WIN-236
Revision 1

EVALUATION OF KRYPTON 85 CONTENTS FOR TRANSPORTATION IN THE MODEL NO. 6400 PACKAGING

IDAHO NATIONAL ENGINEERING LABORATORY

Managed by the U.S. Department of Energy

Prepared by:
Westinghouse Idaho Nuclear Co., Inc.
March 1988

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Westinghouse Idaho Nuclear Company, Inc.
Idaho Falls, Idaho 83403

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CONTRACTING TO THE US DEPARTMENT OF ENERGY
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TABLE OF CONTENTS

	Page
1.0 General Information	1-1
1.1 Introduction	1-1
1.2 Package Description	1-1
1.2.1 Packaging	1-2
1.2.2 Dunnage	1-3
1.2.3 Contents	1-5
1.3 Operational Features	1-13
1.4 Contents of Packaging	1-13
2.0 Structural Evaluation	2-1
2.1 Structural Design	2-1
2.2 Weights and Center of Gravity	2-3
2.3 Mechanical Properties of Materials	2-3
2.4 General Standards for All Packages	2-4
2.5 Lifting and Tie-Down Standards for All Packages	2-5
2.6 Normal Conditions of Transport	2-5
2.7 Hypothetical Accident Conditions	2-10
2.8 Appendix	2-19
3.0 Thermal Evaluation	3-1
3.1 General	3-1
4.0 Containment	4-1
4.1 Introduction	4-1
4.2 Physical Containment of Contents	4-1

4.3 Primary Containment. 4-2
4.4 Normal Conditions of Transport 4-2
4.5 Hypothetical Accident Conditions 4-3

5.0 Shielding Evaluation 5-1
5.1 Introduction 5-1
5.2 Source Specification 5-1
5.2.1 Gamma Source 5-1
5.2.2 Neutron Source 5-3
5.3 Model Specification - Description of the Radial and Axial Shielding Configuration. 5-3
5.4 Radiation Levels 5-3
5.5 Shielding Evaluation 5-6

6.0 Criticality Evaluation 6-1

7.0 Operating Procedures 7-1
7.1 Introduction 7-1
7.2 Procedures for Loading Gas Cylinder. 7-1
7.3 Procedures for Installation of Containment Components Into Thermal Insulation 7-4
7.4 Procedures for Installation of Thermal Insulation Into Plywood Box 7-5
7.5 Procedures for Loading Contents Into the Model No. 6400 Packaging 7-6
7.6 Procedures for Unloading the Shipment. 7-7

8.0 Acceptance Tests and Maintenance Program - QA. 8-1
8.1 Introduction 8-1
8.2 Preventive Maintenance 8-2

8.3 Quality Requirements 8-2
8.4 Quality List 8-4

9.0 References 9-1

LIST OF FIGURES

Page

Figure 1.1 Krypton-85 Shipping Configuration 1-4
Figure 1.2 MF&S Metal Diaphragm Valve. 1-6
Figure 1.3 Lead Shield Cutaway 1-8
Figure 1.4 Contents Without Plywood Box. 1-11
Figure 2.1 Stress/Strain Curve for Douglas Fir Plywood 2-21
Figure 5.1 Contents Shielding Configuration. 5-2
Figure 5.2 Dose Rate vs Krypton-85 Loading at Surface of Thermal Insulation of Contents. 5-4

LIST OF TABLES

Page

Table 2.1 Design Characteristics. 2-11
Table 3.1 Comparison of Actual vs Allowable Conditions. 3-3
Table 8.1 Q-List. 8-4

1.0 GENERAL INFORMATION

1.1 Introduction

This is an evaluation of the addition of the krypton-85 contents for transportation in the Model No. 6400 packaging (Reference 1). This evaluation provides the technical data which shows that the addition of up to 10,000 curies of krypton-85 to the Model No. 6400 packaging meets all defined transport requirements of Code of Federal Regulations (CFR) Title 10, Part 71 and Title 49, Part 173, Subpart I. The Model No. 6400 packaging is a NRC certified package [USA/6400/B( )F] and provides an overpack for the thermal and impact protection for the contents. The contents will provide the containment and the shielding for the krypton-85. Polyurethane foam dunnage provides additional impact protection as an inner liner between the Model No. 6400 packaging the krypton-85 contents.

This combination of Model No. 6400 packaging, polyurethane foam dunnage, and krypton-85 contents was previously certified by the Department of Energy (USA/9761/BX DOE) for a limited number shipments of krypton-85 from the Idaho Chemical Processing Plant at the Idaho National Engineering Laboratory to the Oak Ridge National Laboratory. The certificate was issued September 30, 1987, and expired December 31, 1987.

1.2 Package Description

This is a combination of Model No. 6400 packaging, polyurethane foam dunnage, and krypton-85 contents.

1.2.1 Packaging

(1) Model No. 6400

(2) Description of Model No. 6400

This protective overpack provides physical containment, impact resistance, and thermal protection for its contents and is NRC certified. The inner shell (cavity) is approximately 76 inches by 76 inches by 172 inches and is constructed of 10 gauge and 3/16 inch thick mild steel. Closure of the cavity is by a 1/4 inch thick aluminum plate and silicone rubber gasket bolted to the framework of the cavity. The cavity is centered and supported in an outer 3/16 inch thick mild steel jacket by approximately 32 inches of polyurethane foam insulation at the forward end and 10 inches on the sides. A side hinged rear access door consisting of approximately 34 inches of polyurethane foam insulation encased in mild steel with a silicone rubber gasket is bolted to the main outer steel jacket during transport. The overall dimensions of the package are approximately 96 inches square by 240 inches long. Set into each corner of the outer jacket are standard steel tie down fittings. The weight of an empty Model No. 6400 packaging is approximately 18,600 pounds and the weight of a fully loaded packaging with the polyurethane foam dunnage and krypton-85 contents is approximately 28,000 pounds, which is less than the certified weight of 42,000 pounds. The inner krypton-85 contents weight is approximately 5500 pounds.

(3) Drawings

Packaging is constructed in accordance with one of the following sets of drawings: 1) Protective Packaging Inc., Drawings No.

32106, Sheet 1, Rev. F and 32106, Sheet 2, Rev. 0; or 2) Westinghouse Electric Corporation Drawing No. 2020D08, Sheet 1 and 2, Rev. 0; or 3) Babcock and Wilcox Company Drawing No. 11-D-2130, Rev. 0; or 4) Protective Packaging, Inc., Drawing No. 32106-1, Sheet 1, Rev. F and 32106, Sheet 2, Rev. 0, as modified by Nuclear Packaging Inc., Drawing No. EG-60-01D, Sheets 1 and 2, Rev. 0; or 5) Protective Packaging Inc., Drawing No. 32395, Sheets 1 through 9, Rev. B, as modified by Sandia Laboratories letter dated May 8, 1980, or 6) Lawrence Livermore National Laboratories Drawing No. AAA81-108683-00, Rev. 0 and AAA-81-110194-00, Rev. 0.

1.2.2 Dunnage

The dunnage between the Model No. 6400 inner shell and krypton-85 contents (Figure 1.1) consists of a polyurethane foam inner liner (made to mil spec MIL-P-26514, Type I, Class 1 to a density of 5 lb/ft^3 and a compressive yield of 80 psi) which is the same mil spec foam that is currently NRC certified for use in the Model No. 6400 packaging (Reference 2).

The multi-section inner liner is fabricated of molded polyurethane foam. This inner liner will snugly shore the contents within the center of the packaging cavity to keep the center of gravity centralized and provide additional shock absorbing features for the contents. The liner will support the contents during normal transport conditions and, together with the configuration of the contents, will distribute impact loads over at least 60% of the applicable packaging inner cavity walls as required under the accident drop criteria (page 105 of Reference 1).

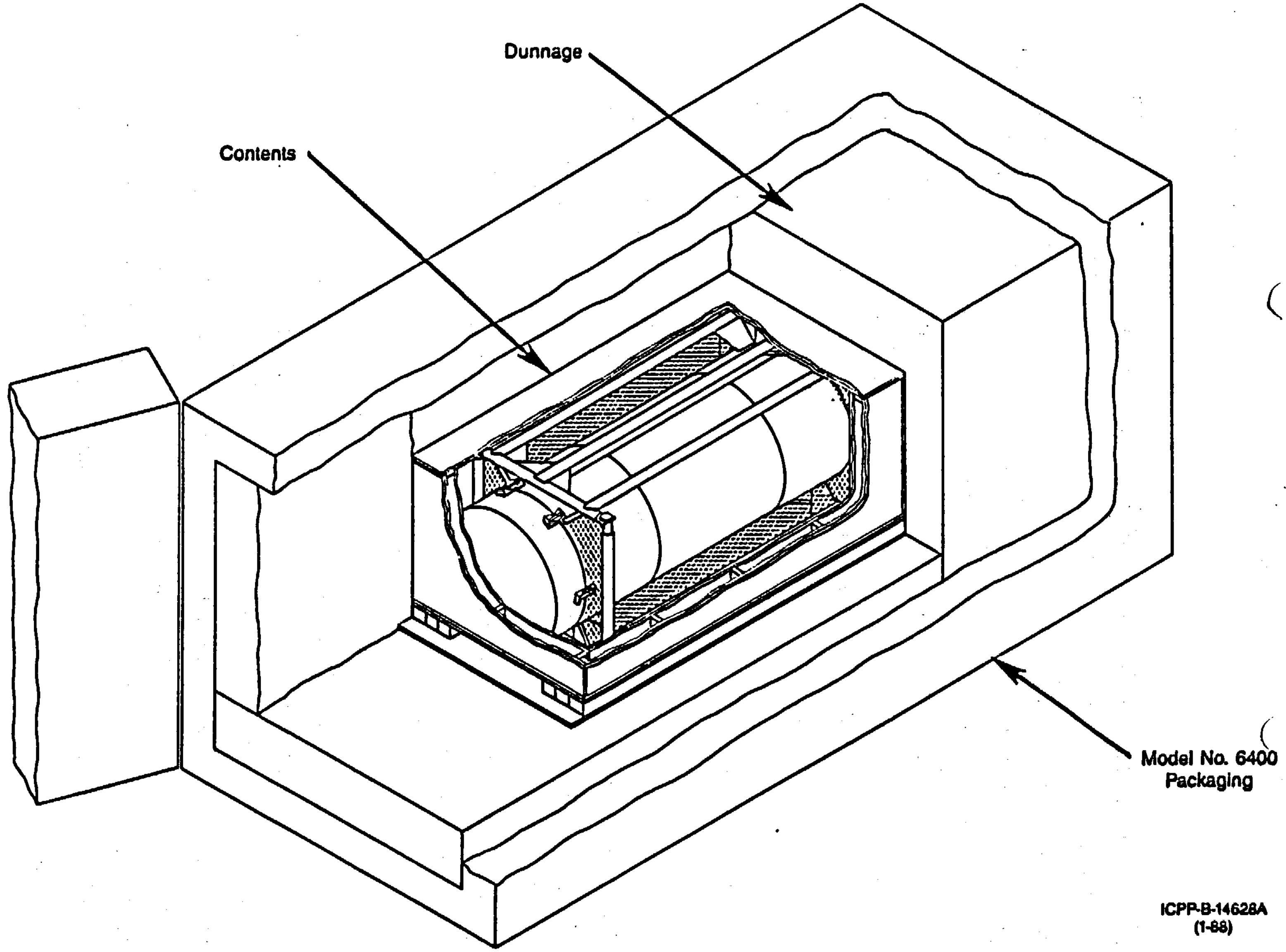

Figure 1.1 Krypton-85 Shipping Configuration.

1.2.3 Contents

The contents include the following: 1) up to 10,000 curies of krypton-85 in a DOT 3AA cylinder equipped with a metal diaphragm valve, 2) lead shield, 3) thermal insulation, and 4) plywood box.

The primary containment for the krypton-85 is a standard Department of Transportation specification 3AA-2015, 4130X steel, compressed gas cylinder, as described in 49 CFR Part 178, Subpart C 178.37. The cylinder has a nominal volume of 1.5 cubic feet and is authorized by DOT spec for pressures up to 2015 psig. The cylinder will be loaded to a maximum pressure of 500 psia at 80°F. The cylinder has an outside diameter of 9 inches and is 52 inches high, and its empty weight is approximately 100 pounds.

The compressed gas cylinder is equipped with a Manifold Fabricators and Supply metal diaphragm valve. The valve has a pressure rating of 1000 psig and has been tested to 2200 psig and is depicted in Figure 1.2. Each valve is equipped with a brass cap, fitted over the valve outlet, to serve as a thread protector and is also an additional barrier to prevent leakage. This brass cap is on the valve at all times during transportation.

The Manifold Fabricators and Supply metal diaphragm valve is constructed of Type 316 stainless steel with the exceptions of the valve spring which is Inconel X-750 and the diaphragm which is Inconel 718. The diaphragm and other valve components are retained within the valve body by the bonnet/nut assembly which is fabricated as a single unit.

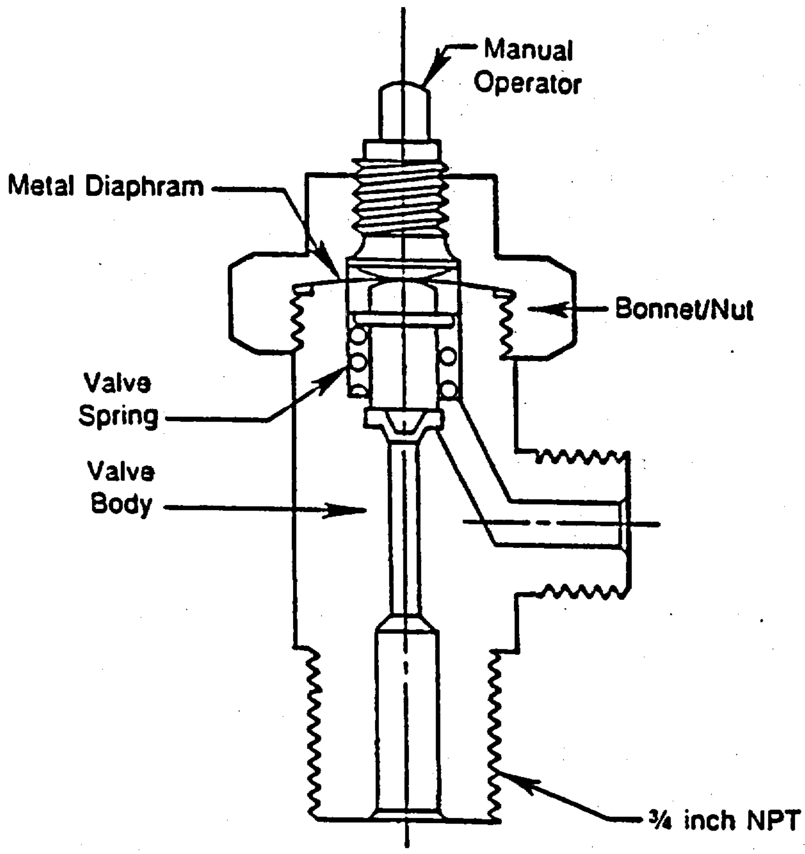

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Figure 1.2 MF&S Metal Diaphragm Valve.

The bonnet/nut is tightened using 100 foot-pounds of torque. The valve is closed using a maximum of 100 inch-pounds of torque. Torque values applied to the valve components during opening would preclude inadvertent loosening of the bonnet/nut. This was demonstrated by securing a properly assembled valve and cylinder in a bench vise. The specified torque was applied to the valve components. The valve was then opened to the full-open position, up to a maximum of 50 foot-pounds. At no time during the test did any component other than the valve stem turn. It should be noted that the valve turns only 3/4 of a turn from the full-closed position to the full-open position.

The valve is inserted in accordance with approved procedures* into the compressed gas cylinder using a litharge-and-glycerine-based, pipe joint compound. Thread engagement and torque plus the use of procedures and QA inspection are used to ensure the valve is properly placed in the cylinder. A minimum thread engagement of at least six full threads and a torque of 80 to 100 ft-lbs are required.

The primary containment cylinder and valve is inserted into a lead-filled, carbon-steel shield prior to filling with krypton-85 gas. The shield is 17-3/4 inches in diameter by 71-1/2 inches long and weighs approximately 3300 pounds. Lifting lugs are provided as part of the shield outer shell to facilitate handling. The lead shield is shown in Figure 1.3.

* This task is done in accordance with the WINCO Standard Operating Procedures Manual, IPM-XVII-I (Reference 3). Specifically, the procedures used are WP-1, Job Control Center and WP-12, Work Order Control. Each maintenance task is reviewed and approved by the cognizant personnel of the Job Control Center and each step of the task is witnessed and signed by the QA inspector.

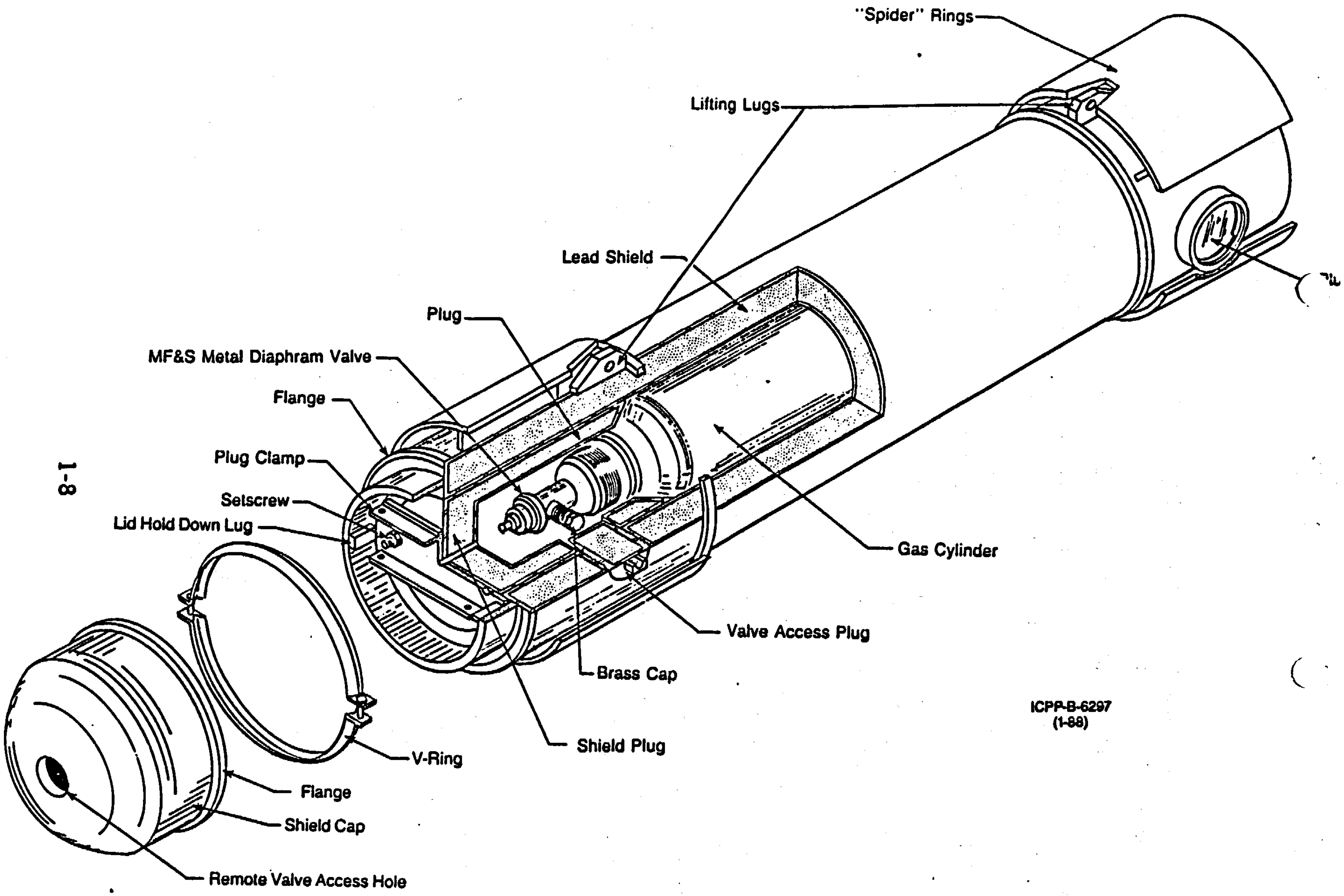


Figure 1.3 Lead Shield Cutaway.

The shield shell is constructed of 1/4-inch-thick carbon steel. Carbon steel is ASTM A36 for components fabricated from plates or sheets, ASTM A53 for piping, and ASTM A575 for merchant quality carbon steel bars. Two inches of lead are provided on the sides with four inches of lead in the top plug and in the bottom base. The primary containment packaging is oriented in the shield by a 2-inch-wide, 1/8-inch-thick steel band. The band encompasses 330 degrees inside the bottom of the shield and is welded for 240 degrees.

There are three openings provided in the shield. The first is the 9-1/2 inch end opening, through which the primary containment packaging is inserted. This opening is closed with the shield plug. The shield plug is constructed from 1/4-inch thick carbon steel and filled with lead. The bottom of the shield plug is shaped to fit the top of the compressed gas cylinder, resting on the cylinder shoulders and covering the closure valve. This protects the valve assembly from damage during all operations and hypothetical accidents. The shield plug is held in place with an 11-inch by 4-1/2 inch clamp. The ends of the clamp are beveled which causes the clamp to bind against two 1-7/8-inch by 1-inch by 5/8-inch lugs, welded onto the shield, when the two 5/8 inch set screws in the clamps are tightened. A cap further protects the shield plug. The cap consists of a 14-inch pipe cap, 3/4-inch thick. The cap is held in place with a carbon steel V-ring clamp and two 5/16-inch bolts. The second opening in the shield is on the side of the shield near the top. This opening is provided to allow access to the primary containment valve for filling the cylinder. The access port is closed using a 3-inch, lead-filled, pipe-type threaded plug. The third opening in the shield is on the same side of the shield as the second opening, only near the bottom. This opening is provided to gain access to the "Nylok" set screw that tightens the band that secures the primary containment cylinder and valve assembly into the shield. Closure of this opening is accomplished using a stepped, lead- filled plug held in place by a steel plate and retaining ring.

Steel "spider rings" at both ends of the shield packaging provide support for the shield in the thermal insulation. The rings are 12 inches wide by 1/4 inch thick with eight supporting legs. The legs are 1-3/8 inches by 1/2 inch. A 6-inch-diameter hole in each ring is provided to allow access to the valve access plug and the band-tightening plug.

The cylinder and valve assembly are completely surrounded with the lead in the lead shield, and the valve assembly is protected by the lead filled shield plug as previously noted. It should be noted that the cylinder and valve assembly are inserted into the lead shield prior to the addition of krypton and remains in the lead shield for all handling, shipping, and receiving. Thus, the valve assembly is always surrounded and protected by the lead shield while the cylinder contains krypton.

The thermal insulation is a cylindrical, end-loading overpack 30 inches in diameter by 83-1/2 inches long and weighs about 2100 pounds. Inner and outer casings are 16-gauge ASTM A240 Type 304 L stainless steel. The outer casing is reinforced with 20-inch-wide "bellybands" of 7-gauge ASTM A240 Type 304 L stainless steel. The center portion of the thermal insulation overpack, between the "bellybands", has an additional layer of 16 gauge stainless steel welded to the outer skin. Eight 1/2-inch gusset plates are welded onto the frame for added strength. A cutaway sketch of the contents without the plywood box is shown in Figure 1.4.

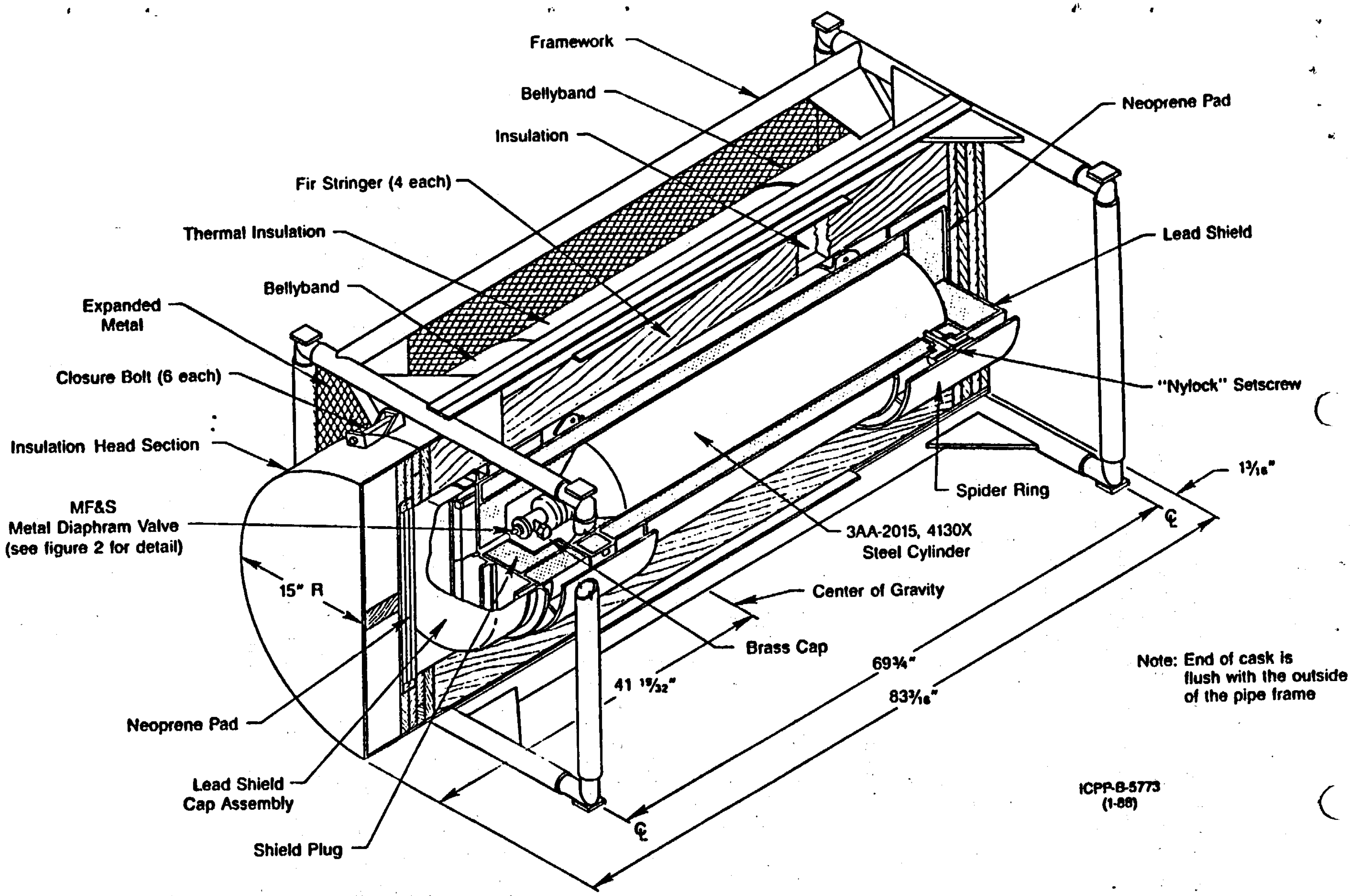


Figure 1.4 Contents Without Plywood Box.

Four 4-inch by 6-inch fir stringers, positioned 90 degrees apart, are placed as spacers between the inner and outer casing skin and extend the entire length of the thermal insulation overpack. A 5-3/4-inch-thick layer of Pittsburgh Corning Foamglas fills the remainder of the void between the inner and outer skin between the fir stringers. Laminated marine plywood is used to provide end support and insulation for the closed end of the overpack. The lid uses solid fir spacers with Foamglas for insulation. Neoprene pads, 1/2 inch thick, are used in the inner shell base and in the head section to cushion the lead shield during loading and shipment.

The thermal insulation overpack is supported in a rectangular framework of 2-inch, Schedule 40 ASTM A312 Type 304 L stainless steel pipe. This framework is welded to the "bellybands" of the overpack at eight locations, four places radially around each end. The framework is 39-1/2 inches wide by 72-1/8 inches long. The framework is used as the attachment points for lifting when external to the plywood box. Expanded metal mesh is tack welded between the framework and the "bellybands".

A plywood box snugly encloses the contents to prevent movement in the box and to provide large area bearing surfaces against the foam dunnage. The box is a 1-1/2 inch outer shell composed of two 3/4-inch pieces (except for the top which is composed of two 1/2-inch pieces) that have been laminated together with Carpenter's wood glue. The sides and ends have a 3/4-inch plywood inner liner separated by 2x4 framing boards. The entire box is loaded on a 3/4-inch piece of plywood placed inside the foam dunnage separated by two stringers (References 4 and 5).

1.3 Operational Features

Shipments in the Model No. 6400 packaging are made dry with only natural modes of heat removal. The passive nature of the packaging dunnage and contents design requires no analysis of operational features since no operations during shipment are required. See Section 7.0 for detailed operational features.

1.4 Contents of Packaging

The contents are compressed, radioactive, gaseous krypton-85 and associated impurities including: non-radioactive krypton, oxygen, nitrogen, and xenon. These impurities will have no deleterious effects on the cylinder.

The maximum amount of krypton in each shipment will be 10,000 curies with an initial maximum loading pressure of 500 psia at normal room conditions. This is approximately 1480 liters of gas at one atmosphere and 25°C. Thermal heat generation will be about 14.6 watts. Dose rates from the krypton-85 contents are about 7 millirem/h at the outside surface of the lead shield and about 2 millirem/h at one meter from this surface. The dose rates at the surface of the Model No. 6400 packaging and one meter from the surface are calculated to be <0.5 millirem/h and <0.2 millirem/h, respectively. With this krypton-85 loading, the transport index has been calculated to be 0.2.

2.0 STRUCTURAL EVALUATION

2.1 Structural Design

The structural components which contribute to safe transport are: the Model No. 6400 packaging, the polyurethane foam dunnage, and the contents which consist of a plywood box, thermal insulation, lead shield, and a compressed gas cylinder with a metal diaphragm valve. The structural design of the Model No. 6400 packaging is described in Reference 1, the foam dunnage in Reference 2 and the contents in this document. The plywood box sides and ends are fabricated of a 3/4-inch plywood liner and a 1-1/2 inch plywood outer shell separated by 3-1/2 inches. The floor and lid of the box are 1-1/2 and 1 inch thick plywood, respectively. The purpose of the box is to transform the cylindrical body and pipe framework of the thermal insulation into rectangular flat surfaces so the contents will bear uniformly on the foam dunnage very similarly to the arrangement of Reference 2. There are two differences between the foam dunnage of Reference 2 and this foam dunnage. First, the cavity inside the foam of Reference 2 is 27-1/2 x 27-1/2 x 128 inches compared to this foam's cavity size of 43 x 52 x 96-1/2 inches. This results in foam thicknesses, for Reference 2, of 23-3/4 inches on the sides, top and bottom and 21 inches on the ends. For krypton shipment, the foam thicknesses are 16 inches on the top and bottom, 11-1/2 inches on the sides, and 36-3/4 inches on the ends. Second, the weight of the contents in the foam dunnage is different. For Reference 2 the contents weight is 23,000 pounds, whereas for this package it is about 6500 pounds. (The actual weight is expected to be between 6000 and 6500 pounds. The appropriate weight will be used for calculational purposes, which will yield the more conservative results.)

The Model No. 6400 packaging was designed to absorb all normal transport and hypothetical accident loads without significant deformation to the inner cavity. Impact loads are absorbed by local yielding of the ductile outer shell and the polyurethane liner material. Puncture criteria are met through local ultimate failure of the outer shell and the polyurethane liner. A Model No. 6400 packaging prototype was analyzed and tested to the performance requirements of Code of Federal Regulations 10 CFR 71 as documented by Reference 1. The contents are subjected only to the impact loads of the defined drop tests since the Model No. 6400 packaging chassis provides isolation from the other transport parameters (e.g., water spray, compression, thermal, etc.).

The polyurethane foam dunnage will absorb additional impact loads through compressive yield and the contents, including the plywood box, will withstand all induced impact loads without structural yield or change in geometric form. Energy relationships are used to evaluate the effects of the free drop accidents on the components. The potential energy of the component is equated to the work of deformation in crushing the polyurethane foam dunnage to obtain static equilibrium. The crush area of the foam evaluated at crush depth times the material's crush stress is considered the crush force incident to impact. Normally the crush force is divided by the mass of the dropped object to obtain the peak deceleration. This deceleration is in "feet per second squared" units or in the units of the gravitational constant. To obtain deceleration in "g" units, deceleration in "feet per second squared" units is divided by the appropriate gravitational constant. Consequently, the crush force divided by the dropped weight results in deceleration in "g" units. The internal stresses within the component are determined on the basis of the calculated deceleration loading and are used to assess the appropriate modes of failure for the defined normal transport and hypothetical accident impact loads. The compressive yield of the dunnage is sufficient to support the contents under accident induced loads such that the additional impact absorbing characteristics of the as-built Model No. 6400 packaging chassis are not required. However, in Section 2.7, two analyses are performed; one where all the impact energy of the drop test is absorbed by the Model No. 6400 packaging and the second where all the energy is absorbed by the foam dunnage. Either procedure produces sufficiently low decelertions, so that the contents will survive the drop test.

2.2 Weights and Center of Gravity

The allowable gross weight of the Model No. 6400 packaging shipping container is 45,000 pounds. The maximum weight of the individual components is as follows:

a.	Empty Model No. 6400 Packaging	19,000 lbs
b.	Polyurethane Foam Dunnage	2,500 lbs
c.	Plywood Box	1,000 lbs
d.	Thermal Insulation	2,100 lbs
e.	Lead Shield	3,300 lbs
f.	Compressed Gas Cylinder With Valve	100 lbs
TOTAL (maximum)		28,000 lbs

All components are symmetrical and the center of gravity of the empty or loaded Model No. 6400 packaging is at the approximate mid-point for all orientations.

2.3 Mechanical Properties of Materials

The materials of construction of the Model No. 6400 packaging are documented in Reference 1, the polyurethane foam dunnage in Section 1.2.2 of this report, and the contents in Section 1.2.3. The plywood box is constructed of American Plywood Association (APA) grade "A-C" with exterior glue plywood and the solid wood is National Forest Products

Association (NFPA) Douglas Fir (North) grade "No. 2 or better". The plywood box walls are essentially sandwiched between the outer steel cylindrical body and pipe framework of the thermal insulation on the inside and the polyurethane foam dunnage on the outside and, as such, the walls are subjected to direct bearing loads (see Section 7.0).

The inner and outer shells, bellybands, pipe and structural frame of the thermal insulation (see Figure 1.4 and attached drawings) are manufactured of Type 300 stainless steel. Most of the stainless steel is Type 304 L which has a yield strength of 25,000 psi and an ultimate strength of 70,000 psi. The remaining stainless steel is Type 304, which has a yield strength of 30,000 psi and an ultimate strength of 75,000 psi. These properties are from the ASME Boiler and Pressure Vessel codes. These types of stainless steel are relatively unaffected by temperatures over the range of -40°F to +100°F. Fir stringers, spacers, and marine plywood are used between the stainless steel shells. They serve the function of spacers rather than a structural function. Also located between the shells and the wood spacers is Pittsburg Corning Foamglas. It provides thermal insulation and not structural support.

The lead shield (see Figure 1.3) is constructed of ASTM A36, A53, and A575 carbon steel and ASTM B29 pig-lead. The yield and ultimate strengths are 36,000 psi and 58,000 psi, 35,000 psi and 60,000 psi, and 45,000 psi and 71,000 psi (for ASTM A575 grade 1117) for the carbon steels, respectively. The lead is used for shielding and not structural support. The materials of the compressed gas cylinder and metal diaphragm valve are documented in Section 1.2.3.

2.4 General Standards For All Packages

Most requirements of this section are addressed in References 1 and 2.

Positive closure of the primary containment packaging (the compressed gas cylinders and valve) is accomplished using the Manifold Fabricators and Supply metal diaphragm valve. The valve is tested prior to shipment and required to meet the "leak tight" definition of ANSI N14.5. The "leak tight" definition is more restrictive than the allowed leak rate of 10 CFR 71 for krypton-85 (see Chapter 4.0 for detailed values). Valve operation requires that tools be inserted through openings provided in the shield packaging. These tools are removed or secured by a set screw to preclude inadvertent turning. As a secondary precaution, a brass cap is installed on the valve outlet, plugging the outlet to help prevent release of material should the valve develop a leak during transit. The entire valve assembly is protected from physical damage by the top of the lead shield which totally surrounds the valve.

Krypton-85 gas has no chemical or galvanic reactions between it and the materials used to fabricate the packaging. The krypton-85, as intended for shipment, is a noble, inert gas contaminated with xenon, nitrogen, and oxygen.

2.5 Lifting and Tie-Down Standards For All Packages

The requirements of this section are applicable only to the Model No. 6400 packaging and are addressed in References 1 and 2.

2.6 Normal Conditions of Transport

The first requirement for normal conditions of transport is the heat condition. The thermal evaluation is presented in Section 3.0. It is based on a krypton-85 content of 10,000 curies. This curie content generates about 14.6 watts of heat which is within the 30 watt limit for the Model No. 6400 packaging. The maximum temperature of the krypton gas will be about 144°F, which will result in an internal gas pressure of 560 psia. The maximum temperature noted in the entire system is the internal gas temperature of 144°F which is well below the Model No. 6400 packaging design temperature of 200°F. The gas will be initially loaded to a maximum of 500 psia at 80°F. The outside surface of the Model No. 6400 packaging would be at 101°F with the outside ambient air at 100°F. Reference 2 states that the solar induced thermal loading would not exceed the insulational features of the Model No. 6400 packaging foam insulation. In summary, the heat generation of the krypton-85 is not detrimental to the krypton gas cylinder, lead shield, thermal insulation, plywood box, polyurethane foam dunnage or the Model No. 6400 packaging.

The cold requirement of -40°F in still air and shade would decrease the temperature of the loaded primary containment packaging to 3.3°F. This would result in an internal pressure of 430 psig, assuming an initial loading of 10,000 curies of krypton-85 to a maximum pressure of 500 psia. The surface temperature of the loaded Model No. 6400 packaging would be about -39°F.

A more severe case for thermal stress (because a lower temperature is achieved) during normal conditions of transport would be that of a package subjected to -20°F containing virtually no krypton-85 (1000 curies) and consequently having very little internal heat decay. In this case, the krypton gas would eventually attain a temperature of -15.3°F and the initial cylinder pressure of 500 psig would be reduced to 412 psig.

For both of these cases (with and without internal decay heat), the final package pressure is well within the package design pressure of 1,000 psig.

The pressure requirement is addressed in References 1 and 2. The Model No. 6400 packaging is vented which eliminates differential pressure. The foam dunnage and plywood box are not air tight. The thermal insulation and lead shielding also are not pressure resisting. The compressed gas cylinder and the metal diaphragm valve, which are rated for 2015 psig and 1000 psig, respectively, can easily sustain the differential pressure requirement.

Vibration and water spray requirements are addressed in Reference 2.

Reference 2 addresses the effects of a one foot free drop. Since the krypton shipment in the Model No. 6400 packaging results in a lower total weight (28,000 pounds), the regulations require a 2 foot free drop. From Reference 2, the maximum damage to the Model No. 6400 packaging was expected during a corner drop due to the smaller cross section of material to absorb the impact loads. A total of four 40-inch drop tests and one 30-foot drop test produced no noticeable effect on the prototype inner containment boundary; therefore, none would be expected for a 2 foot corner drop. However, the greatest shock load to the contents will occur during a side drop or an end drop. During these drops the foam dunnage would be subjected to compressive yield. Using the theory of Reference 2 and absorbing all the energy by the foam dunnage (none by the Model No. 6400 packaging), results in the following:

From the energy balance where Potential Energy = Internal Energy

$$W(H + D_c) = K_D \, S_c \, A_c \, D_c$$

Then

$$D_c = \frac{WH}{K_D S_c A_c - W}$$

where

D_c	=	Material crush depth (inches)
W	=	Weight of loaded storage compartment (6500 pounds maximum or 6000 pounds minimum)
H	=	Drop height (24 inches)
K_D	=	Dynamic crush strength to static crush strength factor (approximately 1.0 for foam)
S_c	=	Static crush strength (80 pounds/inch^2 for foam)
A_c	=	Crush area (2236 square inches of foam for end drop) (5018 square inches of foam for bottom drop)

For maximum weight contents:

$$D_c = \frac{6500\ (24)}{1(80)2236 - 6500} = 0.9 \text{ inches for end drop}$$

$$D_c = \frac{6500\ (24)}{1(80)5018 - 6500} = 0.4 \text{ inches for bottom drop}$$

For minimum weight contents:

$$D_c = \frac{6000\ (24)}{1(80)2236 - 6000} = 0.8 \text{ inches for end drop}$$

$$D_c = \frac{6000\ (24)}{1(80)5018 - 6000} = 0.4 \text{ inches for bottom drop}$$

Deceleration G_a (in the units of the gravitational constant) is:

$$G_a = \frac{K_D S_c A_c}{M}$$

where

$$M = \text{Mass of object} = \frac{W}{g_c}$$

g_c = Gravitational constant = 32.2 feet/second^2

To obtain deceleration G in "g" units, divide by the gravitational constant

$$G = \frac{K_D S_c A_c}{(W/g_c)} \frac{1}{g_c} = \frac{K_D S_c A_c}{W}$$

For maximum weight contents:

$$G = \frac{1(80)2236}{6500} = 27.5 \text{ g for end drop}$$

$$G = \frac{1(80)5018}{6500} = 61.8 \text{ g for bottom drop}$$

For minimum weight contents:

$$G = \frac{1(80)2236}{6000} = 29.8 \text{ g for end drop}$$

$$G = \frac{1(80)5018}{6000} = 66.9 \text{ g for bottom drop}$$

The actual decelerations will be less since the above calculations neglected the energy absorbing features of the Model No. 6400 packaging.

From Reference 2, maximum damage to the Model No. 6400 packaging is expected during a corner drop due to the smaller cross section of material to absorb the impact loads. During an actual 2 foot corner drop, the Model No. 6400 packaging would be slightly damaged (Reference 2).

In summary, the Model No. 6400 packaging corner would be slightly damaged during a 2 foot corner drop (from Reference 2) and the end of the foam dunnage, would be crushed a maximum of 0.9 inches during a 2 foot end drop. Since the contents, without the plywood box, as shown in Appendix 2.8, are capable of withstanding a 177 g deceleration, they will easily sustain a 67 g deceleration (assuming the foam dunnage absorbs all the energy) from a 2 foot bottom drop. The gas cylinder and valve have been tested at 200 g deceleration. Consequently, no loss of krypton-85 or radiation shielding would occur. An in-process shipment could be completed; however, the Model No. 6400 packaging chassis and the polyurethane foam dunnage would be evaluated for possible repair prior to subsequent shipments.

The corner drop, compression and penetration requirement are addressed in Reference 2.

2.7 Hypothetical Accident Conditions

Reference 1 and 2 report the results of the 30 foot drop test on a fully loaded (45,000 pound) Model No. 6400 packaging. Since the krypton carrying Model No. 6400 packaging weighs 28,000 pounds, these results will be revised to accurately predict the crush depth and peak deceleration for the lighter loaded packaging. For all drop configurations, the crushed volume is approximately proportional to weight. For the flat end and side drops, the crushed volume is proportional to crushed depth. For the edge drops, the crushed volume is proportional to the square of the crushed depth. For the corner drop, the crushed volume is proportional to the cube of the crushed depth. This is evident from the relationships developed on page 68 of Reference 1. Deceleration is approximately inversely proportional to weight and proportional to the crushed area. For the flat end and side drop the crushed area is constant. For the edge drops, the crushed area is proportional to the cushed depth. For the corner drop, the crushed area is proportional to the crushed depth squared. These relationships, also, are from page 68 of Reference 1. The following, Table 2.1, lists the design characteristics, from References 1 and 2, of the fully loaded Model No. 6400 packaging and the adjusted values for the krypton carrying Model No. 6400 packaging.

TABLE 2.1

Design Characteristics

	45,000 Pound Model No. 6400 Packaging		28,000 Pound Model No. 6400 Packaging	
Orientation of Impact	Peak Deceleration (g)	Crush Depth (in)	Peak Deceleration (g)	Crush Depth (in)
Flat, End	19.7	18.39	32	11.4
Flat, Side	50.6	7.14	81	4.4
Edge, 240 In.	39.4	18.79	50	14.8
Edge, 96 In.	24.9	30.12	32	23.8
Corner	25.0	47.21	29	40.3

This tabulation considers only the impact absorbing features of the polyurethane foam contained in the walls of the Model No. 6400 packaging. The calculated deceleration for the flat drops are considered realistic since the crushing of the outer shell is not a factor.

The polyurethane foam dunnage will retain the contents within the center of the 76 inch x 76 inch x 172 inch Model No. 6400 packaging cavity. During a hypothetical 30 foot drop, the deceleration energy of the storage compartment will be absorbed by the combined dunnage foam and Model No. 6400 packaging liner foam. Five-pound per cubic foot density polyurethane foam has been compression tested and found to fail along an approximate 45° shear plane such that the deceleration energy is absorbed by the compression of an obelisk volume of foam under the applicable plywood box surface. This compression failure characteristic distributes the plywood box impact load over the applicable Model No. 6400 packaging inner wall as required of Reference 1. The plywood box load would be distributed over approximately 100% of the inner wall during an end drop, at least 60% of the side wall during a side drop, and approximately 83% of the top or bottom walls during a top or bottom drop, as compared to the minimum of 60% required by Reference 1. A check of inner wall bearing pressure insured that the Model No. 6400 packaging inner wall would not be overstressed in bearing.

Using the previously developed equation:

$$D_C = \frac{WH}{K_D S_C A_C - W}$$

where:

A_C = Effective crush area $= \frac{V_C}{D_C}$

V_C = Effective crush volume $= \frac{1}{6} D_C \left[AB+(A+A_1)(B+B_1)+A_1B_1\right]$

(Obelisk or frustrum of a rectangular pyramid)

Where: A and B are the lengths of the adjacent sides of the base of the obelisk (page 2-18 of Reference 2)

A_1 and B_1 are the lengths of the adjacent sides of the top surface of the obelisk.

The other terms are previously defined.

For an end drop with maximum contents weight, D_c is assumed to be 9.3 inches.

Then

$$A_1 = 43 \text{ in}$$
$$B_1 = 52 \text{ in}$$
$$A = 61.6 \text{ in}$$
$$B = 70.6 \text{ in}$$
$$V_c = 30{,}084 \text{ in}^3$$
$$A_c = 3235 \text{ in}^2$$

$$D_c = \frac{6500(360)}{1(80)3235-6500} = 9.28 \text{ in}$$

At maximum crush depth

$$A_c = AB = 4349 \text{ in}^2$$

and deceleration is

$$G = \frac{K_D S_c A_c}{W}$$

$$G = \frac{1(80)4349}{6500} = 54 \text{ g}$$

For an end drop with minimum contents weight, D_c is assumed to be 8.74 inches.

Then

A_1 = 43 in

B_1 = 52 in

A = 60.48 in

B = 69.48 in

V_c = 27,690 in^3

A_c = 3168 in^2

$$D_c = \frac{6000(360)}{1(80)3168-6000} = 8.73 \text{ in}$$

At maximum crush depth

A_c = 4202 in^2

$$G = \frac{1(80)4202}{6000} = 56 \text{ g}$$

For a side drop with maximum contents weight, D_c is assumed to be 5.9 inches.

Then

A_1 = 43 in

B_1 = 96.5 in

A = 54.8 in

B = 108.3 in

V_c = 29,612 in^3

A_c = 5019 in^2

$$D_c = \frac{6500\ (360)}{1(80)5019-6500} = 5.92 \text{ in}$$

At maximum crush depth

$$A_c = 5935\ in^2$$

$$G = \frac{1(80)5935}{6500} = 73\ g$$

For a side drop with minimum contents weight, D_c is assumed to be 5.5 inches.

Then

$$A_1 = 43\ in$$
$$B_1 = 96.5\ in$$
$$A = 54\ in$$
$$B = 107.5\ in$$
$$V_c = 27{,}264\ in^3$$
$$A_c = 4957\ in^2$$

$$D_c = \frac{6000\ (360)}{1(80)4957-6000} = 5.53\ in$$

At maximum crush depth

$$A_c = 5805\ in^2$$

$$G = \frac{1(80)5805}{6000} = 77\ g$$

For a bottom drop with maximum contents weight, D_c is assumed to be 5.1 inches.

Then

A_1 = 52 in
B_1 = 96.5 in
A = 62.2 in
B = 106.7 in
V_c = 29,631 in^3
A_c = 5810 in^2

$$D_c = \frac{6500\ (360)}{1(80)5810-6500} = 5.11 \text{ in}$$

At maximum crush depth

A_c = 6637 in^2

$$G = \frac{1(80)6637}{6500} = 82 \text{ g}$$

For a bottom drop with minimum contents weight, D_c is assumed to be 4.76 inches.

Then

A_1 = 52 in
B_1 = 96.5 in
A = 61.52 in

$$B = 106.02 \text{ in}$$
$$V_c = 27{,}394 \text{ in}^3$$
$$A_c = 5755 \text{ in}^2$$

$$D_c = \frac{6000\ (360)}{1(80)5755-6000} = 4.75 \text{ in}$$

At maximum crush depth

$$A_c = 6522 \text{ in}^2$$

$$G = \frac{1(80)6522}{6000} = 87 \text{ g}$$

Two sets of calculations have been presented. The first assumed all the energy from a 30 foot drop test would be absorbed by the Model No. 6400 packaging. This resulted in a maximum peak deceleration of 81 g for the Model No. 6400 packaging impacting on its side or bottom. The second assumed all the energy was absorbed by the foam dunnage. This resulted in a maximum peak deceleration of 87 g for the Model No. 6400 packaging impacting on its bottom with the minimum contents weight. When these two energy absorbing features are combined, the contents will be subjected to a deceleration less than 81 g. In Appendix 2.8, it has been shown that the contents, without the plywood box, will withstand 177 g. Therefore, this combined packaging will sustain the most severe 30 foot drop without leaking krypton-85 or compromising the radiation shielding.

The puncture test damages the exterior of the Model No. 6400 packaging and causes deceleration forces on the contents. The effects on the Model No. 6400 packaging are discussed fully in References 1 and 2. Since the puncture test involves only a rather small crushed area compared to the bottom impact, 30 foot drop test crushed area, the deceleration forces on the contents will be less than for the 30 foot drop test.

The thermal test involves assessing the effects of exposure of the Model No. 6400 packaging to 1475°F for 30 minutes. The effect of this test is discussed in References 1 and 2 and Section 3.0 of this report. The contents of the Model No. 6400 packaging will experience a calculated temperature rise of less than 10°F from this test. This test has an insignificant effect on the contents of the Model No. 6400 packaging.

The effects of the immersion test on the Model No. 6400 packaging are documented in References 1 and 2. Since the Model No. 6400 packaging is a vented container, water will penetrate the dunnage and the contents. There is no water seal in the head section of the thermal insulation. Water would enter the thermal insulation and subsequently, into the lead shield through the tool entry ports. Water could not penetrate into the gas cylinder since it has a sealed closure and is pressurized to 500 psig. There are no nuclear or radiological consequences from the immersion tests.

In summary (from References 1 and 2), the Model No. 6400 packaging, when subjected to a hypothetical accident condition, e.g., 30 foot drop test, puncture test or the thermal test, will sustain some damage. The outer shell would deform and might rupture, the polyurethane liner would crush, and possibly the inner liner might plastically deform. However, in all cases, the contents remain protected. That is, the lead shield will remain intact and will continue to provide protection from radiation and the gas cylinder and valve will continue to provide containment for the krypton-85 gas. During the 30 foot drop test, the polyurethane foam dunnage will be subjected to compressive yield failure; however, the contents will not be damaged. The water immersion test will fill the cavities of the Model No. 6400 packaging, the inner foam dunnage, and plywood box, the thermal insulation, and the lead shield with water, but will cause no damage.

It is concluded that this combination packaging will retain the material and protect the public and the environment from radiation and contamination under these hypothetical accident conditions.

2.8 Appendix

The contents, without the plywood box, have been analyzed for a 30 foot drop onto an unyielding surface. Several cask orientations were investigated. The side drop, where the impact first occurs on the pipe framework causing pipe deformation and weld failures and secondarily on the body causing crushing of the Foamglas insulation, was found to be less severe in deceleration than the end drops. Likewise, oblique drops on either end corners were found to be less severe in deceleration than the end drops. The closed end of the thermal insulation is layers of solid plywood (no Foamglas). The head section end contains 97 square inches of solid fir wood and 598 square inches of foam. Since wood has a higher compressive yield (980 psi) than Foamglas (25 psi) and a lower strain at yield, the deceleration for end drops is greater than for other drop orientations. This Appendix presents the deceleration calculations for the two end drops of an assembly consisting of the thermal insulation, lead shield, and the compressed gas cylinder (without the Model No. 6400 packaging, the foam dunnage, and the plywood box).

An end drop on the closed end was analyzed first. The closed end of the thermal insulation contains four layers of plywood totaling 3-3/8 inches thick. Since the volume of wood that would be crushed greatly exceeds the volume of metal, the metal skin will be omitted in this calculation. The stress-strain curve for the Douglas fir plywood is shown in Figure 2.1. A trilinear representation of the curve resulted in the following data:

σ_{pl}	=	stress at point of plasticity	=	980 psi
ϵ_{pl}	=	strain at point of plasticity	=	0.0175 in/in
σ_m	=	stress at mid point of plasticity	=	2850 psi
ϵ_m	=	strain at mid point of plasticity	=	0.3836 in/in
σ_E	=	stress at end of test	=	5390 psi
ϵ_E	=	strain at end of test	=	0.5064 in/in
E_1	=	Elastic modulus	=	56,000 psi
E_2	=	first plastic modulus	=	5110 psi
E_3	=	second plastic modulus	=	20,700 psi

Deformation of the plywood during the 30 foot drop test is found by equating potential energy to strain energy.

$$P.E. = W\,(h + \delta)$$

$$\epsilon.E. = [1/2\ \sigma_{pl}\epsilon_{pl} + \sigma_{pl}\ (\epsilon_m - \epsilon_{pl}) + 1/2\ (\sigma_m - \sigma_{pl})(\epsilon_m - \epsilon_{pl}) + \sigma_m(\epsilon - \epsilon_m) + 1/2\ (\sigma - \sigma_m)(\epsilon - \epsilon_m)]V_{total}$$

for

$$\epsilon \geq \epsilon_m$$

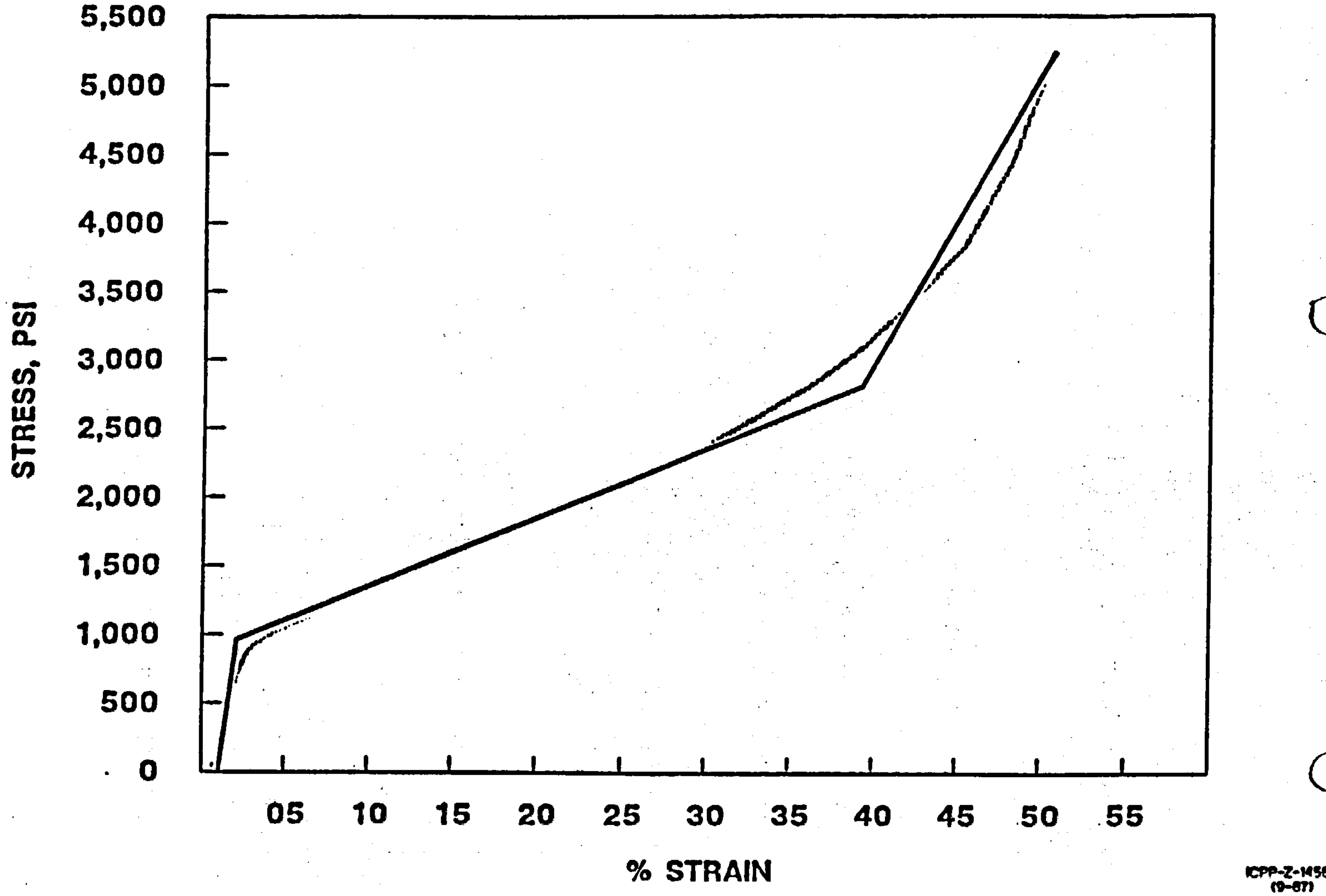


Figure 2.1 Stress/Strain Curve for Douglas Fir Plywood

Recognizing: $\epsilon = \frac{\delta}{l}$

$$\sigma = E_3 (\epsilon - \epsilon_m) + \sigma_m = E_3 (\frac{\delta}{l} - \epsilon_m) + \sigma_m$$

$$V_{total} = Al$$

and simplifying:

$$\epsilon.E. = \frac{E_3 A}{2l} \delta^2 + A (\sigma_m - E_3 \epsilon_m)\delta +$$

$$\frac{Al}{2}(\sigma_{pl}\epsilon_m - \sigma_m \epsilon_{pl} - \sigma_m \epsilon_m + E_3 \epsilon^2_m)$$

Equating strain energy to potential energy gives:

$$\frac{E_3 A}{2l} \delta^2 + [A(\sigma_m - E_3 \epsilon_m) - W]\delta + \frac{Al}{2}(\sigma_{pl}\epsilon_m -$$

$$\sigma_m \epsilon_{pl} \sigma_m \epsilon_m + E_3 \epsilon^2_m) - Wh = 0$$

where:

$$A = \frac{\pi}{4}(14.5)^2 + 12(1/2)\ 1\ 3/8 + \frac{\pi}{4}(17.75^2 - 17.25^2)$$

$$= 187.12 \text{ in}^2$$

l = thickness of plywood = 3 3/8 in.

W = weight of contents = 3250 lb

h = height of drop = 360 in.

Substituting into the equation and solving the quadratic for δ results in:

$$\delta = 2.05 \text{ in.}$$

$$\epsilon = \frac{\delta}{l} = 0.607 \text{ in/in} > \epsilon_m = 0.384 \text{ in/in}$$

The strain is in the strain range assumed.

It should be noted that since this deflection (from an end drop) was calculated for the plywood and will occur internal to the outer steel cylindrical shell of the thermal insulation (see item 5 of Reference WINCO Dwg. 134524), it is expected that the external pipe framework will have very little effect on this result.

Average deceleration

$$d = \frac{h}{\delta} + 1 = \frac{360}{2.05} + 1$$

$$= 177 \text{ g.}$$

Note that the peak deceleration will be somewhat higher than 177 g. However, it is shown later that the 177 g deceleration is about the maximum deceleration, by easy analytical methods, that the lead shield can sustain.

Check the deceleration for a 30 foot drop onto head section end of the thermal insulation. The lid contains fir wood 2 inches wide by 5-3/4 inches thick.

$$A = [(\frac{17.5 + 14.4}{2}) 2 + (20.375 - 4)]2$$

$$= 96.6 \text{ in}^2$$

$$l = 5.75 \text{ in.}$$

h = 360 in.

W = 3250 lb

σ_y = 3400 psi (from the previous end drop calculation)

Deceleration is:

$$d = \frac{\sigma_y A}{W} = \frac{3400\ (96.8)}{3250}$$

$$= 101\ g.$$

This deceleration represents an upper bound since σ_y was calculated from a confined plywood test. The diameter of the plywood test specimen was about twice the diameter of the loaded area. The three wood segments in the head section are 2 inches wide by 5-3/4 inches thick planks totalling about 4 feet long arranged in a cross-hatched pattern. The spaces between the planks are filled with Foamglas. When the planks are impact loaded on the 2 inch wide edge, the wood crushes by both compression and lateral deflection. Therefore, it behaves as if it is unconfined and the deceleration is an upper bound.

To verify that the strain is in the appropriate strain range:

$$\delta = \frac{h}{d - 1} = \frac{360}{101 - 1}$$

$$= 3.6 \text{ in.}$$

$$\epsilon = \frac{\delta}{l} = \frac{3.6}{5.75}$$

$$= 0.62 \text{ in/in} > \epsilon^m = 0.384 \text{ in/in}$$

Therefore, the 30 foot drop test on the closed end of the thermal overpack produces a more severe deceleration than the drop test on the head section end (177 g versus 101 g, respectively).

As an upper bound the 177 g deceleration from the closed end drop test will be used to determined whether the lead in the lead shield may slump.

$$\sigma = \frac{dW}{A}$$

where

d = deceleration
W = component weight
A = component cross-sectional area

Addressing the lead in the base of the closed end of the lead shielding package:

$$A = \frac{\pi}{4}(14)^2 = 154 \text{ in}^2$$

W = Total weight of lead shield plus contents

= 3250 lb

$$\sigma = \frac{177\ (3250)}{154} = 3{,}740 \text{ psi} < 5{,}000 \text{ psi}$$

According to the "Cask Designers Guide", the dynamic flow pressure of lead is 5,000 psi. Addressing the lead in the walls of the lead shielding package:

$$A = \frac{\pi}{4}(14^2 - 10^2) = 75.4 \text{ in}^2$$

$$W = \text{weight of lead in the walls}$$

$$= (75.4)(60.25)\frac{710}{1728}$$

$$= 1{,}870 \text{ lb}$$

$$\sigma = \frac{177\ (1870)}{75.4} = 4{,}390 \text{ psi} < 5{,}000 \text{ psi}$$

Therefore, the stresses in the lead in both components of the body of the lead shielding package do not exceed the dynamic flow pressure of lead. The lead will not slump. Furthermore, the lead is enclosed by 1/4 inch carbon steel shells both inside and outside. Analyses of both the inside and outside shells were performed to determine the maximum allowable pressure in the lead cavity. Hoop tension in the outer shell produces lower pressure. From the ASME B&PV Code, Section 8, Division 1, Paragraph UG-27:

$$P = \frac{SE\ t}{R + 0.6t}$$

where

S = maximum allowable stress value
= 12,000 psi (ASTM A-53)

E = joint efficiency
= 1.0

t = shell thickness
= 0.25 in.

R = inside radius of the outer shell
= 7.0 in.

$$P = \frac{12,000\ (1.0)\ 0.25}{7 + 0.6\ (0.25)}$$

= 420 psig (allowable internal pressure for the outside shell)

For S = material yield = 30,000 psi

$$P = \frac{30,000\ (1.0)\ 0.25}{7 + 0.6\ (0.25)}$$

= 1050 psig (internal pressure to yield the outside shell)

For the inside shell, which would be under external pressure, using the procedures of paragraph UG-28, the allowable pressure is 443 psig. The weld between the bottom plate and outer wall is a 1/4 inch fillet weld. The bottom plate of the inside cavity is welded continuously to the outer wall with a 3/16 inch fillet weld. Since the lead stress does not exceed the dynamic flow pressure for lead, these welds should be only lightly loaded. Therefore, the steel structure substantially reinforces the lead and provides an additional barrier to prevent lead slump. The lead will not slump when the completely assembled contents without the plywood box are subjected to the 30 foot end drop test. The end drop test has been determined to be an upper bound for all drop tests.

Since the compressed gas cylinder and valve assembly has been successfully drop tested to 200 g, and since the lead shield can sustain a 177 g deceleration on the closed end (which has been shown to be the worst case), the contents, without the plywood box, have been analytically demonstrated capable of sustaining a 177 g deceleration.

3.0 THERMAL EVALUATION

3.1 General

The thermal performance of the Model No. 6400 packaging, dunnage, and contents was analyzed in view of the proposed shipment of up to 10,000 curies of krypton-85 gas contained in the DOT 3AA-2015 gas cylinder. Results indicate that the pressure of the krypton-85 contained in the gas cylinder and the maximum temperatures of the shipping container are well within the specified limits. The proposed krypton-85 shipment complies with the requirements for thermal limitations as given in 49 CFR 173.442 and for normal conditions of transport as given in 10 CFR 71.71.

The allowable pressure of the gas contained within the gas cylinder is limited by the valve to 1000 psig. The certified heat load for the Model No. 6400 packaging is 30 watts and the design temperature is 200°F [Docket 71-6400: Package ID: USA/6400/B()F]. The limiting surface temperature is 180°F, and the limiting temperature for the foam insulation is about 350°F where the foam will start to shrink prior to decomposing (at about 400°F) (Docket 71-6400, Reference 1).

The analysis considers conduction and convection with material properties of the foam taken from Marks Standard Mechanical Engineering Handbook, Perry's Chemical Engineering Handbook, and the manufacturer's data. The analysis is conservative in that the heat rejection from the ends and from the bottom of the Model No. 6400 packaging were neglected.

Results of the analysis show that the heat generation of the 10,000 curies of krypton-85 is about 14.6 watts which is well within the certified 30 watt limit for the Model No. 6400 packaging. The maximum temperature of the krypton-85 gas will be about 144°F and the corresponding gas pressure will be about 560 psia which is well below the limiting 1000 psig. The maximum temperature noted in the entire system was the internal gas temperature of 144°F which is well below the Model No. 6400 packaging design temperature of 200°F (Reference 1). The maximum skin temperature of the Model No. 6400 packaging was calculated to be about 101°F which is well below the 180°F (exclusive use shipment) limitations given in 49 CFR 173.442. These results as summarized in Table 3.1 are noted to be well below the specified limits and indicate that the use of the Model No. 6400 packaging for the proposed shipment of up to 10,000 curies of krypton-85 is acceptable from a thermal viewpoint.

The Model No. 6400 packaging was analyzed for solar induced thermal loads (Docket 71-6400); the results show that solar induced thermal loading would not exceed the insulational features of the foam liner which thereby inhibits an extensive internal temperature rise.

The required 30 minute, 1475°F fire condition (10 CFR 71.73) was analytically and experimentally considered in Docket 71-6400. Analysis results indicate that "...the content's temperature will at no time be raised more than 10°F". The fire test conditions (time and temperature) significantly exceeded the test requirements and the internal temperature did not exceed 150°F. The fire analysis and test were conducted for a urethane thickness of only seven inches. The Model No. 6400 packaging and contents has a minimum of 21-1/2 inches of urethane foam between the cylinder containing the krypton gas and the outside walls of the shipping container. Therefore, the thermal protection provided by the Model No. 6400 packaging and contents exceeds the requirements for protecting the gas cylinder in the event of a fire.

Analysis results considering a shipment of 10,000 curies of krypton-85 in an environment of -40°F indicate that the temperature of the gas

TABLE 3.1

Comparison of Actual vs Allowable Conditions

Parameter	Design/Limit	Analytical Results
Heat Load, Watts	30.0	14.6
Gas Temperature, °F	NA	144
Gas Pressure, psia	1015	560
Skin Temperature, °F		
Exclusive Use	180	101
Other Than Exclusive Use	122	101
Maximum Temperature, °F		
Shipping Overpack	200	120

cylinder will be about 3.3°F, the temperature of the gas will be about 4.0°F and the corresponding pressure of the gas will be about 430 psia (assuming a maximum initial pressure of 500 psia). Neither the low-alloy steel gas cylinder, nor the stainless steel valve are adversely affected at any temperature between 355°F and -40°F. Therefore, a shipment of 10,000 curies of krypton-85 in a -40°F environment is acceptable from a thermal viewpoint.

A "normal condition of transport" (10 CFR 71) includes an environment ranging between -20°F and 100°F. A small krypton-85 shipment of 1,000 curies (1.46 watts) was, therefore, considered in a -20°F environment. Results of the analysis indicates that the temperature of the krypton-85 gas and of the gas cylinder will be about -15.3°F. The corresponding pressure of the gas will be about 411.8 psia (assuming a maximum initial pressure of 500 psia). The maximum temperature of the entire system is the -15.3°F temperature of the gas. These conditions are well within the limits of the Model No. 6400 packaging and contents and are, therefore, acceptable from a thermal viewpoint.

4.0 Containment

4.1 Introduction

The primary containment of the krypton-85 is a DOT gas cylinder equipped with a metal diaphragm valve. The cylinder in turn is contained in the additional contents (i.e., lead shield, etc.), the dunnage, and the Model No. 6400 packaging; however, these items which contain the cylinder are not air tight and will permit any leakage from the cylinder/valve to escape without damage to the Model No. 6400 packaging.

4.2 Physical Containment of Contents

The Model No. 6400 packaging shipping container physical containment (vented) boundary consists of the 3/16 inch thick mild steel inner shell and the 1/4 inch thick aluminum closure plate with full length silicone rubber gasket. The closure plate is secured to the inner shell with 36-1/2 inch diameter steel bolts torqued to 35-45 foot pounds. The addition of the krypton contents is compatible with the original container design criteria as summarized below:

1. The existing Model No. 6400 chassis will be used without modification and no new containment penetrations are incorporated (Reference 1, Paragraph 2.1.1.1).

2. Shipments will continue to be made dry with only natural modes of heat removal (Reference 1, Paragraph 1.2.2).

3. The center of gravity of the loaded Model No. 6400 packaging will remain near the geometric center of the container with the use of the polyurethane foam inner liner dunnage.

4. The impact loads of the new storage compartment will be distributed over the applicable surface area of the Model No. 6400 cavity (Reference 1, Paragraph 2.7.1.2).

5. Acceptable internal temperatures and pressure will be generated during transport (Reference Chapter 3).

4.3 Primary Containment

As noted in the general description (Section 1), the primary containment of the krypton is a DOT 3AA-2015, 4130X steel, compressed gas cylinder equipped with a Manifold Fabricators and Supply metal diaphragm valve. The cylinder is authorized for pressure up to 2015 psig and was tested to 2200 psig at room temperature, but the cylinders will be loaded only to a maximum of 500 psia at room temperature. The maximum pressure under the worst accident conditions is calculated to be 614 psia (Section 3.0). The gas cylinder bottles will be hydrotested to 3360 psig within five years of use in accordance with DOT requirements. The valves have a pressure rating of 1000 psig, and similar valves have been tested to 2200 psig. The cylinders and valves are for one time use only and are not reused for krypton transportation.

4.4 Normal Conditions of Transport

All operations, e.g., the cylinder and valve assembly, krypton loading in the cylinder, and the valve closure, are done in accordance with tested and approved procedures (Reference 3) to assure consistent and proper assembly in order to maintain a leak tight containment. In addition, the primary containment bare cylinder and valve arrangement will be tested to ensure that the leak rate is less than 0.0014 μCi/sec prior to shipment. This requirement for leak tightness is applied to the normal conditions of transportation. Previous shipments of krypton and the recent limited number of shipments with the Department of Energy certification (Section 1.1) were all loaded in this manner and met the "leak tight" criteria for loading and during normal transportation. Also, as noted in Section 1.0, the cylinder and valve arrangement are well protected with the contents itself plus the protection of the dunnage and the Model No. 6400 packaging. This primary containment for krypton was also previously tested for leak tightness under conditions simulating actual loading of 74,000 curies of krypton-85 gas which is at a higher pressure than for the 10,000 curies. The tests showed the primary containment was and can be made leak tight to less than 0.0014 μCi/sec. Prior to shipping, the primary containment will be tested to assure the leak rate is less than 0.0014 μCi/sec.

4.5 Hypothetical Accident Condition

During the hypothetical accident condition, the containment would meet the criteria if all of the krypton were lost because the criteria permits the loss of 10,000 curies of krypton in one week [10 CFR 71.51, Subparagraph (A)(Item 2)]. However, the formal procedures, the design, the actual transportation experience, and individual tests of the cylinder and valve arrangement provide assurance that even under the accident conditions, the leakage rate will be less than allowable for normal operation, as well as accident conditions.

The primary containment was tested under more severe loaded conditions than for hypothetical drop accident conditions, i.e., the bare cylinder with attached valve was thermal cycled and drop tested at a deceleration of 200 g and remained "leak tight" (helium leak rate of $<6.9\times10^{-11}$ atm cc/sec, equivalent krypton leak rate of 2.8×10^{-13} atm cc/sec) after the drop (no change in leak rate). The deceleration this primary containment will experience will be much less than that tested under the worst case scenario. First, the Model No. 6400 packaging will assure a maximum deceleration of approximately 50 g to its contents when fully loaded to 45,000 pounds (Reference 1); however, as noted in Section 2.0, the deceleration accredited to the Model No. 6400 packaging loaded to 28,000 pounds (this case) is approximately 87 g. Second, the foam inner liner dunnage will reduce the 87 g to an ever lower value (Reference 2). The layering of the inner components of the contents (Section 1.2.3) will reduce the deceleration of the bare cylinder to even a smaller number. It can be concluded, therefore, that the testing during 200 g deceleration is more than adequate for both normal conditions of transport and the hypothetical accident conditions. Thus, the primary containment will remain "leak tight" under both normal conditions of transport and hypothetical accident conditions.

Also, as noted in Section 1.2.3., the cylinder and valve arrangement is always in the lead shield when the cylinder contains krypton, and this lead shield protects the valve from any direct impacts. Thus, the valve assembly arrangement is very well protected during normal handling, as well as during transport.

In summary, the primary containment bare cylinder and valve arrangement is more than adequate to meet the minimum leak rate requirements for both the normal conditions of transport and hypothetical accident conditions. It should be noted that during the hypothetical accident conditions the containment would still meet the criteria if all of the krypton were lost because the criteria permits the loss of 10,000 curies of krypton in one week [10 CFR 71.51, Subparagraph (A)(Item 2)]. If this were the case, the various components of the contents and the dunnage are not air tight, which will allow any gas to escape without damage to the packaging and without excessive holdup. The HEPA filtered opening in the door of Model No. 6400 packaging will prevent overpressure and allow venting of the krypton gas if failure of the primary containment did occur.

5.0 SHIELDING EVALUATION

5.1 Introduction

Shielding evaluation was performed by using the QAD-FN point kernal shielding code. This code uses built-in attenuation coefficients and calculates standard conversion factors. The content configuration used for calculations is shown in Figure 5.1. The calculated outer radii are somewhat different than those shown on the packaging blueprints. However, all values used are conservative which will result in the actual dose rates being lower than calculated dose rates.

Shielding for the primary containment cylinder and valve arrangement is provided by the lead shield. The shield is lead-filled, carbon-steel shell, providing two inches of shielding on the sides of the packaging and four inches of shielding on the top and bottom. There is no neutron generating material present. Bremsstrahlung contributions will be attenuated to non-consequential levels by the lead shielding (as shown by measured radiation levels).

5.2 Source Specification

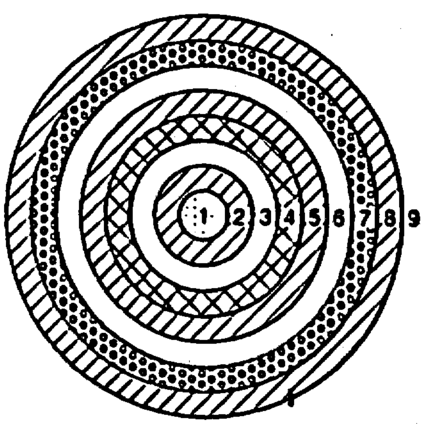
The source of radiation is krypton-85 (10.72-year half-life) which has a beta energy of 0.687 MeV. A delayed gamma ray is emitted 0.41% of the time and has an energy of 0.514 MeV.

5.2.1 Gamma Source

The computer runs were made using 7.13 E+12 gamma photons per second at 0.514 MeV for 47,000 curies of krypton-85. The 47,000 curie

Symbol	Materials Used	
	1. Gas- Containing Oxygen, Krypton, Xenon, Nitrogen	Total density of gas mixture = 0.0961 g/cm^3
	2. Iron	Density = 7.86 g/cm^3
	3. Lead	Density = 11.35 g/cm^3
	4. Air Containing Oxygen, Nitrogen	Total density of air = 0.0012 g/cm^3
	5. Foam Containing Carbon, Hydrogen	Total density of foam = 0.1872 g/cm^3

Cylindrical Geometry Used



Volume	Material	Radius Outer Boundary (cm)
1	1 Gas	10.8
2	2 Iron	11.4
3	4 Air	12.7
4	3 Lead	17.8
5	2 Iron	18.6
6	4 Air	25.9
7	5 Foam	35.3
8	2 Iron	35.4
9	4 Air	—

Total Source Length = 190.5 cm

NOTE: Tolerances are not used in QAD-FN calculations

ICPP-A-14408
(9-87)

Figure 5.1 Contents Shielding Configuration.

number was arbitrarily chosen to use for calculational purposes. Any other number could have been chosen since the dose rate is directly proportional to curie loading.

5.2.2 Neutron Source

No neutron source is present.

5.3 Model Specification - Description of the Radial and Axial Shielding Configuration

Axial doses were not calculated. Radial doses were considered to be the worst case since the shielding on the ends is thicker than the shielding on the sides.

5.4 Radiation Levels

The calculated maximum dose rates at the surface and one meter from the surface of the thermal insulation of the contents are shown in Figure 5.2.

As noted in Section 1.1, the combination of Model No. 6400 packaging, foam dunnage, and krypton-85 was used for a limited number of shipments of krypton-85. Measured and/or calculated radiation levels for these shipments and the projected shipments of 10,000 curies of krypton for normal conditions of transport are as listed.

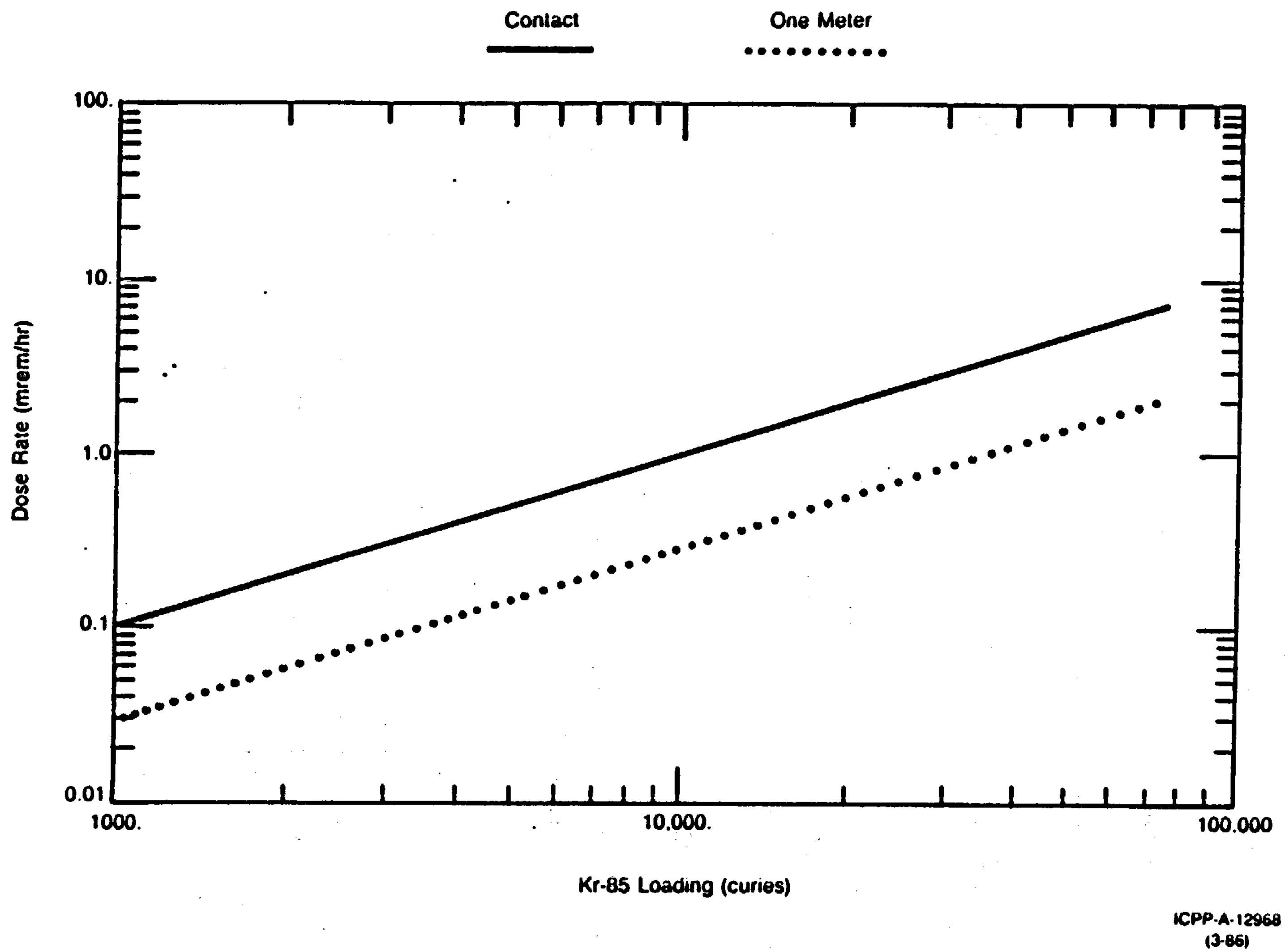


Figure 5.2 Dose Rate vs Krypton-85 Loading at Surface of Thermal Insulation of Contents

Loading, curies of krypton-85	1700	3500	7800	10,000
Surface of bare cylinder, rem/h	35	150*	185*	230*
One meter from bare cylinder, rem/h	0.9	2.0	2.6*	3.5*
Surface of lead shield, millirem/h	2	5*	5	7*
One meter from surface of lead shield, millirem/h	<1	1*	2	2*
Surface of Model No. 6400 packaging, millirem/h	0.1	0.1	<0.5	<0.5*
One meter from surface of Model No. 6400 packaging, millirem/h	0.1	0.1	0.1	<0.2*

* Calculated

Most of the measurements were made in a background of 2 millirem/h except those for the outside surface of the Model No. 6400 packaging which were made in a background of 1 millirem/h; therefore, actual radiation levels will be less than those measured. Thus, the measured values are compatible with the calculated values as listed and as shown in Figure 5.2.

In the event of a hypothetical accident condition of a 30 foot drop, radiation levels will not increase. Shielding is provided by the lead-filled, steel shell of the contents as described in Section 1.2.3. It is the structure of the Model No. 6400 packaging, however, which will provide impact resistance and ensure that the lead shielding remains undamaged. That is, lead slump will not occur. Additional energy absorption is supplied by the foam dunnage and other components of the contents.

The fully loaded Model No. 6400 packaging will provide a deceleration of 50 g to its contents (Reference 1); however, for this case with the Super Tiger loaded to 28,000 pounds, it will provide a deceleration if 82 g (Section 2). The foam dunnage will provide additional energy absorption to decrease the deceleration below the 87 g. Additional energy absorption is also provided by the components of the contents to decrease the deceleration to a value much below the 87 g. Analysis in Section 2.0 shows that the lead shielding will remain elastic and experience no deformation up to 177 g. Thus, the shielding will remain totally intact under the hypothetical accident conditions.

Melting of the lead will not occur since the maximum temperature of the bottle during the worst case scenario is 144°F (Section 3.0) while melting temperature of lead is 621°F.

5.5 Shielding Evaluation

Shielding integrity was inspected during manufacture by a quality engineer. The purpose of this inspection was to perform a gamma scan, visual inspection, and dimensional inspection of the shielded portion of the packaging. The inspection report is Reference 8.

QAD-FN is a point kernal shielding code based on the QAD code written by R. E. Malenfant, and is a modified version of QAD-P5F. Modifications were made by introducing a FASTER geometry routine. Flux-to-dose-rate conversion factors are calculated internally in the code using the ANSI/ANS 6.1.1-1977 standard equations. The calculated flux to dose value for 0.514 MeV is 1.207 E-3 mrem per hour per photon per square centimeter. QAD-FN calculates the flux distribution at points in space.

QAD-FN represents the gamma-ray source by a number of point isotopic sources. The line-of-sight distance from each point to the dose point is calculated. Based on the distance traveled through each material region and the shielding characteristics of each material, the uncollided gamma-ray flux at the dose point is calculated. The total gamma-ray energy transferred to the dose point is calculated on the basis of the strength and energy distribution of the point source, the uncollided flux, and the appropriate gamma-ray buildup factor. QAD-FN employs a third-order polynomial representation for gamma-ray buildup factors. After the gamma-ray energy transfer has been calculated for each source point, numerical integration is performed over the source volume for each source energy considered. Finally, the calculated energy flux at the dose point is converted to the quantity of interest, in this case, dose rate, as determined by the weighted functions that the user inputs to the code.

6.0 Criticality Evaluation

Nuclear criticality control is not applicable to the shipment of krypton-85 because it is not a fissile material. Erroneously filling with fissile material is not possible since gaseous fissile material does not exist at the Idaho Chemical Processing Plant. The use of the Model No. 6400 packaging, polyurethane foam dunnage, and krypton-85 contents is administratively controlled.

All personnel involved with the loading of the krypton-85 gas are trained and certified in the proper procedures for loading of the krypton contents. This also applies to the loading of other shipment packaging.

Nuclear criticality is not addressed further.

7.0 OPERATING PROCEDURES

7.1 Introduction

All activities associated with the loading, handling, and unloading of the krypton shipment will be monitored by Operational Health Physics (HP), Safety, and Quality Assurance (QA) personnel using established procedures and equipment to ensure personnel safety and compliance with all set requirements during the operation.

7.2 Procedures for Loading Gas Cylinder

The complete loading sequence of the gas cylinder is documented by formal procedures (Reference 3) and is summarized as follows:

Certify the condition of the gas cylinder and the mating valve by the helium leak test. The helium leak test must be performed a maximum of six (6) months prior to loading the gas cylinder with krypton gas. The gas cylinder and valve arrangement shall have a leak rate less than 0.0014 microcuries per second at the maximum pressure.

Verify the lead shield has had a preventive maintenance check within six (6) months prior to loading and that no unresolved non-conformance situations exist with the lead shield.

Inspect the cylinder and the lead shield for inadvertent damage that may have resulted during storage or handling.

Ensure that all the components for the lead shield are the proper components and will fit and function as designed when assembled.

Insert a cylinder into an approved shield. This is accomplished with both the cylinder and the lead shield in a horizontal position. The lead shield will be supported on a handling dolly. The lead shield with a gas cylinder in it will be referred to as the containment components hereafter.

Remove the retaining ring access plug and tighten the retaining ring around the gas cylinder to secure the gas cylinder within the lead shield. Replace the access plug. Record the serial numbers of the gas cylinder and the lead shield and verify that both the gas cylinder and the lead shield meet the certification requirements previously described.

Move the containment components to the loading area and connect the loadout manifold. This is accomplished by removing the valve access plug from the lead shield. The end opening of the lead shield should be closed by inserting the shield plug and securing the closure clamp. Tools can then be inserted through the opening provided in the lead shield to close the valve at the completion of the gas loading procedure.

Sample the product at least at the completion of the gas loading process. A complete mass spectrometer analysis is conducted to identify all constituents contained within the cylinder. The contents of the cylinder are evaluated by analysis to verify the number of curies of krypton. The number of curies of krypton and the pressure in the bottle shall be recorded. Due to the cryogenic separation process and the evacuation of the gas cylinder prior to loading, the product is essentially moisture free.

Torque the valve stem to 100 inch-pounds. Remove the supply lines and install the brass closure cap over the valve outlet opening. Tighten the cap using 100 inch-pounds of torque.

Check the containment components for gas leaks using a constant air monitor to assure that leak rates are below 0.0014 microcuries per second. After loading the gas cylinder with krypton gas, the cylinder and valve arrangement is tested with a constant air monitor equipped with a sniffer hose to verify that no gas is leaking from the primary containment. The sniffer leak test will be performed a minimum of 24 hours after loading the gas cylinder with krypton or a maximum of five days prior to shipping. The gas cylinder valve stem can be re-tightened using 150 inch-pounds of torque if a leak rate above allowable limits is discovered. If the leak rate is still above allowable limits after re-tightening the valve stem, the krypton gas will be unloaded into another gas cylinder that meets the previously stated requirements.

Install the valve access plug on the lead shield, measure and record radiation levels, apply tamper evidence seals, either lead wire or paper tape seals, and install the protective end cap. Tighten the two 5/16-inch bolts on the V-ring clamp using a torque of 60 to 80 inch-pounds.

The containment components are now ready for installation into the thermal insulation.

7.3 Procedures for Installation of Containment Components Into the Thermal Insulation

The complete loading sequence of the cylinder and valve arrangement with lead shield into the thermal insulation is controlled by approved procedures which are summarized as follows:

Move the containment components from the gas loading area to the thermal insulation. All handling of the containment components and the thermal insulation will be in accordance to the requirements set forth in the DOE Hoisting and Rigging Manual.

Orient the thermal insulation in the vertical position with the top facing up. A neoprene pad will be placed in the bottom of the thermal insulation.

Lower the containment components into the thermal insulation and place a second neoprene pad on top of the containment components.

Secure the steel plate to the inner flange of the thermal insulation using six 1/2-inch diameter bolts. Apply a torque of 96 to 120 inch-pounds to secure the bolts.

Install the thermal insulation head section. Tighten the six 3/4-inch bolts using a torque of 96 to 120 inch-pounds. Apply tamper evidence seals, either lead wire or paper tape seals, under the direction of the WINCO Shipping Agent.

The containment components and the thermal insulation are now ready for installation in the plywood box.

7.4 Procedure for Installation of Thermal Insulation Into Plywood box

The complete installation of the thermal insulation with containment components is controlled by approved procedures which are summarized as follows:

Lift the thermal insulation and its contents and place it in the plywood box with the top of the thermal insulation at the front of the plywood box (Drawing 059887, Reference 6). The thermal insulation should only be lifted with a minimum two-point lift and at those points that have been designated for lifting. The lifting points have been labeled and expanded metal has been installed on the thermal insulation to minimize the possibility of lifting the wrong location.

Shim the thermal insulation in the plywood box to preclude movement of the thermal insulation in the plywood box. The shims will be secured to the plywood box using nails or screws so that the shims will not become dislodged during transit.

Secure the lid on the plywood box as shown in Drawing 059886, Reference 5.

The thermal insulation and its containment components and the plywood box, hereafter to be called contents, is now ready to be placed into the Model No. 6400 packaging.

7.5 Procedure for Loading Contents Into the Model No. 6400 Packaging

The installation of the thermal insulation with contents is controlled by approved procedures which are summarized as follows:

Area 1 of the dunnage will be placed in the Model No. 6400 packaging. See Drawing 05988, Reference 7 for installation of Area 1 of dunnage in the Model No. 6400 packaging. See Drawing 909134, Reference 4 for configuration of specific components of dunnage that make up Area 1.

Area 2 of the dunnage will be placed on the Model No. 6400 packaging.

Plywood floor will be placed in the Model No. 6400 packaging, centered on the top of Area 2 dunnage. See Drawing 090134 for configuration of plywood floor.

Area 5 of the dunnage will be placed in the Model No. 6400 packaging.

Contents will then be picked up with a lift-all forklift equipped with 6-foot tines. The forklift will then reposition, lift the back end of the contents, and then push the contents into place. The contents will be placed securely against Areas 1 and 5 of dunnage.

Area 6 of the dunnage will be placed in the Model No. 6400 packaging.

Area 3 of the dunnage will be placed in the Model No. 6400 packaging.

Area 4 of the dunnage will be placed in the Model No. 6400 packaging.

It should be noted that the maximum allowed gap between any component of the dunnage, the contents, or the Model No. 6400 packaging is one inch.

The lid to the Model No. 6400 packaging will then be secured and the package will be prepared for shipment according to the requirements of Engineering Evaluation of the Super Tiger Overpack Designed for the Shipment of Large Quantities of Hazardous Material, Reference 1.

Before the shipment will be allowed to leave the loading facility, it must be checked and approved by the WINCO Shipping Agent. WINCO Shipping Agent will require a copy of the helium leak test results, the sniffer leak test results, number of curies in the gas cylinder, pressure in the gas cylinder, and the radiation levels of the shipment.

7.6 Procedures for Unloading the Shipment

Procedures used to unload the shipment should follow the above procedure only in reverse. The shipment should be inspected by Health Physics personnel as each component of the shipment packaging is removed.

The closure valve on the gas cylinder packaging turns only 3/4 turns from the full-closed position. Do not open more than 3/4 turns.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM - QA

8.1 Introduction

Westinghouse Idaho Nuclear Company (WINCO), a subsidiary of Westinghouse Electric Corporation, operates the Idaho Chemical Processing Plant under contract to the owner, the United States Department of Energy (DOE). WINCO's policy is to perform all work activities in such a manner that required quality is attained or exceeded.

In pursuit of this objective, WINCO has developed a quality assurance program which meets the requirements of ANSI/ASME NQA-1, Quality Assurance Program Requirements for Nuclear Facilities, and satisfies the special needs of a nuclear fuel reprocessing plant. This program is described in the WINCO Quality Assurance Manual, containing a series of quality methods and procedures which define requirements for the entire company. The WINCO quality assurance program also meets the requirements of 10 CFR 71, Subpart H, Quality Assurance Requirements - Packaging and Transportation of Radioactive Materials. The WINCO quality assurance program is further documented by, and implemented through, the use of a more specific and detailed functional procedures.

This section describes the WINCO quality assurance program requirements as they apply to the Model No. 6400 packaging when used for the transportation of the krypton-85 contents.

8.2 Preventive Maintenance

Preventive maintenance activities are performed annually or within one year prior to shipment on components of the contents which are important to safety. The responsible organization for performance of preventive maintenance shall be that of the user. This section describes the basic requirements of the preventive maintenance which is performed in accordance with approved procedures. These basic preventive maintenance requirements for the lead shield and thermal insulation are as follows:

Perform visual inspection for dents, punctures, wear, corrosion, chipped paint, bent structures, weld cracks, missing fasteners. Check function of mechanical components and lubricate. Remove gas cylinder and inspect interior of shielding as specified above. Remove epoxy/ paint from welds of four lifting lugs; liquid penetrant inspect the lifting lugs. Repaint as required. Report identified defects to the preventive maintenance engineer for resolution.

8.3 Quality Requirements

The following quality requirements apply.

Maximum pressure of gas cylinder shall be independently verified to not exceed 500 psia at 25°C.

The gas cylinder shall be a DOT Spec-3AA bottle as certified by vendor documentation. Additionally, the gas cylinder shall have been hydro tested within five (5) years to a test pressure of 3360 psig.

A krypton-85 leak test shall be performed in accordance with approved procedures a minimum of 24 hours after filling of the gas cylinder or a maximum of five days prior to shipping. The leak rate shall not exceed 0.0014 μCi/sec.

The contents of the gas cylinder has been verified by sampling and analysis using a mass spectrometer.

Prior to loading the contents within the Model No. 6400 packaging, radiation levels shall be checked on the outside of the wooden box as follows:

Surface radiation levels <200 millirem/h
Two meters from surface <10 millirem/h

Preventive maintenance shall have been performed on the lead shield and thermal insulation within the past twelve (12) months prior to shipment date.

The krypton-85 gas cylinder, lead shield, and thermal insulation shall be transported within the Model No. 6400 packaging as follows:

Enclosed within a tight fitting plywood box, Drawing Number 059886 and 059887.

Consistent to limitations and restrictions identified within the Certificate of Compliance for this shipment.

The contents shall be positioned as closely as possible to the center of gravity of the Model No. 6400 packaging. Polyurethane dunnage shall be used to reduce secondary impact within the Model No. 6400 packaging in the event of an accident during transportation.

The maximum weight of the Model No. 6400 packaging with dunnage and contents shall not exceed 30,000 pounds.

8.4 Quality List

The quality levels of all components of the contents are noted in the Table 8.1 (see References 9 through 15).

TABLE 8.1

Q-List

Component	Quality Level
Compressed Gas Cylinder, DOT 3AA	A
Manifold Fabricators and Supply Metal Diaphragm Valve	A
Brass Cap (valve outlet)	B
Lifting Lugs (shield packaging) 3/4 Inch Plate, 3-1/2 Inch x 17 Inch, A36	C
Shield Shell, 1/4 Inch A36 Plate	B
Lead	A
1/8-Inch Steel Band, 2-Inch Wide (secure cylinder)	B
Nylok Set Screw	B
Spider Rings and Legs	B
Casings (thermal overpack) 16 Gauge Stainless Steel	B
Bellybands (thermal overpack casings) 7 Gauge Stainless Steel	B
Center Casing Outer Skin, 16 Gauge Stainless Steel	B
Gusset Plates, 1/2 Inch Stainless Steel	B

TABLE 8.1 (Continued)

Component	Quality Level
Fir Stringer Spacers	N
Pittsburg Corning Foamglas	C
Laminated Marine Plywood	C
Neoprene Pads, 1/2 Inch	B
Steel Pipe Framework, 2 Inch Sch 40 Stainless Steel	B
Expanded Metal	N
Shield Plug, 1/4 Inch Carbon Steel	A
Pipe Cap, Lead-Lined, 14 Inch, Extra Strong	A
Shield Plug Clamp, 11 Inch x 4-1/2 Inch	B
Clamp Lugs	B
5/8 Clamp Set Screws	B
Cap V-Ring Clamp	B
5/16 Inch Cap Clamp Bolts	B
Valve Access Threaded Plug, 3 Inch Lead-Filled	A
Nylock Set Screw Plug	C
Inner Casing Flange, Angle 1-1/2 x 1-1/2 x 3/16 Carbon Steel	B
20 Inch Diameter Steel Closure Plate, 1/2 Inch Thick	B
Flange Bolts, 1/2 Inch	C

TABLE 8.1 (Continued)

Component	Quality Level
Overpack head Section, 3/16 Inch	B
16 Gauge Steel Disk (holds insulation)	N
3/4 Head Section Bolts and Nuts	B
Head Section Lugs	B
Nameplate, 16 Gauge Stainless Steel	N
Head Section Lip, 16 Gauge Stainless Steel	C

Quality level definitions are as follows:

Quality Level A - Items whose failure or malfunction could result directly in a condition adversely affecting public health and safety.

Quality Level B - Items whose failure or malfunction could indirectly result in a condition adversely affecting public health and safety.

Quality Level C - Items whose failure or malfunction would not significantly reduce the packaging effectiveness and would be unlikely to create a condition adversely affecting public health and safety.

Quality Level N - Not safety related.

9.0 REFERENCES

1. Mechanics Research Inc., Report No. C2378, "Engineering Evaluation of the Super Tiger Overpack Designed for Shipment of Large Quantities of Hazardous Materials", dated March 4, 1970.

2. K. D. Richardson, WAPD-LP(FE)-220, "Safety Analysis Report for Packaging Super Tiger Shipping Containers as Adopted for LWBR Type Fuel Rods", dated December 1980 (Original) and August 1985 (Revision 4).

3. WINCO Standard Operating Procedures, IPM-XVII-I.

4. WINCO Drawing No. 090134, Krypton Shipment Model No. 6400 Packaging Details and Section.

5. WINCO Drawing No. 059886, Krypton Shipment Plywood Box Details and Assembly.

6. WINCO Drawing No. 059887, Krypton Shipment Plywood Box With Thermal Insulation Overpack Installed.

7. WINCO Drawing No. 059888, Krypton Shipment Model No. 6400 Packaging With Dunnage Contents.

8. B. C. Smith, WINCO Quality Assurance Procurement Activites Report, dated October 30, 1985.

9. WINCO Drawing No. 134521, Krypton Shipment Lead Shield Assembly.

10. WINCO Drawing No. 134522, Krypton Shipment Lead Shield Details.

11. WINCO Drawing No. 134523, Krypton Shipment Lead Shield Details.

12. WINCO Drawing No. 134524, Krypton Shipment Thermal Insulation Assembly.

13. WINCO Drawing No. 134525, Krypton Shipment Thermal Insulation Details.

14. WINCO Drawing No. 134526, Krypton Shipment Thermal Insulation Details.

15. WINCO Drawing No. 134527, Krypton Shipment Thermal Insulation Details.

FIGURE WITHHELD UNDER 10 CFR 2.390

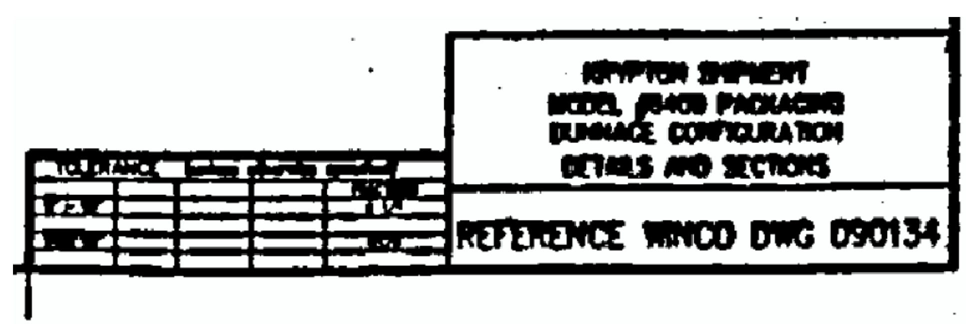


FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT PLYWOOD BOX
DETAILS AND ASSEMBLY

REFERENCE WNCO DWG 059886

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT PLYWOOD BOX
WITH THERMAL INSULATION
OVERPACK INSTALLED

WINCO DWG 059887

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT
MODEL [illegible] PACKAGING
WITH DUNNAGE CONTENTS

REFERENCE WINCO DWG 059888

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT LEAD SHIELD ASSEMBLY
REFERENCE WINCO DWG 134521

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT
LEAD SHIELD
DETAILS

REFERENCE WINCO DWG 134522

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT LEAD SHIELD DETAILS
REFERENCE WNCO DWG 134523

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT THERMAL INSULATION ASSEMBLY
REFERENCE WINCO DWG 134524

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT THERMAL INSULATION DETAILS
REFERENCE MINCO DWG 134525

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT
THERMAL INSULATION
DETAILS

REFERENCE WINCO DWG 134526

FIGURE WITHHELD UNDER 10 CFR 2.390

KRYPTON SHIPMENT THERMAL INSULATION DETAILS
REFERENCE WINCO DWG 134527