That damage consisted of local distortion of the steel overpack; the cask was not damaged (ref: NRC Docket No. 71-5926, GE letter dated January 25, 1980). The question remaining to be addressed is whether the g-loadings, resulting from a 30 foot drop, would result in loss of integrity of the cask liner.

It appears, from damage suffered by the GE 100 package, that the average deceleration of the cask liner would be in the range of 50 to 100 g. However, Neutron Products has no quantitative data from which to determine the maximum g-loading. Therefore, to establish a conservatively high g-loading, it is assumed that all of the kinetic energy of the shipping package (cask, contents, and overpack) is absorbed by deformation of the lead shielding of the cask. The deformation and maximum g-loading are calculated using a "dynamic flow pressure" and the geometry of the cask. A conservatively high value of the g-loading is obtained by using a dynamic flow pressure of 10,000 psi (ref: ORNL-NSIC-68, A Guide for the Design, Fabrication, and Operation of Shipping Casks for Nuclear Applications, February 1970).

On this conservative basis, the energy to be absorbed by lead deformation is 35,500 lbs x 30 ft or 1.065×10^6 ft lbs. The worst case impact, with respect to liner integrity, is an upside down impact. The cross-sectional area of lead is 988 in^2. Thus the force to deform the lead is 9.88×10^6 lbs. As the lead cross-sectional area is uniform in the axial direction, the depth of lead deformation is 1.065/9.88 or .108 ft or 1.29 in. The corresponding g-loading, which is uniform with deformation, is 30/.108 or 278 g. All of the weight of the liner, its contents and the cavity sleeve (670 lbs; ref: Enclosure 1) is carried in this postulated impact by the short section of 10 IPS Schedule 10 piping and the two transverse plates. That cross-sectional area is 11.7 in^2. Therefore, the compressive stress at 278 g is 278 x 670/11.7 or 15,920 psi, which is well below the yield stress of the material. Therefore, the shut-off valves and other hardware on top of the lid will not be damaged. The total weight of the bottom section of the liner and cask sleeve (370 lbs) is carried across the closure flange by the shim ring, which prevents further compression of the seal ring, that might affect the integrity of the seal. Other stresses in the liner are also well below the material yield stress.

A bottom-down impact results in lower stresses than those analyzed above because (1) the bottom of the lead has a convex shape, which would result in a lower g-loading and (2) the load carried by the liner wall is relatively low (230 lbs). A side-down impact, analyzed by the same conservative methodology results in a maximum g-loading of 270 g. Under this condition, the wall of the liner is subjected to an equivalent pressure of 90 psia, which results in a hoop stress of 3,520 psi, well below the material yield stress.

From this conservative analysis, it is concluded that the liner will retain its integrity if the shipping container were subjected to a free drop of 30 feet.

Puncture: General Electric has analyzed the consequences of this postulated occurrence to be not greater than for the GE Model 100 package (ref: GE application). A test of the Model 100 package, consisting of a 40 inch drop onto a 6 inch diameter by 8 inch long steel bar, resulted in local yielding of the protective jacket (overpack) but no penetration of the protective jacket and no damage to the cask (ref: Docket No. 71-5926, GE letter dated January 25, 1980). If the local deformation of the protective jacket is greater than .144 inch for an impact in line with the center of gravity of the package, the g-loading on the liner will be less than calculated for the 30 foot free drop. Analyses of the strength and stiffness of the liner indicate that for such impacts, the local deformation will exceed .144 inch. Therefore, the cask liner and its seal would not be damaged.

Thermal: General Electric has analyzed the GE 700 shipping package for exposure to the fire prescribed by 10 CFR 71.73. A coast up analysis indicated that a maximum temperature of 464°F could result at the innermost lead node (ref: GE application). The materials of construction of the liner, bellows-type shut-off valves, and cask sleeve have acceptable mechanical properties at this temperature. The stainless steel and asbestos gasket will retain its function up to 1000°F (ref: Parker Seals catalog). Further, if the steady-state temperature difference of 125°F from the centerline of the liner to the liner surface is conservatively assumed to exist, the maximum centerline temperature would be approximately 590°F and the pressure within the liner would be approximately 18 psig. This is well below the capability of the seal and liner. Therefore, it is concluded that the cask liner will retain its sealing function throughout the postulated exposure fire.

Water Immersion: The seal on the cask liner is rated for a differential pressure of 250 psi (ref: Parker Seal catalog). Therefore, the seal is capable of preventing in-leakage of water at an external pressure of 21 psig.

Summary and Conclusions: The assessments set forth above provide assurance that the Neutron Products liner, transported within the GE Model 700 shipping package, will not be adversely affected by the Hypothetical Accident Conditions and will retain its sealing function.

ENCLOSURE 4

PROPOSED WORDING OF MODIFICATIONS TO CERTIFICATE OF COMPLIANCE NO. 5942

NOTE: Underlining designates proposed additions to existing wording.

5. (b) (1) Type and form of material

Byproduct, source, and special nuclear material contained in solid oxide or metal form and in special form, or sealed within a liner constructed in accordance with Neutron Products" drawings 240139 and 240138.

6. The radioactive material must be in the form of fuel rods, or plates, fuel assemblies, or meeting the requirements of special form radioactive material, or of normal form if sealed within a liner constructed in accordance with Neutron Products' drawings 240139 and 240138.

8. Prior to each shipment the silicone rubber lid gasket(s) must be inspected. This gasket(s) must be replaced if inspection shows any defects or every twelve (12) months, whichever occurs first. Cavity drain line must be sealed with appropriate sealant applied to threads of pipe plug. Sealable liner, if used, must be vacuum-dried, such that a vacuum of 27" Hg can be maintained for 5 minutes with the vacuum pump turned off, before sealing and pressurized with helium to 2 to 3 psi above ambient hydrostatic pressure, with no visible release of helium while the liner is underwater.

Region 1

NEUTRON PRODUCTS inc

'85 ... -1 ...

December 4, 1985

DOCKETED USNRC DEC 9 1985 MAIL SECTION DOCKET CLERK

Mr. Charles E. MacDonald, Chief
Transportation Certification Branch
Division of Fuel Cycle and
Material Safety, NMSS
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, Maryland 20014

Dear Mr. MacDonald:

I have enclosed copies of Neutron Products, Incorporated, Quality Assurance Program for the Transportation of Radioactive Materials, Revision 5, December -, 1985. This revision is submitted in support of our request for renewal of our Approval for Radioactive Packages, Number 0121.

As stated in the enclosed Quality Assurance Program, it is Neutron Products corporate policy to perform work on items important to safety in accordance with the requirements of 10CFR 71 Subpart H Quality Assurance. The objective of this quality assurance program is to ensure the safety of company personnel, the public, the local environment, and the users of the company's products, control of shipments and timely delivery in compliance with transportation regulations.

We would be pleased to provide any further clarification that might be required.

Very Truly Yours,

NEUTRON PRODUCTS, INC.

J. A. Ransohoff
President

Enclosures

JAR/ksg

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QUALITY ASSURANCE PROGRAM

FOR THE

TRANSPORTATION OF RADIOACTIVE MATERIALS

NEUTRON PRODUCTS, INCORPORATED

DIVISION III

REVISION 5

DECEMBER 4, 1985

Wayne J. Costley

W.J. Costley, Manager
Quality Assurance, Division III

J.A. Ransohoff

J.A. Ransohoff, President

Control Copy Number _______

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QUALITY ASSURANCE PROGRAM FOR THE
TRANSPORTATION OF RADIOACTIVE MATERIALS

CONTENTS

1.0 INTRODUCTION

Neutron Products, Inc. (NPI) was established in 1959 to produce radioisotopes commercially. In part, the company is engaged in the business of selling Cobalt-60 sources for teletherapy, intercavity, and industrial applications. Toward this end, company activities include Cobalt-59 target design, procurement, transportation, and irradiation, as well as Cobalt-60 transportation, processing, encapsulations, delivery, installation, maintenance, and source replacement.

Neutron Products operates under the regulatory authority of the U.S. Nuclear Regulatory Commission (NRC), the U.S. Food and Drug Administration (FDA), the U.S. Department of Transportation (DOT), and the State of Maryland Department of Health and Mental Hygiene. This Quality Assurance (Q.A.) Program, for the Transportation of Radioactive Material has been developed in accordance with the regulations of the U.S. Nuclear Regulatory Commission contained in 10 CFR 71, Subpart H, and satisfies the criteria of the subpart.

In keeping with its corporate commitment Neutron Products has provided, and will continue to provide, quality products and services to its customers. Efforts to ensure the safety of company personnel, the public, the local environment, and the users of the company's products is the objective of this Quality Assurance Program. Stated in another way, Quality Assurance at Neutron Products is:

- a planning process whereby we ensure, to the greatest extent possible, to perform to our commitments;
- an investigative process that discovers on a timely basis, if we fail to meet our commitments, the cause(s) of such failure; and,
- a remedial process for correcting any such deficiencies and such repetition.

Neutron Products' approach to quality assurance and the content of our Quality Assurance Program are presented in the following sections.

2.0 GENERAL QUALITY ASSURANCE APPROACH

10 CFR 71, Subpart H, provides 18 requirements for establishing and implementing a quality assurance program for components of packaging which are important to safety. The NPI Quality Assurance Program complies with these requirements. This QA plan represents NPI's application of these requirements to the transportation of radioactive materials. The QA approach presented in this document consists of the following key elements:

Control Copy Number ____

- Planning - what to do to provide quality
- Execution - of the plans established
- Documentation - of the execution and verifications
- Inspecting and Auditing - to see if activities are performed and documented correctly

NPI division management will assess the scope, status, implementation, and effectiveness of the QA program once a year, to ensure that the program is adequate and complies with all applicable regulations. The following are definitions of key terms in the QA program:

- Quality packaging - the loading of radioactive materials in a NPI or other organization's shipping container for shipment in conformance with applicable regulatory requirements, and completion of the documentation of this activity.
- Off-site location - a location other than Dickerson, Maryland, at which a radioactive shipment controlled by NPI may originate or terminate.
- Quality transportation - the safe and efficient transport of radioactive materials from one site to another in accordance with applicable requirements and the completion of documentation of this activity.
- Radioactive materials shipping container - herein called container, is one complying with the applicable regulations of the DOT and NRC.
- Quality related items - any packaging items for which the design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair and modification are safety related and to which quality assurance requirements apply.

3.0 QUALITY ASSURANCE PROGRAM CONTENT

The content of Neutron Products' QA program is organized in this section in conformance with the 18 numbered paragraphs of Subpart H that delineate the requirements of the regulation.

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3.1 Quality Assurance Organization

The transportation of nuclear materials is the responsibility of Division III of Neutron Products and is monitored by the Quality Assurance organization of Division III.

The QA Manager of Division III, reports directly to the President of Neutron Products. He has the responsibility to establish standards and identify instances of this performance or non compliance, and the authority to initiate, recommend, or require solutions, and to verify the implementation of solutions for quality related operations. Also, he has the authority and responsibility to secure such additional assistance as is necessary to ensure that operations are conducted in conformance with quality assurance requirements, and to suspend operations until these requirements have been met. The responsibilities of Neutron Products' personnel in executing this QA program are detailed in Table 1.0 "Quality Assurance Responsibility Matrix."

At NPI the line organization has the responsibility for the planning, execution, and documenting activities. The QA Manager, as appropriate, participates and concurs in these activities and has the responsibility for auditing tasks. In view of NPI's size, maximum use of line individuals has been made. Line individuals will be qualified to check, verify, test, and inspect actions of other line individuals. The QA Manager will continually assess the effectiveness of the overall program and be responsible for program change, indoctrination, monitoring, and coordination.

Line management at NPI shall be responsible to provide that:

- Personnel responsible for performing quality related activities are instructed as to the purpose, scope and implementation of the QA program, and applicable procedures;
- Personnel performing quality related activities are qualified in the principles and techniques of the activity being performed; and,
- Proficiency of personnel performing quality related activities is maintained.

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RELATED ACTIVITY	ORGANIZATIONAL RESPONSIBILITY				
	PRESIDENT	QA MANAGER	DEPARTMENT MANAGEMENT	FIELD SUPERVISOR	HEALTH PHYSICS TECHNICIAN
Define QA Program	1,2	3	4	4	4
Training	2	1,3	1,3	3,4	3,4
Handling, Storage Shipping		2	1,3,4	2,3,4	5
Inspection Test, Operational Status		2	1,3,4	3,4	5
Revisions or Corrective Actions	5	1,5	1,3	3	3
Package Maintenance, Repair and Modifications	5	1,2	1,3,4	1,3,4	3
Document Control	2	1,2,3	1	1	3
Audits	1,5	1,2,3	4	4	4

QUALITY ASSURANCE RESPONSIBILITY MATRIX

TABLE 1.0

Key: (1) Initiate
(2) Approve
(3) Perform
(4) Accept
(5) Concur

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3.2 Quality Assurance Program

The quality assurance program elements described in this document are further delineated and implemented by quality assurance procedures and detailed operational procedures that cover all quality related transport operations at Neutron Products. A master list of these procedures is updated and maintained by the Quality Assurance Manager. These procedures address the personnel, sequence of steps to be followed, and the equipment to be used in safety related operations.

The qualifications for personnel engaged in these operations is established by Neutron Products' division management. Training which is primarily on the job, is required before personnel perform safety related activities. These training activities are documented. As stated throughout the sections that follow, safety related activities are carried out by qualified personnel, in accordance with approved drawings and specifications, according to quality standards, in observance of recognized engineering practice, with appropriate equipment, and under quality controls. The quality related items to which this QA program applies are documented.

3.3 Design Control

For each quality related design activity for a transportation package, specific organizational responsibilities shall be established. When such transportation package design is required, existing specifications, procedures, or instructions will be followed, or if necessary, new ones will be developed, to assure that all applicable design criteria will be translated into the required drawings and specifications.

To ensure that quality related design control is achieved, emphasis in the design process will be placed on design process planning to determine quality related aspects of the design, subsequent periodic design reviews, maintenance of quality standards, and observance of recognized engineering standards.

The adequacy of quality related design and verification that the required design criteria have been achieved, shall be accomplished by a Quality Assurance audit of the design process and the final design. Results of the audit shall be documented.

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3.4 Procurement Document Control

Procurement documents for quality related items, are the products of the development of drawings and specifications. As such, the criteria established in Section 3.3 "Design Control" shall provide the necessary assurance that the procurement documents meet the requirements of the Quality Assurance program. Further, purchase orders issued for the procurement of quality related items shall clearly show that the order is subject to the provisions of Neutron Products' Quality Assurance program and that the materials, components, and equipment furnished by the vendor must meet the required specifications.

Changes and revisions to procurement documents shall be subject to the same review and approval as the original documents as specified in Section 3.3.

3.5 Instructions, Procedures and Drawings

Specific controls in the form of instructions, procedures, and applicable drawings shall be prepared, reviewed, approved, and put into use for the:

- design of packages and components;
- preparation of quality related transport packaging for use;
- loading and unloading of radioactive materials from quality related transport packaging;
- transport of the package; and,
- maintenance of the package.

These shall include such activities as.

- development of criteria, specifications, etc.;
- inspection and decontamination;
- surveys for contamination and radiation;
- procedures for loading, flushing and package closure;
- rigging and hoisting;
- overpack placement;
- securing the package for transport;

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- sealing, marking and labeling the package:
- transport vehicle radiation surveys;
- package unloading;
- removal of the package radioactive contents;
- package decontamination; and,
- package maintenance.

Reviews and approvals shall be accomplished in accordance with the requirements of Section 3.3 and Corporate approvals for radiation safety, adequacy for intented purpose, and quality assurance progra compliance.

3.6 Document Control

The following documents shall be under the control of Neutron Products' Quality Assurance program:

- Quality Assurance manual;
- Operating Procedures;
- Procedures for the Loading and Unloading of Radioactive Contents to Transport Packages;
- Procedures for Packaging for Transport;
- Inspection and Test Procedures; and,
- Maintenance Procedures.

Reviews and approvals of these documents shall be accomplished in accordance with Corporate approvals for radiation safety, adequacy for intended purpose, and Quality Assurance program compliance.

The quality assurance manual shall be a controlled document and shall be issued accordingly. A master file of current procedures with appropriate revision numbers and dates shall be maintained by the Manager, Quality Assurance. Copies of procedures shall be made available as required.

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Changes to these documents receive the same reviews and approvals as the original and are noted by revision number and date to be the current version.

3.7 Control of Purchased Material, Equipment and Services

The Quality Assurance Manager, or his designee, shall be responsible for ensuring that an evaluation of suppliers of quality related items shall be done to assess their capability to provide quality services and products. This evaluation can be based on a survey of the supplier's facility, a review of the suppli .'s quality assurance program, if appropriate, and a review of other records of the supplier. These surveys and reviews shall be documented and such documentation shall be maintained.

Documentation accompanying the receipt of quality related items shall be reviewed for conformance with the purchase request.

3.8 Identification and Control of Materials, Parts and Components

The Quality Assurance Manager, or his designee, shall be responsible for assuring that materials, parts and components for quality related items are adequately identified and controlled in accordance with drawings, specifications or procedures established for their use. A record of such evaluations shall be made.

3.9 Special Processes

Loading and unloading packages for radioactive shipments are special processes. These shall be performed in accordance with Neutron Products' Quality Assurance procedures, QA 1003, Package Loading Procedure for Radioactive Material, and QA 1004, Package Unloading Procedure for Radioactive Materials and Neutron Products' procedures applicable to the specific shipping container. For other special processes, e.g. welding, radiography, etc. that require certification and conformance with standards, personnel and equipment qualifications shall be verified and documented.

3.10 Inspection Control

Quality related items shall be inspected upon receipt, receive periodic inspections based on their use, and maintained in satisfactory operating condition. The inspections and required maintenance shall be performed under the supervision of Neutron Products' management, or another qualified person designated by Neutron Products' management. Modifications or repairs to quality related items shall be inspected in accordance with the original design and inspection requirements, or acceptable alternatives.

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NRC approval shall be obtained prior to returning to service a container that requires maintenance work that would result in a safety related change in design, as depicted in drawings referenced in a Certificate of Compliance.

All inspections and modifications of shipping containers shall be recorded in the maintenance log for that container.

3.11 Test Control

Tests required on quality related items are to be conducted in accordance with the requirements of applicable regulations and those contained in the approvals of specific package or its components. Test results are to be reviewed, approved and documented. Prior to any special testing operation a technical description of the test will be prepared, evaluated and documented. This shall include an evaluation of the prerequisites for the test, appropriate instrumentation and required environmental conditions.

3.12 Control of Measuring and Test Equipment

Measuring and test instruments required for use on quality related items, shall be calibrated at specific intervals to assure its sufficient accuracy for the use intended. Calibration test data for these instruments shall be identifiable and traceable.

Whenever such test equipment is found to be out of calibration, previous tests will be evaluated for validity and so documented. Where applicable, as in the case of radiation measuring instruments, the basis for calibration shall be traceable to nationally recognized standards.

3.13 Handling, Storage and Shipping

All operations concerning handling, storage and shipping of radioactive transport packages shall be in accordance with NPI QC Procedure 1005, Handling Storage, and Shipping Procedure for Shipment of Radioactive Materials.

In addition, Neutron Products' operational procedures govern such operations with specific transport packages. The handling, preservation, storage, cleaning, packaging, and shipping requirements contained in these procedures are accomplished by specifically designated qualified individuals of Neutron Products under the supervisi[illegible] manag[illegible]

All conditions of NRC package approval and U.S. DOT shipping requirements shall be satisfied prior to any shipments, and all necessary shipping papers shall be properly prepared.

3.14 Inspection, Test and Operating Status

Inspection, testing, and operating status of all shipping packages and components shall be in accordance with NPI QC Procedure 1006, Inspection, Testing, and Operating Status Procedure for shipping of Radioactive Materials.

Identification, test, and operating status of each package and component shall be known by the responsible line managers. Application and removal of inspection tag markings, and shipping or other labels shall be controlled in accordance with QC Procedure 1006.

The status of nonconforming, inoperative, or malfunctioning packages or components shall be clearly identified to prevent inadvertent use.

3.15 Nonconforming Parts

Nonconforming materials, parts, components, and services shall be controlled in accordance with NPI QC Procedures 1005 and 1006 which require the identification, documentation, segregation of nonconforming items and the notification of the responsible individual. Designations of individuals responsible for the review and disposition of the materials are made in these procedures.

Documentation shall identify the nonconforming item, state its inspection requirements, describe the nonconformance, and identify final disposition. Approval of division management is required for final disposition.

Acceptability of rework or repair shall be verified by reinspection and retesting, as required, and as originally inspected, or by an equivalent method.

3.16 Corrective Action

The Quality Assurance Manager, or his designee, shall conduct an evaluation, in conjunction with the appropriate line manager, of any conditions determined to be adverse to quality (such as nonconformances, failures, malfunctions, deficiencies, deviations, and defective materials and equipment) to determine the need for corrective action. Repair or replacement of nonconforming parts or the correction of other deficiencies must be approved by division management.

Follow-up reviews shall be conducted by the QA Manager to verify the proper implementation of corrective actions and to close out the corrective action documentation.

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3.17 Quality Assurance Records

Neutron Products shall maintain the following Quality Assurance records:

- Quality assurance procedures
- Detailed operational procedures
- NRC Certificates of Compliance
- IAEA Certificates of Competent Authority
- Drawings, specifications and instructions
- Procurement documents
- Contract agreements
- Inspection and test records
- Transport package documents
- Health physics records
- Quality assurance audit reports

These records shall contain sufficient information to describe or document quality related activities or items. The distribution of these records shall be documented.

3.18 Audits

The level of audits of the Quality Assurance Program will be dependent on the safety significance of the activity being audited. Audits of any given activity shall include an evaluation of the shipping and manufacturing practices and/or procedures, and shall be concerned with the safety and effectiveness of their implementation. Audits shall be planned and include the monitoring of operations and activities, review and pertinent documents and their control and maintenance. Audits shall be conducted in accordance with NPI Procedure QC 1007. Audits shall be performed at least once a year with spot checks as deemed necessary by the QA Manager. Audits shall be performed by persons who do not have responsibility for the area being audited, and who possess the ability to evaluate adequately the functions under investigation.
The results of these audits shall be documented and maintained by the QA Manager and reported to the President along with any suggestions of recommendations for improvement. Subsequently, the President shall direct line management to take appropriate corrective actions.

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Region I

71-5942

neutron products inc

22301 Mt. Ephraim Road, P.O. Box 68
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301/349-5001 TWX: 710-828-0542

January 8, 1986

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

Ref: Certificate of Compliance No. 5942

Dear Mr. MacDonald:

This letter responds to your letter dated December 12, 1985; and supplements our application of November 11, 1985, in which we requested a modification to the subject Certificate of Compliance, to allow Neutron Products to utilize the G.E. Model 700 shipping package to ship cobalt-60 from the Savannah River plant to Neutron Products' Dickerson, Maryland facility.

The following supplementary information is submitted with this letter.

1. Complete engineering drawings of the liner, which includes: weld symbols, welder qualification requirements, and a bill of materials.

2. Demonstration of the leak tightness of the liner under normal and accident conditions, by analyses described in Enclosures 3 and 3A.

3. Modified procedures to assure the dryness of the liner, described in Enclosure 2.

This additional information is submitted in the form of revised drawings and revised pages, in which the revisions are identified by vertical lines in the right hand margin.

Very truly yours,

NEUTRON PRODUCTS, INC

Frank Schwoerer

Frank Schwoerer, Vice President

FS:mvc
Enclosures

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DESCRIPTION OF SEALABLE LINER AND SLEEVE

Liner Design

The cask liner is shown in Neutron Products drawing 240139.

The lower portion is a 10 IPS Schedule 10 stainless steel pipe, with a flanged opening at the top and a flat-plate bottom. The underside of the bottom is grooved to allow water to drain from the cask cavity, outside the liner, and to provide rotational restraint when the cover bolts are torqued. A small diameter pipe for purging water from within the liner runs from the flanged opening to the bottom of the liner. Savannah River cobalt is in the form of aluminum rods of approximately 0.94 inch diameter and 8 inch length. These rods will be loaded into the liner, on basically a triangular pitch, with up to 64 rods per 8 inch high layer. Appropriate spacers/supports of stainless steel will be used to keep the rods in an upright position. There is room for four such layers. The actual number in any shipment will be established by the allowable curie loading or geometry, whichever is more limiting.

The lid of the liner contains a spiral-wound stainless steel and asbestos gasket, which seals the large opening in the liner. The mating flanges are machined with grooves that match the stainless steel chevrons of the seal. The lid is held in place and the gasket compressed by twelve 3/4 inch bolts. This design is close to that of a standard flange for 10 IPS piping. The differences are in the outer diameter of the flange (14-7/8 vs. 16 inch) and in the bolt diameter (3/4 vs. 7/8 inch), which are limited by the 15 inch cavity diameter. The closure meets the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Div. 1, as described in Enclosure 3A.

The lid of the liner is penetrated by two openings: one to introduce gas, the other to purge water. Each opening has a stainless steel bellows valve, for sealing the opening, and a stainless steel hose connection. Enclosure 2 describes how these connections are utilized to purge water from within the liner, vacuum dry the contents, and fill with an inert gas. The valves and hose connections are protected against impacts, which can result from the normal conditions of transport and hypothetical accident conditions of 10 CFR 71.71 and 71.73 by a section of 10 IPS Schedule 10 stainless steel piping and two transverse plates of stainless steel. The transverse plates also support a lifting pin.

The liner will be assembled, sealed and leak-tested prior to use. The gap between the flanges (nominally 0.100 inch) will be measured after the lid bolts are fully torqued and the liner is demonstrated to be leak-tight. A shim ring will then be machined to the thickness of the gap between flanges and will be used, with a new gasket, when the liner is used to transport normal form radioactive material. This will ensure metal to metal contact at the flanges to transmit impact loads if the shipping package is dropped.

The weight of the liner is approximately 250 pounds. The maximum weight of the contents is 180 pounds. Thus, the loaded weight is a maximum of 430 pounds.

Sleeve Design

The sleeve design is shown in Neutron Products drawing 240138.

The sleeve is an annular cylinder of aluminum, that fills the space between the wall of the liner and wall of the cavity. Its purposes are to enhance radial heat transfer and to support the liner against lateral impacts.

The weight of the sleeve is approximately 240 pounds.

Total weight of Cask Contents

With a maximum weight of 430 pounds for the liner and its contents and a sleeve weight of 240 pounds, the maximum weight of the contents of the shipping package is 670 pounds, which conforms to the limit of 700 pounds specified in article 5(b)(2) of Certificate of Compliance No. 5942.

SUMMARY PROCEDURE FOR LOADING, DRYING AND SEALING LINER

1. Place the bottom portion of the liner in a holding fixture in a working platform, that is submerged at least ten (10) feet below the surface of the water in the storage pool (basin).

2. Transfer the cobalt-60 containing aluminum rods from storage buckets to the liner.

3. When the liner is filled, install the lid, with its integral seal and with hoses attached to the two hose connections on the lid. One hose shall connect to a source of helium; the other shall run to a water container. Install and tighten the lid bolts with a long-handled tool.

4. Supply helium with sufficient pressure (approximately 25 psia) to displace water from within the liner. Collect the discharged water in a container and measure its volume to ensure that essentially all of the water has been removed. During this step, observe the top of the liner for indication of helium leakage. If such indication exists, retorque the lid bolts and/or replace the gasket and repeat this step.

5. Connect a vacuum pump to the discharge line. Run the vacuum pump until a vacuum of 29.5" Hg can be maintained for 5 minutes with the pump turned off. (This is indication that all water has been removed from the liner.)

6. Close the discharge valve, using a long-handled tool.

7. Fill the liner with helium to 2 to 3 psi above the ambient hydrostatic pressure. (Pressure in psia is given by: water depth in feet times 0.43 plus 14.7.)

8. Close the helium inlet valve with a long-handled tool. Observe the liner for indication of helium leakage. If leakage is indicated, make the necessary corrections and repeat steps as necessary to ensure that the liner is dry and filled with helium to the specified overpressure.

9. Pull the hoses off the hose connections.

10. Lower the GE 700 cask, with the sleeve inserted, into the pool.

11. Lift the sealed liner from the work platform and insert it into the GE 700 cask.

EVALUATION OF PACKAGE PERFORMANCE UNDER NORMAL CONDITIONS OF TRANSPORT (10 CFR 71.71) AND HYPOTHETICAL ACCIDENT CONDITIONS (10 CFR 71.73)

General

General Electric Company has demonstrated (in a consolidated application for certification, submitted to the NRC by letter dated March 18, 1980) that the GE Model 700 shipping package will survive normal conditions of transport and hypothetical accident conditions, except that the lid gasket may fail. A way to prevent any dispersal of radioactive material under normal conditions of transport and hypothetical accident conditions, since irradiated cobalt from the Savannah River plant can not be demonstrated to meet the clad integrity requirements for special form material, is to seal the cobalt within a cask liner. This enclosure demonstrates that the cask liner and seal described in Enclosure 1, when loaded and dried as described in Enclosure 2 and contained within the GE Model 700 shipping package, will remain intact through normal conditions of transport and hypothetical accident conditions; and thus ensure containment of radioactive material.

The following evaluation supplements General Electric's consolidated application for certification, referenced above.

Normal Conditions of Transport

Thermal: The liner components (stainless steel shell, and stainless steel, bellows-type shutoff valves, and stainless steel/asbestos gasket), the aluminum sleeve, and the contents of the liner are unaffected by ambient temperature extremes defined in 10 CFR 71.71. Calculated temperatures at an ambient temperature of 80°F and a limiting heat load of 6500 watts are:

Cask surface	300°F	(ref: GE application)
Sleeve I.D.	339°F	
Liner O.D.	380°F	
Gasket & valves	<400°F	
Contents @ centerline	505°F.	

These temperatures are sufficiently above and below limiting temperatures for the materials that ambient temperature extremes will have no effect on liner or seal integrity. The pressure within the liner will be approximately 15 psig, which is well within the capability of the seal and liner. The bolted closure of the liner and the isolation valves are designed for these conditions, as described in Enclosure 3A.

Pressure: The GE 700 package will withstand the range of external pressures defined in 10 CFR 71.71 (ref: GE application). The liner and its contents will therefore be unaffected by external pressure.

Vibration: The GE 700 package will withstand vibration normally incident to transport (ref: GE application). The effects of vibration on the liner are discussed in Enclosure 3A, item A.9. It is shown that the integrity of the liner will be maintained when the package is subjected to vibration under normal conditions of transport.

Water spray: Water spray will not adversely affect the cask, including the lid gasket. Therefore the liner will be unaffected.

Free drop: There is no damage to the GE 700 cask from dropping the distance prescribed by 10 CFR 71.71 (ref: GE application). It will be shown that, even when subjected to the higher loads resulting from a postulated 30 foot drop, the liner will retain its integrity. Therefore, the liner, its seal, and its shut-off valves will retain their integrity for the one (1) foot free drop prescribed by 10 CFR 71.71.

Corner drop: Not applicable.

Compression: Not applicable.

Penetration: There is no damage to the GE 700 cask from the penetration impact prescribed by 10 CFR 71.71 (ref: GE application). Therefore the liner will be unaffected.

Summary and Conclusions: The assessments set forth above provide assurance that the Neutron Products liner, transported within the GE Model 700 shipping package, will not be adversely affected by Normal Conditions of Transport and will retain its sealing function.

<u>Hypothetical Accident Conditions</u>

Free drop: Based on analyses done by General Electric, damage to the GE 700 shipping package from a 30 foot drop would not exceed that suffered by the GE Model 100 package in a 30 foot drop test (ref: GE application). That damage consisted of local distortion of the steel overpack; the cask was not damaged (ref: NRC Docket No. 71-5926, GE letter dated January 25, 1980). The question remaining to be addressed is whether the g-loadings, resulting from a 30 foot drop, would result in loss of integrity of the cask liner.

Damage sustained by the GE 100 package in a test 30 ft. drop, and its general similarity to the GE 700 package, indicates that the average deceleration of the cask liner upon impact from a 30 ft. drop would be in the range of 50 to 100 g. However, Neutron Products has no quantitative data from which to determine the maximum g-loading. To establish a conservatively high g-loading, it is assumed that all of the kinetic energy of the shipping package (cask, contents, and overpack) is absorbed by deformation of the lead shielding of the cask. The deformation and maximum g-loading are calculated using a "dynamic flow pressure" and the geometry of the cask. A conservatively high value of the g-loading is obtained by using a dynamic flow pressure of 10,000 psi (ref: ORNL-NSIC-68, A Guide for the Design, Fabrication, and Operation of Shipping Casks for Nuclear Applications, February 1970).

On this conservative basis, the energy to be absorbed by lead deformation is 35,500 lbs x 30 ft or 1.065×10^6 ft lbs. The worst case impact, with respect to liner integrity, is an upside down impact. The cross-sectional area of lead is 988 in^2. Thus the force to deform the lead is 9.88×10^6 lbs. As the lead cross-sectional area is uniform in the axial direction, the depth of lead deformation is 1.065/9.88 or .108 ft or 1.29 in. The corresponding g-loading, which is uniform with deformation, is 30/.108 or 278 g. The integrity of the liner, the bolted closure and gasket, and the shutoff valves and tubing have been analyzed for these conditions, as described in Enclosure 3A. It is concluded that resultant bolt and gasket loads and stresses are acceptable and, therefore, the integrity of the liner will be maintained.

A bottom-down impact is less severe than a top-down impact because (1) the bottom of the lead has a convex shape, which would result in a lower g-loading and (2) the loads on the closure of the liner are relatively low. A side-down impact, analyzed by the same conservative methodology results in a maximum g-loading of 270 g. The integrity of the liner under these conditions is also discussed in Enclosure 3A and it is demonstrated that the integrity of the liner will be maintained.

From this conservative analysis, it is concluded that the liner will retain its integrity if the shipping package is subjected to a free drop of 30 feet.

Puncture: General Electric has analyzed the consequences of this postulated occurrence to be not greater than for the GE Model 100 package (ref: GE application). A test of the Model 100 package, consisting of a 40 inch drop onto a 6 inch diameter by 8 inch long steel bar, resulted in local yielding of the protective jacket (overpack) but no penetration of the protective jacket and no damage to the cask (ref: Docket No. 71-5926, GE letter dated January 25, 1980). If the local deformation of the protective jacket is greater than .144 inch for an impact in line with the center of gravity of the package, the g-loading on the liner will be less than calculated for the 30 foot free drop. Analyses of the strength and stiffness of the protective jacket indicate that for such impacts, the local deformation will exceed .144 inch. Therefore, the cask liner and its seal would not be damaged.

Thermal: General Electric has analyzed the GE 700 shipping package for exposure to the fire prescribed by 10 CFR 71.73. A coast up analysis indicated that a maximum temperature of 464°F could result at the innermost lead node (ref: GE application). The materials of construction of the liner, bellows-type shut-off valves, and cask sleeve have acceptable mechanical properties at this temperature. The stainless steel and asbestos gasket will retain its function up to 1000°F (ref: Parker Seals catalog). Further, if the steady-state temperature difference of 125°F from the centerline of the liner to the liner surface is conservatively assumed to exist, the maximum centerline temperature would be approximately 590°F and the pressure within the liner would be approximately 18 psig. This is well below the capability of the seal and liner. Therefore, it is concluded that the cask liner will retain its sealing function throughout the postulated exposure fire.

Water Immersion: The closure of the cask liner has been analyzed for a differential pressure of 150 psi as described in Enclosure 3A. Therefore, the seal is capable of preventing in-leakage of water at an external pressure of 21 psig.

Summary and Conclusions: The assessments set forth above provide assurance that the Neutron Products liner, transported within the GE Model 700 shipping package, will not be adversely affected by the Hypothetical Accident Conditions and will retain its sealing function.

ANALYSIS OF LINER INTEGRITY

This enclosure discusses the integrity of the liner, including the bolted closure and the valves and fittings on the top plate, for normal conditions of transport and hypothetical accident conditions. This enclosure supplements the analyses described in Enclosure 3.

A. Normal Conditions - Bolted Closure

The analyses in this section follow the methodology of Appendix II (Rules for Bolted Flange Connections) to Section VIII, Division I of the ASME Boiler and Pressure Vessel Code. The calculations are done in accordance with the procedures for flanges with ring type gaskets, because that is the type of gasket used. The shim in the liner closure is designed to carry essentially no load during bolt up and normal operating conditions. These analyses are applicable to initial boltup and conditions seen by the liner under normal conditions of transport. Potential free drops under normal conditions of transport are enveloped by the free drops analyzed as hypothetical accident conditions in the next section.

1. Material Properties

Liner and flange material (304 SS plate, ref: Subsection C of ASME VIII)

	<100°F	<500°F
Tensile strength	75,000 psi	
Yield strength	30,000	
Working allowable strength	18,800 (S_a)	12,100 (S_b)

Bolt material (Unbrako 1960 Series alloy steel, or equivalent)

Tensile strength	180,000 psi	
Yield strength	155,000	
Working allowable strength	50,000 (S_a)	>40,000 (S_b)

In order to limit the torque that must be applied by a long-handled tool, the bolt-up stresse will be limited to:

Bolt-up stress	30,000 ($S_{a'}$)

2. Bolt Loads (ref: UA-49, ASME Section VIII)

It is necessary to examine two separate and independent conditions, as follows:

Operating conditions:

$$W_{ml} = 0.785\ G^2\ P + (2b \times 3.14\ G\ m\ P) = 24{,}788 \text{ lbs.}$$

where: P = design pressure = 150 psi
b = effective seating width of gasket = .293 in.
G = dia at gasket load reaction = 11.413 in.
m = gasket factor = 3.0

Gasket seating:

W_{m2} = 3.14 b G y = 105,002 lbs

where: y = gasket seating load = 10,000 psi (ref: Table UA-49.1)

3. Required Bolt Area (ref: UA-49)

The required total bolt area is the larger of the following:

$A_{m1} = W_{m1}/S_b$
$A_{m2} = W_{m2}/S_a'$

where S_a' is the bolt-up stress, used instead of S_a as specified by ASME Section VIII, and S_a and S_b are the allowable working stresses. Thus:

A_{m1} = 24,798/12,100 = 2.05 in^2
A_{m2} = 105,002/30,000 = 3.50 in^2

The latter case (gasket seating) governs.

The bolt area at the base of the threads is .785 $(.620)^2$ = .302 in^2. The total bolt area (A_b) = 12 x .302 = 3.62 in^2, which exceeds the required bolt area.

4. Flange Design Bolt Load (ref: UA-49)

Operating conditions: = W_{m1} = 24,788 lbs
Gasket seating: = 1/2 (A_{m2} + A_b) S_a = 106,800 lbs

5. Flange Moments (ref: UA-50)

Operating conditions:
$M = M_D + M_T + M_G$ = 48,096 in lb
Gasket seating:
M = 103,007 in lb

6. Flange Stresses (ref: UA-51)

		(Allowable Stress)
Operating conditions:		
Longitudinal hub stress =	8,785 psi	(18,100 psi)
Radial flange stress =	220	(12,100)
Tangential flange stress =	5,977	(12,100)
Gasket seating:		
Longitudinal hub stress =	18,850	(28,200)
Radial flange stress =	472	(18,800)
Tangential flange stress =	12,794	(18,800)

7. Stresses in Top Plate (ref: Roark, Formulas for Stress and Strain, Table X)

The boltup loads impose a bending moment on the top plate and, as a result, a maximum bending stress of 6,705 psi, which is well within the allowable working stress of the material.

8. Bolt Torque

The required bolt torque is established by the gasket seating condition. A tentative value, based on data provided by Unbrako, is 1320 in.lb. The actual value will be established in the course of pressure testing the first liner, prior to the first shipment, by measuring the torque required to compress the gasket to its nominal seated thickness of 0.100 in. or whatever is required to prevent leakage of helium at the design pressure of 150 psig. That experimentally determined torque will be used when sealing the liner for shipments.

9. Vibration

The GE 700 cask and the liner are shipped in an upright position. The only type of vibration that potentially threatens the integrity of the liner and bolted closure is a lateral, rocking motion in which the edge of the top plate impacts the inside of the cask cavity. This would impose a shear loading between the top plate and flange of the liner, which would be resisted by friction between the heads of the bolts and top plate and by shear and bending loads in the bolts. Any vibration that may occur will be damped by friction between the liner and sleeve and by relative motions of the contents of the liner. It is estimated that the maximum lateral vibrational impact loading will be no greater than lg, which is a factor of approximately 500 below the loading that could cause relative motion between the top plate and flange. Therefore, the integrity of the liner is not threatened by vibration incident to normal conditions of transport.

B. Liner Integrity - Hypothetical Accident Conditions

1. Free Drop

Upside-Down Impact

In an upside-down impact, the contents of the liner (180 lbs) transfer their load directly to the central portion of the top plate. The load is essentially uniformly distributed. The top plate itself and its appurtenances weigh 115 lbs. The loads from the bottom of the liner (250 lbs) and the sleeve (240 lbs) are transmitted to the top plate through the shim ring. The maximum compressive stress in the shim ring for a 278g impact is 4,100 psi. The maximum compressive stress in the liner wall is 3750 psi. Both of these values are within acceptable limits for 304 SS.

These impact loads impose a bending moment on the top plate opposite in direction from the boltup loads. The maximum combined bending stress in the top plate is approximately 5000 psi, which is well below the allowable working stress. The deflections at the bolt circle and at the gasket are less than .001 in. The bolt loading and gasket compression are essentially unaffected.

One of the isolation valves on the top of the liner and its attached tubing weigh less than 0.75 lb. If all of the load from a top-down impact of 278g is carried by the two #10-32 screws in the bottom of the valve body, the tensile stress in the screws is only 7,840 psi. The stresses in other portions of the valves and fittings are even lower. Therefore, the valves and fittings will remain in place.

The valves and fittings are surrounded and protected from impact by the short section of 10 IPS piping and two cross plates, which extend above the tops of the valves. The total cross-sectional area of the pipe and cross plates is 11.7 in^2. The compressive stress in these parts from a 278g top-down impact is 15,920 psi, which is below the yield stress of 304 SS. No significant deformations of these structural members will occur and the valves and fittings will not be contact the interior of the cask cavity.

In summary, the liner, including the bolted closure and pressure boundary fittings on the top plate, will retain its integrity in case of a 30 ft. free drop with a top-down impact.

Bottom-Down Impact

In a bottom-down impact, the mass of the top plate is supported by shim ring and the wall of the bottom section of the liner. The contents, bottom plate of the liner, and sleeve do not impose loads on the closure or liner wall. The maximum compressive stress in the shim for a 278g impact is only 1000 psi. The maximum compressive stress in the liner wall is 10,790 psi. Both of these values are within acceptable limits for compressive stress. The moment on the top plate is opposite in direction and smaller than the moment from the boltup loads. The resultant stresses and the deflections at the bolt circle and gasket are negligibly small. The bolt loading and gasket compression are essentially unaffected.

A bottom-down drop subjects the valves and fittings on the top plate to lower loadings than described above for a top-side down impact and will not violate the pressure boundary.

In summary, the liner, including the bolted closure and fittings on the top plate, will retain its integrity in a 30 ft. free drop with a bottom-down impact.

Side-Down Impact

In a side-down impact, the assembly clearances are such that the edges of the flange and top plate could impact the wall of the cask cavity before the body of the liner obtains lateral support from the sleeve. In this case, there is a potential shear loading in the liner wall just below the flange, from the mass of the liner and its contents. The resultant stress from a 270g impact is 12,300 lbs, which is an acceptable shear stress.

A side-down impact would impose a moment on the supports of the valves on the top plate. The moment is resisted by the two screws in the base of the valve body and by the tubing attached to the valve body. If it is conservatively assumed that the moment is resisted by the screws only, the tensile stress in the screws is 35,350 psi. As this is less than the ultimate tensile strength of the screw material (about 48,000 psi at 500°F), it is concluded that the valve will remain in place.

In summary, the liner will retain its integrity in a 30 ft. free drop with side-down impact.

Oblique Impacts

An oblique, e.g., corner, impact of the shipping package will result in larger distortions and hence lower g loads than postulated for the other impacts discussed above. The loadings on the liner and its appurtenances can be regarded as superpositions of fractions of the loadings described above and the total loads will be lower. Therefore, the liner will retain its integrity.

2. <u>Hypothetical Fire</u>

As described in Enclosure 3, the maximum temperature of the lead in the cask is 464°F, which indicates that the liner, bolted closure and gasket, and valves and fittings on the top plate will have a maximum temperature of no more than 500°F.

All of the materials, except the asbestos filler in the gasket and the head bolts, have the same coefficient of thermal expansion. All parts of the bolted closure will be at essentially the same temperature, because the heat flux through the top of the liner is negligible and stainless steel has a relatively high thermal conductivity. The differential thermal expansion between the neck of a bolt and thickness of the top plate is approximately .0018 in. and is in the direction of increasing the gasket seating force. The bolts have ample margin to assume the additional load

The maximum internal pressure in the liner will be 18 psig (ref: Enclosure 3), which is well below the design pressure of 150 psi and the rated pressure of the gasket (250 psi). Based on data from the gasket manufacturer, the gasket will retain its function up to 1000°F.

All of the parts of the valves and fittings on the top plate, that comprise the pressure boundary, are stainless steel and will retain their integrity and sealing function to a temperature of at least 500°F.

In summary, the liner will retain its integrity during exposure of the shipping package to a hypothetical fire as prescribed by 10 CFR 71.

Region 1

71-5942

NEUTRON PRODUCTS inc

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 U.S.A.
301/349-5001 TWX: 710-828-0542

'86 FEB -4 P2:05

February 6, 1986

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

Refs: 1. Certificate of Compliance No. 5942
2. Neutron Products Letter dated January 8, 1986

Dear Mr. MacDonald:

Confirming a telephone conversation of today between Mr. Odegaarden and myself, Neutron Products has no objection to your filing drawings, submitted by reference 2, in the Public Document Room.

Very truly yours,

NEUTRON PRODUCTS, INC.

F. Schwoerer

F. Schwoerer, Vice President

FS:mvc

B/26

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71-5942

NEUTRON PRODUCTS INC

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 USA
[illegible]

February 28, 1986

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MAR 3 1986
U.S. NUCLEAR REGULATORY COMMISSION
NMSS
Mail Section

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

Ref: Certificate of Compliance No. 5942

Dear Mr. MacDonald:

This letter supplements our application of November 11, 1985, in which we requested a modification to the subject Certificate of Compliance, to allow Neutron Products to utilize the G.E. Model 700 shipping package to ship cobalt-60 from the Savannah River plant to Neutron Products' Dickerson, Maryland facility.

The following supplementary information is submitted with this letter.

1. Complete engineering drawings of the liner, Revision D, dated 2/27/86, which supersede drawings submitted by our letter dated January 8, 1986.

2. Demonstration of the leak tightness of the liner under normal and accident conditions, by engineering analyses that are (a) summarized in Enclosures 3 and 3A, which supersede earlier versions submitted by our letter dated January 8, 1986, and (b) detailed in Enclosures 3B, 3C, and 3D, which contain information not previously submitted.

3. Modified procedures to assure the dryness of the liner, described in Enclosure 2, Rev. 2, which supersedes the version submitted by our letter dated January 8, 1986.

We believe that, with this submittal, our application is fully responsive to your requests for additional information.

Very truly yours,

NEUTRON PRODUCTS, INC.

Frank Schwoerer

Frank Schwoerer, Vice President

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USNRC
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FS:mvc
Enclosures

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SUMMARY PROCEDURE FOR LOADING, DRYING AND SEALING LINER

1. Place the bottom portion of the liner in a holding fixture in a working platform, that is submerged at least ten (10) feet below the surface of the water in the storage pool (basin).

2. Transfer the cobalt-60 target rods from storage buckets to the liner.

3. When the liner is filled, install the lid, with its integral seal and with transparent hoses attached to the two hose connections on the lid. One hose connects to a source of helium; the other loops above the surface of the pool but ends in the pool. Install and tighten the lid bolts with a long-handled tool.

4. Supply helium with sufficient pressure (approximately 25 psia) to displace water from within the liner. Observe the discharge hose to ensure that essentially all of the water has been removed. Also observe the top of the liner for indication of helium leakage. If such indication exists, retorque the lid bolts and/or replace the gasket and repeat this step.

5. Close the discharge valve, using a long-handled tool.

6. Connect a vacuum pump to the inlet line. Run the pump until a vacuum of 29.5" Hg (0.5" Hg absolute pressure) can be maintained for 5 minutes with the pump turned off. (This vacuum corresponds to a saturation temperature of 58.8°F, which is lower than the pool temperature and is, therefore, indication that all water has been removed from the liner.)

7. Fill the liner with helium to 2 to 3 psi above the ambient hydrostatic pressure. (Pressure in psia is given by: water depth in feet times 0.43 plus 14.7.)

8. Close the inlet valve with a long-handled tool. Observe the liner for indication of helium leakage. If leakage is indicated, make the necessary corrections and repeat steps as necessary to ensure that the liner is dry and filled with helium to the specified overpressure.

9. Pull the hoses off the hose connections.

10. Lower the GE 700 cask, with the sleeve inserted, into the pool.

11. Lift the sealed liner from the work platform and insert it into the GE 700 cask.

EVALUATION OF PACKAGE PERFORMANCE UNDER NORMAL CONDITIONS OF TRANSPORT (10 CFR 71.71) AND HYPOTHETICAL ACCIDENT CONDITIONS (10 CFR 71.73)

General

General Electric Company has demonstrated (in a consolidated application for certification, submitted to the NRC by letter dated March 18, 1980) that the GE Model 700 shipping package will survive normal conditions of transport and hypothetical accident conditions, except that the lid gasket may fail. A way to prevent any dispersal of radioactive material under normal conditions of transport and hypothetical accident conditions, since irradiated cobalt from the Savannah River plant can not be demonstrated to meet the clad integrity requirements for special form material, is to seal the cobalt within a cask liner. This enclosure demonstrates that the cask liner and seal described in Enclosure 1, when loaded and dried as described in Enclosure 2 and contained within the GE Model 700 shipping package, will remain intact through normal conditions of transport and hypothetical accident conditions; and thus ensure containment of radioactive material.

The following evaluation supplements General Electric's consolidated application for certification, referenced above.

Normal Conditions of Transport

Thermal: The liner components (stainless steel shell, and stainless steel, bellows-type shutoff valves, and stainless steel/asbestos gasket), the aluminum sleeve, and the contents of the liner are unaffected by ambient temperature extremes defined in 10 CFR 71.71. Calculated temperatures at an ambient temperature of 80°F and a limiting heat load of 6500 watts are:

Cask surface	300°F	(ref: GE application)
Sleeve I.D.	339°F	
Liner O.D.	380°F	
Gasket & valves	<400°F	
Contents @ centerline	491°F.	

These temperatures are sufficiently above and below limiting temperatures for the materials that ambient temperature extremes will have no effect on liner or seal integrity. The pressure within the liner will be approximately 26 psig, which is well within the capability of the seal and liner. The bolted closure of the liner and the isolation valves are designed for these conditions, as described in Enclosure 3A. The heat transfer calculations are detailed in Enclosure 3B.

Pressure: The GE 700 package will withstand the range of external pressures defined in 10 CFR 71.71 (ref: GE application). The liner and its contents will therefore be unaffected by external pressure.

Vibration: The GE 700 package will withstand vibration normally incident to transport (ref: GE application). The effects of vibration on the liner are discussed in Enclosure 3A, item A.9. It is shown that the integrity of the liner will be maintained when the package is subjected to vibration under normal conditions of transport.

Water spray: Water spray will not adversely affect the cask, including the lid gasket. Therefore the liner will be unaffected.

Free drop: There is no damage to the GE 700 cask from dropping the distance prescribed by 10 CFR 71.71 (ref: GE application). It will be shown that, even when subjected to the higher loads resulting from a postulated 30 foot drop, the liner will retain its integrity. Therefore, the liner, its seal, and its shut-off valves will retain their integrity for the one (1) foot free drop prescribed by 10 CFR 71.71.

Corner drop: Not applicable.

Compression: Not applicable.

Penetration: There is no damage to the GE 700 cask from the penetration impact prescribed by 10 CFR 71.71 (ref: GE application). Therefore the liner will be unaffected.

Summary and Conclusions: The assessments set forth above provide assurance that the Neutron Products liner, transported within the GE Model 700 shipping package, will not be adversely affected by Normal Conditions of Transport and will retain its sealing function.

Hypothetical Accident Conditions

Free drop: Based on analyses done by General Electric, damage to the GE 700 shipping package from a 30 foot drop would not exceed that suffered by the GE Model 100 package in a 30 foot drop test (ref: GE application). That damage consisted of local distortion of the steel overpack; the cask was not damaged (ref: NRC Docket No. 71-5926, GE letter dated January 25, 1980). The question remaining to be addressed is whether the g-loadings, resulting from a 30 foot drop, would result in loss of integrity of the cask liner.

Damage sustained by the GE 100 package in a test 30 ft. drop, and its general similarity to the GE 700 package, indicates that the average deceleration of the cask liner upon impact from a 30 ft. drop would be in the range of 50 to 100 g. However, Neutron Products has no quantitative data from which to determine the maximum g-loading. To establish a conservatively high g-loading, it is assumed that all of the kinetic energy of the shipping package (cask, contents, and overpack) is absorbed by deformation of the lead shielding of the cask. The deformation and maximum g-loading are calculated using a "dynamic flow pressure" and the geometry of the cask. A conservatively high value of the g-loading is obtained by using a dynamic flow pressure of 10,000 psi (ref: ORNL-NSIC-68, A Guide for the Design, Fabrication, and Operation of Shipping Casks for Nuclear Applications, February 1970).

On this conservative basis, the energy to be absorbed by lead deformation is 35,500 lbs x 30 ft or 1.065×10^6 ft lbs. The worst case impact, with respect to liner integrity, is an upside down impact. The cross-sectional area of lead is 988 in^2. Thus the force to deform the lead is 9.88×10^6 lbs. As the lead cross-sectional area is uniform in the axial direction, the depth of lead deformation is 1.065/9.88 or .108 ft or 1.29 in. The corresponding g-loading, which is uniform with deformation, is 30/.108 or 278 g. The integrity of the liner, the bolted closure and gasket, and the shutoff valves and tubing have been analyzed for these conditions, as described in Enclosure 3A. It is concluded that resultant bolt and gasket loads and stresses are acceptable and, therefore, the integrity of the liner will be maintained.

A bottom-down impact is less severe than a top-down impact because (1) the bottom of the lead has a convex shape, which would result in a lower g-loading and (2) the loads on the closure of the liner are relatively low. A side-down impact, analyzed by the same conservative methodology results in a maximum g-loading of 270 g. The integrity of the liner under these conditions is also discussed in Enclosure 3A and it is demonstrated that the integrity of the liner will be maintained.

From this conservative analysis, it is concluded that the liner will retain its integrity if the shipping package is subjected to a free drop of 30 feet.

Puncture: General Electric has analyzed the consequences of this postulated occurrence to be not greater than for the GE Model 100 package (ref: GE application). A test of the Model 100 package, consisting of a 40 inch drop onto a 6 inch diameter by 8 inch long steel bar, resulted in local yielding of the protective jacket (overpack) but no penetration of the protective jacket and no damage to the cask (ref: Docket No. 71-5926, GE letter dated January 25, 1980). As shown by detailed analyses in Enclosure 3C, the g-loading on the liner will be less than calculated for the 30 foot free drop. Therefore, the cask liner and its seal would not be damaged.

Thermal: General Electric has analyzed the GE 700 shipping package for exposure to the fire prescribed by 10 CFR 71.73. A coast up analysis indicated that a maximum temperature of 464°F could result at the innermost lead node (ref: GE application). The materials of construction of the liner, bellows-type shut-off valves, and cask sleeve have acceptable mechanical properties at this temperature. The stainless steel and asbestos gasket will retain its function up to 1000°F (ref: Parker Seals catalog). Further, if the steady-state temperature difference of 110°F from the centerline of the liner to the liner surface is conservatively assumed to exist, the maximum centerline temperature would be approximately 575°F and the pressure within the liner would be approximately 30 psig. This is well below the capability of the seal and liner. Therefore, it is concluded that the cask liner will retain its sealing function throughout the postulated exposure fire.

Water Immersion: The closure of the cask liner has been analyzed for a differential pressure of 150 psi as described in Enclosure 3A. Therefore, the seal is capable of preventing in-leakage of water at an external pressure of 21 psig.

Summary and Conclusions: The assessments set forth above provide assurance that the Neutron Products liner, transported within the GE Model 700 shipping package, will not be adversely affected by the Hypothetical Accident Conditions and will retain its sealing function.

ANALYSIS OF LINER INTEGRITY

This enclosure discusses the integrity of the liner (including the bolted closure and the valves and fittings on the top plate), for normal conditions of transport and hypothetical accident conditions. This enclosure supplements the analyses described in Enclosure 3.

A. Normal Conditions - Bolted Closure

The analyses described in this section follow the methodology of Appendix II (Rules for Bolted Flange Connections) to Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. The calculations are done in accordance with the procedures for flanges with ring type gaskets, because that is the type of gasket used. The shim in the liner closure is designed to carry essentially no load during bolt up and normal operating conditions. These analyses are applicable to initial boltup and conditions seen by the liner under normal conditions of transport. Potential free drops under normal conditions of transport are enveloped by the free drops analyzed as hypothetical accident conditions in the next section. The development of these results is detailed in Enclosure 3D.

1. Material Properties

Liner and flange material (304 SS plate, ref: Subsection C of ASME VIII)

	<100°F	<500°F
Tensile strength	75,000 psi	
Yield strength	30,000	
Working allowable strength	18,800 (S_a)	12,100 (S_b)

Bolt material (Unbrako 1960 Series alloy steel, or equivalent)

Tensile strength	180,000 psi	
Yield strength	155,000	
Working allowable strength	50,000 (S_a)	>40,000 (S_b)

In order to limit the torque that must be applied by a long-handled tool, the bolt-up stresse will be limited to:

Bolt-up stress 30,000 ($S_{a'}$)

2. Bolt Loads (ref: UA-49, ASME Section VIII)

It is necessary to examine two separate and independent conditions, as follows:

Operating conditions:

$$W_{m1} = 0.785\ G^2\ P + (2b \times 3.14\ G\ m\ P) = 24{,}791 \text{ lbs.}$$

where: P = design pressure = 150 psi
b = effective seating width of gasket = .293 in.
G = dia at gasket load reaction = 11.414 in.
m = gasket factor = 3.0

Gasket seating:

W_{m2} = 3.14 b G y = 105,011 lbs

where: y = gasket seating load = 10,000 psi (ref: Table UA-49.1)

3. Required Bolt Area (ref: UA-49)

The required total bolt area is the larger of the following:

$A_{m1} = W_{m1}/S_b$
$A_{m2} = W_{m2}/S_{a'}$

where $S_{a'}$ is the bolt-up stress, used instead of S_a as specified by ASME Section VIII, and S_a and S_b are the allowable working stresses. Thus:

A_{m1} = 24,791/12,100 = 2.05 in^2
A_{m2} = 105,011/30,000 = 3.50 in^2

The latter case (gasket seating) governs.

The bolt area at the base of the threads is .785 $(.620)^2$ = .302 in^2. The total bolt area (A_b) = 12 x .302 = 3.62 in^2, which exceeds the required bolt area.

4. Flange Design Bolt Load (ref: UA-49)

Operating conditions: = W_{m1} = 24,791 lbs
Gasket seating: = 1/2 (A_{m2} + A_b) S_a = 106,800 lbs

5. Flange Moments (ref: UA-50)

Operating conditions:
$M = M_D + M_T + M_G$ = 29,060 in lb
Gasket seating:
M = 104,717 in lb

6. Flange Stresses (ref: UA-51)

Operating conditions:	Stress	Allowable	Sfty Fctr*
Longitudinal hub stress =	5,202 psi	18,100 psi	3.5
Radial flange stress =	131	12,100	92.
Tangential flange stress=	3,662	12,100	3.3
$(S_H+S_R)/2$ =	2,667	12,100	4.5
$(S_H+S_T)/2$ =	4,432	12,100	2.7

* Acceptable value = 1.0 or greater

Gasket seating:	Stress	Allowable	Sfty Fctr*
Longitudinal hub stress =	18,744	28,200	1.5
Radial flange stress =	471	18,800	40.
Tangential flange stress=	13,194	18,800	1.4
$(S_H+S_R)/2$ =	9,608	18,800	2.0
$(S_H+S_T)/2$ =	15,969	18,800	1.2

* Acceptable value is 1.0 or greater

7. Stresses in Top Plate

The boltup loads impose a bending moment on the top plate and, as a result, a maximum bending stress of 6,383 psi. The allowable working stress of the material is 18,800 psi and the Safety Factor to the allowable working stress is 2.9.

8. Bolt Torque

The required bolt torque is established by the gasket seating condition. A tentative value, based on data provided by Unbrako, is 1320 in.lb. The actual value will be established in the course of pressure testing the first liner, prior to the first shipment, by measuring the torque required to compress the gasket to its nominal seated thickness of 0.100 in. or whatever is required to prevent leakage of helium at the design pressure of 150 psig. That experimentally determined torque will be used when sealing the liner for shipments.

9. Vibration

The GE 700 cask and the liner are shipped in an upright position. The only type of vibration that potentially threatens the integrity of the liner and bolted closure is a lateral, rocking motion in which the edge of the top plate impacts the inside of the cask cavity. This would impose a shear loading between the top plate and flange of the liner, which would be resisted by friction between the heads of the bolts and top plate and by shear and bending loads in the bolts. Any vibration that may occur will be damped by friction between the liner and sleeve and by relative motions of the contents of the liner. It is estimated that the maximum lateral vibrational impact loading will be no greater than 1g, which is a factor of approximately 50 below the loading that could cause relative motion between the top plate and flange. Therefore, the integrity of the liner is not threatened by vibration incident to normal conditions of transport.

B. Liner Integrity - Hypothetical Accident Conditions

1. Free Drop

Upside-Down Impact

In an upside-down impact, the contents of the liner (180 lbs) transfer their load directly to the central portion of the top plate. The load is essentially uniformly distributed. The top plate itself and its

appurtenances weigh 115 lbs. The loads from the bottom of the liner (135 lbs) and the sleeve (240 lbs) are transmitted to the top plate through the shim ring. The maximum compressive stress in the shim ring for a 278g impact is 3,363 psi. The maximum compressive stress in the liner wall is 3950 psi. The yield stress at 400°F is 20,700 psi and the Safety Factors to yield are 6.2 and 5.2, respectively.

These impact loads impose a bending moment on the top plate opposite in direction from the boltup loads. The maximum combined bending stress in the top plate is approximately 14,000 psi, which is below the yield stress of 20,700 psi. The Safety Factor to yield is 1.5. The deflections at the bolt circle and at the gasket are approximately .001 in, which means that the bolt loading and gasket compression are essentially unaffected.

One of the isolation valves on the top of the liner and its attached tubing weigh less than 0.75 lb. The load from a top-down impact of 278g is carried by two #10-32 screws in the bottom of the valve body and four welds at the base of the hold-down channel. The tensile stress is 2,840 psi, which gives a Safety Factor to yield of 7.3. As the stresses in other portions of the valves and fittings are even lower, it can be concluded that the valves and fittings will remain in place.

The valves and fittings are surrounded and protected from impact by the short section of 10 IPS piping and two cross plates, which extend above the tops of the valves. The total cross-sectional area of the pipe and cross plates is 12.8 in^2. The compressive stress in these parts from a 278g top-down impact is 14,563 psi. As the yield stress at 400°F is 20,700 psi, the Safety Factor to yield is 1.4. No inelastic deformation of these structural members will occur and the valves and fittings will not be contact the interior of the cask cavity.

In summary, the liner, including the bolted closure and pressure boundary fittings on the top plate, will retain its integrity in case of a 30 ft. free drop with a top-down impact.

Bottom-Down Impact

In a bottom-down impact, the mass of the top plate is supported by shim ring and the wall of the bottom section of the liner. The contents, bottom plate of the liner, and sleeve do not impose loads on the closure or liner wall. The maximum compressive stress in the shim for a 278g impact is only about 1000 psi. The maximum compressive stress in the liner wall is 10,179 psi. Both of these values are within the yield stress at 400°F (20,700 psi) and the Safety Factors to yield are 20 and 2.0, respectively. The moment on the top plate is opposite in direction and smaller than the moment from the boltup loads. The resultant stresses and the deflections at the bolt circle and gasket are negligibly small. The bolt loading and gasket compression are essentially unaffected.

A bottom-down drop subjects the valves and fittings on the top plate to lower loadings than described above for a top-side down impact and will not violate the pressure boundary.

In summary, the liner, including the bolted closure and fittings on the top plate, will retain its integrity in a 30 ft. free drop with a bottom-down impact.

Side-Down Impact

In a side-down impact, the assembly clearances are such that the edges of the flange and top plate could impact the wall of the cask cavity before the body of the liner obtains lateral support from the sleeve. In this case, there is a potential shear loading in the liner wall just below the flange, from the mass of the liner and its contents. The resultant stress from a 270g impact is 13,770 lbs, which is less than the ultimate shear strength of the material at 400°F (35,400 psi). The corresponding Safety Factor is 2.6.

A side-down impact would impose a moment on the supports of the valves on the top plate. The moment is resisted by the two screws in the base of the valve body and by the hold-down channel over the valve body. The maximum tensile stress in the screws is 12,156 psi. As the yield stress at 400°F is 20,700 psi, the Safety Factor to yield is 1.7. The load on the hold-down channel loads the welds in shear and gives a stress of 5,250 psi. As the yield stress in shear is 11,385 psi, the Safety Factor to yield is 2.2. This demonstrates that the valve will remain in place.

In summary, the liner will retain its integrity in a 30 ft. free drop with side-down impact.

Oblique Impacts

An oblique, e.g., corner, impact of the shipping package will result in larger distortions and hence lower g loads than postulated for the other impacts discussed above. The loadings on the liner and its appurtenances can be regarded as superpositions of fractions of the loadings described above and the total loads will be lower. Therefore, the liner will retain its integrity.

2. Hypothetical Fire

As described in Enclosure 3, the maximum temperature of the lead in the cask is 464°F, which indicates that the liner, bolted closure and gasket, and valves and fittings on the top plate will have a maximum temperature of no more than 500°F.

All of the materials, except the asbestos filler in the gasket and the head bolts, have the same coefficient of thermal expansion. All parts of the bolted closure will be at essentially the same temperature, because the heat flux through the top of the liner is negligible and stainless steel has a relatively high thermal conductivity. The differential thermal expansion between the neck of a bolt and thickness of the top plate is approximately .0016 in. and is in the direction of increasing the gasket seating force. The bolts have ample margin to assume the additional load

The maximum internal pressure in the liner will be 30 psig (ref: Enclosure 3), which is well below the design pressure of 150 psi and the rated pressure of the gasket (250 psi). Based on data from the gasket manufacturer, the gasket will retain its function up to 1000°F.

All of the parts of the valves and fittings on the top plate, that comprise the pressure boundary, are stainless steel and will retain their integrity and sealing function to a temperature of at least 500°F.

In summary, the liner will retain its integrity during exposure of the shipping package to a hypothetical fire as prescribed by 10 CFR 71.

Table 1

Summary of Minimum Safety Factors

Stress Condition	Safety Factor	To:
Liner Flange Stress		
Operating Conditions	2.7	Allowable Working Stress
Gasket Seating	1.2	Allowable Working Stress
Liner Lid Bending Stress		
Gasket Seating	2.9	Allowable Working Stress
30 ft Upside Down Drop	1.5	Yield Stress at 400°F
Protective Pipe and Plates on Lid		
30 ft Upside Down Drop	1.4	Yield Stress at 400°F
Liner Wall		
30 ft Side Down Drop	2.6	Shear Strength at 400°F
Valve Supports on Lid		
30 ft Side Down Drop	1.7	Yield Stress at 400°F

HEAT TRANSFER ANALYSIS - COBALT-60 SHIPMENTS FROM SAVANNAH RIVER

Assumptions:

1. Use GE 700 shipping container, which consists of a cask and protective jacket, with an aluminum inner sleeve and liner, per Neutron Products drawings nos. 240138 and 240139.

2. The maximum allowable heat load per shipment is 6500 watts.

3. Target slugs are positioned in the liner by egg-crate spacers approximately as shown in Figure 1. There are 4 layers of 8" long slugs, for a maximum loading of 240 slugs per shipment. This results in 50% of the liner volume occupied by slugs and 50% by fill gas.

4. The target slugs are loaded into the liner at random. Actually our personnel will be instructed to load higher activity slugs adjacent to the liner wall.

5. The fill gas in the liner is He at 2 atmospheres absolute (after reaching thermal equilibrium).

6. The fill gas in the cask is air at 1 atmosphere absolute.

7. 85% of the thermal energy is deposited in the slugs; 7% in the Al sleeve; and 8% in the lead shielding of the cask.

8. All heat transferred from the liner is in the radial direction, i.e., heat transfer from the ends is neglected.

9. Ambient temperature is 80°F.

10. At a heat load of 6566 watts, the cask surface temperature is 300°F (GE calculation, ref: GE letter to NRC dated 3/18/80). At other heat loads, the temperature difference between the cask surface and ambient is directly proportional to heat load.

Method of Analysis

A BASIC language program (RADXFR), written for an IBM-PC computer, was used to calculate temperatures inside the cask and liner. A listing of the program is given in Appendix A. The program utilizes a very simple model to calculate heat transfer within the liner. Supplementary hand calculations were then performed to refine the analysis of heat transfer inside the liner.

The shipping container, aluminum sleeve, and liner are represented in RADXFR as concentric cylinders, as illustrated in Figure 2. The temperature at node 1, the cask surface, is obtained as described in Assumption #10. For a heat load of 6500 watts, the temperature is 298°F.

The temperature difference across the wall of the cask is given by:

$$T_2 - T_1 = (Q / 2\pi k_1 L) \ln r_1/r_2$$

Heat deposited in the cask wall is conservatively assumed to be deposited at the inner surface (node 2). The thermal conductivity used is that of lead, as given by Table 28, Chapter 2 of Handbook of Heat Transfer, Rohsenow and Hartnett, McGraw-Hill, 1973. The carbon steel inner shell and stainless steel inner shells have been neglected.

The temperature difference across the annular gap between the inner shell of the cask and the aluminum sleeve is given by:

$$T_3 - T_2 = (f_1 + f_2) (Q / 2\pi k_2 L) \ln r_2/r_3$$

where: $k_2 = k_{c,v} + k_{rad}$
$k_{c,v} = k_g f(N_{Gr})$, per data of Mull & Reiher for heat transfer through vertical air layers by free convection
k_g = thermal conductivity of air at 1 atmosphere (from Handbook of Heat Transfer
k_{rad} = radiation component = $(T_3^4 - T_2^4) t/(T_3 - T_2)$
f_1 = fraction of thermal energy deposited within liner
f_2 = fraction of thermal energy deposited in sleeve

The temperature difference across the aluminum sleeve is given by:

$$T_4 - T_3 = (f_1 + f_2) (Q / 2\pi k_3 L) \ln r_3/r_4$$

Heat deposited in the sleeve is conservatively assumed to be deposited at the inner surface. The thermal conductivity is that of aluminum, from Handbook of Heat Transfer, as cited above.

The temperature difference across the annular gap between the aluminum sleeve and the liner ($T_5 - T_4$) is calculated in the same way, outlined above, as for the gap between the sleeve and the cask inner shell, except that f_2 is omitted.

The temperature difference from the centerline of the liner to the liner outer surface is given by:

$$T_6 - T_5 = q''' \, r_5^2 \, / \, 4 \, k_5$$

where: $q''' \, r_5^2 \quad L = f_1 \, Q$
L = height of source
k_5 is based on series heat conduction through layers of metal (aluminum) and gas (helium), such that:
$1/k_5 = [vf_m/k_m + vf_g/k_g]$
vf_m, vf_g = volume fractions of metal and gas
k_m, k_g = thermal conductivities of metal and gas, where the latter is conservatively evaluated at 1 atmosphere

In supplementary calculations, the heat transfer within the liner was slightly refined by assuming that the slugs are in four concentric rings, with an average gap of 0.35" between each ring. Temperature differences across these gaps were calculated by:

$$T = Q \, t \, / \, k \, A$$

where: Q varies from ring to ring, based on uniform heat deposition
k = thermal conductivity of helium (2 times the value at 1 atm. from Handbook of Heat Transfer)
$A = \pi D L$
D = average diameter of gap

The resulting temperature differences are conservatively high because both convection and radiation, within the liner, have been neglected.

Results

The printouts from two computer runs of RADXFR are given in Appendix B. The first is for the heat load of 6566 watts (QR) used by General Electric in its calculations. The second is for 6500 watts. From the second run, the maximum temperature in the liner is 560°F and the liner surface temperature is 380°F.

The supplementary hand calculations resulted in temperature differences across the gas-filled gaps and target slug temperatures as follows:

Ring No.	Gap T	Slug Temperature
1	47°F	427°F
2	31	458
3	22	480
4	11	491

These values conservatively neglect both convection and radiation.

The internal pressure at these conditions is obtained as follows. The fill pressure (per Enclosure 2) is 14.7 + 10′ x .43 + 3 = 22 psia at 80°F (540°R). The absolute pressure is directly proportional to the absolute temperature. At an average temperature of 460°F (1000°R) in the liner, the pressure is 41 psia, or 26 psig.

Figure 1

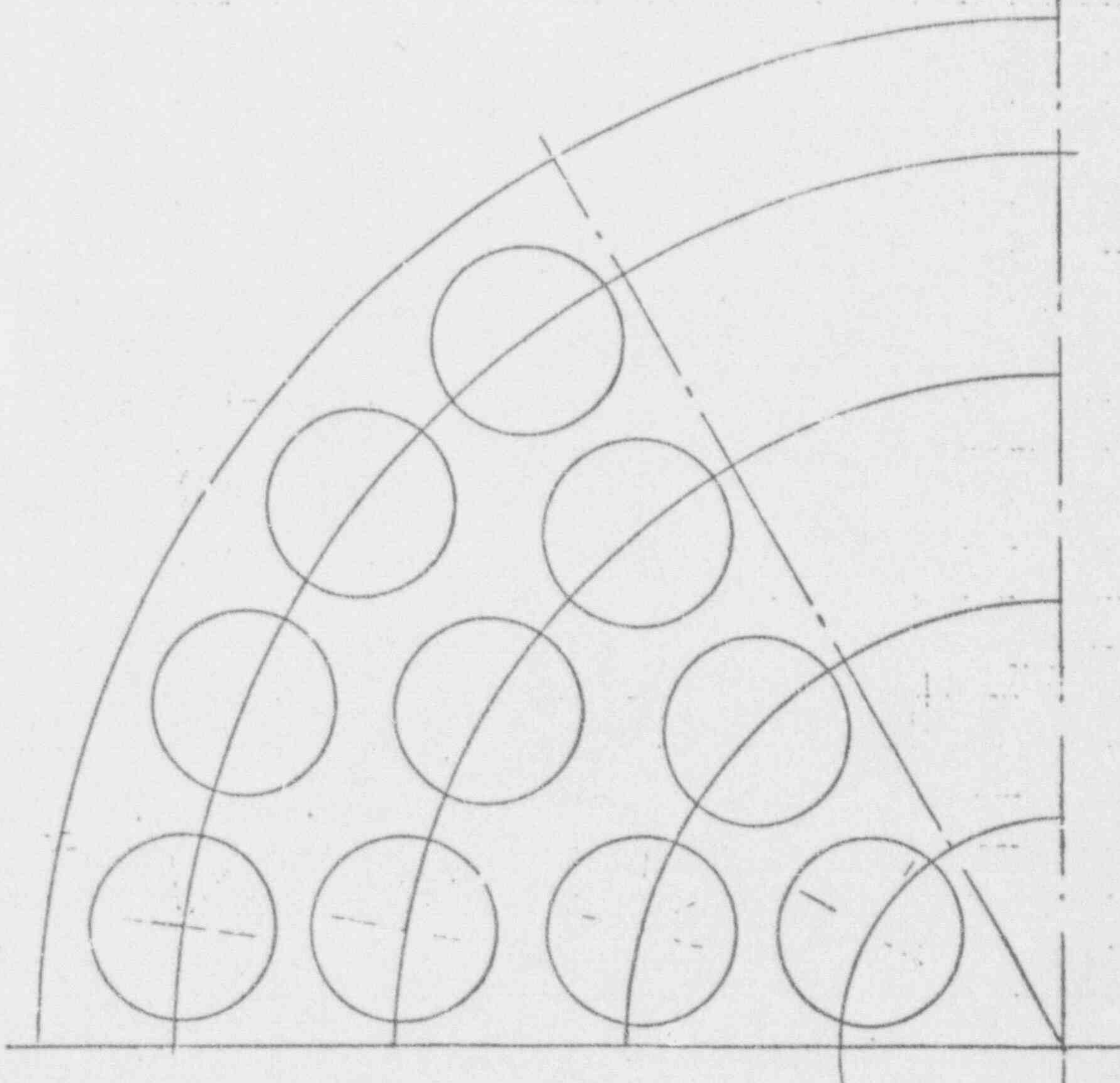
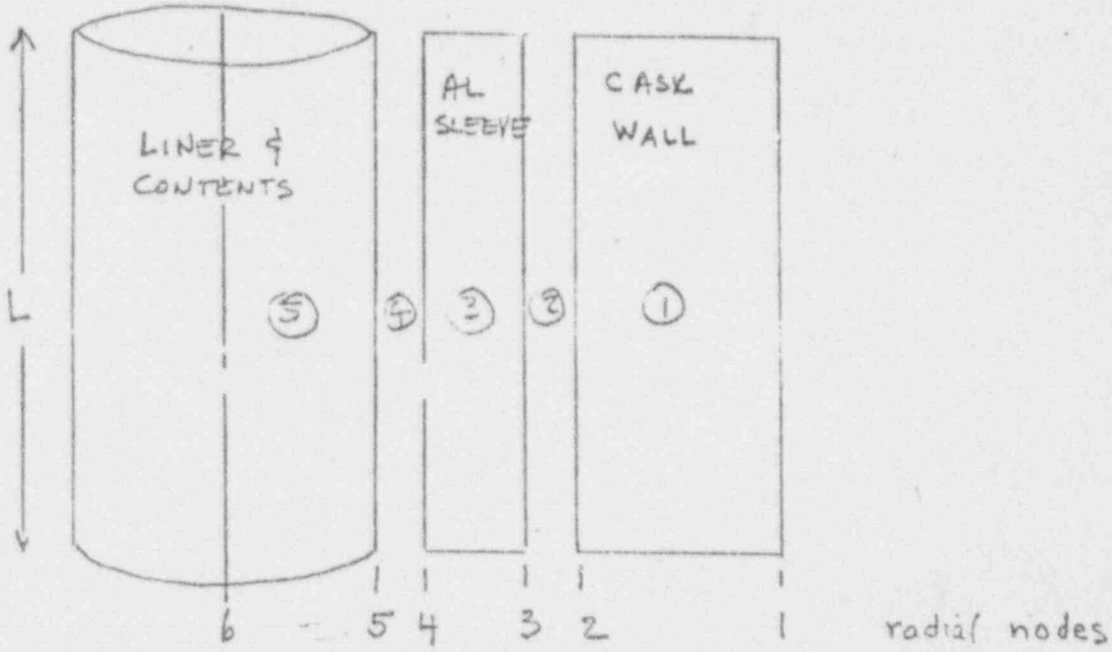


Figure 2


LINER &
CONTENTS
AL
SLEEVE
CASK
WALL
L
5
4
3
2
1
6
5 4
3 2
1
radial nodes

APPENDIX A

```
100 REM PROGRAM RADXFR
110 REM CALCULATES STEADY STATE TEMPS IN CYLINDRICAL SOURCE & SHIELDING
120 CLEAR
130 DEFINT I,J,M,N
140 DIM M(6),R(5),T(6),A(6),B(6),C(6),AV(2),BV(2),CV(2),WM(2),F(2)
150 REM READ CONSTANTS FOR THERMAL CONDUCTIVITY FITS
160 REM 1=AIR; 2=HELIUM; 3=LEAD; 4=ALUMINUM; 5=BRASS; 6=STLSS STEEL
170 FOR I=1 TO 6
180 READ A(I),B(I),C(I)
190 DATA .0043,.0036,0,.0274,.020,0,20.3,-.983,-.017
200 DATA 117.,.5,1.5,58.87,18.2,-3.067,9.4,.368,.022
210 NEXT I
220 REM READ CONSTANTS FOR VISCOSITY FITS
230 FOR I=1 TO 2
240 READ AV(I),BV(I),CV(I)
250 DATA 27.9,59.0,-2.2,51.0,54.2.-1.6
260 NEXT I
270 WM(1)=28.96 : WM(2)=4!
280 PRINT "INPUT TITLE AND DATE"
290 INPUT TITDAT$
300 PRINT "INPUT RADII (5 VALUES), INCHES"
310 INPUT R(1),R(2),R(3),R(4),R(5)
320 PRINT "INPUT SOURCE HEIGHT, INCHES"
330 INPUT H
340 PRINT "INPUT MATERIAL INDEX FOR CASK"
350 PRINT "1=AIR, 2=HE, 3=PB, 4=AL, 5=BRASS, 6=SS"
360 INPUT M(1)
370 PRINT "INPUT MATERIAL INDEX FOR OUTER GAP"
380 INPUT M(2)
390 IF R(4)=R(3) THEN 440
400 PRINT "INPUT MATERIAL INDEX FOR SHIELD RING"
410 INPUT M(3)
420 PRINT "INPUT MATERIAL INDEX FOR INNER GAP"
430 INPUT M(4)
440 PRINT "INPUT MATERIAL INDICES FOR SOURCE: METAL, GAS"
450 INPUT M(5),M(6)
460 PRINT "INPUT VOLUME FRACTIONS OF SOURCE MTLS: METAL, GAS"
470 INPUT VF1,VF2
480 PRINT "INPUT TAMB,DTR"
490 INPUT TAMB,DTR
500 PRINT "INPUT Q,QR"
510 INPUT Q,QR
520 PRINT "INPUT HEAT DEPOSITION DISTR FACTORS: SOURCE - F(1), RING - F(2)"
530 INPUT F(1),F(2)
```

```
540 LPRINT TITDAT$
550 LPRINT
560 LPRINT "RADII & SOURCE HEIGHT (INCHES)"
570 LPRINT R(1),R(2),R(3),R(4),R(5),H
580 LPRINT
590 LPRINT "MATERIAL INDICES"
600 LPRINT M(1),M(2),M(3),M(4),M(5),M(6)
610 LPRINT
620 LPRINT "VOLUME FRACTIONS OF SOURCE MTLS: METAL, GAS"
630 LPRINT VF1,VF2
640 LPRINT
650 LPRINT "Q","F(1)","F(2)"
660 LPRINT Q,F(1),F(2)
670 LPRINT
680 LPRINT "TAMB=" TAMB
690 L=L/12!
700 FOR I=1 TO 5
710 R(I)=R(I)/12!
720 NEXT I
730 PI=3.1416
740 REM CALCULATE DT FOR OVERPACK
750 DT=DTR*Q/QR
760 T(1)=TAMB+DT
770 LPRINT "T(1)=" T(1)
780 REM CALCULATE DT ACROSS CASK
790 J=M(1)
800 N=0
810 TAV=(T(1)-32!)/1.8
820 N=N+1
830 K=A(J)+B(J)*(TAV/100!)+C(J)*(TAV/100!)^2
840 DT=(Q/H)*LOG(R(1)/R(2))/(2!*PI*K)
850 TAV=(T(1)+.5*DT-32!)/1.8
860 IF N<3 THEN 820
870 T(2)=T(1)+DT
880 LPRINT "T(2)=" T(2)
890 REM CALCULATE DT ACROSS OUTER GAP
900 J=M(2)
910 N=0
920 T(3)=T(2)+100!
930 N=N+1
940 TAV=(T(2)+T(3)-64!)/3.6+273!
950 TABS=(T(2)+T(3))/2!+460!
960 KC=A(J)+B(J)*(TAV/100!)
970 V=AV(J)+BV(J)*(TAV/100!)+CV(J)*(TAV/100!)^2!
980 VN=V*6.72E-08*1545!*TABS/(14.7*144!*WM(J))
```

```
950 L=R(2)-R(3)
1000 GR=32.2*L^3*(T(3)-T(2))/(VN^2*TABS)
1010 IF GR<20000! THEN 1070
1020 IF GR>200000! THEN 1050
1030 KCV=KC*.18*GR^.25/(H/L)^.11
1040 GOTO 1110
1050 KCV=KC*.065*GR^.333/(H/L)^.11
1060 GOTO 1110
1070 Y=LOG(GR)*.4343
1080 X=.04+.05*(Y-3.3)^2/LOG(H/L) : IF Y<3.3 THEN X=.04
1100 KCV=KC*10!^X
1110 SUMT=(T(2)+460!)^3+(T(2)+460!)^2*(T(3)+460!)+(T(2)+460!)*(T(3)+460!)^2
1120 SUMT=SUMT+(T(3)+460!)^3
1130 KR=1.714E-10*SUMT*(R(2)-R(3))
1140 K=KCV+KR
1150 DT=(F(1)+F(2))*(Q/H)*LOG(R(2)/R(3))/(2!*PI*K)
1160 T(3)=(T(3)+T(2)+DT)/2!
1170 IF N<5 THEN 930
1180 T(3)=T(2)+DT
1190 LPRINT "T(3)=" T(3)
1200 REM CALCULATE DT ACROSS SHIELD RING
1210 TEMP=R(4)-R(5)
1220 IF TEMP>.001 THEN 1250
1230 T(4)=T(3) : T(5)=T(4)
1240 GOTO 1660
1250 J=M(3)
1260 N=0
1270 TAV=(T(3)-32!)/1.8
1280 N=N+1
1290 K=A(J)+B(J)*(TAV/100!)+C(J)*(TAV/100!)^2
1300 DT=(F(1)+F(2))*(Q/H)*LOG(R(3)/R(4))/(2!*PI*K)
1310 TAV=(T(3)+.5*DT-32!)/1.8
1320 IF N<3 THEN 1280
1330 T(4)=T(3)+DT
1340 LPRINT "T(4)=" T(4)
1350 REM CALCULATE DT ACROSS INNER GAP
1360 J=M(4)
1370 N=0
1380 T(5)=T(4)+100!
1390 N=N+1
1400 TAV=(T(4)+T(5)-64!)/3.6+273!
1410 TABS=(T(4)+T(5))/2!+460!
1420 KC=A(J)+B(J)*TAV/100!
1430 V=AV(J)+BV(J)*(TAV/100!)+CV(J)*(TAV/100!)^2
1440 VN=V*6.72E-08*1545!*TABS/(14.7*144!*WM(J))
1450 L=R(4)-R(5)
```

```
1460 GR=32.2*L^3*(T(5)-T(4))/(VN^2*TABS)
1470 IF GR<20000! THEN 1530
1480 IF GR>200000! THEN 1510
1490 KCV=KC*.18*GR^.25/(H/L)^.11
1500 GOTO 1560
1510 KCV=KC*.065*GR^.333/(H PRINT L)^.11
1520 GOTO 1560
1530 Y=LOG(GR)*.4343
1540 X=.04+.05*(Y-3.3)^2/LOG(H/L) : IF Y<3.3 THEN X=.04
1550 KCV=KC*10!^X
1560 SUMT=(T(4)+460!)^3+(T(4)+460!)^2*(T(5)+460!)+(T(4)+460!)*(T(5)+460!)^2
1570 SUMT=SUMT+(T(5)+460!)^3
1580 KR=1.714E-10*SUMT*(R(4)-R(5))
1590 K=KCV+KR
1600 DT=F(1)*(Q/H)*LOG(R(4)/R(5))/(2!*PI*K)
1610 Y(5)=(T(5)+T(4)+DT)/2!
1620 IF N<5 THEN 1390
1630 T(5)=T(4)+DT
1640 LPRINT "T(5)=" T(5)
1650 REM CALCULATE DT WITHIN SOURCE
1660 I=M(5)
1670 J=M(6)
1680 N=0
1690 T(6)=T(5)+200!
1700 N=N+1
1710 TAV=(T(5)+T(6)-64!)/3.6
1720 K1=A(I)+B(I)*(TAV/100!)+C(I)*(TAV/100!)^2
1730 TAV=TAV+273!
1740 K2=A(J)+B(J)*(TAV/100!)
1750 TEMP=(VF1/K1+VF2/K2)
1760 DT=F(1)*(Q/H)*TEMP/(4!*PI)
1770 T(6)=T(5)+DT
1780 IF N<4 THEN 1700
1790 LPRINT "T(6)=" T(6)
1800 LPRINT
1810 LPRINT "CALCULATION COMPLETE"
1820 END
```

APPENDIX_B

GE700 @ 6566 WATTS, SR TARGETS

RADII & SOURCE HEIGHT (INCHES)

18.375	7.5	7.44	5.435	5.375	32

MATERIAL INDICES

3	1	4	1	4	2

VOLUME FRACTIONS OF SOURCE MTLS: METAL, GAS

.5	.5

Q	F(1)	F(2)
22410	.85	.07

TAMB= 80
T(1)= 300
T(2)= 305.3172
T(3)= 340.2648
T(4)= 340.5282
T(5)= 383.1472
T(6)= 564.043

CALCULATION COMPLETE

GE700 @ 6500 WATTS, SR TARGETS

RADII & SOURCE HEIGHT (INCHES)

18.375	7.5	7.44	5.435	5.375	32

MATERIAL INDICES

3	1	4	1	4	2

VOLUME FRACTIONS OF SOURCE MTLS: METAL, GAS

.5	.5

Q	F(1)	F(2)
22185	.85	.07

TAMB= 80
T(1)= 297.7912
T(2)= 303.0514
T(3)= 337.7473
T(4)= 338.0082
T(5)= 380.331
T(6)= 559.9371

CALCULATION COMPLETE

Weise calculated individual coefficients of heat transfer from the temperature drop, close to the plate, to check the mean coefficient as found by direct measurement.

25-3. Free Convection in Enclosed Plane Gas Layers

The heat transmission by free convection in horizontal and vertical plane air layers has been measured by different investigators; the most elaborate experiments seem to be those of Mull and Reiher [1930]. As a measure for the heat exchange in a gas layer they used an equivalent thermal conductivity, k_e. This includes the effect of convection and radiation and is defined by

$$k_e = k_c + k_r \tag{25-19}$$

where k_c is itself an equivalent thermal conductivity, including the effect of conduction and convection, and k_r is another equivalent conductivity superseding the effect of radiation.

Whereas k_r can be very simply calculated from Stefan-Boltzmann's law or the corresponding relations for gray or metallic radiators, the determination of k_c requires special experiments under varying conditions. Mull and Reiher used air layers between two plane surfaces, 40 in. long and 24 in. wide. Different sections were formed by thin strips of balsa wood as boundaries, so that the influence of length and width could be studied on surfaces of 30 to 960 sq in. Air layers of seven different thicknesses from ½ to 7¾ in. were employed. An electrical heater composed of five separate sections was used with a secondary heating plate at the rear side and a ring heater at the edges, both insulated from the main heater and held at the same temperature. Thus the heat flow was restricted to the front side, from where it crossed the air layer under consideration and afterward a cork plate which served as an auxiliary heat-flow meter. The whole plate system was bedded in a well-insulating material and was turnable in a metal frame so that the air layer could be brought into horizontal, vertical, or oblique position.

The rate of heat flow by convection between a warmer surface (subscript 1) and a cooler surface (subscript 2) can be expressed by

$$q_e = k_e \frac{A}{L}(t_1 - t_2) \quad \text{or} \quad q_e'' = \frac{k_e}{L}(t_1 - t_2) \tag{25-20}$$

where L = the thickness of the gas layer,
$A = H \cdot W$ = the area of this layer,
H = the height of the layer, when used in vertical position, and
W = the width of the layer.

Further, from the theory of similarity, for air and probably also for any other diatomic gases,

$$(N_{Nu})_L = \Phi\left[(N_{Gr})_L, \frac{H}{L}, \frac{W}{L}\right] \tag{25-21}$$

where slightly modified Nusselt and Grashof numbers are defined by

$$(N_{Nu})_L = \frac{q_c''}{t_1 - t_2} \cdot \frac{L}{k} = \frac{k_c}{k} \tag{25-22}$$

and

$$(N_{Gr})_L = \frac{\beta g}{\nu^2} L^3 (t_1 - t_2) \tag{25-23}$$

From Eqs. 25-21 and 22

$$\frac{k_c}{k} = \Phi\left[(N_{Gr})_L, \frac{H}{L}, \frac{W}{L}\right] \tag{25-24}$$

Obviously

$$\frac{k_c}{k} \to 1 \quad \text{when} \quad (N_{Gr})_L \to 0 \tag{25-25}$$

Considering, now, first *horizontal layers* (subscript h), the experiments with heat flow upward showed that $k_{c,h}/k$ is independent of H and W. Then, for reasons of similitude, it will also be independent of H/L and W/L. Hence Eq. 25-24 simplifies to

$$\frac{k_{c,h}}{k} = \Phi(N_{Gr})_L \tag{25-26}$$

Mull and Reiher represented their experiments by plotting $k_{c,h}/k$ versus $\log N_{Gr}$ and obtained a smooth curve in the experimental range of $(N_{Gr})_L$ = 2100 to 8,890,000. Jakob [1946], however, representing these results in bilogarithmic coordinates, has shown that there is at least one bend in the curve, in analogy to other cases of free convection. Figure 25-6 reveals that, in analogy to the cases of a heated surface facing upward and a vertical surface at high Grashof numbers,

$$\frac{k_{c,h}}{k} = 0.068(N_{Gr})_L^{1/3} \tag{25-27}$$

This is valid from $N_{Gr} \approx$ 400,000 upward.

In the range from about 10,000 to 400,000, on the other hand, as for vertical surfaces in a medium range of Grashof numbers,

$$\frac{k_{c,h}}{k} = 0.195 N_{Gr}^{1/4} \tag{25-28}$$

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For very small Grashof numbers log k_e/k approaches zero according to Eq. 25-25. This is indicated by the dotted line in Fig. 25-6.

The meaning of Eq. 25-27, obviously, is that, above a certain thickness L, the coefficient of heat transfer by convection does not change any more, so that there should be no difference between the heat transfer through the layer and that from a single horizontal plate facing upward.

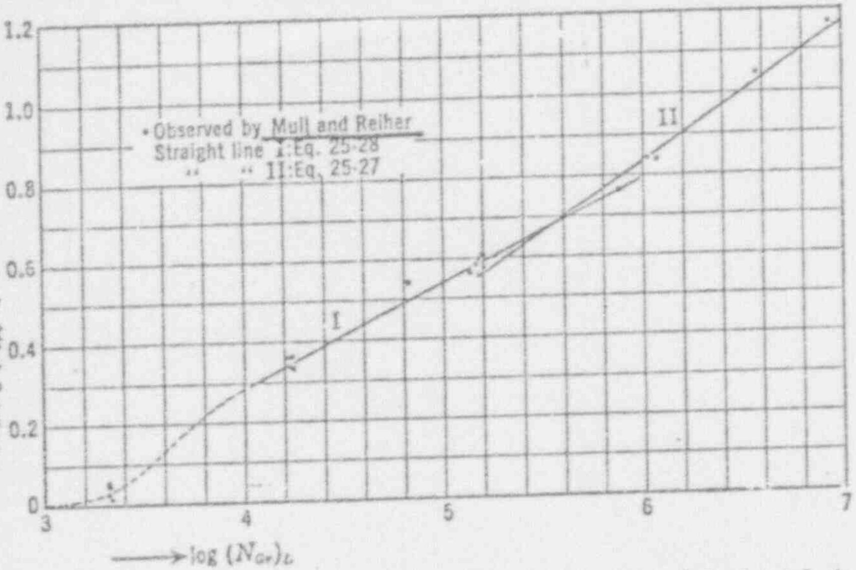

FIG. 25-6. Dimensionless representation of heat transfer through horizontal air layers by free convection.

This may be checked by calculating an example. According to Eqs. 25-22 and 27,

$$q_{c,h}'' = 0.068k\left(\frac{\beta g}{\nu^2}\right)^{1/3}(t_1 - t_2)^{4/3}$$

For $t_1 - t_2 = 50$ C and an atmospheric pressure of 730 mm Hg, Mull and Reiher used $\beta g/\nu^2 = 0.110(10^9)$ m^{-3} C^{-1} and $k = 23.0(10^{-3})$ kcal hr^{-1} m^{-1} C^{-1}. Employing these values and converting to British technical units,

$$q_{c,h}'' = 0.068(23.0)10^{-3}(0.673)0.110^{1/3}(10^3)0.3048(1.8)(t_1 - t_2)^{4/3}$$
$$= 0.277\theta^{4/3}$$

in excellent agreement with Eq. 25-14.

For *vertical air layers* (subscript v) the conditions are less simple than for horizontal layers, because $k_{e,v}/k$ will not be independent of H and

W. Mull and Reiher, in one of their tests, kept H/L and N_{Gr} constant, but reduced W/L from 25.7 to 12.8, i.e., by 50%. However, the term $(k_{e,v}/k)\cdot(H/L)$ changed only by 1.3%. Hence, omitting W/L as an independent variable in Eq. 25-24, the corresponding equation for vertical air layers becomes

$$\frac{k_{e,v}}{k} = \Phi\left[(N_{Gr})_L, \frac{H}{L}\right] \qquad (25\text{-}29)$$

As in the case of horizontal air layers, $k_{e,v}/k$ decreases with N_{Gr} and approaches $k_e/k = 1$ when N_{Gr} approaches zero. Hence, at this limit,

$$\frac{k_{e,v}}{k}\cdot\frac{H}{L} = \frac{H}{L} \qquad (25\text{-}30)$$

For very large distances, the problem also simplifies because of the vanishing of the frictional resistance between two parallel vertical surfaces, very distant from each other. Obviously

$$t_1 - t_m = t_m - t_2$$

and

$$q_{c,v}'' = h(t_1 - t_m) = h(t_m - t_2)$$

or

$$q_{c,v}'' = \tfrac{1}{2}h(t_1 - t_2) \qquad (25\text{-}31)$$

where h is the coefficient of heat transfer for a single vertical surface, which may be found from Eq. 25-10 or 11.

From Eqs. 25-20 and 31

$$k_{e,v} = \frac{hL}{2} \quad \text{or} \quad \frac{k_{e,v}}{k}\cdot\frac{H}{L} = \frac{h}{k}\cdot\frac{H}{2} = \frac{1}{2}\cdot\frac{h}{k}\cdot\frac{H}{L}L \qquad (25\text{-}32)$$

Hence, $k_{e,v}$ becomes proportional to L for very thick air layers, and the resistance against thermal convection, $L/(k_{e,v}A)$ approaches a limit. The resistance against heat transfer by radiation is also constant when the surface temperatures and emissivities remain unvaried. Therefore, the insulating power of air layers cannot be increased infinitely by increasing the layer thickness, as would be the case with a solid body, but is limited. For this reason it is advisable to divide thick air layers by separating sheets or other solid bodies. The resistances against convection and radiation increase almost proportionally to the number of divisions. Under such conditions as exist in buildings the heat resistance has a maximum for vertical air layers of about 2 in. thickness, whereas horizontal layers of 2 to 8 in. thickness have about the same resistance.

For a general representation Mull and Reiher plotted $(k_{e,v}/k)\cdot(H/L)$, as measured, versus log N_{Gr} and built up 27 curves with H/L as param-

Enclosure 30, Rev0
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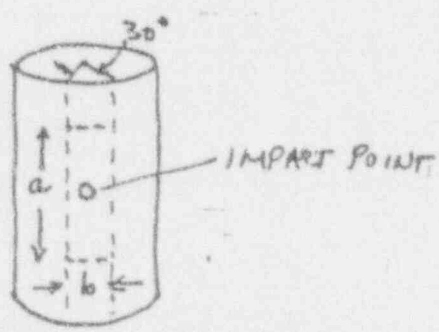
PUNCTURE (ref: ENC. 3, p. 4)

GE HAS ADDRESSED CONSEQUENCES OF 40" DROP ONTO 6" DIA. BAR ON THE PROTECTIVE JACKET & CASK AND HAS SHOWN THE RESULTS TO BE ACCEPTABLE. IT IS NECESSARY TO EVALUATE WHETHER THIS EVENT CREATES G-LOADINGS ON THE LINER GREATER THAN THOSE FROM A 30 FT. DROP.

FOR EXAMPLE, ASSUME THE PACKAGE IMPACTS SIDE-DOWN ON THE STEEL BAR. WE WILL ANALYZE THE DEFLECTION OF THE OUTER PROTECTIVE SHELL UNDER 1 G LOAD, CALCULATE THE RESULTANT ENERGY ABSORPTION, & INFER WHETHER THE STOPPING DISTANCE FROM A 40" DROP COULD BE SUCH AS TO CAUSE A G-LOADING IN EXCESS OF 278 g (ref: ENCL 3, p 3)

USE CASE No. 37 FROM TABLE X OF 4TH EDITION OF ROARK, FORMULAS FOR STRESS AND STRAIN (SEE ATTACHED COPY). ASSUME THAT AFFECTED PORTION OF SHELL IS A 30° ARC, AS SKETCHED BELOW:



$$MAX\ y = \frac{\alpha W b^2}{E t^3}$$

ASSUME $a/b = 2$; $\therefore \alpha = 0.1805$

$W = 35{,}500$ lbs

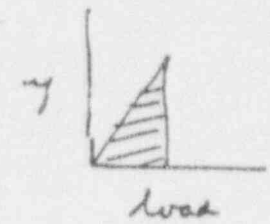
$$b = \frac{\pi}{12} \times OD = \frac{\pi}{12} \times 51.5" = 13.5"$$

$E = 30 \times 10^6$ lb/in^2 FOR STEEL

$t = 0.62"$ (outer shell thickness)

$$\text{MAX } y = \frac{(0.1805)(35,500)(13.5)^2}{(30\times10^6)(.62)^3} = 0.163" \quad (\text{FOR 1-g})$$

ENERGY ABSORPTION :



for: Elastic Range

$$= \frac{Wy}{2} = \frac{(35500)(.163)}{2(12)}$$

$$= 241 \text{ ft lb} \quad (\text{FOR 1-g})$$

KINETIC ENERGY FROM 40" DROP

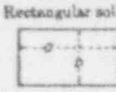
$$= (35,500)\left(\frac{40}{12}\right) = 118,333 \text{ ft lb}$$

CONCLUSION IS THAT THE STOPPING DISTANCE WILL BE MUCH GREATER THAN 0.163". THE STOPPING DISTANCE FOR A UNIFO[RM] g-LOADING OF 278 g IS $\frac{40}{278} = 0.144"$. THEREFORE, EVEN ALLOWING FOR NON-UNIFORM g-LOADING DURING DECELERATION FROM A 40" DROP, THE MAX. G-LOADING WILL BE SIGNIFICANT[LY] LESS THAN 278-g. AS THE MARGIN IS LARGE, IT CAN BE INFERRED WITHOUT CALCULATIONS THAT A SIMILAR CONCLUSION APPLIES FOR OTHER ATTITUDES OF THE PACKAGE (i.e., TOP DOWN, [illegible] DOWN, OBLIQUE).

ENCLOSURE — 3 of 4

TABLE X.—FORMULAS FOR FLAT PLATES.—(*Continued*)

Manner of loading and Case No.	Formulas for stress and deflection
	Elliptical, solid  $\frac{b}{a} = \alpha$ (C)
Edge supported 26. Uniform load over entire surface	(At center) $s_b = -\frac{0.3125(2-\alpha)wb^2}{t^2}$ = Max s Max $y = \frac{(0.146-0.1\alpha)wb^4}{Et^3}$ $\left(\text{for } \nu = \frac{1}{3}\right)$ (Approximate formula after Morley, Ref. 3)
Edge supported 27. Uniform load over small concentric circular area of radius r_0	(At center) $s_b = -\frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{b}{2r_0} + 6.57 - 2.57\alpha\right]$ = Max s Max $y = \frac{Wb^2}{Et^3}(0.19 - 0.045\alpha)$ $\left(\text{for } \nu = \frac{1}{4}\right)$ (Approximate formulas by interpolation between cases of circular plate and infinitely long narrow strip, Ref. 4)
Edge fixed 28. Uniform load over entire surface	(At edge) (Span a) $s_a = \frac{3wb^2\alpha^2}{2t^2(3+2\alpha^2+3\alpha^4)}$ (Span b) $s_b = \frac{3wb^2}{2t^2(3+2\alpha^2+3\alpha^4)}$ = Max s (At center) $s_a = -\frac{3wb^2(\alpha^2 m+1)}{4t^2(3+2\alpha^2+3\alpha^4)m}$ $s_b = \frac{-3wb^2(m+\alpha^2)}{4t^2(3+2\alpha^2+3\alpha^4)m}$ Max $y = -\frac{3w(m^2-1)b^4}{16m^2Et^3(6+4\alpha^2+6\alpha^4)}$ (Formulas due to Prescott, Ref. 5)
Edge fixed 29. Uniform load over small concentric circular area of radius r_0	(At center) $s_b = -\frac{3W(m+1)}{2\pi m t^2}\left[\log\frac{b}{r_0} - 0.317\alpha - 0.376\right]$ Max $y = -\frac{Wb^2(0.0815-0.026\alpha)}{Et^3}$ (Approximate formulas by interpolation between cases of circular plate and infinitely long narrow strip, Ref. 6. $\nu = 0.25$ for Max y)
	Square, solid  (D)
Edges supported above and below. (Corners held down) 30. Uniform load over entire surface	(At center) $s_a = -\frac{0.2208\,wa^2(m+1)}{mt^2}$ = Max s Max $y = -\frac{0.0487wa^4(m^2-1)}{m^2Et^3}$ (Formulas due to Prescott, Ref. 5)

Manner of loading and Case No.	Formulas for stress and deflection
Edges supported above and below. (Corners held down) 31. Uniform load over small concentric circular area of radius r_0	(At center) Max $s = -\frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{2r_0} + \text{[illegible]}5m\right]$ Max $y = -\frac{0.1391Wa^2(m^2-1)}{m^2Et^3}$
Edges supported below only (corners free to rise) 32. Uniform load over entire surface	(At center, on diagonal section) $s = -\frac{0.2214wa^2}{t^2}$ Max $y = -\frac{.0443wa^4}{Et^3}$ ($\nu = 0.3$) (At corners, on diagonal section) $s = -\frac{0.2778wa^2}{t^2}$ = Max s
Edges supported below only (corners free to rise) 33. Uniform load over small concentric circular area of radius r_0	Same as Case 31
All edges fixed 34. Uniform load over entire surface	(At center of each edge) $s_a = \frac{0.308wa^2}{t^2}$ = Max s (At center) $s = -\frac{6w(m+1)a^2}{47mt^2}$ (Ref. 5). Max $y = -\frac{0.0138wa^4}{Et^3}$ (Other formulas based on coefficients given by Timoshenko, Ref. 7. $\nu = 0.3$)
35. Uniform load over small concentric circular area of radius r_0	(At center) Max $s = -\frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{2r_0}\right]$ $y = \frac{0.0624(m^2-1)Wa^2}{m^2Et^3}$ (Ref. 6)
	Rectangular solid  (E)
All edges supported 36. Uniform load over entire surface	(At center) Max $s = s_b = \beta\frac{wb^2}{t^2}$ Max $y = \alpha\frac{wb^4}{Et^3}$ (Ref. 21)
All edges supported 37. Uniform load over small concentric circular area of radius r_0	(At center) Max $s = \frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{2b}{\pi r_0} + 1 - \beta m\right]$ Max $y = \alpha\frac{Wb^2}{Et^3}$

Case 36:

$\frac{a}{b}$	1	1.2	1.4	1.6	1.8	2	3	4	5	∞
β	0.2874	0.3762	0.4530	0.5172	0.5688	0.6102	0.7134	0.7410	0.7476	0.750
α	0.0444	0.0616	0.0770	0.0906	0.1017	0.1110	0.1335	0.1400	0.1417	0.1421

Case 37:

$\frac{a}{b}$	1	1.2	1.4	1.6	1.8	2
β	0.565	0.350	0.211	0.125	0.073	0.042

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BACKUP CALCULATIONS FOR ENCLOSURE 3A

THE FLANGE IS ANALYSED PER ASME SECTION VIII, APPENDIX II, RULES FOR FLANGES WITH RING TYPE GASKETS. SIMILAR RULES ARE GIVEN IN ASME SECTION III, APPENDIX XI FOR CLASS RF FLANGES.

GEOMETRY OF FLANGE (NOTATION IS PER UA-47 OF ASME VIII)

A = OUTSIDE DIA. OF FLANGE = 14.875"
A_b = TOTAL CROSS SECTIONAL AREA OF BOLTS (AT ROOT OF THREAD) = 3.62 in
B = INSIDE DIA. OF FLANGE = 10.42"
b = EFFECTIVE GASKET SEATING WIDTH = $\sqrt{b_0}/2$ = .293"
b_0 = BASIC GASKET SEATING WIDTH = $N/2$ = .344"
C = BOLT CIRCLE DIA. = 13.375"
D = DIA. OF BOLT HOLES = .812"
G = DIA. AT GASKET REACTION = GASKET OD − 2b = 11.414
g_0 = THICKNESS OF HUB AT SMALL END = .165"
g_1 = THICKNESS OF HUB AT BACK OF FLANGE = $g_0 + 3/16$ = .352"
h = HUB LENGTH = 3/16 = .188"
h_0 = FACTOR $\sqrt{Bg_0}$ = 1.311"
N = WIDTH OF GASKET = $(12 - 10\frac{5}{8})/2$ = .688"
n = No. OF BOLTS = 12
R = $(C-B)/2 - g_1$ = 1.126"
t = FLANGE THICKNESS = 2"
t_n = THICKNESS OF SHELL TO WHICH FLANGE IS ATTACHED = .165"
t_{lid} = LID THICKNESS = 1.5"

A/B = 1.428
g_1/g_0 = 2.13
h/h_0 = .143

$d = \frac{U}{V} h_0 g_0^2$ = .587
$e = F/h_0$ = .686
$F = f(g_1/g_0, h/h_0)$ = 0.9 ref: Fig. UA-51.2
$f = f(g_1/g_0, h/h_0)$ = 3.45 ref: Fig. UA-51.6
$L = (te+1)/T + t^3/d$ = 14.95
$T = f(A/B)$ = 1.8 ref: Fig. UA-51.1
$U = f(A/B)$ = 6.5 "
$V = f(g_1/g_0, h/h_0)$ = .395 ref: Fig. UA-51.3

$Y = f(A/B) = 5.8$ ref: Fig. UA-57.1
$Z = f(A/B) = 3.0$ "

A. NORMAL CONDITIONS - BOLTED CLOSURE

1. MATERIAL PROPERTIES
ENCL. 3A IS SELF-EXPLANATORY

2. BOLT LOADS
* $W_{m_1} = .785\, G^2 P + 2b\, 3.14\, G\, m\, P$ (Eqn (1) of UA-49)
$= \underline{24,791}$ lbs

FOR: $p = 150$ psi
$m = 3$ (from TABLE UA-49.1 for SS material)

* $W_{m_2} = 3.14\, b\, G\, y$
$= \underline{105,011}$ lbs

FOR $y = 10,000$ (from TABLE UA-49.1 for SS material)

3. REQUIRED BOLT AREA
ENCL 3A IS SELF-EXPLANATORY

4. FLANGE DESIGN BOLT LOAD

For operating conditions: $W = W_{m_1} = \underline{24,791}$ lbs

For gasket seating: $W = \frac{(A_m + A_b) S_a}{2} = \frac{(3.50 + 3.62)(30,000)}{2}$

$= \underline{106,800}$ lbs

5. FLANGE MOMENTS

For operating conditions: $M_o = M_D + M_T + M_G$

where: $M_D = H_D h_D$; $M_T = H_T h_T$; $M_G = H_G h_G$

$H_D = .785 B^2 P = 12785$ lbs
$H_G = W_{m_1} - H = 24791 - 15340 = 9451$ lbs
$H = .785 G^2 P = 15340$ lbs
$H_T = H - H_D = 2555$ lbs
$P = 150$ psi
$h_D = R + 0.5 g_1 = 1.30?$ ref: TABLE UA-50
$h_G = (C - G)/2 = .981$ "
$h_T = (R + g_1 + h_G)/2 = 1.230$ "

$\therefore$ $M_D = 12785 \times 1.302 = 16{,}646$
$M_G = 9457 \times .981 = 9{,}271$
$M_T = 2555 \times 1.230 = 3{,}143$
$M_o = 29{,}060$ in/lbs

For gasket seating: $M_o = W\left(\frac{C-G}{2}\right)$

where: $W = 106{,}800$ lbs

$\therefore$ $M_o = 104{,}717$ in.lbs

6. FLANGE STRESSES

LONGITUDINAL HUB STRESS: $S_H = \frac{f M_o}{L g_1^2 B}$

RADIAL FLANGE STRESS: $S_R = \frac{(1.33te + 1) M_o}{L t^2 B}$

TANGENTIAL FLANGE STRESS: $S_T = \frac{Y M_o}{t^2 B} - Z S_R$

$$S_H = \frac{(3.45) M_o}{(14.95)(.352)^2(10.42)} = 0.179 M_o$$

$$S_R = \frac{[(1.33)(2)(.686) + 1] M_o}{(14.95)(2)^2(10.42)} = 0.0045 M_o$$

$$S_T = \left[\frac{5.8}{(2)^2(10.42)} - (3)(.0045)\right] M_o = 0.126 M_o$$

ALLOWABLE FLANGE STRESSES (ref: UA-52)

$$S_H \le 1.5 S_f \; ; \; S_R \le S_f \; ; \; S_T \le S_f \; ; \; \frac{S_H + S_R}{2} \le S_f \; ; \; \frac{S_H + S_T}{2} \le S_f$$

AT OPERATING CONDITIONS (M_0 = 29,060 in lbs, p.3 ; S_f = 12,100 psi, p1 of ENCL3A)

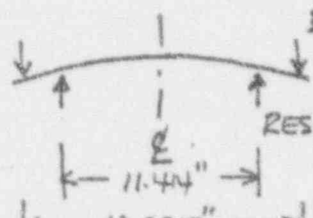
	STRESS	ALLOWABLE	SAFETY FACTOR (1.0 is ACCEPTABLE)
S_H	5,202	18150	3.5
S_R	131	12100	92.
S_T	3,662	12100	3.3
$(S_H+S_R)/2$	2,667	12100	4.5
$(S_H+S_T)/2$	4,432	12100	2.7

AT GASKET SEATING CONDITIONS (M_0 = 104,717 in lbs, p3; S_f = 18,800 psi, p1 of ENCL3A)

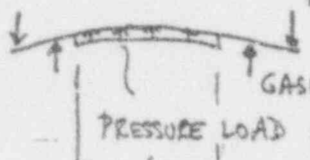
	STRESS	ALLOWABLE	SAFETY FACTOR (1.0 is ACCEPTABLE)
S_H	18,744	28,200	1.5
S_R	471	18,800	40.
S_T	13,194	18,800	1.4
$(S_H+S_R)/2$	9,608	18,800	2.0
$(S_H+S_T)/2$	15,969	18,800	1.2

7. STRESSES IN TOP PLATE (LID)

BOLT UP:



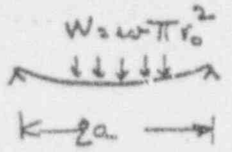
BOLT UP PLUS PRESSURE OF NORMAL CONDITIONS OF TRANSPORT:



ASSUME (CONSERVATIVELY) THAT BOLT LOAD IS INCREASED BY MAGNITUDE OF PRESSURE LOAD

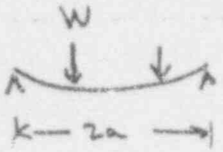
ROARK GIVES TWO CASES THAT CAN BE USED FOR THE ABOVE SITUATIONS: TABLE X, CASES 2 3 (SEE ATTACHED COPY, p11)

Case 2:



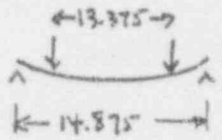
Circular plate, with uniform load over concentric circular area of radius r_o & supported at edges.

Case 3:

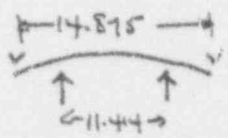


Circular plate, with uniform load on concentric circular ring of radius r_o & supported at edges

THE BOLT UP CASE CAN BE REPRESENTED AS THE SUM OF 2 LOADINGS OF THE TYPE OF CASE 3:

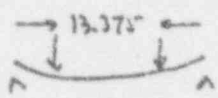


W = 106,800



W = −106,800

THE ADDITION OF PRESSURE CAN BE REPRESENTED AS THE SUM OF A CASE 2 & A CASE 3 TYPE LOADING:



W = 2,300

W = −2,300

THE EQNS GIVEN BY ROARK HAVE BEEN PROGRAMMED IN "BASIC" (SEE LISTING pp 12 & 13) TO CALCULATE STRESSES. A POSITIVE STRESS INDICATES TENSION AT UPPER SURFACE AND EQUAL COMPRESSION AT LOWER SURFACE. A NEGATIVE STRESS INDICATES THE REVERSE. THE VARIABLES P1, P2 etc IN PROGRAM ARE DUMMY VARIABLES. OTHER VARIABLES IN THE PROGRAM FOLLOW NOTATION OF ROARK. THE RESULTS OF THE COMPUTER CALCULATIONS ARE SHOWN ON p 14.

8. BOLT TORQUE

ENCL. 3A IS SELF-EXPLANATORY

9. VIBRATION

1-g IS A CONSERVATIVELY HIGH ACCELERATION FOR LATERAL ROCKING MOTION DURING TRANSPORT. A CONSERVATIVELY LOW VALUE FOR THE COEFFICIENT OF FRICTION AT THE GASKET, CONSIDERING THE GROOVED FACES, IS 0.2. THE GASKET COMPRESSION LOAD IS 106,800 lbs. THE FRICTION LOAD IS THUS 0.2 × 106,800 = 21360 lbs. THE LINER PLUS CONTENTS WEIGH 250 + 180 lbs = 430 lbs. IF THIS ENTIRE WEIGHT IS APPLIED TO MOVE THE LID LATERALLY, THE MARGIN IS: 21360 / 430 = 49.7.

B. LINER INTEGRITY - HYPOTHETICAL ACCIDENT CONDITIONS

Upside-Down Impact

THE SHIM RING IS SHOWN ON SHEET 3 OF NEUTRON PRODUCTS DWG 240/139. ITS AREA IS 31. in^2.

- LOAD TRANSMITTED THROUGH SHIM RING:

  $= 278 \times (135 + 240) = 104250$ lbs

COMPRESSIVE STRESS IN SHIM RING $= \frac{104250}{31} = \underline{3363}$ psi

YIELD STRESS AT 400°F = 20,700 psi (ASME Sect III Div 1 Table I-2.2) ∴ SF = 6.2

- LOAD TRANSMITTED THROUGH LINER WALL

  $= 278 \times (135 - \text{WT OF FLANGE \& BOLTS}) = 278 \times (135 - 57) = 21684$ lbs

COMPRESSIVE STRESS IN WALL $= \frac{21684}{.1658/10.59} = \underline{3950}$ psi

YIELD STRESS AT 400°F = 20,700 psi ∴ SF = 5.2

- LOAD TRANSMITTED THROUGH PIPE + CROSS PLATES ON LID = 278 × 670 = 186,260 lbs

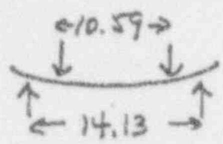
  AREA OF PIPE + CROSS PLATES = 5.49 in² (PIPE) + 7.30 in² (CROSS PLATES)
  = 12.79 in²

  COMPRESSIVE STRESS = 14563 psi ; YIELD STRESS @ 400F = 20,700 psi
  ∴ SF = 1.4

Bending Stresses in Lid

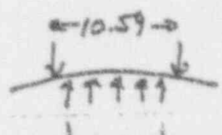
TO MAXIMIZE THE CALCULATED BENDING STRESSES, NEGLECT THE CROSS PLATES + ASSUME ALL LOAD IS CARRIED FROM LINER TO CASK BY THE SHORT SECTION OF PIPE.

THE LINER, SLEEVE + OUTER PORTION OF THE LID CREATE A LOADING PATTERN AS FOLLOWS:



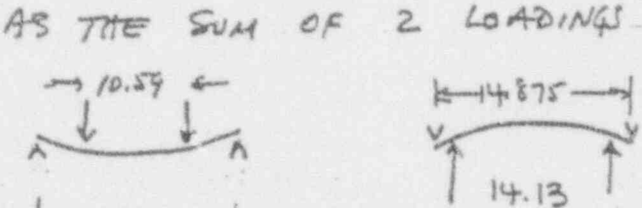
where: W = 278 (135 + 270 + 36)
= 114,258 lbs

THE CONTENTS OF THE LINER + INNER PORTION OF THE LID CREATE A LOADING PATTERN AS FOLLOWS:



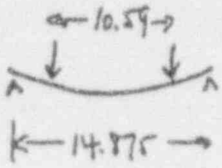
where: W = 278 (180 + 36)
= 60,048 lbs

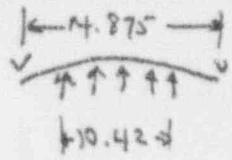
THE FIRST LOADING PATTERN CAN BE REPRESENTED AS THE SUM OF 2 LOADINGS OF ROARK, CASE 3:



W = 114,258.　　　W = −114,258

THE SECOND LOADING PATTERN CAN BE REPRESENTED AS THE SUM OF TWO CASES AS FOLLOWS:





W = 60,048   W = −60,048

THESE CASES HAVE ALSO BEEN ANALYZED NUMERICALLY BY THE "BASIC" PROGRAM. THE RESULTS ARE GIVEN ON p.14.

Retention of Isolation Valves

VALVE WEIGHT = 0.75 lbs

IMPACT LOAD CARRIED BY VALVE SUPPORTS = 278 × 0.75
= 208.5 lbs

LOAD IS CARRIED BY 2 #10-32 SCREWS, EACH WITH CROSS-SECTIONAL AREA (AT ROOT OF THREADS) = $\frac{\pi}{4} \times .130^2 = .0133$ in², PLUS 4 WELDS, EACH WITH AN AREA OF $\frac{1}{16} \times \frac{3}{16} = .0117$ in²

$$\text{STRESS} = \frac{208.5}{(2 \times .0133) + (4 \times .0117)} = \underline{2840 \text{ psi}}$$

YIELD STRESS @ 400°F = 20,700 psi : SF = 7.3

Bottom-Down Impact

LOAD CARRIED BY SHIM = 278 × WT. OF LID
= 278 × 115
= 31,970 lbs

COMPRESSIVE STRESS = 31970/31 = <u>1031 psi</u>

YIELD STRESS @ 400°F = 20,700 : SF = 20.

LOAD CARRIED BY LINER WALL = 278 × (WT OF LID + WT OF LINER − WT OF BOTTOM PLATE)
= 278 (115 + 135 − 49) = 55,878 lbs

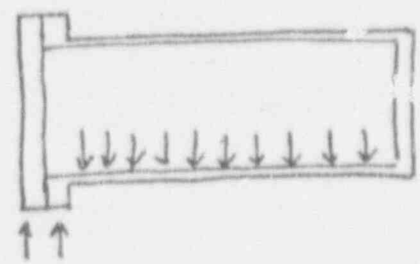
$$\text{COMPRESSIVE STRESS} = \frac{55878}{.165 \pi \, 10.59} = \underline{10,179 \text{ psi}}$$

YIELD STRESS @ 400°F = 20,700 : SF = 20

FOR A BOTTOM-DOWN IMPACT THE BENDING STRESSES IN THE HEAD (LID) ARE RELATIVELY LOW, BECAUSE THE ONLY LOAD IS THE WEIGHT OF THE LID ITSELF (115 lbs), WHICH IS MUCH LESS THAN THE LOADS IMPOSED IN A TOP-DOWN IMPACT. THEREFORE, IT IS OBVIOUS WITHOUT DOING EXPLICIT ANALYSES THAT THE BENDING STRESSES AND DEFLECTIONS ARE ACCEPTABLE.

Side-Down Impact

EXAMINE SHEAR LOADING IN LINER WALL BELOW FLANGE.



W = 180 (CONTENTS) + 100 (LINER BELOW FLANGE
= 280 lbs

SHEAR LOAD = 270g × 280 = 75,600 lbs

SHEAR AREA = .165 π 10.59 = 5.49 in^2

∴ STRESS = 13,770 psi

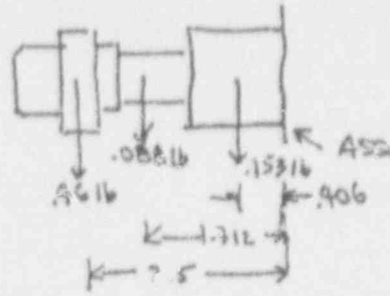
FOR THIS CASE YIELDING IS PERMISSIBLE BECAUSE YIELDING WILL NOT CAUSE LOSS OF INTEGRITY OF LINER.

MAX. TENSILE STRESS @ 500°F = 64,400 (ASME III TABLE I-3.1)

MAX. SHEAR = .55 × 64,400 = 35,400

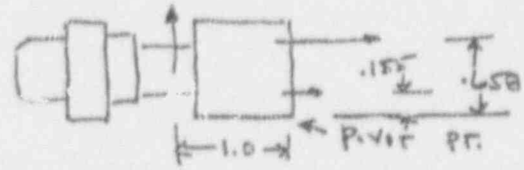
$SF = \frac{35400}{13770} = 2.6$

EXAMINE THE SUPPORT OF THE ISOLATION VALVES. OVERTURNING MOMENT IS AS DEVELOPED BELOW.



$\therefore$ MOMENT = 1.33 in lb @ 1g
= 358 in lb @ 270 g

RESISTING MOMENT IS PROVIDED BY 2 #10-32 SCREWS & CAPTURE CHANNEL WITH 4 1/32 x 3/16 WELDS



ASSUME FORCE IS PROPORTIONAL TO DEFLECTION (RIGID BODY ROTATION)

$$\text{RESISTING MOMENT} = F\left(1.0 + \frac{.658^2}{1.0} + \frac{.155^2}{1.0}\right) = 1.457F = 358 \text{ in lb}$$

$\therefore F = 245.7$ lb.

$$\text{STRESS IN WELDS} = \frac{245.7}{4 \times .0117} = 5250 \text{ psi (in shear)}$$

YIELD STRESS @ 400°F = 0.55 x 20700 = 11385 psi
SF = 2.2

STRESS IN FAR SCREW

$$= \frac{.658 \times 245.7}{.0133} = 12{,}156 \text{ psi}$$

YIELD STRESS = 20,700
SF = 1.7

B.2 HYPOTHETICAL FIRE

EVALUATE DIFFERENTIAL THERMAL EXPANSION BETWEEN BOLTS (FERRITIC) AND LID (AUSTENITIC) FROM HEATING LID FROM 70°F TO 500°F.

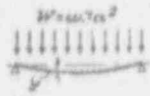
COEFS OF THERMAL EXPANSION: BOLTS 6.91×10^{-6} in/in °F
LID 9.37×10^{-6} in/in °F
Difference 2.46×10^{-6}

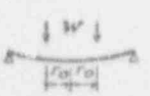
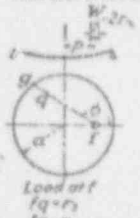
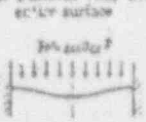
$\Delta T = 430$ °F ; $t = 1.5$ in

$\therefore$ Differential expansion $= 2.46 \times 10^{-6} \times 430 \times 1.5 =$ .0016 in
In direction of compressing the gasket

TABLE X.—FORMULAS FOR FLAT PLATES

Notation: W = total applied load (lb.); w = unit applied load (lb. per sq. in.); t = thickness of plate (in.); s = unit stress at surface of plate (lb. per sq. in.); y = vertical deflection of plate from original position (in.); θ = slope of plate measured from horizontal (rad); E = modulus of elasticity; m = reciprocal of ν, Poisson's ratio. q denotes any given point on the surface of plate; r denotes the distance of q from the center of a circular plate. Other dimensions and corresponding symbols are indicated on figures. Positive sign for s indicates tension at upper surface and equal compression at lower surface; negative sign indicates reverse condition. Positive sign for y indicates upward deflection, negative sign downward deflection. Subscripts r, t, a, and b used with s denote respectively radial direction, tangential direction, direction of dimension a, and direction of dimension b. All dimensions are in inches. All logarithms are to the base e, ($\log_e x = 2.3026 \log_{10} x$). (See pp. 215, 216 and 218 for stress and deflection coefficients.)

Manner of loading and Case No.	Formulas for stress and deflection
	Circular and solid  (A)
Edges supported 1. Uniform load over entire surface 	(At q) $s_r = -\frac{3W}{8\pi mt^2}\left[(3m+1)\left(1-\frac{r^2}{a^2}\right)\right]$ $s_t = -\frac{3W}{8\pi mt^2}\left[(3m+1)-(m+3)\frac{r^2}{a^2}\right]$ $y = -\frac{3W(m^2-1)}{8\pi Em^2t^3}\left[\frac{(5m+1)a^2}{2(m+1)}+\frac{r^4}{2a^2}-\frac{(3m+1)r^2}{m+1}\right]$ (At center) Max $s_r = s_t = -\frac{3W}{8\pi mt^2}(3m+1)$ Max $y = -\frac{3W(m-1)(5m+1)a^2}{16\pi Em^2t^3}$ (At edge) $\theta = \frac{3W(m-1)a}{2\pi Emt^3}$
Edges supported 2. Uniform load over concentric circular area of radius r_0 	(At q, $r < r_0$) $s_r = -\frac{3W}{2\pi mt^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}-(3m+1)\frac{r^2}{4r_0^2}\right]$ $s_t = -\frac{3W}{2\pi mt^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}-(m+3)\frac{r^2}{4r_0^2}\right]$ $y = -\frac{3W(m^2-1)}{16\pi Em^2t^3}\left[4a^2-5r_0^2+\frac{r^4}{r_0^2}-(8r^2+4r_0^2)\log\frac{a}{r_0}-\frac{2(m-1)r_0^2(a^2-r^2)}{(m+1)a^2}+\frac{8m(a^2-r^2)}{m+1}\right]$ (At q, $r > r_0$) $s_r = -\frac{3W}{2\pi mt^2}\left[(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{4a^2}+(m-1)\frac{r_0^2}{4r^2}\right]$ $s_t = -\frac{3W}{2\pi mt^2}\left[(m-1)+(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{4a^2}-(m-1)\frac{r_0^2}{4r^2}\right]$ $y = -\frac{3W(m^2-1)}{16\pi Em^2t^3}\left[\frac{(12m+4)(a^2-r^2)}{m+1}-\frac{2(m-1)r_0^2(a^2-r^2)}{(m+1)a^2}-(8r^2+4r_0^2)\log\frac{a}{r}\right]$ (At center) Max $s_r = s_t = -\frac{3W}{2\pi mt^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}\right]$ Max $y = -\frac{3W(m^2-1)}{16\pi Em^2t^3}\left[\frac{(12m+4)a^2}{m+1}-4r_0^2\log\frac{a}{r_0}-\frac{(7m+3)r_0^2}{m+1}\right]$ For r_0 very small (concentrated load) Max $y = -\frac{3W(m-1)(3m+1)a^2}{4\pi Em^2t^3}$ (At edge) $\theta = \frac{3W(m-1)a}{\pi Emt^3}$

Manner of loading and Case No.	Formulas for stress and deflection
Edges supported 3. Uniform load on concentric circular ring of radius r_0 	(At q, $r < r_0$) Max $s_r = s_t = -\frac{3W}{2\pi mt^2}\left[\frac{1}{2}(m-1)+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{2a^2}\right]$ $y = -\frac{3W(m^2-1)}{2\pi Em^2t^3}\left[\frac{(3m+1)(a^2-r^2)}{2(m+1)}-(r^2+r_0^2)\log\frac{a}{r_0}+(r^2-r_0^2)-\frac{(m-1)r_0^2(a^2-r^2)}{2(m+1)a^2}\right]$ (At q, $r > r_0$) $s_r = -\frac{3W}{2\pi mt^2}\left[(m+1)\log\frac{a}{r}+(m-1)\frac{r_0^2}{2r^2}-(m-1)\frac{r_0^2}{2a^2}\right]$ $s_t = -\frac{3W}{2\pi mt^2}\left[(m-1)+(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{2r^2}-(m-1)\frac{r_0^2}{2a^2}\right]$ $y = -\frac{3W(m^2-1)}{2\pi Em^2t^3}\left[\frac{(3m+1)(a^2-r^2)}{2(m+1)}-(r^2+r_0^2)\log\frac{a}{r}-\frac{(m-1)r_0^2(a^2-r^2)}{2(m+1)a^2}\right]$ (At center) Max $y = -\frac{3W(m^2-1)}{2\pi Em^2t^3}\left[\frac{(3m+1)a^2-(m-1)r_0^2}{2(m+1)}-r_0^2\left(\log\frac{a}{r_0}+1\right)\right]$
Edges supported 4. Uniform load over small eccentric circular area of radius r_0 	(At point of load, f) Max $s_r = s_t = -\frac{3W}{2\pi mt^2}\left[m+(m+1)\log\frac{a-p}{r_0}-(m-1)\left(\frac{r_0^2}{4(a-p)^2}\right)\right]$ (At q) $s_r = (\text{Max } s_r)\left[\frac{(m+1)\log\frac{a_1}{r_1}}{1+(m+1)\log\frac{a_1}{r_0}}\right]$ $s_t = (\text{Max } s_t)\left[\frac{(m+1)\log\frac{a_1}{r_1}+(m-1)}{m+(m+1)\log\frac{a_1}{r_0}}\right]$ $y = K_0(r_1^4 - b_0ar_1^3 + c_0a^4) + K_1(r_1^4 - b_1ar_1^3 + c_1a^3r_1)\cos\phi + K_2(r_1^4 - b_2ar_1^3 + c_2a^2r_1^2)\cos 2\phi$ Where $K_0 = \frac{2(m+1)W(p^4-b_0ap^3+c_0a^4)}{9(5m+1)K\pi a^4}$; $K_1 = \frac{2(3m+1)W(p^4-b_1ap^3+c_1a^3p)}{3(9m+1)K\pi a^4}$; $K_2 = \frac{(4m+1)^2W(p^4-b_2ap^3+c_2a^2p^2)}{(9m+1)(5m+1)K\pi a^4}$ Where $K = \frac{m^2Et^3}{12(m^2-1)}$; $b_0 = \frac{3(2m+1)}{2(m+1)}$; $b_1 = \frac{3(4m+1)}{2(3m+1)}$; $b_2 = \frac{2(5m+1)}{4m+1}$; $c_0 = \frac{4m+1}{2(m+1)}$; $c_1 = \frac{6m+1}{2(3m+1)}$; $c_2 = \frac{6m+1}{4m+1}$ (Ref. 1)
Edges supported 5. Central couple (trunnion loading) 	(At $r = r_0$) Max $s_r = \frac{3M}{4\pi t^2r_0}\left[1+\left(\frac{m+1}{m}\right)\log\frac{2(a-r_0)}{Ka}\right]$ where $K = \frac{0.49a^3}{(r_0+0.7a)^3}$ (Ref. 1) (See also p. 216)
Edges fixed 6. Uniform load over entire surface 	(At q) $s_r = \frac{3W}{8\pi mt^2}\left[(3m+1)\frac{r^2}{a^2}-(m+1)\right]$ $s_t = \frac{3W}{8\pi mt^2}\left[(m+3)\frac{r^2}{a^2}-(m+1)\right]$ $y = -\frac{3W(m^2-1)}{16\pi Em^2t^3}\left[\frac{(a^2-r^2)^2}{a^2}\right]$ (At edge) Max $s_r = \frac{3W}{4\pi t^2}$; $s_t = \frac{3W}{4\pi mt^2}$ (At center) $s_r = s_t = -\frac{3W(m+1)}{8\pi mt^2}$ Max $y = -\frac{3W(m^2-1)a^2}{16\pi Em^2t^3}$

LISTING OF BASIC PROGRAM TO CALCULATE BENDING STRESSES IN LINER LID

```
100 REM GE700 LINER, STRESSES IN TOP PLATE
110 CLEAR
120 DIM R(7),SR(7),ST(7),Y(7)
130 DEFINT I
140 FOR I=1 TO 7
150 READ R(I)
160 DATA 0,2.65,5.3,5.71,6.688,7.038,7.44
170 NEXT I
180 M=1!/.27 : T=1.5 : E=3E+07 : A=R(7)
190 SF=-3/(6.28*M*T^2)
200 YF3=-3*(M^2-1)/(6.28*E* ^2*T^3)
210 YF2=YF3/8!
220 LPRINT "R(IN)","SR(PSI)","ST(PSI)","Y(IN)"
230 LPRINT
240 REM BOLTUP LOADS
250 LPRINT "STRESSES AND DEFLECTIONS FROM BOLTUP"
260 REM LOAD COMBINATION 1
270 R0=13.375/2! : W=106800!
280 FOR I=1 TO 7
290 GOSUB 3000
300 NEXT I
310 REM LOAD COMBINATION 2
320 R0=1..414/2! : W=-106800!
330 FOR I=1 TO 7
340 GOSUB 3000
350 LPRINT R(I),SR(I),ST(I),Y(I)
360 NEXT I
370 LPRINT
380 REM ADD PRESSURE LOADS
390 LPRINT "STRESSES AND DEFLECTIONS FROM BOLTUP PLUS PRESSURE"
400 REM LOAD COMBINATION 1
410 R0=13.375/2! : W=2 00!
420 FOR I=1 TO 7
430 GOSUB 3000
440 NEXT I
450 REM LOAD COMBINATION 2
460 R0=10.62/2! : W=-2300!
470 FOR I=1 TO 7
480 GOSUB 2000
490 LPRINT R(I),SR(I),ST(I),Y(I)
500 NEXT I
510 LPRINT
520 REM ADD LOADS FROM TOP DOWN IMPACT
530 LPRINT "STRESSES AND DEFLECTIONS WITH TOP-DOWN IMPACT"
540 REM LOAD COMBINATION 1
550 R0=10.59/2 : W=114258!+60048!
560 FOR I=1 TO 7
570 GOSUB 3000
580 NEXT I
590 REM LOAD COMBINATION 2
600 R0=14.13/2 : W=-114258!
```

```
610 FOR I=1 TO 7
620 GOSUB 3000
630 NEXT I
640 REM LOAD COMBINATION 3
650 R0=10.42/2 : W=-60048'
660 FOR I=1 TO 7
670 GOSUB 2000
680 LPRINT R(I),SR(I),ST(I),Y(I)
690 NEXT I
700 END
2000 REM CASE 2, ROARK TABLE X
2010 IF R(I)>R0 THEN 2200
2020 P1=M+(M+1)*LOG(A/R0)-(M-1)*R0^2/(4*A^2)
2030 P2=-(3*M+1)*R(I)^2/(4*R0^2)
2040 P3=-(M+3)*R(I)^2/(4*R0^2)
2050 SR(I)=SR(I)+W*SF*(P1+P2)
2060 ST(I)=ST(I)+W*SF*(P1+P3)
2070 P1=4*A^2-5*R0^2+R(I)^4/R0^2-(8*R(I)^2+4*R0^2)*LOG(A/R0)
2080 P2=-2*(M-1)*R0^2*(A^2-R(I)^2)/((M+1)*A^2)
2090 P3=8*M*(A^2-R(I)^2)/(M+1)
2100 Y(I)=Y(I)+W*YF2*(P1+P2+P3)
2110 GOTO 2400
2200 P1=(M+1)*LOG(A/R(I))-(M-1)*R0^2/(4*A^2)
2210 P2=(M-1)*R0^2/(4*R(I)^2)
2220 SR(I)=SR(I)+W*SF*(P1+P2)
2230 ST(I)=ST(I)+W*SF*((M-1)+P1-P2)
2240 P1=(12*M+4)*(A^2-R(I)^2)/(M+1)
2250 P2=-2*(M-1)*R0^2*(A^2-R(I)^2)/((M+1)*A^2)
2260 P3=-(8*R(I)^2+4*R0^2)*LOG(A/R(I))
2270 Y(I)=Y(I)+W*YF2*(P1+P2+P3)
2400 RETURN
3000 REM CASE 3, ROARK TABLE X
3010 IF R(I)>R0 THEN 3200
3020 P1=(M-1)/2+(M+1)*LOG(A/R0)
3030 P2=-(M-1)*R0^2/(2*A^2)
3040 SR(I)=SR(I)+W*SF*(P1+P2)
3050 ST(I)=ST(I)+W*SF*(P1+P2)
3060 P1=(3*M+1)*(A^2-R(I)^2)/(2*(M+1))
3070 P2=-(R(I)^2+R0^2)*LOG(A/R0) + (R(I)^2-R0^2)
3080 P3=-(M-1)*R0^2*(A^2-R(I)^2)/(2*(M+1)*A^2)
3090 Y(I)=Y(I)+W*YF3*(P1+P2+P3)
3100 GOTO 3400
3200 P1=(M+1)*LOG(A/R(I))
3210 P2=(M-1)*R0^2/(2*R(I)^2)
3220 P3=-(M-1)*R0^2/(2*A^2)
3230 SR(I)=SR(I)+W*SF*(P1+P2+P3)
3240 ST(I)=ST(I)=W*SF*((M-1)+P1-P2+P3)
3250 P1=(3*M+1)*(A^2-R(I)^2)/(2*(M+1))-(R(I)^2+R0^2)*LOG(A/R(I))
3260 P2=-(M-1)*R0^2*(A^2-R(I)^2)/(2*(M+1)*A^2)
3270 Y(I)=Y(I)+W*YF3*(P1+P2)
3400 RETURN
```

ANALYSIS OF GE700 CASK WITH NEUTRON PRODUCTS LINER

R(IN)	SR(PSI)	ST(PSI)	Y(IN)
STRESSES AND DEFLECTIONS FROM BOLTUP			
0	6382.82	6382.82	5.501994E-03
2.65	6382.82	6382.82	4.774858E-03
5.3	6382.82	6382.82	2.593454E-03
5.71	6358.99	0	2.126049E-03
6.688	-431.5991	0	9.181204E-04
7.038	-213.5056	0	4.869167E-04
7.44	0	0	0
STRESSES AND DEFLECTIONS FROM BOLTUP PLUS PRESSURE			
0	6934.557	6934.557	5.863322E-03
2.65	6835.131	6879.523	5.075533E-03
5.3	6536.855	6714.422	2.738558E-03
5.71	6454.433	297.7783	2.242967E-03
6.688	-455.0215	320.9848	9.679457E-04
7.0 9	-225.0923	294.7991	5.133411E-04
7.44	0	265.6846	0
STRESSES AND DEFLECTIONS WITH TOP-DOWN IMPACT			
0	4123.919	4123.919	4.972629E-04
2.65	1328.11	2576.392	8.931384E-05
5.3	-6981.948	13872.42	-3.923448E-04
5.71	-3213.401	12977.26	-3.575273E-04
6.688	-2628.494	10942.58	-1.832279E-04
7.038	-142.8217	10253.62	-9.854301E-05
7.44	0	7024.885	0

Region I

71-579

NEUTRON PRODUCTS inc

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 USA
301/349-5001 TWX: 710-828-0542

March 31, 1986

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

Ref: (1) Certificate of Compliance No. 5942
(2) Neutron Products submittal dated November 11, 1985
(3) Neutron Products submittal dated February 28, 1986
(4) Neutron Products submittal dated March 11, 1986

Dear Mr. MacDonald:

Neutron Products gives its approval for drawings submitted by references (2) and (3) to be filed in the Public Document Room. The note on Neutron Products drawing 240139 regarding proprietary information should be ignored.

Enclosed are three copies of reference (4) and the enclosed drawing for filing in the Public Document Room.

Very truly yours,

NEUTRON PRODUCTS, INC.

Frank Schwoerer

Frank Schwoerer, Vice President

FS:mvc
Enclosure

2682

8/28

8604080034 1P

NRC FORM 218
(4-78)
NRCM 0240

U.S. NUCLEAR REGULATORY COMMISSION

TELEPHONE OR VERBAL CONVERSATION RECORD

DATE	6/2/86
TIME	12:00 ☐ A.M. ☒ P.M.

☐ INCOMING CALL ☐ OUTGOING CALL ☐ VISIT

PERSON CALLING	OFFICE/ADDRESS	PHONE NUMBER	EXTENSION
Pat Butler	Nuclear Products	321-352-3581	
PERSON CALLED	**OFFICE/ADDRESS**	**PHONE NUMBER**	**EXTENSION**
Rosanne Taylor			

CONVERSATION

SUBJECT

Work Notification

SUMMARY

They will be installing a 3,736 Ci Co-60 teletherapy source at St Rita Medical Center Lima Ohio. The work will be done on June 3 '86 by Lee Brown. The contact at St. Rita is Dr. Longe Foster [illegible]

file (P)

REFERRED TO: T Kinneman

ACTION REQUESTED

☐ ADVISE ME OF ACTION TAKEN.

INITIALS

DATE

ACTION TAKEN

INITIALS

DATE 8/~~[illegible]~~ 29

NRC FORM 218 (4-78)

NRC FORM 218
(1-76)
NRCM 0240

U.S. NUCLEAR REGULATORY COMMISSION

TELEPHONE OR VERBAL CONVERSATION RECORD

DATE	6-24-86
TIME	9:40 ☒ A.M. ☐ P.M.

☒ INCOMING CALL ☐ OUTGOING CALL ☐ VISIT

PERSON CALLING	OFFICE/ADDRESS	PHONE NUMBER	EXTENSION
Pat Butler	Neutron Products	301-349-5001	
PERSON CALLED	**OFFICE/ADDRESS**	**PHONE NUMBER**	**EXTENSION**
Maurice J Taylor			

CONVERSATION

SUBJECT Work Notification

SUMMARY

On June 27th 1986 a 5,720 Ci Co-60 source will be installed in a teletherapy unit at Christ Hospital, Cincinnati, Ohio. The technician performing the work will be Russ Brown. The work will be done on June 27th and 28th. The principle contact is Clifford Born (513-369-2383).

A [illegible] Ci Co-60 source will be installed in a teletherapy unit at St Peter's Medical Center, New Brunswick, New Jersey. The technician performing the job is not known at this time. Work will be conducted on June [illegible] and [illegible]. The principal contact is Mr. Daniel Alessandro ([illegible]).

REFERRED TO: J. Kinneman	☐ ADVISE ME OF ACTION TAKEN.
ACTION REQUESTED Form 241 will be sent in by Neutron Prod. (10)	INITIALS
	DATE
ACTION TAKEN	INITIALS
	DATE 6/30

CONVERSATION RECORD	TIME: 2:26 pm	DATE: 7-9-86

TYPE: ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☒ INCOMING ☐ OUTGOING

Location of Visit/Conference:

ROUTING	
NAME/SYMBOL	INT

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO
Pat Butler	Neutron Products	301-349-5001

SUBJECT: Work Notification

SUMMARY

On July 11th and 12th, 1986 they will be installing a new teletherapy source at West Virginia University Hospital, Morgantown, West Virginia. The source (model # NPI-20-7800W) contains 7,910 Ci of Co-60. The old teletherapy source will be removed and returned to Neutron Products, Dickerson, Maryland. Russ Brown will be performing the work.

License No 47-23066-01

ACTION REQUIRED: Necessary forms will be forwarded.

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
Marianne J Taylor		7/9/86

ACTION TAKEN

file

SIGNATURE	TITLE	DATE
(10)		7/10/86

B/31

CONVERSATION RECORD

TIME: 1150 AM DATE: 8/4/86

TYPE: ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☒ INCOMING ☐ OUTGOING

ROUTING

NAME/SYMBOL	INT

Location of Visit/Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU: Ms Pat Butler

ORGANIZATION (Office, dept, bureau, etc.): Neutron Products

TELEPHONE NO: 301-349 5001

SUBJECT: Report of Impending 60Co Teletherapy Source Transfer

SUMMARY

Called to inform RI of Source transfer from St Cloud Hosp. St Cloud, MN to Neutron Prod Dickerson, MD. Source to be removed on Friday, 8/8/86; 60Co strength ~ 2503 Ci on 7/21/86. Should arrive ~ 8/12/86.

Ed Kordatz - driver and Dale Repp is Engr. on job under Neutron Products Inc. License MD. 31-025-03

No info on Source Model and Serial No.s Will furnish with forms when forwarded

ACTION REQUIRED

Forms to be forwarded

NAME OF PERSON DOCUMENTING CONVERSATION: Oberg

SIGNATURE: C. E. Oberg

DATE: 8/8/86

ACTION TAKEN

SIGNATURE

TITLE

DATE

B/32

CONVERSATION RECORD

TIME: 9:15
DATE: 9/9/86

TYPE: ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☒ INCOMING ☐ OUTGOING

ROUTING: NAME/SYMBOL INT — FILE

Location of Visit/Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO.
Pat	Neutron Products	301 - 349 - 5001

SUBJECT: Work Notification

SUMMARY

On 9/9/86 they will be removing a 5,146 Ci Co-60 source from Malcolm Grove Hospital. This will be transferred back to Neutron Products. Mr Russ Brown will be doing the work. On 9/14/86 they will be installing a new Co-60 source approx. 6,000 Ci at St Joseph Hospital in Joliet, Ill. They will be removing the old source and transferring it back to Neutron Products. Mr Russ Brown will be doing the work. On 9/19/86 they will be installing a new Co-60 source, approx. 6,000 Ci, at Washington Hospital Ctr, Washington, D.C. They will be removing the existing source and transferring back to Neutron Products. Mr Russ Brown will be doing the work. The necessary information is being forwarded to the R-I office.

MD - 31 - 025 - 03

ACTION REQUIRED

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
Marlene J Taylor		9/9/86

ACTION TAKEN

file

SIGNATURE	TITLE	DATE
[signature]		9/9/86

50271-101 CONVERSATION RECORD OPTIONAL FORM 271 (12-76) DEPARTMENT OF DEFENSE

U.S. G.P.O. 1983-381-526/8346

CONVERSATION RECORD

TIME	DATE
11:45	10-29-86

TYPE: ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☒ INCOMING ☐ OUTGOING

ROUTING	
NAME/SYMBOL	INT

Location of Visit/Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
Pat Butler	Neutron Products	301-349-5001

SUBJECT: Work Notification

SUMMARY

On Tuesday and Wednesday, November 4 and 5, 1986 at 8:00 am they will be removing an AECL Theratron Junior containing a 575 Ci Co-60 source from St. Margaret Hospital, Hammond Indiana. Mr. Dale Ripp will be doing the removal. The unit and source will be returned to Neutron Products, Dickerson, Maryland

Maryland License No. MD-31-025-03

ACTION REQUIRED

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
	Marlene J Taylor	10-29-86

ACTION TAKEN

241 file

B/34

SIGNATURE	TITLE	DATE
(D)		10/29/86

50271-101 CONVERSATION RECORD OPTIONAL FORM 271 (12-76) DEPARTMENT OF DEFENSE

U.S. G.P.O. 1983-381-526/8346

Region 1

11- 71VC

'86 NOV 28 A9:36

NEUTRON PRODUCTS inc

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 USA
301/349-5001 TWX: 710-828-0542

November 25, 1986

Mr. Charles E. MacDonald, Chief
Transportation Certification Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Ref: Our Application dated August 5, 1986 for Model No. NPI-20WC-6 MK II Package

Dear Sir:

In response to your letter dated October 29, 1986, we will provide the requested information by December 31, 1986.

Very truly yours,

NEUTRON PRODUCTS, INC.

Frank Schwoerer

Frank Schwoerer
Vice President

FS/kmw

B/35

27643

8701140559 2p.

71-9102-3?

neutron products inc

22301 Mt. Ephraim Road, P.O. Box 68
Dickerson, Maryland 20842 U.S.A.
301-349-5001 TWX 710-828-0542

December 30, 1986

Mr. Charles E. MacDonald, Chief
Transportation Certification Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: Model No. NPI-20WC-6 MKII Package
Docket No. 71-9102

Dear Mr. MacDonald:

This transmits the information requested in your letter of October 29, 1986 in connection with our application for approval of the Model No. NPI-20WC-6 MKII package. As you requested, the information is submitted in the form of revised pages to our application of August 5, 1986.

Also included is a copy of the enclosure to your letter, with marginal notation added identifying the location of the response to each item.

In the information provided, reference to a permanent tungsten alloy shielding insert within the drum of the inner container has been deleted. A recent radiation survey of a package employing the new inner container with a completely lead filled drum provided results which, when scaled to 15,000 curies, show that the shielding requirements are met with margin. The results of the survey are provided in section 5.4.3 of the enclosed documentation. A review of our previous calculations and comparisons support the conclusion and are presented in sections 5.4.1 and 5.4.2, also enclosed.

Sincerely,

NEUTRON PRODUCTS, INC.

Frank Schwoerer

Frank Schwoerer
Vice President

FS/kmw

B/36

8701270002 42 pp.

27729

1. GENERAL INFORMATION

1.1 Introduction

This application is in support of obtaining a B(U) rated Certificate of Compliance for a radioactive material transportation package that is essentially identical in dimensions and configuration to an existing shipping package, Model Number NPI-20WC-6, presently in use under Certificate of Compliance Number 9102, with package identification number USA/9102/B( ). Both packages are for shipment of encapsulated cobalt-60 sources and comprise a shielded inner container which fits snugly within an overpack meeting DOT Specification 20WC-6 requirements. The overpack is made up of a Wooden Protective Jacket and a Steel Shell which encloses the Wooden Protective Jacket.

The package design is service proven; the existing containers having been in use for over 12 years. During this period, 3 containers of this design have been used to make more than 100 shipments per year without an adverse incident.

The new package differs from the original principally in the materials used for construction of the shielded inner container. The structure of the shielded inner container is fabricated of either a normalized high strength carbon steel made to fine grain practice, or an austenitic stainless steel. Both have superior fracture toughness properties at low temperatures.

The original package, Model Number NPI-20WC-6, is authorized for transport of a maximum activity of 9,500 curies and a maximum internal decay heat of 150 thermal watts. The new package is presently licensed for use under Certificate Number 9102 at the same ratings as the original package. It is designated as Model Number NPI-20WC-6 MkII. However, this configuration is capable of meeting applicable regulatory requirements at a maximum activity of 15,000 curies of cobalt-60 and the associated decay heat of 240 watts. The higher capability results from increased lead shielding and reduced gamma streaming, which in turn results from the combination of a reduced drum liner diameter and shell liner wall thickness as compared with the original package.

All references to the new package in this document are to the new transportation package at the 15,000 curie rating. Results of development and operational experience with the existing transportation package are used, as appropriate, in support of the certification application of the new transportation package, and where used are so identified.

1.2 Package Description

1.2.1 Packaging

The inner container serves as a transfer cask to mate with and exchange cobalt-60 sources with teletherapy devices, as well as providing a shielding and containment function during shipment. As a shipping/transfer cask, it is designated Model S/TC MkII. Each cask is numbered serially as TC-X. The overpack, consisting of both the Wooden Protective Jacket and the surrounding Steel Shell, is designated OP-Y, again numbered serially. Overpacks and inner containers are interchangeable and are used in any combination.

Figure 1.2.1 is a vertical section drawing of the Model NPI-20WC-6 MkII shipping packaging. Figure 1.2.2 is a horizontal section drawing. A vertical section of the S/TC inner container is shown in Figure 1.2.3. The principal components of the packaging are identified in the drawings. Drawings of the S/TC inner container and the overpack are provided in the front and back inside cover pockets, respectively, and are referenced in Appendix 1.3.

The S/TC shielded inner container consists of a 3/8 inch thick spherical shell, 24 inches inside diameter, containing a chambered, shielded Drum Assembly held in place by two Cover Assemblies. The Drum Assembly fits into an 8-1/4 inch inside diameter by 3/16 inch thick horizontally oriented cylinder, which forms a weldment with the shell through a steel flange. The toroidal cavity formed by the horizontal cylinder penetrating the sphere is filled with lead. The cavity within the cylinder houses the chambered source positioning Drum Assembly.

The Drum Assembly chambers carry the source holders, which may vary from one model of teletherapy machine to another. The Drum Assembly is removable and can be interchanged with another to provide for the different design of source holders. During shipment, the chambers, or section of chambers, that are not filled with source holders, are fitted with full diameter, steel encased lead or tungsten plugs and spacers, which restrict movement to less than 0.25 inches laterally and 0.1 inches radially. The Drum Assembly, source holders, and plugs are secured in the container by shielded Cover Assemblies bolted to the Shell Assembly at both ends of the Drum Assembly containing cylinder. The bolted Cover Assemblies are sealed using silicone rubber gaskets.

The shielded inner container is enclosed within the overpack, consisting of a Wooden Protective Jacket (WPJ) surrounded by a Steel Shell. The overpack meets the requirement of DOT Specification 20WC-6 Wooden Protective Jacket. The WPJ is a right circular cylinder consisting of 3/4 inch thick exterior grade, Douglas Fir plywood discs glued together with a resorcinal resin adhesive and nailed. In addition, the WPJ is reinforced with 16 axial, 5/8 inch diameter, full length steel rods. The WPJ has a plywood sidewall of six inch minimum thickness and a plywood top and bottom, each of 8-1/4 inch thickness. The WPJ is surrounded by the 12 gage Steel Shell. The Steel Shell has a flanged, bolted closure and 12 or more 1/2 inch vent holes; these are covered with durable, weatherproof tape, or fitted with plugs which relieve under pressure.

2.4.4 Tie Down Devices

Four brackets are provided for tie down of the package, should it be convenient to use them. Their use is not mandatory for safe transport of the package.

The brackets are fabricated from 3 X 3 X 3/8 inch structural steel angle, placed back-to-back, and welded to a 6 inch wide, 3/16 inch thick reinforcing support band, which encircles the body of the Steel Shell just below the lower closure flange. They are spaced at 90° intervals around the periphery of the shell and oriented 45° from the direction of the support rails. The tie down brackets are shown in Drawing N 24011 (see Appendix 1.3.3). The brackets and package meet the specific tie down requirements of 10 CFR 71.45(b). The supporting calculations are provided in Appendix 2.10.1.

While not designed to be used regularly in this manner, the brackets can be used as lifting devices. The total load would be uniformly shared between the four brackets. When used as lifting devices, the brackets and attachments meet the structural requirements of 10 CFR 71.45(a); specifically, a minimum safety factor of three against yielding. The supporting calculations are provided in Appendix 2.10.10.

If the brackets are not used, lines placed across the top or around the Steel Shell fastened to the transport vehicle will adequately secure the package under the required loads. The support rails can also be clamped and shored for hold down. The package can be secured by any method acceptable for the intended mode of transport.

2.5 Standards for Type B Packaging

The application package meets the standards for Type B packaging, as specified in the following paragraphs of 10 CFR 71:

71.43 General standards for all packages
71.45 Lifting and tie down standards for all packages
71.47 External radiation standards for all packages
71.51 Additional requirements for Type B packages

2.5.1 Load Resistance

Not applicable

2.5.2 External Pressure

Demonstration that the containment vessel would suffer no loss of contents if the package were subjected to an external pressure of 25 psig is no longer a regulatory requirement. However, both the inner container, which is the secondary barrier, and the contained special form source capsule substantially exceed this requirement. Both are internally supported and can withstand high hydrostatic pressures. The spherical shell of the inner container is suitable for a sustained working pressure of over 500 psi, even without support.

There is an additional energy absorbing mechanism for the inner container in the inverted position. The inner cask lifting bail could crush the wood of the protective jacket from the inside under the inertial loading of the inner container. This effect was not included in calculating the inertial loading, although it would serve to reduce the loading.

As in the case of the upright end drop, the inverted end drop does not result in adverse effects on either the shielding or containment capability of the capsule or inner container. The heaviest loads on the inner container are distributed bearing loads and the capsule stresses are well within the elastic limit.

The principal package damage would be to the Steel Shell and locally to the Wooden Protective Jacket. Local penetration to the Wooden Protective Jacket would be less than two inches of the total top thickness of nine inches. The intogrity of the shielding and containment would be maintained.

2.7.1.2 Side Drop

In the side drop most of the energy absorption is taken by crushing of the shock rings on the Wooden Protective Jacket. The remaining energy is dissipated in deflecting the body of the protective jacket. A small contribution to energy absorption is provided by the crushing of the enclosing Steel Shell. Crushing of the shock rings is calculated to impose a 180 g loading. Calculations are shown in Appendix 2.10.5.C.

The capsule loads will not result in stresses exceeding the elastic limit. The containment capability of the capsule will not be impaired.

The limiting loading on the inner container is cover bolt shear. The maximum loading on the bolts occurs if the plane of the cover face is perpendicular to the striking surface. The maximum load can be calculated as the product of the cover weight and the g loading, or 77 pounds X 180 = 13,900 pounds. The eight 1/2-13 UNC bolts have a minimum root diameter of 0.400 inches for a total shear area of 1.009 in.^{2}. The associated shear stress is 13,900/1.008 = 13,800 psi. For the ASTM-193 Grade B7 bolt material at the maximum temperature of 300°F, a shear stress of 0.55 (94,200) = 51,800 psi would have to be exceeded to reach yield conditions (see Appendix 2.10.7, B3). The safety factor to yield is 3.8. No change in shielding configuration results from the side drop.

Damage to the package from this drop would be crushing of the shock rings of the Wooden Protective Jacket and crushing of the external Steel Shell. Integrity of the shielding and containment would be maintained.

2.7.1.3 Corner Drop

Not applicable

2.7.1.4 Oblique Drop

The oblique drop results in a strike on the cylindrical edge of the package. While in some orientations crushing of the Steel Shell appurtenances provide some energy absorption, the principal energy dissipation mechanism is crushing of the edge of the Wooden Protective Jacket. With the package center of gravity directly over the strike, the calculated loading of the inner container is approximately 65 g. The results are the same for the top edge or bottom edge drop. The calculations are provided in Appendix 2.10.5.D.

Loads on the capsule will not result in stresses exceeding the elastic limit and the containment capability of the capsule will not be impaired.

The limiting load on the inner container taken as shear on the cover bolts is below the failure limit by a factor of 14.

Damage to the package from this drop would be crushing the end shock rings of the Wooden Protective Jacket and also crushing sections of the external Steel Shell. Integrity of the shielding and containment would be maintained.

2.7.1.5 Summary of Results

Discussion of the condition of the package is provided under each of the preceding drop configurations. Summary of the loadings and factors of safety are provided in Table 2.7.1.1.

2.7.2 Puncture

Free drop of the package through a distance of one meter (40 inches) onto the standard, six inch diameter cylindrical bar was examined analytically for all of the principal drop configurations and damage sensitive parts of the package. The local package deflection and g loadings were estimated for each of the drop configurations. In all cases the strike was considered as being located directly under the center of gravity of the package. The calculations are presented in Appendix 2.10.8. Results are summarized in Table 2.7.2.1.

The local deflections range from about 0.6 inches for a strike against the bottom plate of the package (the bar missing the skids) to about 1.4 inches for several of the orientations in which it was postulated that all of the energy was absorbed in crushing the wood of the protective jacket. The associated loadings range from 70 g for the smaller deflections to 25 g for the larger ones.

In all cases the overpack Steel Shell would experience some permanent deformation and when the strike is directly on the 12 gage shell material, some perforation and tearing might occur. Since the shell is neither lead containing or essential to fire protection, a shell tear does not measurably reduce the effectiveness of the package. The loadings are not high and there would be no damage to the inner container or its contents.

2.7.3 Thermal

2.7.3.1 Summary of Temperature and Pressures. Maximum package temperatures under HAC are summarized in Table 2.7.3.1 which is identical to Table 3.5.1. The upper limit pressure is calculated to be 16.6 psig (see Appendix 3.6.4), although even under maximum internal heating and post fire temperature conditions the pressure would likely be very little above atmospheric pressure.

TABLE 2.7.2.1

PUNCTURE SUMMARY

	Deformation or Deflection (in.)	Loading, g	Steel Shell Penetration	S/TC Damage
Bottom				
Plate strike	0.58	70	Not likely	None
Skid strike	1.6	25	Not likely	None
Top	0.9	45	Possibly	None
Side	$0.9 < \delta < 1.4$	45	Possibly	None
Oblique (edge)	$0.9 < \delta < 1.4$	45	Possibly	*None

2.10 APPENDIX

2.10.10 Tiedown Bracket Used As Lifting Attachment

Requirement: "Any lifting attachment that is a structural part of a package must be designed with a minimum safety factor of three against yielding when used to lift the package in the intended manner, and must be designed so that failure of any lifting device under excessive load would not impair the ability of the package to meet other requirements of this subpart." (10 CFR 71.45(a))

Load: Maximum weight of package (6,000 pounds) acting vertically upward, uniformly distributed between the brackets. Maximum static load per bracket: 1,500 pounds.

Component Adequacy: Reference Drawing N240116

1. Bracket eye - shear
   Shear area = 31/32 X 3/8 X 2 X 2 = 1.45 in.^{2}
   Load capability = (y.s.)(.55)(area)
   = 36,000 (.55) 1.45
   = 28,700 pounds
   Three times maximum load = 3 X 1,500 = 4,500 pounds
   No yielding
   Safety factor(1) - 6.4

2. Bracket - tension
   For a vertical load - each bracket
   Section area = 2 X 3 X 3 X 3/8 = 3.2 in.^{2}
   Load capability = (y.s.)(area)
   = 36,000 (3.2) = 115,000 pounds
   Three times maximum load = 4,500 pounds - No yielding
   Safety factor(1) - 25

3. Support band and body flange - shear
   Upward force on bracket to reach shear limit in support ring and body flange cross section only
   Section area = 3.68 in.^{2}
   Load capability = 36,000 (.55)(3.68) = 72,800 pounds
   Three times maximum load = 4,500 pounds - No yielding
   Safety factor(1) - 16

4. Bracket attachment weld - shear
   Weld length = 8 inches (sides only considered)
   Minimum weld section = (1/4)(.707)(8) = 1.4 in.^{2}
   Weld efficiency = 75%
   Load capability = 2(36,000)(.55)(1.4)(.75) = 41,600 pounds
   Three times maximum load = 4,500 pounds - No yielding
   Safety factor(1) - 9.2

(1)Safety factor to 3X yield strength

5. Shell - tension
Tension in shell
Area = 48.5(.1072) = 16.3 in.^{2}
Load capability = 36,000(16.3) = 587,000 pounds
Three times maximum load = 4 X 4,500 = 18,000 pounds
No yielding
Safety factor[(1)] - 33

(1)Safety factor to 3X yield strength

To calculate the post fire adiabatic equilibrium temperature, T, when the radiation source temperature is specified, use is made of the different geometry and boundary condition cases worked out in Table 3 of the reference to obtain an equivalent heat flux. Only constant heat flux solutions are available for the cylindrical and spherical geometry cases. However, the semiinfinite slab geometry, for which both constant temperature and constant heat flux solutions are available, is used to develop a constant heat flux equivalent to the imposed constant temperature condition. The equivalent heat flux is used to obtain cylindrical and spherical geometry solutions. The adiabatic temperature rise, $T = T - T_i$, where the subscript designates the particular case, using the nomenclature of the reference.

1. Semi-Infinite Slab, Constant Surface Temperature

$\overline{T_{x2}} = (6/\ell)(\alpha t_f/24)^{1/2}\ (T_o - T_i)$ ref. equ. 27

$= (6/0.5)[(0.0036)(0.5)/24]^{1/2} \cdot (1282)$

$= 133°F$

2. Semi-Infinite Slab, Constant Heat Input

The equivalent constant heat input is obtained from this case using the temperature rise calculated from the previous constant temperature case.

$\overline{\Delta T_{x3}} = (q_o \alpha t_f)/(k \ell)$ ref. equ. 28

$q_o = (\Delta T\ k \ell)/(\alpha\ t_f)$

$= (132) \times (0.085)(0.5)/(0.00353)(0.5) = 3114$ B/hr. ft.^{2}

3. Infinite Cylinder, Constant Heat Input

$\overline{\Delta T_c} = (2\ H_o R_o \alpha\ t_f)/[k(R_o^2 - R_i^2)$ ref. equ. 29

$= [2(3114)(1.833)(0.00363)(0.5)]/[0.085(1.833^2 - 1.333^2)]$

$= 154°F$

4. Sphere, Constant Heat Input

$$\overline{\Delta T_s} = (3q_o R_o^2 \alpha t_f)/[k(R_o^3 - R_1^3)] \quad \text{ref. equ. 30}$$

$$= [3(3114)(1.883)^2(0.00363)0.5]/[0.085(1.883^3 - 1.333^3)]$$

$$= 177^\circ F$$

The Wooden Protective Jacket is 45 inches high and 44 inches in outside diameter and is probably better represented by a sphere than by an infinite cylinder. The spherical values are used for evaluating the temperature rise using the inside and outside diameters of the Wooden Protective Jacket as the inside and outside diameters of the equivalent sphere.

The peak backface temperature, T_{BF} = peak inside wall temperature of the Wooden Protective Jacket is less than, but for the present purpose, taken equal to the adiabatic equilibrium temperature, T_{AE}

$$T_{BF} = T_{AE} = 193 \text{ (initial)} + 177 \text{ (adiabatic rise)} = 370^\circ F$$

C. Peak S/TC Temperatures

The peak S/TC surface temperature is equal to the peak backface temperature plus the drop (15°F) needed to transfer internal heat generated through the space between overpack and S/TC.

T (S/TC surface, post fire maximum) = 370 + 15 = 385°F

The peak temperatures for the S/TC become:

o S/TC surface	385°F	(196°C)
o S/TC shell liner and drum O.D. (local max.)	450°F	(232°C)
o S/TC drum liner (local max.)	545°F	(285°C)
o Source capsule surface	670°F	(355°C)

These temperatures are unlikely to be reached because the inner container is unlikely to remain adiabatic for 22 hours (120°F/5.43°F/hr.) after the termination of the fire. Nevertheless, making the evaluation of the consequence of the hypothetical accident on this basis: (1) there would be no lead melting; the peak lead temperature is less than 545°F (the maximum local lead temperature is lower than the local maximum temperature of the drum liner) as compared with a melting point of 618°F; and, (2) the maximum source capsule surface temperature (355°C) remains well below the weld sensitization temperature (above 480°C).

Specifications for welds and seals are included in the purchase documentation. As discussed in Chapters 2 and 3, the internal pressure under normal transport is essentially atmospheric. Postulating extreme circumstances under hypothetical accident conditions results in a calculated pressure of about one atmosphere gage.

4.1.4 Closure

The closure is mechanical, using 8 one half inch bolts on an 11-1/4 inch bolt circle. The cover is bolted to the Shell Assembly and the closure seal is provided by a flat, full diameter, 1/16 inch thick silicone rubber gasket. The bolts are tightened to firmly compress the gasket with a torque of approximately 100 inch-pounds.

The overpack provides two additional closures, but these are not gasketed and are not intended to provide a gas tight seal.

4.2 Requirements for Normal Conditions of Transport

The source capsule qualifies as special form material. The evaluation in Chapters 2 and 3 indicates that the shipping/transfer cask will provide a secondary seal under normal transport conditions. One of the principal functions of the seal is to prevent any external contaminants, such as liquids or particulates, from reaching the source chamber.

4.2.1 Release of Radioactive Material

None

4.2.2 Pressurization of Containment Vessel

There are no gases that can form and/or explode in the containment chamber. There has been no evidence of pressure build up in the sealed drum chamber in practice. Any foreseeable change in chamber pressure will not reduce package effectiveness.

4.2.3 Coolant Contamination

Not applicable

4.2.4 Coolant Loss

Not applicable

4.3 Containment Requirements for the Hypothetical Accident Conditions

The evaluation of test information and associated analysis presented in Chapters 2 and 3 show that the package could experience the sequence of conditions postulated in 10 CFR 71.73 without release of radioactive material or significant change in shielding capability. In addition, the encapsulated source meets special form requirements, which are at least as stringent as the accident conditions for the package.

representative recent shipments with the existing package. These provide a base for comparison with the new package. The design guidelines for the new package are a maximum dose rate of 100 mr./hr. at the accessible surface of the package and 10 mr./hr. at a distance of one meter from the surface of the package for normal conditions of transport. These are the values listed in Table 5.1.2.

A comparison of the radial gamma ray attenuation between the new and existing inner container is detailed in Appendix 5.4.1. On a comparative basis, the new container will permit an increase of 54 percent in source strength for the same cask surface dose. This factor, along with the initial shielding design margin of the casks, as shown in Table 5.1.1, provides a satisfactory 15,000 curie operating limit for cobalt-60. This is further supported by a surface and one meter distant dose rate for the package calculated to be 10.4 mr./hr. and 1.4 mr./hr., respectively, for a contained 15,000 curie source. This calculation is also included in Appendix 5.4.1.

The principal physical change to the drum of the new package has been to decrease the drum liner tube inside diameter from 2.82 to 2.56 inches, while maintaining the 0.095 inch tube wall thickness. In the radial direction, the change amounts to replacing 1/8 to 3/16 inches of steel and clearance with an equal thickness of lead. The change also reduces gamma streaming in the axial direction by factors calculated to be 1.8 to 7.3, depending upon the source holder configuration. The supporting calculations are provided in Appendix 5.4.2.

The only other physical change to the new inner container that impacts shielding is the reduction in the outside diameter of the Shell Assembly Liner. The effect is to replace a 3/16 thickness of steel with an equivalent amount of lead. The principal influence is an increase in radial attenuation. This factor has been included in the calculations shown in Appendix 5.4.1.

Subsequent to the calculations and comparisons described above, a package incorporating the new inner container carrying a 6,650 curie source was radiation surveyed. The results are provided in Appendix 5.4.3. As extrapolated to 15,000 curies, the package maximum surface reading would be 34 mr./hr., as compared with the design basis value of 100 mr./hr. and the 10 CFR 71.47 limit of 200 mr./hr. for general transport. At one meter distant, the level would be about one-third of the 10 mr./hr. general transport limit.

The change in shielding effectiveness under hypothetical accident conditions is due to shifting of the inner container with reference to the outer surface of the package as a consequence of the 30 foot drop. With a maximum estimated inner container shift of seven inches, the surface dose increases by a factor of 2 and the dose at 1 meter by about 25 percent. Both values are below the 10 CFR 71 limit of 1,000 mR/hr. at 1 meter for the hypothetical accident condition. There is no opportunity for any measurable shift of source or shielding within the inner container under the most severe free drop condition. Greater detail is provided in Appendix 5.4.4.

5.2 Source Specification

The only source considered for radiation shielding design and evaluation was the 1.17 MeV a... ..33 MeV photons produced from each cobalt-60 decay. There is no neutron source.

TABLE 5.1.2

SUMMARY OF MAXIMUM DOSE RATES
(mR/hr.)

	Package Surface			One Meter From Surface of Package		
	Side	Top	Bottom	Side	Top	Bottom
Normal Conditions						
Gamma	<100	<100	[illegible]0		<10	<10
Neutron	N/A	N/A	/A	N/A	N/A	N/A
Total	<100	<100	.100	<10	<10	<10
Hypothetical Accident Conditions						
Gamma	<200	<200	<200	<20	<20	<20
Neutron	N/A	N/A	N/A	N/A	N/A	N/A
Total	<200	<200	<200	<20	<20	<20
10 CFR Part 71 Limit	---	---	---	.,000	1,000	1,000

5.3 Model Specification

The shielding evaluation is based on measurements made on generally similar packages and determining the changes in dose rate due to the comparatively small changes in geometry and materials. The changes were made by calculation employing a simple exponential attenuation model postulating an isotropic source. Buildup factors were obtained from the Radiological Health Handbook, Revised Edition (January 1970). Values of material densities and mass attenuation coefficients are shown in Table 5.3.1 and were obtained from the same source. Streaming was also considered. The calculational models employed are described in Appendices 5.4.1 and 5.4.2. Subsequently a radiation survey of a referenced shipping package provided results which compared favorably with the calculations.

TABLE 5.3.1

SHIELDING PARAMETERS

Material	Density gm/cc	Mass Absorption Coefficient cm^2/gm
Tungsten alloy	17	.0555
Lead	11.3	.058
Stainless steel	8.0	.054
Carbon steel	7.85	.054

5.4 APPENDIX

5.4.1 Radial Gamma Attenuation

The specific shielding arrangement within the drawer or holder placed in the drum chamber may vary. However, a comparison of radial (in the plane perpendicular to the axis of the drum) attenuation in the original with that of the new inner container can be made from the drum liner outward. This comparison, along with an overall calculation of dose rate for the new package in the radial direction, is presented in this appendix.

For both purposes a point source model was used. For the comparison, the attenuation from chamber wall to exterior of the inner container, $[I_o/I]_{S/TC}$ was taken as the product of the individual shielding components.

$[I_o/I]_{S/TC} = \prod^{n} B_n(\mu_n X_n, E) \exp(\mu_n X_n)$ where B_n is the buildup factor, μ_n the linear attenuation coefficient, X_n the thickness of the shield component under consideration, and n designates the particular shielding material component.

Table 5.4.1.1 lists the input parameters for the calculation, as well as the results. The configuration is shown schematically in Figure 5.4.1.1. The constituent material attenuations are shown for each of the shielding component materials, as well as the total for both the original and new inner containers. The ratio of the new to the original cask attenuation is 1.54. Looked at in another way, for the same surface dose, the new cask would have to contain a source strength 54 percent greater. The original inner container was not considered shielding limited at 9,500 curies, so that no absolute level of source strength can be determined by this means; however, when applied to actual package measurements, such as those shown in Table 5.1.1, the package dose rates with a 15,000 curie source could easily meet normal shipping requirements.

The dose rate at the package surface and at one meter distant were also calculated in the radial direction. The attenuation due to shielding inside of the source containing drum chamber and the small attenuation due to the overpack were combined with the SITC attenuation shown in Table 5.4.1.1 to provide the total material attenuation of the packaging. The additional constituents, as well as the overall result, are presented in Table 5.4.1.2. The overall shielding attenuation, I_o/I is 5.75×10^{2}. Combining this with the source dose rate relationship(1) in the absence of shielding

I_o = Dose rate at distance d,cm from C curie source
$= 5.2 \times 10^{6}\ C\ E/d^2$ mr./hr.

where

C = 15,000 curies
E = Total gamma energy/disintegration = 2.5 Mev for cobalt-60
d (surface) = [(48.5/2) - 1.75] 2.54 = 57.2 cm
d (@ 1 meter) = 157.2 cm

(1) S. Glasstone, Principles of Nuclear Engineering, pg. 545

TABLE 5.4.1.1

CALCULATED RADIAL GAMMA ATTENUATION COMPARISON

Location(1) and New/Original Inner Container	Material and Thickness, in.	Linear Absorption Coefficient cm.-1	Buildup Factor (2)	Attenuation I_o/I (2)
1. Drum Liner	S.S. (3)			
New	0.095	0.432	1.09	1.02
Original	Same as above			
2. Drum Shielding	Lead			
New	0.782	0.655	1.47	2.50
Original	0.625	0.655	1.40	2.02
3. Drum Casing	S.S.			
New	0.187	0.432	1.17	1.046
Original	0.219	0.432	1.20	1.056
4. Shell Liner	C.S. (3)			
New	0.187	0.424	1.17	1.044
Original	0.375	0.424	1.34	1.115
5. Shell Shielding	C.S.			
New	7.69	0.655	4.75	7.63×10^4
Original	7.50	0.655	4.65	5.68×10^4
6. Shell	C.S.			
New	0.375	0.424	1.34	1.115
Original	Same as above			
S/TC Attenuation, $\overline{\Pi}$ (new)				2.37×10^5
S/TC Attenuation, $\overline{\Pi}$ (original)				1.538×10^5
Ratio, $\overline{\Pi}$ (new) / $\overline{\Pi}$ (original)				1.54

(1) Numbers keyed to locations shown in Figure 5.4.1.1.

(2) Attenuation, $I_o/I = B(\mu x, E) \exp(\mu x)$. Buildup factor based on point isotopic source. (Radiological Health Handbook, pgs. 145-146.)

(3) S.S. = stainless steel, C.S. = carbon steel

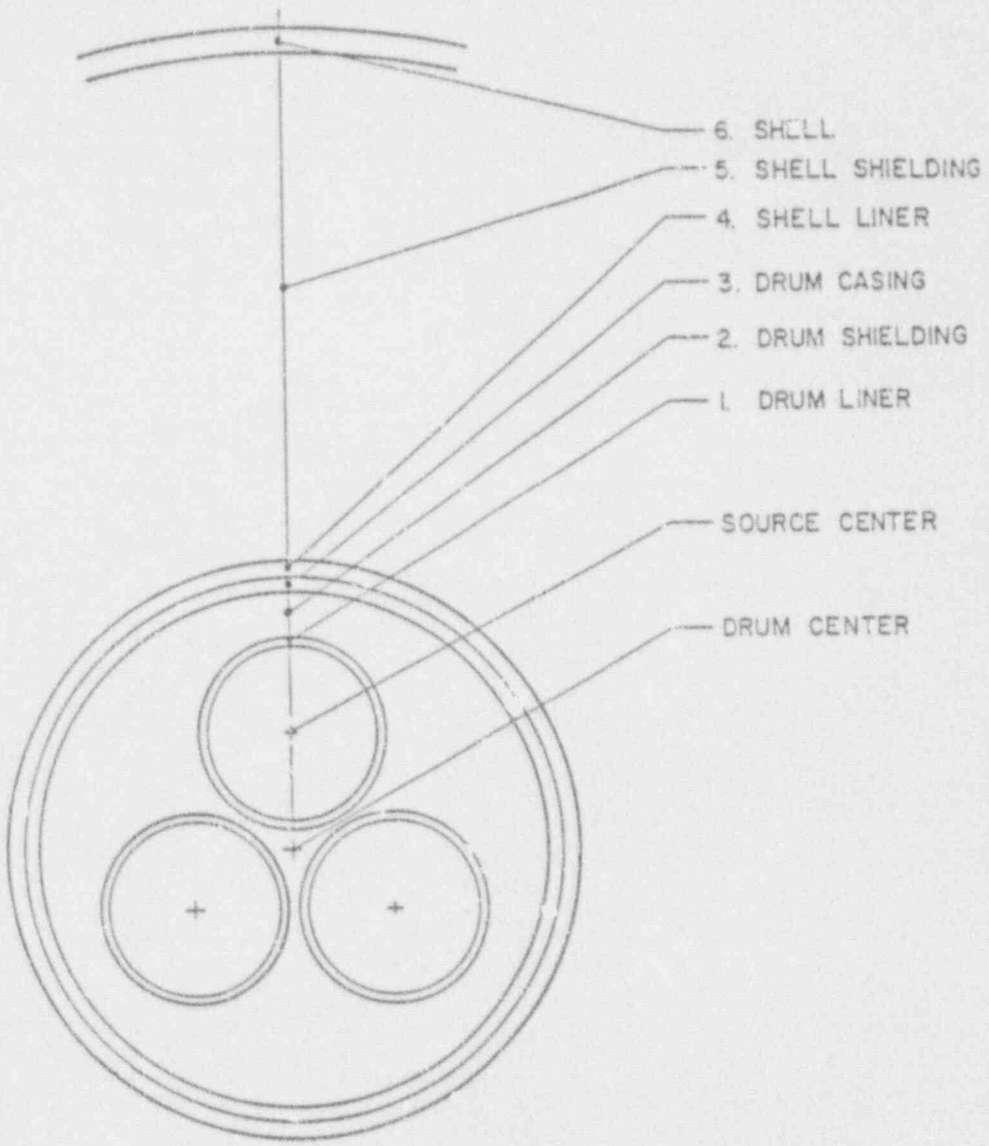


FIG. 5.4.1.1

STRUCTURE & SHIELDING ARRANGEMENT KEY FOR TABLE 5.4.1.1

TABLE 5.4.1.2

CALCULATED DOSE RATE FOR NEW PACKAGE

Location	Material and Thickness, in.	Linear Absorption Coefficient cm.-1	Buildup Factor	Attenuation I_o/I
Source capsule	Tungsten alloy 0.437	0.91[illegible]	1.47	1.94
Source chamber steel	Stainless steel 0.314	0.432	1.29	1.092
Source chamber to inner container surface	From Table 5.4.1.1			2.37×10^6
Wooden protective jacket	Wood 6.0	0.0384	1.62	1.[illegible]1
Steel shell	Carbon steel 0.107	0.424	1.10	1.032

Total material attenuation, source to package surface $(I_o/I) = 5.75 \times 10^6$

Yields the following surface dose:

$$(5.2 \times 10^6)(15,000)(2.5)/(5.75 \times 10^6)(57.2)^2 = 10.4 \text{ mr./hr.}$$

The dose at 1 meter is:

$$(5.2 \times 10^6 \times 15,000)(2.5)/(5.75 \times 10^6)(157.2)^2 = 1.4 \text{ mr./hr.}$$

These values compare with 200 mr./hr. and 10 mr./hr., respectively, for normal shipment. The margin provided appears adequate for slight changes in shielding, thickness, geometry, or calculational uncertainty.

5.4.2 Axial Gamma Attenuation

Evaluation of the shielding in the direction parallel to the axis of the new inner container drum involves the source loading arrangement. The loading arrangement of a source in an international capsule is shown in Figure 4.3. This is representative and one of the more frequent loading arrangements. The 2.56 inch diameter drum chamber is fitted with a stainless steel sleeve having an outside diameter of 2.50 inches and an inside diameter of 2.060 inches. The capsule is placed within the sleeve and held in the axially central region of the drum with two tungsten alloy plugs, one on each side. The covers hold the entire assembly in place.

The arrangement in the original inner container is similar, except the drum chamber is 2.81 inches in diameter and a second sleeve of 0.095 wall thickness, surrounding the first is used to fill the space and center the source.

For both configurations the shielding arrangement in the axial direction is a plug of tungsten alloy 9.8 inches long and 2.03 inches in diameter (about twice the diameter of the source face) surrounded by an annulus of steel with either two or three narrow air gaps. This assembly, in turn, is surrounded by a mantrix of lead. The arrangement is shown for the new drum in Figure 5.4.2.1.

Based on a point source, a simple calculation shows that for a shield thickness of 9.8 inches (the length of the plug and approximate distance from the source to the face of the shell assembly), the attenuation in tungsten alloy is of order 10^{10}, that in lead of order 10^7, and in steel of order 10^4. With the highest leakage path being that through the annulus of steel, a comparative measure of attenuation between the new and the original arrangement can be made by treating the steel annulus as a streaming path. The annulus is thinner in the new arrangement. To determine the relative streaming, the following expression[(1)] for the ratio of entering to leaving gamma flux was used and taken as proportional to the corresponding dose rates:

(1) Source: T. Rockwell, Reactor Shielding Manual, pg. 293

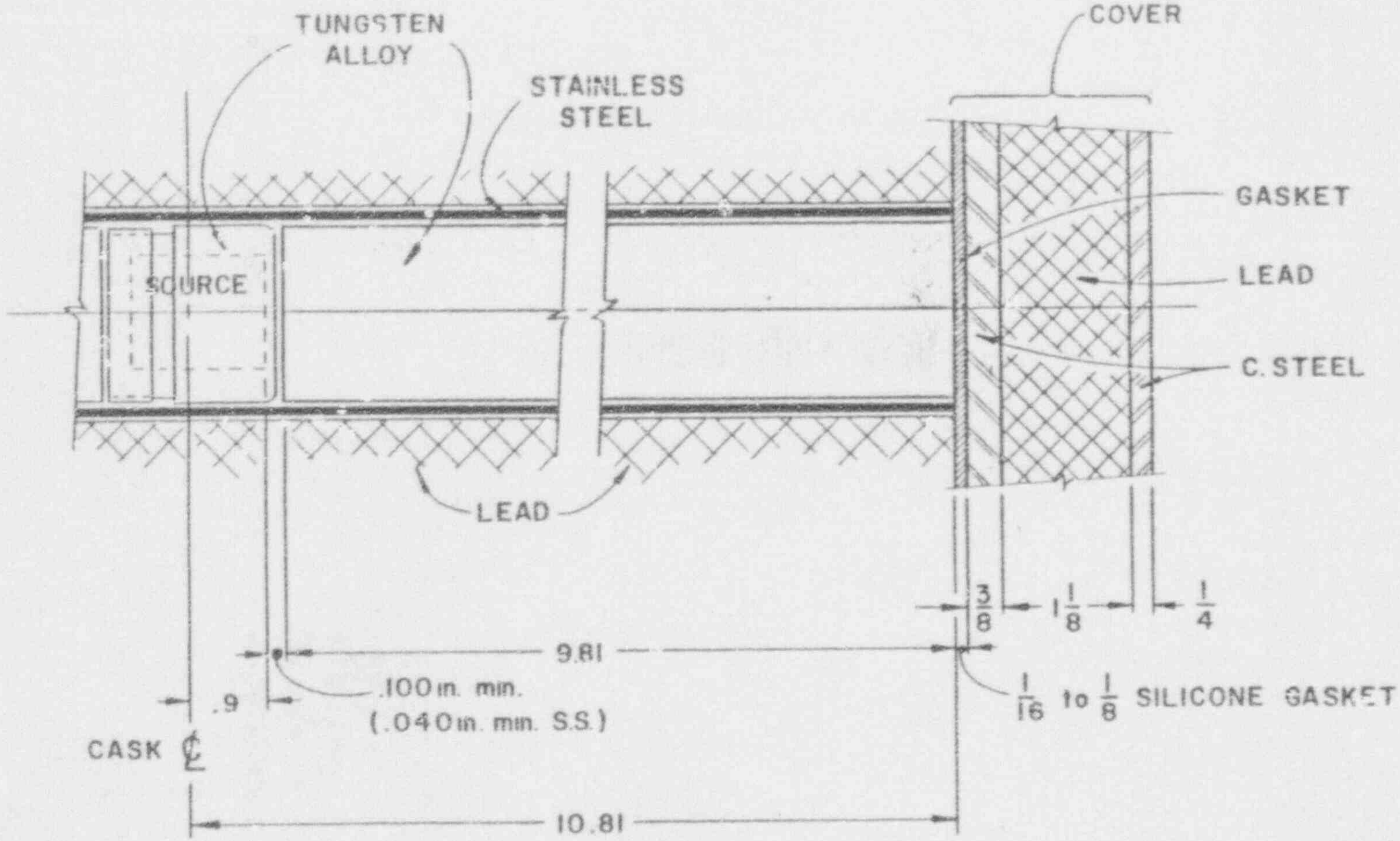


FIG. 5.4.2.1

DETAIL OF INTERNATIONAL CAPSULE POSITIONING WITHIN INNER CONTAINER DRUM.
(REF. FIG. 4.3)

$$\phi / \phi_1 = 1/2 \pi L^2 [(\cos^{-1} r/R)(2R^2 - r^2) - r(R^2 - r^2)^{1/2}]$$

The definition of the symbols and the corresponding values for both the new and original inner containers used in the comparison are as follows:

Value	Original S/TC's	New S/TC's
ϕ, gamma flux (taken proportional to dose rate)	-	-
R, drum chamber radius, in.	1.405	1.280
r, shield plug radius, in.	1.02	1.02
L, comparative shield thickness, in.	9.81	9.81

For the original units:

$$\phi/\phi_0 = 1/2 \pi (9.81)^2 [(\cos^{-1} 1.02/1.405)(2(1.405)^2 - (1.02)^2) - 102((1.405)^2 - (1.02)^2)^{1/2}]$$
$$= 2.01 \times 10^{-3}$$

For the new its:

$$\phi/\phi_0 = 1/2 \pi (9.81)^2 [(\cos^{-1} 1.02/1.28)(2(1.78)^2 - (1.02)^2) - 1.02((1.28)^2 - (1.02)^2)^{1/2}]$$
$$= 1.095 \times 10^{-3}$$

The increase in attenuation is proportional to 2.01/1.095 or 1.84, which is close to a factor of two.

Another loading arrangement that occurs frequently is one in which the entire teletherapy machine drawer, with source loaded, is carried in the drum chamber. In the case of the AECL machine, for example, the shielded drawer, with center positioned source, is the full length of the drum chamber and 2.475 inches in diameter. The input values for the calculation are:

Value	Original S/TC's	New S/TC's
R	1.405	1.280
r	1.234	1.234
L	10.8	10.8

Substituting the new values:

For the original units $\phi/\phi_o = 5.187 \times 10^{-4}$
For the new units $\phi/\phi_o = 7.01 \times 10^{-5}$

The increase in attenuation for the new units is 5.187/.701 = 7.3 or a factor of about seven.

Other specific cases will vary, but the improvement is significant.

5.4.3 Package Radiation Measurements

The results of a radiation survey of a package incorporating the new inner container are provided in this appendix. The survey was made on December 4, 1986, on a package that had been prepared for shipment and sealed a few days before. The source strength was 6,650 curies (12/1/86). The source was fitted into an international capsule and held in the central region of the drum chamber between tungsten alloy end plugs. The remaining drum chambers were loaded with full length, lead filled plugs. Measurements were made with a calibrated G-M detector.

The package surface measurements are shown in Figure 5.4.3.1. All of the radiation entries are in mr./hr. The maximum reading was 15 mr./hr. at the center of the package bottom. The highest side readings were 14 mr./hr. and 6 mr./hr., located 180° from each other at a belt line height of 24 inches. The remaining surface readings were between 0.6 and 5 mr./hr. at locations as shown on Figure 5.4.3.1.

All readings taken at one meter distant from the package surface were 1 mr./hr. or less. No measurement was taken at one meter between the bottom of the package.

Based on these measurements, the design basis 15,000 curie source would result in a maximum surface reading of (15,000/6,650) X 15 = 34 mr./hr., as compared with the design basis value of 100 mr./hr. and the 10 CFR 71.47 limit of 200 mr./hr. At a one meter distance, the level would be one third of the limiting 10 mr./hr. These results also generally support the calculations provided in Appendix 5.4.1.

5.4.4 Hypothetical Accident Conditions

Any change in shielding effect resulting from the Hypothetical Accident Conditions is due to shifting of the inner container within the overpack. There is no opportunity for any measurable shift of source or shielding in the inner container under the most severe free drop and fire conditions. Except for some small clearances, the inner container is completely filled with metal.

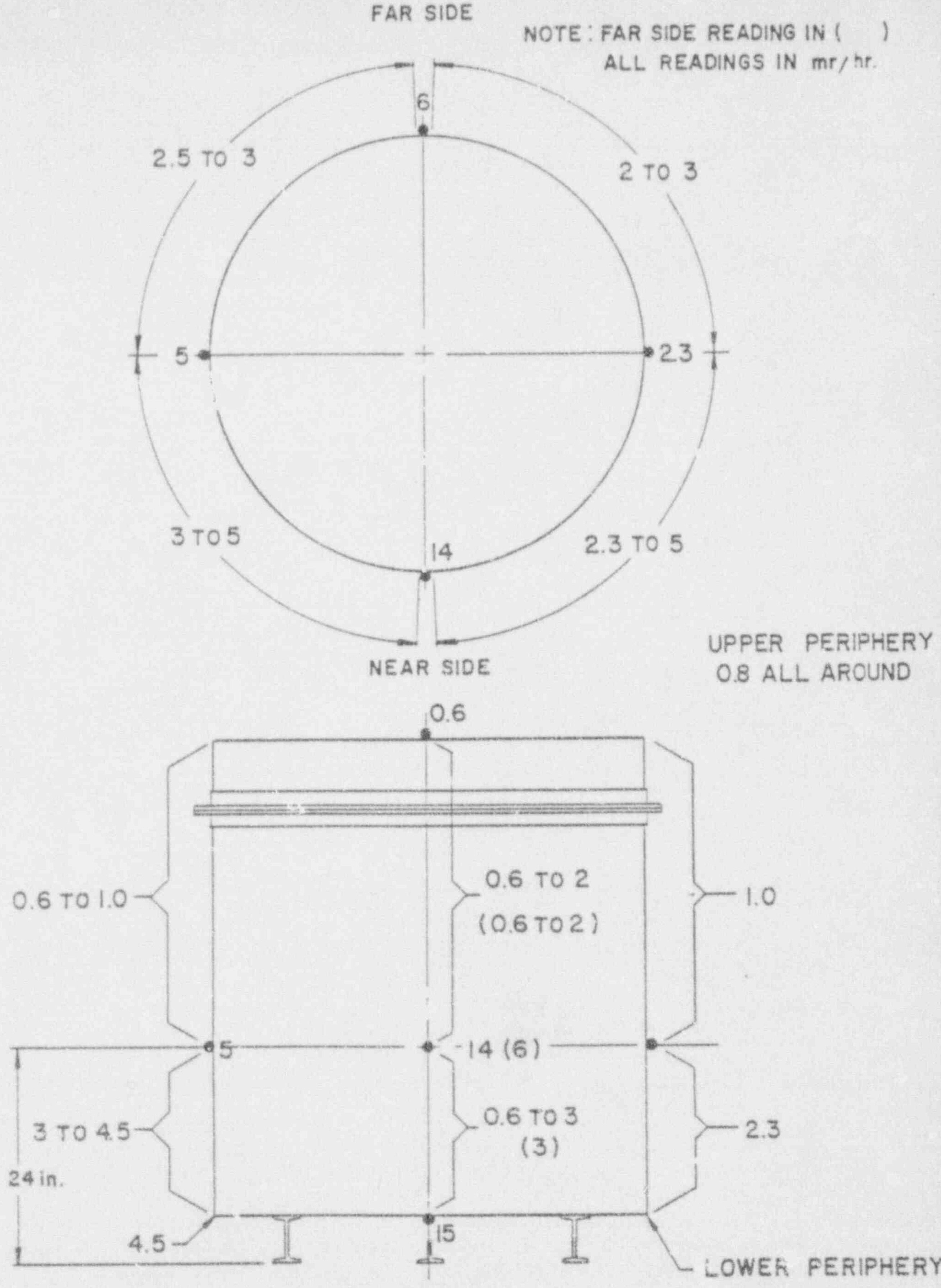


FIG. 5.4.3.1

MEASURED PACKAGE SURFACE RADIATION LEVELS
FOR A CONTAINED SOURCE OF 6650 CURIES

The maximum shift of the inner container within the overpack can be obtained from the analysis of the several hypothetical accident drop conditions. The shift of the source relative to the outer surface of the package is due to the crushing, bending, or other distortion of the overpack wooden protective jacket (WPJ) and steel shell (SS). The results obtained from the accident analysis are summarized in the following table:

Component of Overpack Affected	Maximum Displacement of Source Relative to Normal Location in Packages, inches — Top Drop	Bottom Drop	Side Drop	Edge Drop(1)
Crush support beams (SS)	4	-	-	
Shred shock rings (WPJ)	-	-	2	
Inner container movement	-	1	2	
Inner container penetration of WPJ	-	4	1	
After fire drop, char allowance	2	2	2	-
Maximum Displacement, in.	6	7	7	-

(1)Not critical for shielding

The amount of shielding material will remain the same. The shielding change will result only from geometric factors. Postulating a point isotopic source, the increased transmission due to the seven inch maximum displacement is:

At the surface: $\left(\frac{24.4}{24.4-}\right)^2 = 1.97$

At one meter: $\left(\frac{63.4}{63.8-7}\right)^2 = 1.26$

Assuming the surface radiation level under pre-accident conditions was at the 100 mr./hr. design basis condition, the hypothetical accident would result in a surface radiation level of less than 200 mr./hr. S[illegible]larly, postulating the permissible 10 mr./hr. pre-accident, the postaccident [illegible] meter dose rate increase would be less than 3 mr./hr. In any case, both levels are below the 10 CFR 71.51(a)(2) limit of 1 rem/hr. at one meter from the external surface of the package under hypothetical accident conditions.

TELETHERAPY SHIPPING/TRANSFER CASK
UNLOADING AND LOADING PROCEDURE
PROCEDURE R 2014

Revision 1

December 12, 1986

Reviewed for Radiation Safety and Approved — Frank Schwoerer 12/16/86
Frank Schwoerer, Date

Reviewed for Adequacy of Intended Purpose and Approved — Jeffrey W. Corun 12-17-86
Jeffrey W. Corun, Date

Reviewed per Quality Assurance Program and Approved — Wayne J. Costley 12/17/86
Wayne J. Costley, Date

UNLOADING AND LOADING OF NPI-20WC-6 TELETHERAPY SHIPPING PACKAGE AT THE DICKERSON HOT CELL PROCEDURE R 2014

Revision 1

December 12, 1986

SCOPE

The teletherapy shipping package, NPI-20WC-6, consists of a specially designed inner lead shielded shipping/transfer cask contained within an overpack. This procedure covers hot cell unloading and loading of doubly encapsulated sources out of, and into, the approved shipping/transfer casks, and shall be used in conjunction with "General Procedures for Hot Cell Source Operations." Enclosure of the cask within the overpack and unloading and loading the shipping package is included in the procedure. For operations at other hot cells, this procedure will be modified as necessary.

BACKGROUND

Both unloading and loading is covered here in a single procedure because the most frequent circumstance in the shipping and transfer of teletherapy sources is receipt of a package containing a spent source which, after appropriate initial operations and surveys, is removed from the package in the hot cell and placed in interim storage; whereupon the cask is inspected, cleaned, resleeved as necessary, and loaded with a new source in the hot cell for subsequent shipment off site. Loading an initially empty container and similarly, unloading a container to be placed into standby or serviced in an empty condition are included as variation of the procedure.

1. REFERENCES

- Sampling Procedure R 1002
- General Procedure for Hot Cell Source Operations R 5001
- Opening Hot Cell Door After Processing Single and Double Encapsulated Sources R 5002
- Applicable Certificate of Compliance (for domestic destination) or Certificate of Competent Authority (for foreign destinations) for the Shipping Package
- Package Loading Procedure for Radioactive Materials, QA 1003
- Package Unloading Procedure for Radioactive Materials, QA 1004
- Empty Radioactive Materials Packaging, 49 CFR 173.427

2. GENERAL CONSIDERATIONS

Sources shall be loaded only upon written instruction after it has been determined that the sources meet all specifications, including customer's and cask loading specifications.

2. GENERAL CONSIDERATIONS (Cont'd)

The shipping packages usually contain radioactive material upon receipt and all procedures and precautions associated with handling radioactive materials must be followed.

3. PERSONNEL AND SUPERVISION REQUIREMENTS

Radioactive materials may be loaded or unloaded from transfer containers only by experienced hot cell operators, acting under the authority of the Hot Cell Manager, Vice President of Services and Systems or his designee.

4. EQUIPMENT

- Operating Hot Cell
- Shipping/Transfer Cask
- Shipping/Transfer Cask applicable inserts
- Survey Meter capable of reading up to 2R/hr
- All necessary tools

5. OPERATIONS

5.1 Preparations

5.1.1 Confirm with the Production Manager, or other individual responsible for the shipment, the following:

a) source(s) identification
b) activity of source(s)
c) applicable Shipping/Transfer Cask and source holder
d) applicable overpack (wooden protective jacket and steel shell).

5.1.2 For shipment received, unload the NPI-20WC-6 package from the truck in accordance with QA 1004.

5.1.3 Remove bolts and lids from the steel shell and wooden protective jacket, respectively. Store for reuse.

5.1.4 Remove shipping/transfer cask from the overpack. Do not leave wooden protective jacket open to weather. Inspect overpack for damage and repair if necessary. Store overpack for next use with wooden lid and shell cover in place.

5.1.5 Measure radiation levels to confirm that handling of cask will be a low level operation.

5.1.6 Open hot cell door per applicable procedure.

5.1.7 Place the Shipping/Transfer Cask on the dolly in the hot cell access area. Using the forklift, place the loaded dolly on the cask loading rails.

5.1.8 Remove bolts holding one of the Shipping/Transfer Cask covers. Make certain end of cask faces shielded area when removing cover.

5.1.9 Confirm whether the cask contains a source by both measuring the radiation level near and visually inspecting inserts at the open face of the container. Any reading above background should be considered as indicating a loaded container.

5.1.10 If Shipping/Transfer Cask is <u>loaded</u>, proceed to 5.1.12.

5.1.11 If Shipping/Transfer Cask is <u>empty</u>, remove inserts, clean the inside of the container, check drum rotation (where applicable), wipe test the inside of the container and inserts and reinstall applicable inserts.

The inside surfaces of the Shipping/Transfer Cask and the inserts should not exceed a count rate of 500 dpm per 100 cm^2 on the wipe test. Clean and re-wipe as necessary to meet this limit.

5.1.12 Load Shipping/Transfer Cask, appropriate insert or holder and all necessary tools into cell.

5.1.13 Close hot cell door.

5.1.14 If Shipping/Transfer Cask is <u>empty</u>, proceed to 5.3.

5.1.15 If Shipping/Transfer Cask is <u>loaded</u>, proceed to 5.2

5.2 <u>Unloading</u>

5.2.1 If container is loaded, remove source holders and remove sources from holders.

5.2.2 Visually inspect source for damage and evidence of failure of source integrity.

5.2.3 Wipe test source.

5.2.4 Acceptability for source storage:

5.2.4.1 If the source passed the visual examination and if the removable contamination determin d by the wipe test is less than 0.05 uci, place the source in storage and note in the inventory record.

5.2.4.2 If the removable contamination as determined by wipe test is greater than 0.05 uci, the source should be visually re-examined. If the examination reveals no sign of cladding failure, decontaminate and wipe test again. If the results of the wipe test after decontamination is less than 0.05 uci, the source shall be considered acceptable a d placed in storage.

5.2.5.3 If there is any sign of cladding failure or if the wipe test after decontamination is greater than 0.05, notify the Production Manager and establish corrective action to be taken to prevent significant contamination in storage. Note condition and action taken in the ot cell log.

5.2.5 Open hot cell doo sing reference procedures and move empty cask into not cell access area.

5.2.6 If the empty cask is to be reloaded for outgoing shipment, proceed to step 5.1.11.

5.2.7 If the empty cask is to be shipped empty or taken out of service, remove inserts, clean the inside of the container and wipe test both the inside of the container and the inserts.

The inside surface of the shipping/transfer cask and the inserts should not exceed a count rate of 500dpm per $100cm^2$ on the wipe tests, clean and rewipe as necessary to meet this limit.

5.2.8 If the empty cask is to be shipped empty, install inserts (if appropriate), and bolt gasketed covers into place. Tighten bolts to firmly compress the gasket (approximately 100 inch-pounds torque). Insure requirements of 49 CFR 173.427 regarding shipment of empty radioactive packaging materials are met. Proceed to step 5.3.10 or an alternative special procedure.

5.2.9 If the emtpy cask is to be taken out of service, install the covers along with any internals to be stored and place the cask into storage.

5.3 Loading

Note: Before loading, make certain that all applicable preparation steps starting with 5.1 are completed.

5.3.1 Remove completed and inspected source from storage.

5.3.2 Visually inspect source for damage and evidence of failure of source integrity.

5.3.3 Wipe test source.

5.3.4 Acceptability for source shipment:

5.3.4.1 If the source passed the visual examination and the removable contamination determined by the wipe test is less than 0.001 uci, the source is acceptable for shipment.

5.3.4.2 Repeated decontamination and wipe testing is acceptable in meeting criteria.

5.3.5 Load source into appropriate holder and the holder into the designated position in the Shipping/Transfer cask.

5.3.6 Record the identification and location of each source in the cask.

5.3.7 Open hot cell door using referenced procedures.

5.3.8 Place cover on the Shipping/Transfer Cask.

5.3.9 Remove Shipping/Transfer Cask from hot cell and tighten bolts to firmly compress the gasket (approximately 100 inch-pounds torque).

5.3.10 Decontaminate Shipping/Transfer Cask.

5.3.11 Wipe test Shipping/Transfer Cask and decontaminate as necessary.

5.3.12 Measure and record maximum radiation levels at surface and at 1 meter (3.3 feet).

5.3.13 Complete and place appropriate label on the Shipping/Transfer Cask.

5.3.14 Load Shipping/Transfer Cask into the overpack and install wooden protective jacket cover. Bolt cover firmly into place, making certain that all thread reinforcement rod ends remain recessed at least 1.5 inches below the surface of the wooden protective jacket.

5.3.15 Bolt overpack steel shell.

5.3.16 Fit steel shell cover and bolt into place.

5.3.17 Affix appropriate labels for the shipment and load the NPI-20WC-6 package onto the truck in accordance with QA 1003.

6. RECORD REQUIREMENTS

6.1 The Hot Cell Log Book shall contain:

- Identification of the cask that has been loaded.
- Identification and in-cask location of sources that have been loaded.
- Name of operator.
- Results of all wipe tests and results of source inspections.
- Dose received by operator as read on the dosimeter.

6.2 Make the appropriate entry into the inventory record.

6.3 The Production Manager shall review the Hot Cell Log Book for compliance with the procedure at least once a day and shall either indicate its adequacy by initialling at the end of each days entry or shall note and initial any inadequacy. The RSO shall review the Hot Cell Log Book at least weekly and shall make similar notations.

- Inspection records or certificates of conformance attesting to the acceptance of material and components are available prior to equipment installation or use.

- Items accepted and released are identified as to their inspection status.

8.1.1 Visual Inspections

Visual inspections will be conducted to insure that the packaging is in conformance with the drawings and specifications.

Welds which are part of the boundary of the lead containing cavities of the inner container will be inspected using dye-penetrant or other suitable techniques. This includes the Drums, Covers, and the Shell Assembly. Any evidence of weld cracking will be repaired by removal of the metal in the indicated region and satisfactorily rewelding the joint.

In addition to dimensional checks, visual inspection of the Wooden Protective Jacket will include proper bonding of the plywood sheets and installation of the reinforcing rods. The outer Steel Shell will be visually inspected for weld quality. Any questionable areas will be rewelded or reinforced.

8.1.2 Structural and Pressure Tests

Not applicable

8.1.3 Leak Tests

In fabrication of the inner container, the chambers containing lead shielding will be leak tested before filling to assure containment integrity. Leak tests of the inner container closure are not required in normal service.

8.1.4 Component Tests

Not applicable

8.1.5 Tests for Shielding Integrity

Before delivery, the inner container will be tested and inspected by nondestructive means and evidence submitted to show that the required homogeneity of shielding is provided to meet the shielding specifications. The outer surface of the cask will be surveyed with a cobalt-60 radiation source in the central chamber. Normally this is done by surveying the entire accessible surface of the cask. In the case of the inner container, almost all of the outer surface is accessible. As a minimum, however, a 14 point survey will be made (on the surface face intersecting each of the principal axies, plus the central point on the face of each octant defined by the three principal planes containing the center of the spherical shell) and the values recorded. Any area showing surface radiation more than 15% above the average where lead shielding thickness is comparable will be repaired and retested.

8.1.6 Thermal Acceptance Tests

Not applicable

8.2 Maintenance Program

The shipping package does not contain liquid shielding, coolant, valves, pressure gages, rupture disks, etc., thereby simplifying regular maintenance. In addition to periodic routine visual inspections, the following routine maintenance is performed:

- Components of the package are checked for contamination when it is being loaded or unloaded and decontamination is effected as required.

- When the end covers are installed or removed, the condition of the silicone gasket is inspected and the gasket is replaced when checking, hardening, deterioration, or any damage is observed. The gaskets are replaced within a 12 to 18 month period in any event.

- Prior to each use, the Wooden Protective Jacket is inspected for defects, or conditions potentially leading to defects, such as loss of plywood bonding, cracking, waterlogging, excessive drying, corrosion of the steel rods, or any body or cover warping that would result in an inadequate cover seal. Should any of these conditions be observed, the situation shall be evaluated and a repair made, or the Wooden Protective Jacket taken out of service.

- The overpack Wooden Protective Jacket and Steel Shell are inspected for damage when being put into, or taken out of, service. Spare parts are kept in stock and replacement or repair is made as required.

Neutron Products, Inc.
Model No. NPI-20WC Mk II
Docket No. 71-9102

Encl to ltr dtd: OCT 29 1986

DRAWINGS

1. The applicant has requested an amendment to the certificate of compliance to increase the maximum activity of the Cobalt 60 sealed source from 9,500 curies to 15,000 curies. The application (Page 1-1, Section 4.0 and Section 5.0) makes various statements describing tungsten shields within the sealed source capsule and tungsten alloy inserts used in the drum assembly all of which seem to be required to accommodate the increase in source strength. Cover Letter & Fig. 4.3 Fig 5.4.1.1 Fig. 5.4.2.1

   The shielding requirements should be clarified by revising the package drawing to show, in detail, the arrangement of shielding materials required to accommodate the increase in source strength.

2. Drawing No. 240122, Rev. A. The drawing should identify the weld joints to be nondestructively examined, the method to be used and the code or standard for the examination procedure and acceptance criteria. Dwg 240122 Rev B

   o The drawing should note the torque requirements for the closure bolts.

   o The weld symbol joining Item 27 to Items 29 and 31 should be corrected to agree with the joint pictured in drawing Zone H3.

3. Drawing No. 240116, Rev. B. The drawing should specify, either by note or by detail, the application of a tamperproof feature to satisfy the requirements of 10 CFR §71.43(b). Dwg 240116 Rev. C

   o The drawing should provide, either by note or by detail, the marking and identification requirements of 10 CFR §71.85(c).

   o The drawing should note that the 1/2-inch diameter vent holes in the steel shell should be covered with a durable weatherproof tape or equivalent device.

STRUCTURAL

1. Demonstrate that the tie-down brackets, which could be used as lifting devices, are designed to meet the requirements of 10 CFR §71.45(a). 2.4.4 2.10.10

2. The size of bracket attachment weld is not specified on Drawing No. 240116. All packaging weld joints should be shown by appropriate weld symbol. Dwg. 240116 Rev C

3. Demonstrate that the cover bolts for the inner container will not be stressed beyond the yield stress during the 30-foot flat side drop. 2.7.1.2

SHIELDING

Section 5 of the application discusses the shielding adequacy of the package as based on a combination of dose comparisons with a similar existing package when loaded with Co-60 and simple point source calculations accounting for the differences between the new and existing package. The approach is acceptable. However, the application does not provide drawings or calculations in support of reduced streamings by factors between 2 to 7 depending upon the source holder configuration. 5.1 (pg 5-3)

The application should provide sketches with the appropriate dimensions and materials and the shielding calculations in support of the descriptions and statements both for the normal and accident conditions. 5.4.1 5.4.2 5.4.3 5.4.4

OPERATING PROCEDURES

1. The operations in Procedure R 2014 which address the shipment of an empty package should make reference to 49 CFR §173.427. 7.4.1 R 2014 Rev. 1

2. Operation 5.3.8 should be expanded to include installation of the closure bolts and the torque requirement. pp 1, 4, & 5

ACCEPTANCE TESTS

1. In paragraph 8.1.1, Visual Inspection, specify the nondestructive examination procedures and acceptance criteria that will be used to determine weld joint integrity. 8.1.1

2. In paragraph 8.1.5, Test for Shield Integrity, define the grid pattern that will be used to inspect 100% of the package surface. 8.1.5

MAINTENANCE PROGRAM

1. A gasket replacement schedule should be specified based on maximum gasket service life. 8.2

2. The maintenance program for the wooden protective jacket should address the conditions cited in 49 CFR §178.194.4. 8.2

1

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

71-5364

RECEIVED JUL 0 6 1982 U.S. Nuclear Regulatory Commission NMSS Mail Section

neutron products inc

Dickerson, Maryland 20753 U.S.A.
301/349-5001 TWX: 710-828-0542

RECEIVED JUN 24 1982 U.S. NUCLEAR REGULATORY COMMISSION NMSS Mail Section

June 21, 1982

DOCKETED USNRC JUL 0 6 1982 NMSS MAIL SECTION DOCKET CLERK

Dr. Martin A. Welt
President
Radiation Technology, Inc.
P.O. Box 185
108 Lake Denmark Road
Rockaway, New Jersey 07866

Dear Marty:

I am writing in response to your letter of June 7, 1982. Since receiving this letter I have reviewed the facts with those of our employees who were involved in the shipment. To the best of my knowledge, the facts are as presented below.

1. The number of sources contained in the shipment, per our April 20, 1982 memo, was based on the information we were given by your West Memphis plant manager. I have learned that this figure was calculated by subtracting the number of sources of each type determined by Radiation Technology to be remaining at West Memphis after the cask was loaded, from the number of sources of each type determined by Radiation Technology to be present at West Memphis before the cask was loaded. Neither your people nor ours counted the number of sources of each type which were placed in the cask.

2. In unloading and reloading our shipping container in Dickerson we undertook a concerted effort to assure that all sources removed from the container were returned to the container, and we have every reason to believe that we succeeded in that objective. Unfortunately, our efforts to document that fact only add to the confusion in that we counted 109 C-188 pencils removed from the container, and 109 C-188 pencils returned to the container, but in counting the sources in the holders in which they were temporarily placed, we counted only 108 C-188 pencils. At no point did we count 107 C-188 pencils (as you say we did in your June 7, 1982 letter), so we are unable to confirm your count in any respect.

   In addition, we counted 52 GE capsules removed from the container, and 52 GE capsules returned to the container, but only counted 51 GE capsules when they were in holders. Therefore, although we verified at Dickerson the calculated numbers received from your West Memphis plant in both the removal of sources from the cask, and the return of sources to the cask, our total was only 159 (108 C-188's and 51 GE) sources in between these activities.

FEE EXEMPT C/1
w/o 20899

8701270062 4pp.

3. In view of the discrepancy in the count of sources at Dickerson we undertook a concerted effort to locate any sources which might have been misplaced. There aren't that many possibilities, and we have not located any additional sources here. Also we re-examined our cask to check once again that no sources are hidden in any of the tubes. and can assure you that there are not. Accordingly, we have no reason to believe that we failed to deliver to Rockaway any of the sources we picked up at West Memphis.

   If you would send us a list of serial numbers of the sources in the shipment, we would be pleased, in the course of our next full inventory to be alert to the possibility that one or more of these sources may have indeed been misplaced. In the interim, please be advised that the likelihood that one of your sources is here is remote, and undertake to review your records to see if you can resolve the discrepancy within your own company.

Although we do not believe there is any discrepancy between what was loaded in the cask at West Memphis and removed and reloaded at Dickerson, by copy of this letter we are, in accordance with your suggestion, notifying the Nuclear Regulatory Commission of the potential discrepancy.

Very truly yours,

NEUTRON PRODUCTS, INC.

J.A. Ransohoff
President

JAR/mbn

cc: W/Enclosures:
RTI Letter dated 6/7/82
NPI Memo dated 4/20/82

Mr. Bernard Bevill, St. of Arkansas
Mr. Robert E. Corcoran, St. of MD, DHMH
✓Mr. Charles McDonnell, NRC
Mr. Carmine Smedira, NPI
Mr. Marvin Turkanis, NPI

JUN 1 1982

Radiation Technology, Inc.

P. O. BOX 185, 108 LAKE DENMARK ROAD, ROCKAWAY, N. J. 07866
(201) 625-8400

CERTIFIED MAIL #P30 3554108

June 7, 1982

Mr. Jack Ransohoff, President
Neutron Products, Inc.
22301 Mt. Ephraim Road
Dickerson, Maryland 20753

Dear Jack:

We wish to advise you that we have now re-counted the number of sources delivered to us on Friday, May 28, 1982, and have confirmed that there are only 107 AECL C-188 pencils. This is two pencils less than were supposed to have been delivered in accordance with your letter dated April 20, 1982, which indicated that you were shipping 109 AECL C-188 pencils from our West Memphis facility to our plant in Rockaway, New Jersey. I had mentioned the apparent discrepancy to Marvin Turkanis during our last telephone conversation, and he confirmed that prior to reloading the cask for shipment to our facility, three counts were made, and he indicated that there were 109, 109 and on the final count, only 107. We hereby request that you locate the two pencils and make delivery at the same time that you plan to pick up your demineralizer. Since these pencils were to have been delivered at the time of the final shipment, we would suggest that you make arrangements to unload the sources in our R&D pool, utilizing your A-frame hoist which you were going to use in 1978 to deliver the 12 pencils that were finally delivered on May 28, 1982.

We will assume that you will notify any of the appropriate authorities concerning the discrepancy in the shipping papers as against what was delivered.

Very truly yours,

Martin A. Welt, Ph.D.
President

MAW:ma

April 20, 1982

To Whom It May Concern:

Neutron Products is shipping 161 sources (109 AECL type C188 and 52 GE type GEP916) from Radiation Technology's West Memphis, Arkansas facility to Radiation Technology's Rockaway, New Jersey facility, incidental to the delivery of approximately 1,100,000 curies of Neutron Product's produced cobalt-60 to Radiation Technology's West Memphis facility.

Dr. Welt of Radiation Technology advises that they are licensed to possess these sources at the Rockaway facility.

Radiation Technology has determined that these sources are leak free, based on the measurement of the activity of the water in the storage pool at their West Memphis facility, per Dr. Welt.

Sincerely,

NEUTRON PRODUCTS, INC.

Marvin M. Turkanis
Vice President

MMT/..