Safety Analysis Report for the NLI-1/2 Spent Fuel Shipping Cask USA/9010/B( )F

February 1996

Docket No. 71-9010

T-95001

NAC INTERNATIONAL

ATLANTA WASHINGTON ZURICH TOKYO MOSCOW

RECORD OF REVISIONS

Revision Date	Affected Pages	Description of Changes
10/1990	N/A	Original Release
02/1991	Throughout	Incorporation of Responses to NRC Comments
03/1991	XI-H6, XI-H7, XI-H8, XI-H9, XI-H10, XI-H11, XI-H13	Correction of Drawing References
08/1991	XI-H1, XI-H2, XI-H3, XI-H4, XI-H5, XI-H6, XI-H7, XI-H8, XI-H9, XI-H10, XI-H11, XI-H12, XI-H13, XI-H14, XI-H15, XI-H16, XI-H17, XI-H18, XI-H19, XI-H20, XI-H21, XI-H22, XI-H23, XI-H24, XI-H25	Allow shipping of severely failed metallic fuel contained in filters.
10/2/91	I-1, I-2, I-3, III-4, XI-D1, XI-H19a, XI-H19b, XI-H19c, XI-H10d, XV-1, XV-19, XV-20, XV-21, XV-21a, XV-21b	Incorporation of response to NRC comments concerning shipping of severely failed metallic fuel contained in filters.
10/23/91	II-10, III-2, III-4, VIII-43b, VIII-43c, IX-37d, IX-37e, IX-37g, X-21a, X-22, XI-D1	Allow shipment of 25 BWR rods with maximum burnup of 75,000 MWD/MTU and initial enrichment of 5.0 w/o U-235
04/1992	III-3, III-4, III-20a, III-21a, VIII-43b, IX-iii, IX-37d, IX-37e, IX-37g	Allow shipping of 25 BWR rods with a fuel length of 150 inches.
12/1995	XVI-1, XVI-2, XVI-3	Revise packaging maintenance program to delete annual hydrostatic test requirements.
02/1996	II-10, III-2, III-4, III-21a, VIII-43b, IX-37d, IX-37e	Revised and consolidated Safety Analysis Report for Certificate of Compliance Renewal.

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SECTION I

INTRODUCTION

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SECTION I
INTRODUCTION

The following safety analysis report describes NL Industries, Inc. NLI 1/2 Universal Spent Fuel Shipping Cask. The cask has been designed to accommodate one (1) PWR type, two (2) BWR type light water reactor spent fuel assemblies or one (1) cannister of up to 408 PWR type fuel rods (pins). (The cask can also be used for transport of other types of fuel such as metallic fuel, Fermi, EBR-II, Mark 42, or Mark 22 fuel assemblies.) Accordingly, the cask design is based on fuel decay heat radiation source terms which were derived for certain limiting operating values of fuel exposure, specific power, initial enrichment, and axial peaking factor, thereby permitting shipment of any PWR or BWR fuel assemblies whose parameters do not exceed the design basis fuel values established by this report.

Cask size and capacity are limited to permit legal weight truck shipment (72,380#G.V.W.) of the fully loaded cask. To obtain this objective it was necessary to consider the shipping cask, tractor and trailer as a system with primary consideration being given to the shipping cask integrity and reliability. The trailer is specially designed to accommodate the cask. For the purpose of package evaluation, the shipping cask with impact structures attached to each end is to be considered as the configuration of the package as presented for shipment.

The NLI-1/2 spent Fuel Shipping Cask has been designed to provide maximum safety for the shipment of spent fuel by providing double containment of the fuel assemblies in a dry environment. The cask body has been designed to accommodate a separate inner container which has a bolted and gasketed closure. This design provides for safe shipment of defective or failed fuel assemblies. (Failed fuel rods can also be transported in sealed individual shipping containers within the cask. Severely failed metallic fuel in filters may be shipped in sealed canisters, provided the limits of 10 CFR 71.63 are met.) Use of the inner container for sound fuel assemblies is optional for burnups less than 45,000

MWD/MTU. The normal shipping configuration will not use the inner container. For the normal shipping configuration the cask is fitted with the appropriate fuel basket and the inner closure head is bolted directly to the cask body flange. All other features including double closure are retained.

The overall safety of the NLI system is further enhanced by not having a liquid coolant. The internal pressure of a package under normal conditions of transport can easily reach 100 to 150 psig in a water filled system, whereas the internal pressure for the same fuel load in the NLI system would be in the range of 15-20 psig, considering the air trapped in the cask cavity as gaseous coolant. The difficulties of achieving and maintaining coolant activity levels below the specified maximums are greatly reduced, if not eliminated in the dry system. The problems of contaminated coolant release as a result of the hypothetical accident conditions are eliminated since containment of a low pressure gaseous coolant system is achieved.

Decay heat is removed from the fuel to the cask first by thermal radiation and conduction through a helium filled cavity and then through the cask sides and ends by a combination of conduction, natural convection in the water filled neutron shield, and natural convection and radiation from the surfaces of the cask. Thermal radiation augments the conduction heat transfer across well established air gaps within the cask. Being entirely passive, this means of heat dissipation is highly reliable.

The criticality analysis, which was based on fresh fuel assemblies with zero burnup, shows that an infinite array of NLI 1/2 Spent Fuel Shipping Casks result in a subcritical condition. The NLI 1/2 Spent Fuel Shipping Cask may therefore be considered as a Fissile Class I package in accordance with the requirements of 10 CFR 71.

Appendices have been added to the appropriate sections of this report to demonstrate the integrity of the cask shipping configurations which do not utilize the inner container.

The NLI 1/2 Spent Fuel Shipping Cask has been designed to meet all applicable requirements of 10 CFR, Chapter 1, Part 71 and 49 CFR, Chapter 1, Parts 170-189. The design function was carried out under NL Industries, Inc. Quality Assurance Program for Design and Engineering which is comparable to 10 CFR, Chapter 1, Part 50, Appendix B, Section III, Design Control. Manufacturing and the Quality Assurance Program were carried out in accordance with NL Industries, Inc. Commercial Nuclear Quality Control Manual as applicable by design requirements.

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Section II

SECTION II

CASK SYSTEM DESCRIPTION

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SECTION II
CASK SYSTEM DESCRIPTION

– The shipping cask has been designed to provide for two separate shipping configurations. One arrangement (Configuration A) provides for an inner container which houses the spent fuel and is placed within the cask cavity. The second arrangement (Configuration B) utilizes an aluminum fuel basket, which is placed within the cask cavity in place of the inner container. Both configurations use a double closure design (two separate closure heads). Two additional cask configurations exist for shipment of spent fuel. Configuration C uses a cruciform basket and is the configuration used when shipping the Fermi, EBR-II, Mark 22 or Mark 42 fuel assemblies. Configuration D is used for the shipment of metallic fuel.

The shipping package as presented for shipment consists of the cask body, inner container (optional), inner closure head, outer closure head, and impact structures bolted to each end of the cask. The cask body consists of inner and outer stainless steel shells which are joined by stainless steel forgings at each end to make a continuous weldment. The annulus between the inner and outer cylinders contain a composite lead/uranium gamma shield. Neutron shielding is provided by a water jacket which surrounds the outer stainless steel cylinder and axially blankets the active fuel region of the fuel assembly. (The water jacket is empty in Configuration D.) The internal cask cavity, which is 13.375 inches in diameter, has been sized to accommodate the removable inner container which is designed to carry either one PWR type or two BWR type fuel assemblies. The closure head seals the open end of the cask cavity and is seated on a stainless steel forging when closed. The length of the forging is such that it forms part of the cask cavity. The design provides the necessary material from which two closure head flange seating surfaces can be machined. The design also provides the opportunity to have all the necessary penetrations thru the cask body pass thru the solid stainless steel forgings, eliminating the need for pipe and tube penetrations which pass thru the shielding materials and penetrate the inner and outer shell, compromising the integrity of the cask structure.

The head end forging also provides maximum protection of the inner closure head and closure head seal since the closure head is located within the outer dimensions of the forging. The cask lifting trunnions are located in the head end forgings eliminating the concern of a puncture of the shielding containment shell by an impact on a trunnion.

The shield materials used in the cask design have been selected and arranged to minimize the cask weight while maintaining overall shield effectiveness. Lead and depleted uranium were chosen as effective gamma radiation shields, and a water jacket on the outside of the cask as the light material to efficiently moderate the neutron radiation. The gamma radiation shields at the ends of the cask are made up entirely of uranium and steel, thus eliminating the problems of lead expansion, resolidification level and containment under the hypothetical accident conditions. The lead/uranium shield in the cask body is arranged such that the cylinder of uranium is immediately adjacent to the inner cavity while the lead shielding fills the annulus between the uranium shield and the outer stainless steel shell. Although the thermal calculations show that some amount of lead melts during the fire accident, the problem of controlling the lead is not critical since the uranium shield suffers no damage and provides sufficient shielding to maintain dose rate levels well below the 10 CFR 71 limit of 1000 mrem/hr.

The water jacket neutron shield is designed to provide shielding during all phases of loading and unloading of the cask (except in Configuration D) as well as under the extreme ambient conditions of transport (130° to -40°F) as specified by 10 CFR 71. Having a solid water shield under the above conditions requires that an expansion volume be provided to accommodate the water expansion which results due to heatup as the cask system reaches thermal equilibrium. The expansion volume must be designed to permit the expanded water to flow back into the water jacket when ambient conditions result in lower water temperatures than initially encountered during a given shipment. Design approaches which do not provide for retention of the expanded water volume may result in something less than a solid neutron water shield as ambient temperature changes occur during transit.

Consider a hypothetical case where the cask is loaded with a fuel element that generates the design basis decay heat load and neutron shield water expansion is accommodated by allowing the water to blow off thru a relief valve. When the cask reaches thermal equilibrium, the ambient temperature is 90°F, the bulk water temperature is 295°F and there is solid neutron water shield. The ambient temperature drops 30°F which results in a reduction in the water volume of .712 ft^3. This represents about a 19% reduction in shielding along the vertical axis of the cask when the cask is in the horizontal position. This condition is, of course, in violation of Paragraph 71.35 of 10 CFR 71.

From this hypothetical case which considers an ambient temperature drop only one-sixth of that indicated by the regulations, it can be seen that containment of the shield water as it expands in an expansion tank system that permits free flow in both directions is necessary to maintain a solid neutron shield for even small ambient temperature changes.

The expansion tank system as shown in the Schematic Diagram on Page II-4 provides positive free flow of water in both directions.

The neutron shield water jacket is constructed of 1/4 inch high strength stainless steel. At each end of the 1/4 inch shield is a short shell section of 1/2 inch thick high-strength stainless steel which provides an adequate transition section from the 1/4 inch material to the 2 inch square jacket closure rings which are made of 304 stainless steel. The water jacket design, which is more than adequate to satisfy the design pressure, was developed to provide structural integrity under the normal conditions of transport as defined by 10 CFR 71 as well as to contribute to the overall strength of the cask in the hypothetical accident conditions. In order to maintain a solid water shield, an expansion tank is provided in the form of a second water jacket which is welded to the outside of the neutron shield water jacket. The expansion tank is located at the top or head end of the cask and is connected to the water jacket by a short section of pipe which exits the water jacket thru the upper jacket closure ring.

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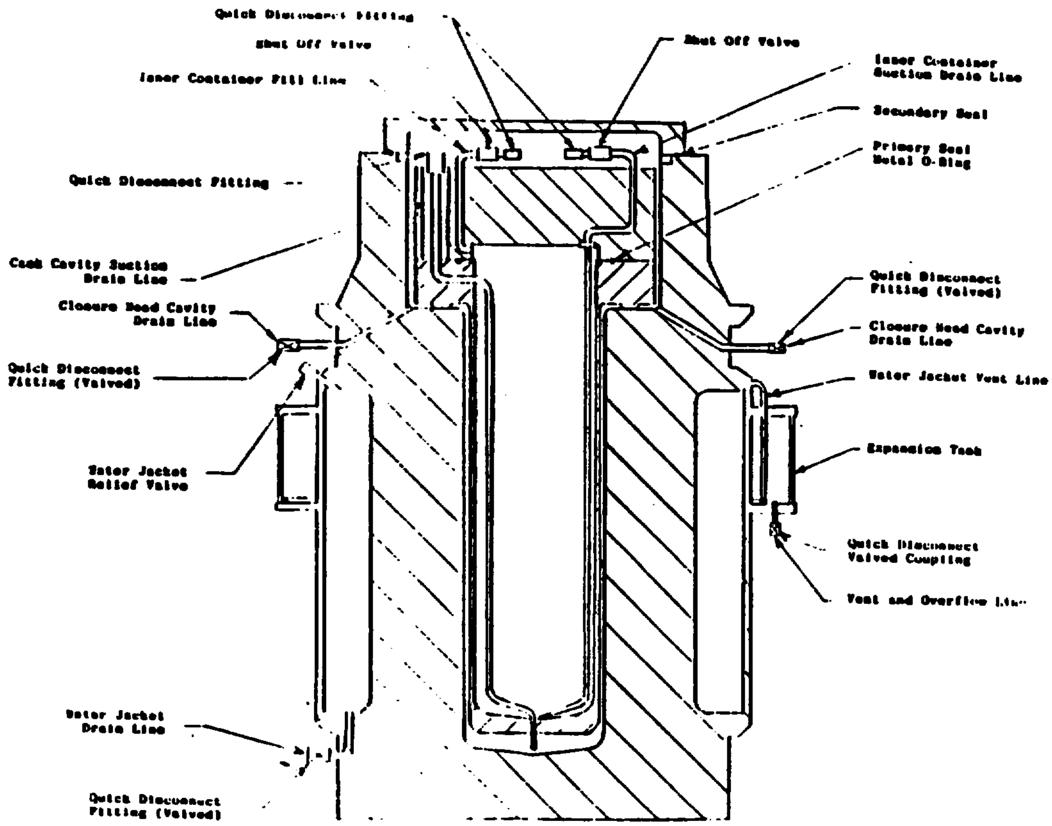

Figure 1A - Schematic, NLI-1/2 with Inner Container, Configuration A

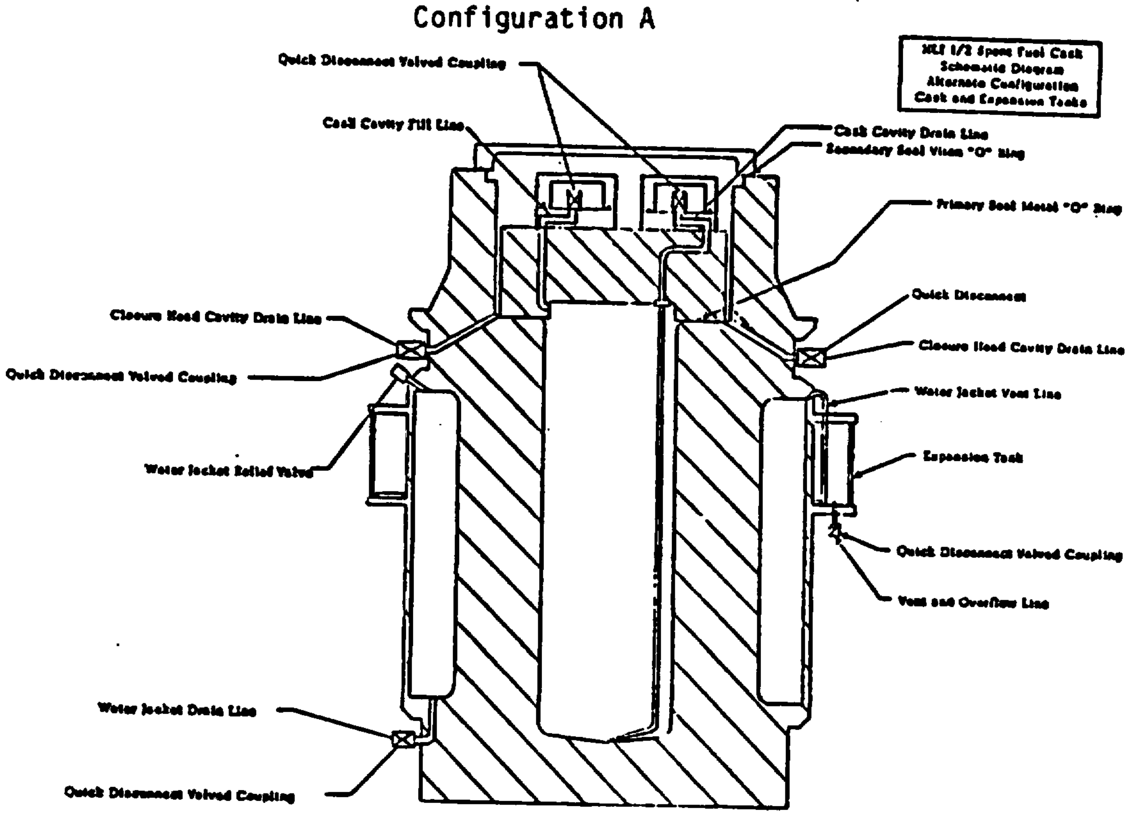

Figure 1B - Schematic, NLI-1/2, Configuration B

The pipe immediately enters the expansion tank and travels around the water jacket shell to the low point of the expansion tank. The low point of the expansion tank is the bottom of the tank in the vertical position and also the underside of the cask in the horizontal shipping position. To avoid air pockets forming in the expansion line, the expansion tank is filled to a pre-determined level which assures that the open end of the expansion line is under water when the cask is in either the vertical or horizontal position. The vent and overflow line, which penetrates the bottom closure ring of the expansion tank, extends into the tank a distance that equals the liquid level required to cover the end of the expansion line. Initial filling of the expansion tank is done with the cask in the vertical position. The overflow line is left open and when water begins to flow from the line the filling operation is complete. The overflow line is disconnected and the valve coupling automatically closes. A segment of the expansion tank is fitted with baffles on the side of the tank which would be on the bottom when the cask is in the horizontal shipping position. The baffles are provided to break up any wave motion that may tend to uncover the end of the expansion line. The short section of pipe which connects the two chambers is protected by a larger half-section of heavy wall pipe which is welded to the cask body. The expansion tank has a vent and overflow line at the bottom of the tank, which terminates with a quick disconnect valved coupling or a pipe cap. The relief valve is set to relieve at 200 psig.

The design requirements for the water jacket neutron shield system are established by the calculated bulkwater temperature in the water jacket at the design decay heat load steady state conditions and 130°F ambient temperatures. The bulk water temperature is calculated to be 296°F. Correcting for the effect of the personnel barrier (+35°F) the design temperature was set at 331°F. The saturation pressure at this temperature is 100 psia. The system is designed for an operating pressure of 200 psia to accommodate the decrease in volume of the air trapped in the expansion tank. The design conditions for the neutron water shield system are:

Design metal temperature	400°F
Design pressure	250 psig
Operating pressure	185 psig
Relief valve setting	200 psig

Under the hypothetical accident conditions, it is assumed that the water jacket or expansion tank would be damaged sufficiently to allow the water to escape. Both the thermal and shielding calculations have assumed a complete loss of neutron shield water. The results of these calculations show that the cask meets the radiation dose levels specified by the post-accident requirements.

For metallic fuel shipments, the neutron shield tanks are drained and the cask is transported in a closed shipping container. The thermal effects of the empty neutron shield tank and the enclosed container are evaluated in Section VII. The dose rate from the metallic fuel is evaluated in Section IX.

There are two valved penetrations thru the head end forging of the cask body. Both penetrations exit into the closure head cavity area and are outside the primary containment seal area. The two penetrations are used to drain the closure head area as the cask is removed from the spent fuel storage pool. Prior to shipment of the loaded cask, the penetrations are used to pressure test the secondary containment system. The fitting used at each of these penetrations is a valved quick-disconnect. The valved quick-disconnect fitting is constructed from 300 series stainless steel and has a pressure rating of 2000 psi (3/4" size). The valve design provided an automatic and positive shut-off when the connecting lines are disconnected. Each valve assembly is housed in a stainless steel valve box which is an integral part of the cask body.

Each valve box has a gasketed cover which is bolted in place. Under hypothetical accident conditions the valves and valve boxes are protected from impact by the impact structures which are attached to the ends of the cask.

The cask body closure head (outer closure head) is a stainless steel forging machined to form a cap. There are no penetrations thru the outer closure head since all necessary service penetrations are made either thru the cask body end forging or the inner closure head. The outer closure head, which is the secondary containment boundary, also serves as a rugged valve box cover for the service penetrations on the inner closure head. The outer closure head seal is an elastomer type "O" ring.

The inner container used in Configuration A, carries the aluminum fuel basket and the fuel. It is a separate removable cylindrical can which has a high integrity sealed closure. The inner container is designed to perform as a pressure vessel. The container consists of a 1/4 inch thick stainless steel shell. The shell is closed at one end by a flat stainless steel head which is machined to permit the head to be butt-welded to the shell, thus eliminating a corner weld type joint. The top end or open end of the container has a stainless steel forged flange section which is butt welded to the end of the shell. The flange is machined to receive the container closure head bolting arrangement. There are two service lines of 3/8 inch stainless steel tubing which extends the full length of the container and are placed inside the container. One line is the section drain line used to evacuate the pool water from the inner container. The line terminates at the center of the bottom head. The opposite end of the line is fitted with a flange, the face of which is machined to effect a seal with the container closure head. An elastomer type seal is used in this installation since a wide range of tolerances must be accommodated in effecting a seal. The thermal calculations show that the temperature in this region under normal conditions of transport permit the use of an elastomer type seal. Failure of this seal in the hypothetical fire accident is of no consequence since it results in an opening within the primary containment boundary and not a breach of the primary containment boundary. The second service line is the suction drain line used to evacuate the pool water from the annulus between the outside of the inner container and the cask cavity. The line is designed such that there are no mechanical gasketed joints between the line and the inner container. The joints between the line and the inner container are welded and provide the same integrity as is inherent in the basic can construction. The line exits thru the bottom head of the inner container and is fitted with a short length of rubber tubing which terminates just above the surface of the cask cavity bottom head. Rubber tubing is used to avoid the problems associated with a rigid piece of tubing relative to the differential thermal expansion between the inner container and the cask cavity. The line exits the top end of the container thru a blind hole in the container flange. The hole in the container flange is fitted with a heavy wall stainless steel tube that extends thru the closure head and terminates with a quick disconnect fitting. The heavy wall tube penetrates the container flange outside of the primary seal area, thereby maintaining the integrity of the inner container. The inner container closure head (inner closure head) consists of a stainless steel forging, the center section of which is filled with uranium, which is covered by a stainless steel plate which is welded to the forging. The bulk of the required gamma shielding is contained in the inner head to provide operator protection during the handling operations involving a loaded cask. The closure head is held in place by twelve high-strength bolts. The inner closure head seal is a metallic "O" ring type seal. The closure head is equipped with two valved penetrations. The penetrations are located between closure head bolts and exit to the interior of the container on the underside of the closure head. One penetration mates with the suction drain line used to evacuate the inner container. The other penetration is used to back-fill the inner container with helium. The valves used at each of the penetrations may be bellows-seal type as manufactured by Hoke, or may be identical to the Configuration B inner head valve arrangement.

The Hoke type valve and bellows seal are made of type 316 stainless steel and have an operating temperature range of -320°F to 1500°F. The valves are designed for liquids and gases of radioactive, reactive or toxic nature, liquid metals and cryogenic service.

The inner closure head used in all of the shipping configurations except Configuration B is of the same basic design as just described with the exception of the valve arrangement. The closure head has two penetrations as does the inner closure head which is used with the inner container. Each penetration is fitted with a stainless steel block that is machined and welded to the top surface of the closure head. The block forms a closed passage from the head penetration to a tapped hole which receives a valved quick disconnect fitting. The block also provides a sealing surface to which is bolted a stainless steel cap which is fitted with double "O" ring gaskets. The inner gasket is a metal "O" ring type, Inconel-X, self-energizing seal. The seal is more than adequate to withstand the temperatures expected as a result of the hypothetical fire accident. The outer gasket is an elastomer "O" ring. The concentric "O" ring seals provide an annulus into which air can be introduced for the purpose of checking seal integrity prior to each shipment.

When PWR or BWR fuel rods are being transported, the fuel is supported within the primary containment vessel by an aluminum basket. The aluminum basket is made up of four pieces of aluminum approximately 150 inches long. Each piece of aluminum is shaped to form a segment of a circle. The internal flat face of each segment forms a square which supports the fuel, or canister, for its entire length. The aluminum basket and fuel are supported axially by stainless steel weldments.

The cruciform basket, used in Configuration C, is described in Appendix F of Section XI. The three-hole basket and the six-hole basket used in Configuration D are described in Appendices G and H of Section XI.

Impact structures are bolted to each end of the assembled shipping cask. The structures have been designed to soften the impact resulting from a 30-foot drop on an unyielding surface. The impact structures have a shape similar to that of a hat and are designed such that the kinetic energy of the system upon impact is spent in the progressive crushing of the impact structure, yet at the end of the failure mode there has been no contact made between any portion of the cask body and the impact surface. The brim of the hat is 74 1/4 inches in diameter and protects the cask from the side impact condition. The top portion of the hat shape is 33 inches in diameter and approximately 17 inches high. The top portion protects the cask from the end and corner impact conditions. The impact structure is constructed of balsa wood which is completely enclosed in an aluminum weldment.

The NLI 1/2 Spent Fuel Shipping Cask has been designed to permit legal weight truck shipment (73280 # G.V.W.). The transport system consists of a specially designed trailer with the cask tie-down arrangement built into the trailer frame. Outriggers are built out from the main trailer frame providing a support and tie-down point for the personnel barrier. The personnel barrier is basically a cage made from expanded sheet metal on a metal frame. Removable panels provide access for inspection of the cask and tie-downs. A specially designed lift rig is provided for cask handling which engages the trunnions on the cask body.

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NLI-1/2 SPENT FUEL SHIPPING CASK DATA

Fuel Data	1-PWR Type Fuel Assembly[1]	2-BWR Type Fuel Assemblies	Consolidated PWR Fuel Rods	Metallic Fuel (Max. 21 Rods)	PWR Rods[3]	PWR Rods[4]	BWR Rods[5]
Envelopes, inches	8.60 sq x 171.5	5.44 sq x 176.25	8.75 sq x 171.5	1.36" diameter	25 rods	18 rods	25 rods
Enrichment (w/o U-235)	3.7	2.65	3.7	Natural	4.9	4.9	5.0
Weight of Uranium	475 kg	197 kg	950 kg	1,145.5 kg 54.5 kg per rod	58.2 kg	58.2 kg	75 kg
Max. Avg. Burnup (MWD/MTU)[2]	40,000	34,000	40,000	1,600	60,000	60,000	75,000
Avg. Specific Power	40 kW/kg U	27 kW/kg U	40 kW/kg U	------------	44 kW/kg U	60 kW/kg	60 kW/kg
Cask Weight, loaded, Calculated	47,350 lbs	47,077 lbs	49,250 lbs	47,480 lbs	46,455 lbs	46,455 lbs	46,455 lbs

Cask Data and Dimensions

Cask Design Weight	48,000 lbs
Gross Vehicle Weight	73,280 lbs
Cask Assembly Envelope	72.25" in diameter 238.31" length
Cask Body Envelope	40" in diameter 193" long
Internal Cavity	13.375" in diameter 178" long
Inner Container	12.625" in diameter 178" long

Normal Cavity Operating Pressure — 26 psig
Maximum Cavity Operating Pressure — 117 (accident conditions)
Neutron Shield Water Jacket — ethylene glycol, 52% volume, -42 degree F freezing point

Notes:

1. With or without control rods or burnable poison rods or with additional irradiated fuel rods inserted and secured in the guide thimbles. Maximum initial uranium content shall be 495 kg and the maximum average initial U-235 enrichment shall be 3.35 w/o.
2. PWR fuel assembly may have a maximum average burnup of 56,000 MWD/MTU, provided that the assembly meets the criteria established in Part 6 of Section III and the neutron shield fluid contains 1.0 w/o boron. (The boron fluid may be left in the shielding tanks during the shipment of other contents.)
3. Up to 25 PWR rods may be shipped provided that the maximum average burnup does not exceed 60,000 MWD/MTU, the initial enrichment does not exceed 4.9 w/o U-235 and that the neutron shield fluid contains 1.0 w/o boron. Up to two of the 25 PWR rods may have a maximum burnup of 65,000 MWD//MTU. Rods with a maximum average burnup that exceeds 45,000 MWD/MTU must be shipped in Configuration A.
4. Up to 18 PWR rods cooled 300 days with an average specific power of 60 kW/kg may be shipped. The conditions of Note 3 apply.
5. Up to 25 BWR rods may be shipped provided that the maximum average burnup does not exceed 75,000 MWD/MTU, the initial enrichment does not exceed 5.0 w/o U-235, and the weight of uranium does not exceed 75 kg.

NLI-1/2 SPENT FUEL SHIPPING CASK DATA

Capacity	Mark 42 Fuel Assembly
Fuel Data	
Envelope	4.11 inches in diameter
Weight of Plutonium	3.350 kg (initial)
Initial Pu^{239} concentration	78.28 w/o
Atom Fission	87%
Cask Weight, loaded	46,000 lbs.

Capacity	Mark 22 Fuel Assembly
Fuel Data	
Envelope	3.20 inches in diameter
Weight of U^{235}	3.2 kg (initial)
Initial U^{235} Concentration	66.0-80.0 w/o
Burnup	1226 MWD
Cask Weight, loaded	46,000 lbs.

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NLI 1/2 SPENT FUEL SHIPPING CASK DATA

Fermi-1
Fuel Assemblies (16 per Cask)

Fuel Data	
Envelope	2.93 sq x 30.5
Enrichment w/o U-235	26.0
Weight of Uranium	18.7 kg
Maximum Average Burnup (MWD/MTU)	2840
Cask Weight, Loaded	46,735 lb

EBR-II
Fuel Assemblies (4 Canisters per Cask)

Fuel Data	
Envelope	4.875 inches in diameter
Enrichment w/o U-235	0.21
Weight of Uranium	291.8 kg
Maximum Average Burnup (MWD/MTU)	2400
Cask Weight, Loaded	48,625 lb

SUMMARY OF MAXIMUM
OPERATING PRESSURES (PSIG)

	Max. Allowable Pressure @ Oper. Temp.	*Max. Operating Pressure @ Oper. Temp.	Design Pressure
Cask Cavity			
Shell	1188 (XI-1-5) (XI-B2)		
Bottom Head	461 (XI-1-6)	117 (XI-1-37E)	120 (XI-1-37E)
Inner Cl. Head	612 (XI-1-38) (XI-B12)		
Inner Container			
Shell	640 (XI-1-37E)		
Bottom Head	543 (XI-1-38)	117 (XI-1-37E)	120 (XI-1-37E)
Closure Head	612 (XI-1-38)		
Closure Head Cavity			
Outer Cl. Head	594 (XI-B4)	**117 (XI-1-37E)	**120 (XI-1-37E)
Water Jacket	***250 (XI-1-8)	***185 (XI-1-8)	***250 (XI-1-8)

*Post fire accident condition

**Assumes inner closure head seal fails

***Normal transport conditions - water jacket relief valve is set for 200 psig and water jacket is not operative under accident conditions.

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Section III

SECTION III

FUEL DESCRIPTION AND SOURCE DATA

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SECTION III

FUEL DESCRIPTION AND SOURCE DATA

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SECTION III
FUEL DESCRIPTION AND SOURCE DATA

1.0 - INTRODUCTION AND SUMMARY

The NLI 1/2 spent fuel cask is a shipping container that was designed to transport one PWR or two BWR spent fuel assemblies. The cask is capable of accommodating the fuel designs of General Electric, Westinghouse, Babcock and Wilcox, and Combustion Engineering as described on Table III-1. The cask design is based on fuel heat and radiation source terms which were derived from certain limiting operating values of fuel exposure, specific power, initial enrichment and axial peaking factor. These limiting operating parameters are given in Table III-2. The design basis PWR fuel will have been cooled for 150 days following discharge from the reactor and prior to loading in the cask. The design basis cooling time for BWR fuel is 120 days following discharge.

By designing for fuel radiation and heat source terms based on limiting fuel parameters, the NLI 1/2 cask will be capable of shipping any PWR or BWR fuel whose parameters are no more restrictive than the design basis values. (The NLI 1/2 cask can also accommodate the shipment of other types of fuel such as metallic fuel, Mark 42 fuel, and Mark 22 fuel.)

The mechanical design parameters of BWR and PWR fuel shown on Table III-1 were developed from a review of PSAR and FSAR data and are considered representative of the designs which will be shipped in the NLI 1/2 cask. These parameters are used as a basis for the fuel thermal and structural analyses performed in this report.

The gamma, neutron and decay heat sources and the noble gas and halogen fission product inventories for the reference cask loadings are summarized

Table III-1

PARAMETERS FOR DESIGN BASIS FUEL

Type	Maximum Average Burnup MWD/MTU	Average Specific Power kW/kg U	Initial Enrichment w/o U-235	kgU per Assembly
PWR[1,2]	40,000	40	3.70	475
BWR	34,000	27	2.65	197
Consolidated PWR Fuel[3]	40,000	40	3.70	950
Metallic Fuel	1,600	-----	Natural	54.5
PWR Rods[4,5,6]	60,000	44	4.9	58 for 25 rods
BWR Rods[4]	75,000	60	5.0	75 for 25 rods

Notes:

1. A PWR fuel assembly having maximum burnup up to 56,000 MWD/MTU may be transported, provided that the assembly meets the criteria given in Section III-6.0, and that the neutron shield water is boronated to 1 w/o boron.

2. A PWR fuel assembly configuration containing additional irradiated fuel rods inserted and secured in the guide thimbles is permissible provided the initial uranium content of the assembly does not exceed 495 kg and the maximum average initial U-235 enrichment does not exceed 3.35 w/o. Such an assembly may have no more than four fuel rods having a cooling time of 120 days.

3. Consolidated PWR fuel consists of the fuel rods from up to two (2) PWR fuel assemblies packed in a stainless steel canister in a triangular array. The loaded canister must be transported in a Configuration A.

4. Up to 25 PWR or 25 BWR rods may be shipped, provided that the parameters of the rod shipment are within the bounds of the parameters shown above for PWR and BWR rods. PWR rods with burnup in excess of 45,000 MWD/MTU, and BWR rods with burnup in excess of 50,000 MWD/MTU, must be shipped in Configuration A.

5. Up to two of the 25 PWR rods may have a maximum burnup of 65,000 MWD/MTU

6. Up to 18 PWR rods, with a maximum specific power of 60 kW/kg U and a minimum cooling time of 300 days, may be packaged per cask.

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Table III-1a

PARAMETERS FOR MARK 42 FUEL

Initial Plutonium Content	3.350 kg
Initial Pu^{239} Concentration	78.28 w/o
Atom Fission	87%

Table III-1b

PARAMETERS FOR MARK 22 FUEL

Initial U^{235} Content	3.2 kg
Initial U^{235} Concentration	66.0-80.0 w/o
Burnup	1226 MWD

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TABLE III-2

FUEL MECHANICAL DESIGN PARAMETERS

Reactor Type	Westinghouse PWR	Combustion Engineering PWR	Babcock & Wilcox PWR	General Electric BWR
Pellet Dia., in.	0.3649	0.3795	0.370	0.487
Pin Array	15 x 15	14 x 14	15 x 15	7 x 7
Pin Pitch, in.	0.563	0.580	0.568	0.738
Pin Dia., in.	0.422	0.440	0.430	0.563
KgU/Assembly	448	395	454	197
Clad Material	Zr-4	Zr-4	Zr-4	Zr-2
Clad Thickness, in.	0.0243	0.026	0.0265	0.032
Fuel Pin/Fuel Assembly	204	176	208	49
Overall Fuel Assembly Cross-Section, in.	8.426 x 8.426	7.98 x 7.98	8.522 x 8.522	5.438 x 5.438
Active Fuel Length, in.*	144	136.7	144	144
Overall Shipping Length, in.	166.1	157	165	175.9
Enrichment w/o U-235	3.35	2.99	3.09	2.65
Specific Power kw/KgU	38.5	24.7	31.8	22.6
Average Burnup MWD/MTU**	33,000	24,000	28,200	30,000
UO_2 Density, % TD	93	93	91	95

* The active fuel length of PWR and BWR rods has been increased to 150.0 inches.

** See table on page II-10 for allowable burnups based on type of fuel.

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Table III-3
REFERENCE DESIGN SUMMARY

Conditions	One PWR[1,2] Fuel Assembly	Two BWR Fuel Assemblies	Consolidated[3] PWR Fuel Rods	Metallic Fuel	25 PWR Rods[4]	25 BWR Rods[4]
Loading	475 kgU	197 x 2 kgU	950 kgU	1,145.5 kgU	58.2 kgU	75 kgU
Initial Enrichment	3.7 w/o	2.65 w/o	3.7 w/o	Natural	4.9 w/o	5.0 w/o
Avg. Specific Power	40 kW/kg	27 kW/kg	40 kW/kg	-----	44 kW/kg[7]	60 kW/kg
Max. Avg. Burnup (MWD/MTU)	40,000	34,000	40,000	1,600	60,000[5,6]	75,000[6]
Cooling Time (days)	150	120	4,380	365	150	150
Sources						
Total Gamma Energy MeV/sec)	3.074×10^{16}	2.257×10^{16}	2.05×10^{16}	1.253×10^{15}	4.01×10^{15}	7.54×10^{15}
Total Decay Heat (kW)	10.63	7.93	0.6	0.75	1.65	4.0

Notes:

1. A PWR fuel assembly having maximum burnup up to 56,000 MWD/MTU may be transported, provided that the assembly meets the criteria given in Section III-6.0, and that the neutron shield water is borated to 1 w/o boron.

2. A PWR fuel assembly configuration containing additional irradiated fuel rods inserted and secured in the guide thimbles is permissible provided the initial uranium content of the assembly does not exceed 495 kg and the maximum average initial U-235 enrichment does not exceed 3.35 w/o. Such an assembly may have no more than four fuel rods having a cooling time of 120 days.

3. Consolidated PWR fuel consists of the fuel rods from up to two (2) PWR fuel assemblies packed in a stainless steel canister in a triangular array. The loaded canister must be transported in a Configuration A.

4. Up to 25 PWR or 25 BWR rods may be shipped, provided that the parameters of the rod shipment are within the bounds of the parameters shown above for PWR and BWR rods. The neutron shield water must be borated to 1 w/o boron when shipping PWR rods. The neutron shield water must be borated to 1 w/o boron when shipping PWR rods.

5. Up to two of the 25 PWR rods may have a maximum burnup of 65,000 MWD/MTU.

6. PWR rods with burnup in excess of 45,000 MWD/MTU and BWR rods with burnup in excess of 50,000 MWD must be shipped in Configuartion A.

7. Up to 18 PWR rods, with a maximum specific power of 60 kw/kgU and a minimum cooling time of 300 days may be packaged per cask.

Table III-3a
REFERENCE DESIGN SUMMARY

Conditions	Mark 42 Fuel Assembly
Loading	3.350 kg Plutonium
Intial Pu^{239} enrichment	78.28 w/o
Atom Fission	87%
Cooling Time (days)	1245
Sources	
Total Gamma Energy	5.80×10^{14} MeV/sec
Total Neutron Source	1.20×10^{9} n/sec
Total Decay Heat	0.45 kW

Table III-3b
REFERENCE DESIGN SUMMARY

Conditions	Two Mark 22 Fuel Assemblies
Loading	3.2 kg U^{235}/Assembly
Intial U^{235} Enrichment	66.0-80.0 w/o
Burnup	1226 MWD
Cooling Time (days)	150
Sources	
Total Gamma Energy	9.753×10^{15} MeV/sec
Total Neutron Source	7.872×10^{5} n/sec
Total Decay Heat	3.451 kW

Page added
August 1988
Revised
February 1990

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in Table III-3. As can be seen the source strengths for the one PWR cask loading are more restrictive than for the two BWR loading and therefore were used to establish the basic cask parameters.

Presented below is a description of the development of the source terms.

Figure III-1 taken from Reference 1 shows the axial burnup distributions in a PWR at various stages in its lifetime. The axial distribution was considered in each of the analyses performed as described in subsequent sections of this report.

2.0 GAMMA SOURCE

The fission product decay gamma source was calculated using the method given in the American Nuclear Society Proposed Standard, "Energy Release Following Shutdown of Uranium-Fueled Thermal Reactors".[2] The method is based on information published by Shure.[3] For a hypothetical infinite reactor operating time, the curve of fraction of operating power $\frac{P}{P_o}$ due to fission products versus cooling time has been fitted by an analytic expression:

$$\frac{P}{P_o}(\infty, t_s) = A t_s^{-a} \qquad (1)$$

where t_s is the decay time in seconds. For decay times such that $4 \times 10^6 \leq t_s \leq 2 \times 10^8$ (which includes the cooling time of interest = 150 days) the fitting constants are

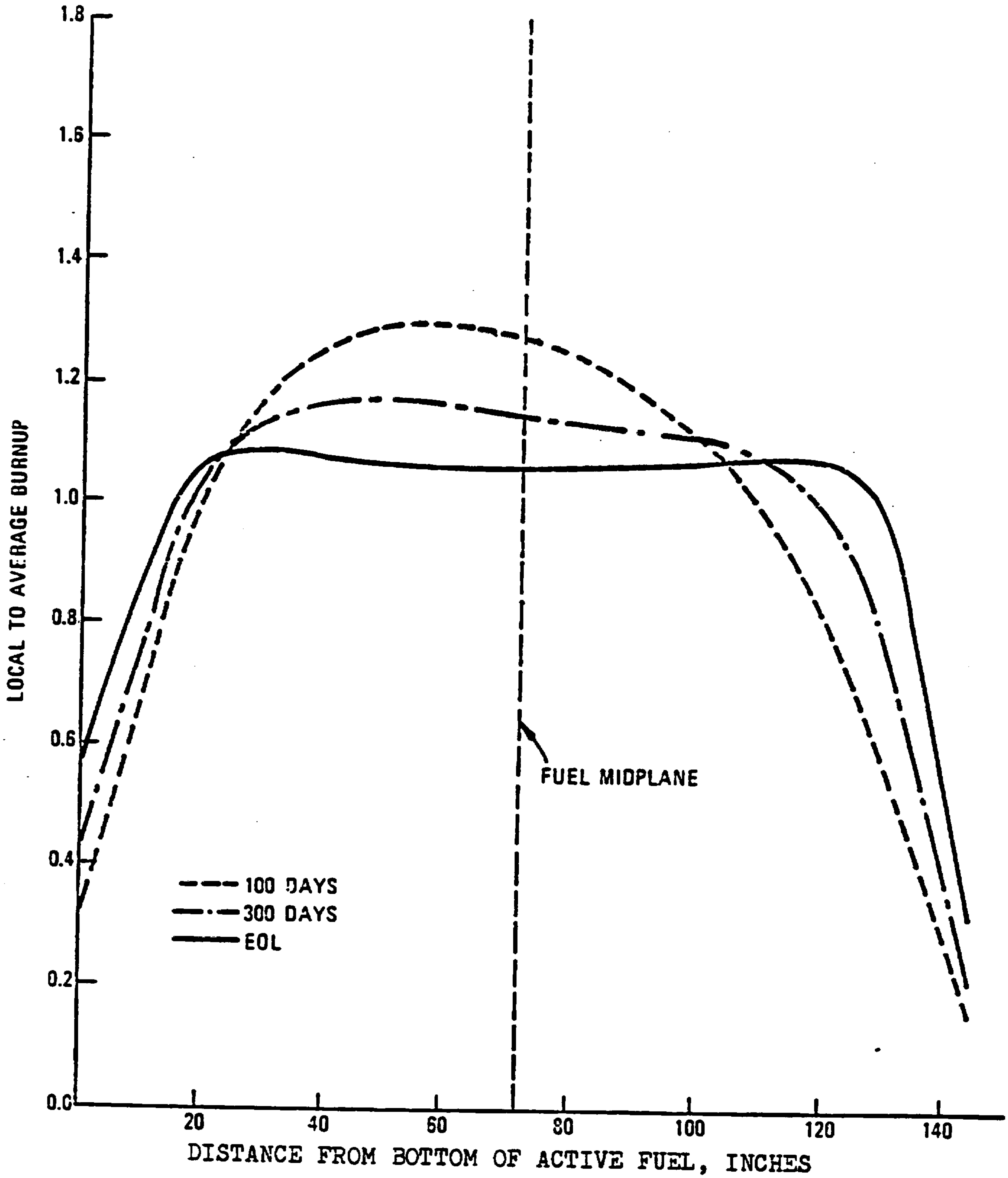
$$A = 0.266$$

$$a = 0.335$$

For a finite reactor operating time $t_o < \infty$, $\frac{P}{P_o}$ is calculated through a correction to Equation (1):

$$\frac{P}{P_o}(T_o, t_s) = \frac{P}{P_o}(\infty, t_s) - \frac{P}{P_o}(\infty, t_o + t_s) \qquad (2)$$

FIGURE III-1
AXIAL LOCAL-TO-AVERAGE BURNUP



For the limiting PWR assembly with a power density of 40 kw/kgU, a burnup of 40,000 MWD/MTU requires an irradiation time of 1000 days. With a loading of 0.454 MTU per assembly, Equation (2) gives a total (gamma + beta) decay heat source of 9.85 kw/assembly assuming 150 days cooling time. The contribution of betas and gammas to the decay energy release is approximately equal so the gamma decay energy is $\approx$ 4.93 kw/assembly or 3.074×10^{16} MeV/sec-assembly. Gamma decay energy production using the ANS standard was checked against earlier data published by Blomeke and Todd[4] and found to be in agreement. The gamma decay energy arrived at above is conservative compared to that given by Shure in Ref. 3 indicating that the assumed equal split between gamma and beta is conservative.

For shielding calculations, the total gamma source defined above is broken down into discrete energy groups. The Shure data in Ref. 3 was used to obtain the relative gamma energy distribution at 150 days after shutdown shown in Table III-4. The previously calculated total gamma source was then assigned to the different energy groups according to this distribution. The resulting energy dependent source distribution is given in Table III-4. As can be seen from the table, almost 99% of the gamma ray energy is emitted below 1 MeV.

It may be necessary on occasion to ship PWR type spent-fuel which contains either burnable poison rods or control rods. These rod clusters are contained within the basic fuel asembly cross section and the additional weight is accounted for in the 1600 lbs. fuel assembly design weight.

The active poison in the burnable rods is B_4C or B_2O_3 and the predominate neutron capture reaction is B^{10} (n, α). In this way, the neutrons are captured without the generation of gamma radiation. The alpha particles will be absorbed within the fuel assemblies. Therefore, if a significant amount of boron were contained in a shipment, the results would be beneficial from a radiation hazard standpoint.

The control rods will contain Ag-In -Cd and/or B_4C as an active poison. The cadmium, indium and silver will generate capture gammas by the (n,γ) reaction, however, this will not result in a net increase in gamma production. The presence of control rods is beneficial in that they will tend to decrease the spent fuel system reactivity.

The composition and melting points of the poson materials used in the various PWR fuels are given in Table III-5. As indicated in Figure VIII-2, the maximum temperature to be expected by a fuel pin (or in this case, a poison rod) is approximately 1100°F. This is well below the melting point of any of the poison materials being used.

Table III-4

DESIGN BASIS PWR ASSEMBLY GAMMA DECAY
HEAT DISTRIBUTION

Shure(3) Energy Group MeV	Relative Distribution 150 Days After Shutdown		Gamma Decay Source* MeV/Sec
0.1 - 0.4	1.2×10^{-2}		3.6888×10^{14}
0.4 - 0.9	0.97526		2.9979×10^{16}
0.9 - 1.35	1.8×10^{-3}		5.5332×10^{13}
1.35 - 1.8	9.4×10^{-4}		2.889×10^{13}
1.8 - 2.2	1.0×10^{-2}		3.074×10^{14}
>2.2	$<2 \times 10^{-4}$		--
		Total	3.074×10^{16}

*Source per assembly with 40,000 MWD/MTU burnup, 40 kw/kgU power density, 150 days cooling time, and 0.454 MTU.

TABLE III-5

PWR POISON COMPOSITIONS AND MELTING POINTS

	Babcock & Wilcox		Combustion Engineering		Westinghouse	
	Control Rods	Burnable Poison Rods	Control Rods *	Burnable Poison Rods	Control Rods	Burnable Poison Rods
Material	Ag-In-Cd	B_4C	B_4C	B_4C	Ag-In-Cd	Borosilicate **
Melting Point (°F)	(1427)	(4350)	(4350)	(4350)	(1427)	(1292)
		Al_2O_3	Al_2O_3	Al_2O_3		
		(3700)	(3700)	(3700)		
			Ag-In-Cd			
			(1427)			

* Various designs are available with different combinations of these materials.

** Softening point given. Various types of Borosilicates may be used with softening points from 1292°F to 1510°F.

3.0 NEUTRON SOURCE

3.1 General

In addition to the production of gamma and beta emitting fission products as a result of U-235 irradiation, neutron emitting transuranium elements will be produced in higher burnup fuel. These neutrons come from both spontaneous fission and from (α,n) reactions in oxygen. Though most of the transuranium elements undergo α decay and have a small probability for spontaneous fission, experimental data[5] indicates that the buildup of these transuranium neutron sources is not significant below exposures of approximately 20,000 MWD/MTU. Above 20,000 MWD/MTU, the isotopes Curium-242 and Curium -244 contribute a significant neutron source.

Most analytical and experimental transuranium source data[5,6,7,8] generated to date has not

- considered transuranium element production rates to 40,000 MWD/MTU;
- completely defined fuel and irradiation characteristics; or
- defined conditions representative of second generation LWR core operation

Accordingly, a study was performed to define a typical PWR assembly neutron source strength after 40,000 MWD/MTU burnup and 150 days cooling time. For this purpose, the LEOPARD code[9] was used in conjunction with the FLYASH-II code.[10]

3.2 Methods of Analysis

The FLYASH-II code was developed to calculate the inventory of fission products, fuel isotopes and transuranium isotopes contained in the fuel from a specific reactor as a function of fuel burnup, reactor power level, reactor operating and shutdown times, and the elapsed cooling or decay time after removal of the fuel from the reactor core.

The following information is supplied as input data to the FLYASH-II code:

1. Total core voume of reactor
2. Initial fuel loading
3. Fuel type (i.e., U, UO_2, or UC_2)
4. Initial isotopic composition of reactor core
5. Time intervals for reactor operation and shutdown
6. Neutron flux (thermal, epithermal and fast) during each time interval
7. Wigner-Wilkins and spatial self-shielding factors for each time step prescribed
8. A description of the nuclide chains to be solved
9. Absorption and fission cross sections for the fissile and fertile isotopes, U-235, U-238, Pu-239, Pu-240, and Pu-242 and any additional transuranium isotopes included in the nuclide chains to be solved.

Within the FLYASH program is incorporated a library of nuclear data for the major fission products. Three hundred and thirty-four nuclides are presently listed in the FLYASH library. The following data are incorporated for each nuclide:

1. The direct fission yield from each of the four fissile species, U-235, U-239, Pu-239 and Pu-241
2. The decay yield from up to two parent nuclides, each of which must also be included in the library
3. The 2,200 meter capture cross section
4. The estimated effective epithermal cross section
5. The decay constant
6. The mean beta energy
7. The average alpha energy
8. The yield and energy of each gamma emission for up to 21 photon energies
9. The decay constant for spontaneous neutron emission

Using the foregoing information, FLYASH calculates the effective reaction rate for each isotope using two neutron energy groups. The inventory of each fission product and transuranium nuclide is then calculated using these reaction rates, the library information on yields, decay, etc., and the appropriate equations for buildup and decay of radioactive nuclides. The equations solved in FLYASH are given in Ref. 11 along with a comparison of calculated isotopic contents using FLYASH with measured isotopic contents of irradiated fuel.

The LEOPARD code [9] was used to generate the input required by FLYASH-II. LEOPARD is a zero-dimensional unit cell depletion program which automatically recalculates the spectrum in the unit cell at each burnup step. The important spatial effects in the unit cell, such as thermal disadvantage factor and resonance shielding are also calculated at each burnup step. The LEOPARD output provided thermal absorption, thermal fission, fast absorption, and fast fission cross section data required by FLYASH-II. In addition, the thermal, epithermal, and fast flux values, Wigner-Wilkins factors, and self shielding factors were obtained from the LEOPARD output.

Production of the transuranium elements in FLYASH-II was calculated in accordance with the flowchart in Figure III-2 which depicts all the important nuclide chains. It should be noted that this flowchart is in agreement with, and is more detailed than, other sources of transuranium element buildup and decay data. [12,13] The half lives and neutron source data for spontaneous fission for the transuranium elements are given in Table III-6. The corresponding data for the (α, n) reactions are given in Table III-7.

3.3 Results

LEOPARD FLYASH-II calculations of transuranium element production were made for the reference PWR fuel design for enrichments of 2.0, 2.68, and 3.35 w/o and for burnups between 20,000 and 45,000 MWD/MTU. The calculations were performed for continuous operation at a constant specific power of 40 kw/kgU. Other calculations indicated the effect of changes in specific power to be negligible. The resulting neutron source data n/gmU-sec) is shown in Fig. III-3.

FIGURE III-2
DECAY CHAINS USED IN FLYASH

KEY:

- n = NEUTRON CAPTURE
- β = BETA DECAY
- α = ALPHA DECAY
- EC = ELECTRON CAPTURE
- DUMMY = NO ACCUMULATION OF NUCLIDE WAS ASSUMED

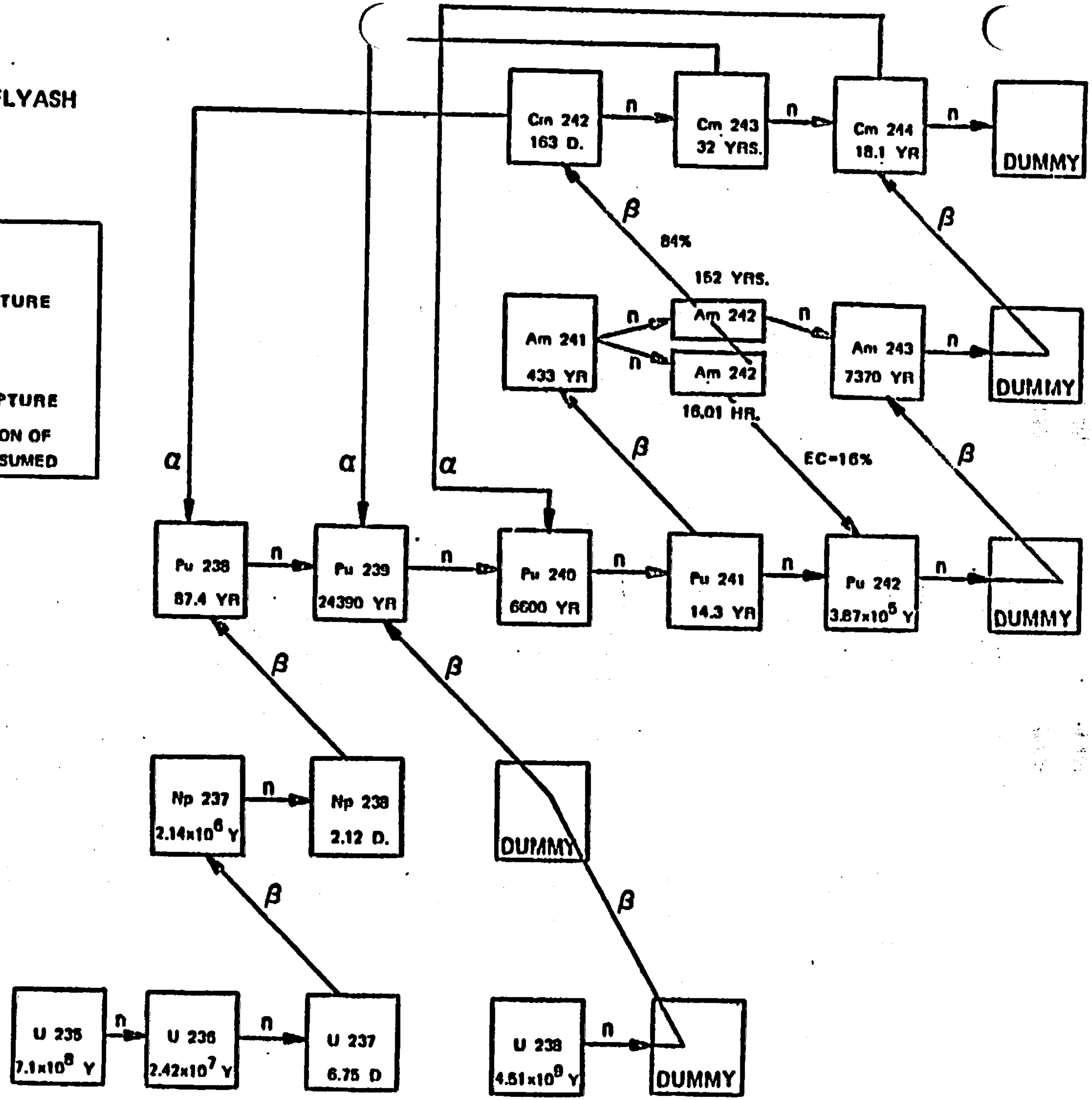


Table III-6

SPONTANEOUS FISSION DATA FOR
TRANSURANIUM ELEMENTS DEFINED
IN FLYASH-II

Nuclide	S.F. Half Life, yrs.	Neutron Source, n/gm-sec
U-235	1.8×10^{17}	8×10^{-4} *
U-236	2×10^{16}	4.4×10^{-3} *
U-238	8×10^{15}	1.6×10^{-2} *
Np-237	$> 4 \times 10^{15}$	-- *
Pu-238	4.9×10^{10}	2.5×10^{3}*
Pu-239	5.5×10^{15}	3.0×10^{-2} *
Pu-240	1.2×10^{11}	1.02×10^{3}*
Pu-242	7.25×10^{10}	1.7×10^{3}*
Am-241	1.4×10^{13}	-- *
Cm-242	7.2×10^{6} **	2.3×10^{7}***
Cm-244	1.4×10^{7} **	1.19×10^{7}***

* See References (12) and (14)

** See Reference (13)

*** See Reference (15)

Table III-7

(α, n) REACTION DATA FOR TRANSURANIUM ELEMENTS DEFINED IN FLYASH-II

Nuclide	Half Life for α Emission, yrs.[c]	Neutron Source from (α,n) in Oxygen n/gm-sec
U-235	7.1×10^{8}	1.09×10^{-2} (a)
U-236	2.42×10^{7}	3.19×10^{-1} (a)
U-238	4.51×10^{9}	1.71×10^{-3} (a)
Np-237	2.14×10^{6}	3.62 (a)
Pu-238	87.4	1.4×10^{4} (b)
Pu-239	24,390	4.5×10^{1} (b)
Pu-240	6600	1.7×10^{2} (b)
Pu-242	3.87×10^{5}	2.7 (b)
Am-241	433	1.79×10^{4} (a)
Am-242m	152	2.45×10^{2} (a)
Cm-242	162.5 days	2.0×10^{7} (d)
Cm-244	18.1	4.29×10^{5} (d)

(a) Calculated based on ratio of indicated half life of Cm-244 (Am-242m α decay is only 0.48%. Am-242 result takes this into consideration. Rest are 100% α decay).

(b) See References (12) and (13)

(c) See Reference (13)

(d) See Reference (15)

As can be seen from Figure III-3, the neutron source from transuranium elements is strongly dependent on initial enrichment as well as fuel burnup. For the enrichment of 2.68 w/o, the neutron source strength increases from 1.2×10^3 to 2.1×10^3 n/gmU-sec as burnup increases from 35,000 to 40,000 MWD/MTU. At a higher enrichment (3.35 w/o) the neutron source at 40,000 MWD/MTU is substantially reduced (1.5×10^3 n/gmU-sec). The fuel with the higher U-235 content produces relatively more energy by U-235 fission and relatively less energy by plutonium fission. In practice it will not be possible to drive 2.68 w/o fuel to an assembly average burnup of 40,000 MWD/MTU and a source based on this assumption would be unnecessarily conservative. Therefore the neutron source was based on an initial enrichment of 3.35 w/o. Applying the specific source results of Figure III-3 to an assembly with an average burnup of 40,000 MWD/MTU with the end of life distribution shown in Figure III-1 results in a total neutron source strength of 7.55×10^8 n/sec for the design basis PWR assembly.

The energy spectra for neutrons coming from spontaneous fission and from (α,n) reactions are given in Reference 15 for both Cm-242 and Cm-244. For both isotopes the spectra were weighted by the relative contributions of spontaneous fission and (α,n) and put into the energy structure used in the shielding studies. The resulting combined spectra are shown in Table III-8 along with the spectrum for neutrons emitted from thermal neutron fissioning of U-235. For a given fuel condition the spectra from the separate isotopes Cm-242 and Cm-244 can be combined based on the fraction of neutrons emitted from the two isotopes. For the reference PWR fuel at 3.35 w/o and 40,000 MWD/MTU, FLYASH-II results gave 32.6% of the neutrons emitted by Cm-242 and 67.4% by Cm-244. Using these weighting factors the combined spectrum for Curium neutrons is shown in Table III-8 .

4.0 DECAY HEAT

As previously described in Section III-2.0, the total decay heat (gamma + beta) for the reference PWR assembly at 40,000 MWD/MTU and 150 days cooling

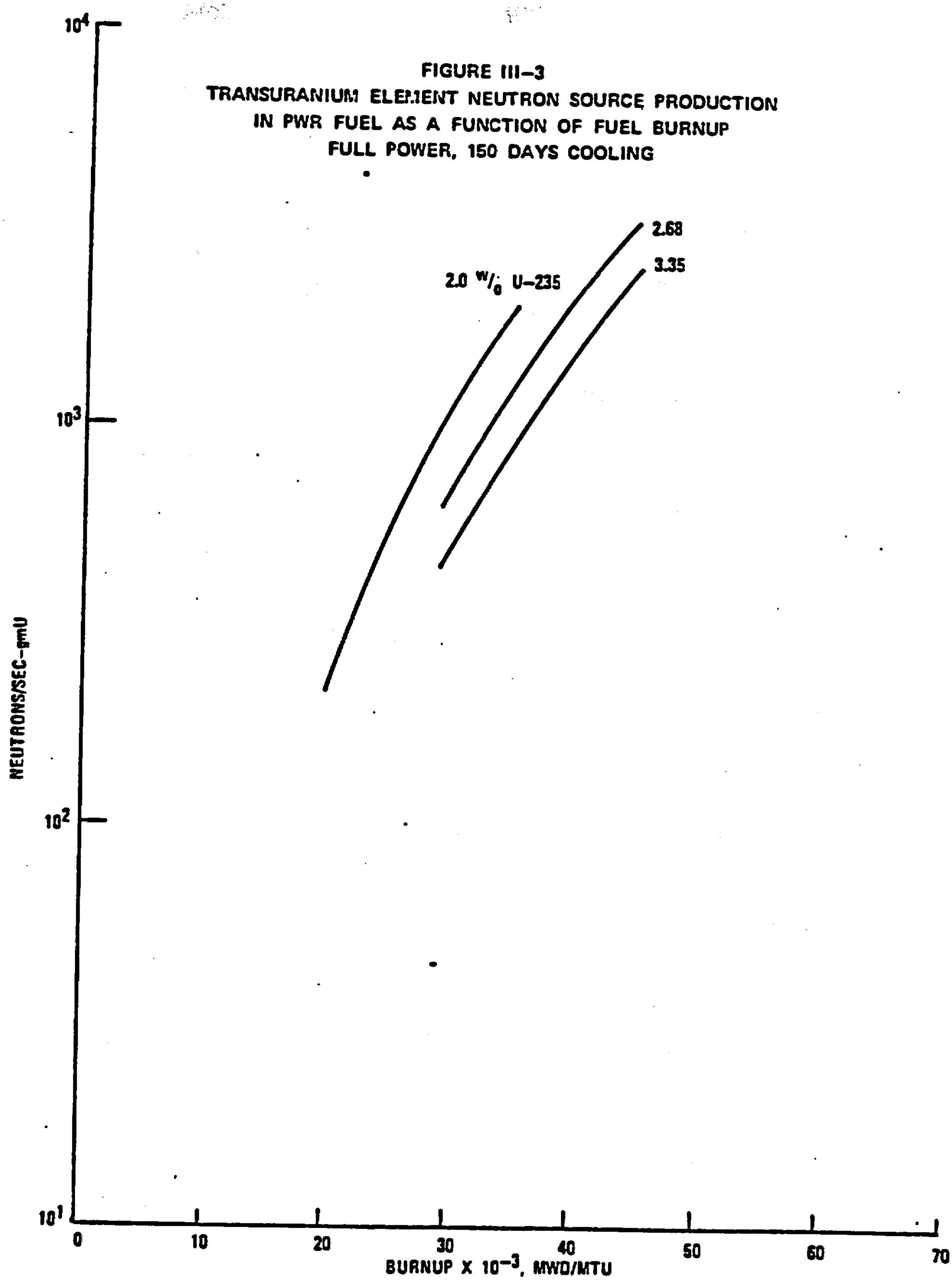


FIGURE III-3
TRANSURANIUM ELEMENT NEUTRON SOURCE PRODUCTION
IN PWR FUEL AS A FUNCTION OF FUEL BURNUP
FULL POWER, 150 DAYS COOLING
2.68
3.35
2.0 w/o U-235
NEUTRONS/SEC-gmU
10^4
10^3
10^2
10^1
0
10
20
30
40
50
60
70
BURNUP X 10^{-3}, MWD/MTU

Table III-8

NEUTRON SPECTRUM FROM CURIUM

Group	Energy	Cm-242	Cm-244	Fission Spectrum	Combined Cm Spectrum (E = 3.35 w/o 40,000 MWD/MTU)
I	> 3.0 MeV	0.358	0.231	0.093	0.273
II	1.4 - 3.0	0.415	0.367	0.208	0.383
III	0.9 - 1.4	0.100	0.174	0.238	0.150
IV	0.4 - 0.9	0.107	0.190	0.225	0.163
V	0.1 - 0.4	0.020	0.038	0.137	0.031
	<0.1	--	--	~0.1	--

is 9.85 kw/assembly due to fission product decay. The contributions of betas and gammas are approximately equal. Energy associated with neutrons and fissioning in the subcritical assembly is negligible. In addition to the heat from fission product decay, there is heat generated by the decay of the transuranium elements. This contribution was obtained from the FLYASH-II calculation described in Section III-3.3 and was equal to 0.78 kw/assembly. For the reference PWR assembly over 95% of the decay heat from transuranium elements is due to α decay in the Curium isotopes. The total decay heat source due to fission products plus transuranium elements is then 9.85 + 0.78 = 10.63 kw/per assembly.

5.0 BWR SOURCES

Calculations similar to the described above were carried out to determine the source strengths associated with two BWR fuel assemblies. The BWR design conditions were taken as 197 kgU/assembly, E = 0.0265 w/o, 27 kw/kg, 34,000 MWD/MTU, and 120 days cooling time. The resulting source strengths for two BWR fuel assemblies are shown in Table III-3. As can be seen from this Table, the PWR source is the limiting design condition.

6.0 HIGH BURNUP PWR SOURCES

Additional analysis has been performed relative to the transport of PWR assemblies with burn-ups up to 56,000 MWD/MTU, as referenced in the notes of Tables III-1 and III-3.

The analysis demonstrates that high burn-up assemblies that meet the following conditions are acceptable for transport:

Maximum Average Initial Enrichment	3.35 w/o
Maximum Initial Uranium Content	475 kg
Gamma Source Strength	1.0×10^{16} MeV/SEC
Neutron Source Strength	1.86×10^{9} n/sec
Thermal Output	Less than 10.6 kw
Minimum Cool Time*	150 days
Assembly Weight (including any additional rods)	1600 pounds

*Cooling time may be less than 450 days, provided that an ORIGEN calculation shows that the neutron and gamma source strengths, and the decay heat, are less than those values given in this table.

For each assembly to be shipped, the thermal output (decay heat) and the gamma and neutron source strengths must be calculated by the ORIGEN computer code. In addition, the neutron shield water must contain one percent boron (by weight). Typically, the required reduction in gamma and neutron source strengths of the high burn-up assembly is achieved by cooling after discharge, which also reduces the decay heat output. The assembly may contain additional fuel rods secured in the thimble tubes, provided that all of the above criteria are met.

Provided that the high burn-up assembly meets the above criteria and the other conditions of the license, the criticality, structural, thermal, and shielding considerations are summarized as follows:

The NLI-1/2 cask is currently licensed to carry PWR fuel enriched to 3.7 w/o U-235, which is reduced to 3.35 w/o if fuel rods are carried in the assembly guide thimbles. A detailed criticality analysis is not necessary because the enrichment of the high burn-up assembly must be equal to, or less than, the licensed limit and subcriticality is assured.

No thermal analysis is required because the decay heat to the high burn-up assembly is required to be equal to or less than the licensed fuel decay heat.

The ORIGEN code provides gamma and neutron source strengths as a function of cool time. The requirements for the high burn-up assembly, as presented above, are that the gamma source strength be less than the design gamma source term of the cask. The neutron source strength may be as high as 1.86×10^9, provided that the neutron shield tanks contain boron to provide additional neutron shielding. A gamma and neutron shielding analysis is presented in Section IX, verifying that adequate neutron shielding is provided.

7.0 METALLIC FUEL SOURCES

Additional analyses have been performed relative to the transport of up to 21 rods of metallic fuel. These rods are 53.75 kgU per rod nominally, using natural uranium metal fuel. The burnups achieved by these rods are low compared to PWR fuel, as shown in Tables III-1 and III-3.

The ORIGEN computer code was used to calculate the source terms given below. The analyses show that up to 21 metallic fuel rods that meet the following conditions are acceptable for transport.

Maximum Average Initial Enrichment	Natural, 0.711 w/o U-235
Maximum Initial Uranium Content	54.5 kgU
Gamma Source Strength	5.97×10^{13} MeV/sec.
Neutron Source Strength	1.07×10^{4} n/sec.
Thermal Output	35.7 watts
Minimum Cool Time	365 days

8.0 PWR AND BWR ROD SOURCES

Additional analyses have been performed relative to the transport of up to 25 rods of PWR or 25 rods of BWR fuel with burnups of 60,000 MWD/MTU* and 75,000 MWD/MTU respectively, and cool times of 150 days minimum in both cases. The total sources for rods of either fuel type are lower than the high burnup PWR fuel as shown below. The analyses show that up to 25 PWR and 25 BWR rods, with the sources given, are acceptable for transport.

PWR

Source Type	High Burnup PWR Assembly	PWR Rods* (25 Total)	Percent Of High Burnup PWR
gamma (MeV/sec)	1.0×10^{16}	4.04×10^{15}	40.4%
neutron (n/sec)	1.86×10^{9}	1.12×10^{9}	60.3%
Heat (kW)	10.63	1.65	16%

BWR

Source Type	High Burnup PWR Assemblies	BWR Rods (25 Total)	Percent of Design Basis BWR
gamma (MeV/sec)	1.0×10^{16}	7.54×10^{15}	75%
neutron (n/sec)	1.86×10^{9}	3.5×10^{8}	19%
Heat (kW)	10.63	4.0	38%

Revised
Oct. 1986
Feb. 1987
May 1987
Jan. 1990
Oct. 1990
Feb. 1991
Apr. 1992

* 23 PWR Rods at 60,000 MWD/MTU and 2 PWR Rods at 65,000 MWD/MTU.

9.0 MARK 42 FUEL ASSEMBLY SOURCES

Additional analyses have been performed relative to the transport of the Mark 42 fuel assembly. The assembly initially contains 3.350 kilograms plutonium with an enrichment of 78.28 w/o plutonium-239.

The CANDU data library for the ORIGEN-2 computer code was used to calculate the gamma source terms given below. Neutron source terms were based on actinide composition calculations made by Savannah River personnel. The analyses show that any Mark 42 fuel assembly that meets the following conditions is acceptable for transport.

Maximum Initial Weight of Plutonium	3.350 kg
Maximum Pu^{239} Concentration	78.28 w/o
Gamma Source Strength	5.80×10^{14} MeV/sec
Neutron Source Strength	1.20×10^{9} n/sec
Thermal Output	0.45 kW

10.0 MARK 22 FUEL ASSEMBLY SOURCES

Additional analyses have been performed to support the transport of two Mark 22 fuel assemblies. The assembly is similar to the previously licensed Mark 42 assembly in design. The Mark 22 is, however, composed of 3.2 kilograms of uranium-235 with an enrichment range of 66.0-80.0 w/o uranium-235. An enrichment of 66.0 w/o uranium-235 was used for the source calculations, because it yields the limiting source terms for 4.85 kilograms of uranium.

The LOR-2 version of ORIGEN2 available from Babcock and Wilcox was used to calculate the source terms given below for the two assemblies. The sources calculated were compared to values supplied by Savannah River personnel and were found to be conservative.

Maximum Initial Weight of Uranium	4.85 kg/assembly
U^{235} Concentration	66.0 w/o
Gamma Source Strength	9.753×10^{15} MeV/sec
Neutron Source Strength	7.872×10^{5} n/sec
Thermal Output	3.451 kW

11.0 FUELS TO BE TRANSPORTED

The following fuels have been evaluated for transport in the NLI-1/2 cask:

a. One irradiated PWR uranium oxide fuel assembly with limiting characteristics as specified in Table III-3. The assembly may be shipped in either Configuration (A) or (B).

b. Up to two irradiated BWR uranium oxide fuel assemblies with limiting characteristics as specified in Table III-3. The assemblies may be shipped in either Configuration (A) or (B).

c. Consolidated PWR or BWR fuel rods with limiting characteristics as specified in Table III-3. Consolidated fuel rods must be shipped in Configuration (A). Consolidated fuel analyses are located in Paragraphs 4.11 of Section VIII, 4.3 of Section IX, 10.0 of Section X and Appendix E of Section XI.

d. Up to 4 canisters containing either Fermi-I or EBR-II Blanket metallic fuels with limiting characteristics as described on pages X-24 and X-32. These fuels must be shipped in Configuration (C). Evaluations of these fuels have been included to provide the supporting analyses for Configuration (C). The criticality evaluation for this configuration is located in Paragraph 10.8 of Section X. The structural evaluation for this configuration is located in Appendix F of Section XI.

e. Up to 21 irradiated research reactor metallic fuel rods with limiting characteristics as specified in Table III-3. Sound research reactor metallic fuel rods must be shipped in Configuration (D). Evaluations for this fuel are located in Paragraphs 4.12 of Section VIII, 4.4 of Section IX, 10.4 of Section X, and Appendices D and G of Section XI. Analyses have also been performed for transport of up to six individually encapsulated failed metallic fuel rods. This analysis can be found in Appendix H of Section XI. Up to three failed rods may be shipped in the normal Configuration (D) three-hole basket. Up to six failed rods may be shipped in the Configuration (D) six-hole basket.

f. Up to 25 irradiated PWR fuel rods or 25 irradiated BWR fuel rods with limiting characteristics as specified in Table III-3. PWR rods with burnup in excess of 45,000 MWD/MTU and BWR rods with burnup in excess of 50,000 MWD/MTU must be shipped in Configuration A. Evaluations of these payloads are found in Paragraphs 4.13 of Section VIII, 4.5 of Section IX, 10.5 of Section X and Appendix D of Section XI.

g. One irradiated Connecticut Yankee fuel assembly with limiting characteristics as specified in Appendix G of Section X. As described in Appendix G, this assembly may be shipped in either Configuration (A) or (B). The evaluation for the Connecticut Yankee fuel assembly is also in Appendix G of Section X.

h. One intact or sectioned irradiated Mark 42 fuel assembly with limiting characteristics as specified in Table III-3a. This fuel must be shipped in Configuration (C). Supporting evaluations are located in Paragraphs 4.14 of Section VIII, 4.6 of Section IX, 10.6 of Section X and Appendix D of Section XI.

i. One sectioned or two intact irradiated Mark 22 fuel assemblies with limiting characteristics as specified in Table III-3b. This fuel must be shipped in Configuration (C). Supporting evaluations are located in Paragraphs 4.15 of Sections VIII, 4.7 of Section IX, 10.7 of Section X and Appendix D of Section XI.

j. Solid, non-fissile, irradiated hardware and neutron source components with source terms below those specified in Table III-3 for one PWR fuel assembly.

k. Byproduct and special nuclear material in the form of irradiated uranium and plutonium oxide fuel rods. Prior to irradiation, the maximum average enrichment in U-235 plus plutonium not to exceed 3.7 weight percent and the maximum enrichment not to exceed 4.0 weight percent. The maximum mass of U-235 plus plutonium not to exceed 4.0 kg.

12.0 REFERENCES

1. North Anna Units 3 & 4 PSAR, VEPCO, DKT 50-404.

2. "Energy Release Following Shutdown of Uranium Fueled Thermal Reactors", Proposed American Nuclear Society Standard, June 1968.

3. Shure, K., "Fission Product Decay Energy", WAPD-B(T)-24, December 1961.

4. Blomeke, J. O., Todd, M. F., "Uranium-235 Fission Product Production as a Function of Thermal Neutron Flux, Irradiation Time and Decay Time", ORNL-2127, August 1957.

5. Roberts, F. P., and Van Tuyl, H. H., "Promethium-146, Fission Product and Transuranium Isotope Content of Power Reactor Fuels, Comprehensive Chemical Analyses", BNWL-45, March 1965.

6. Bell, M. J., "Heavy Element Composition of Spent Power Reactor Fuels", ORNL-TM-2897, May 1970.

7. Deonigi, D. E., "Formation of Transuranium Isotopes in Power Reactors", BNWL-140 (Rev. 1), May 1970.

8. Deonigi, D. E., et al, "Isotope Production and Availability from Power Reactors", BNWL-716, July 1968.

9. Barry, R. F., "LEOPARD - A Spectrum Dependent Non-Spatial Depletion Code for the IBM-7094", WCAP-3269-26, September 1963.

10. Kim, Y. S., "FLYASH-II - A CDC-6600 Computer Code to Calculate Time-Dependent Isotopic Inventory and Radioactive Disintegration Rates in a Nuclear Reactor", NUS-878, February 1972.

11. Allied Gulf Nuclear Services, Barnwell Nuclear Fuel Plant Safety Analysis Report, DKT 50-332.

12. Nuclear Safety, Volume 5, No. 4, Summer, 1964.

13. Lederer, C. M., et al, "Table of Isotopes", Sixth Edition, John Wiley & Sons, N.Y., March 1968.

14. "Reactor Physics Constants", ANL-5800, Second Edition, USAEC, July 1963.

Revised
Feb. 1987
May 1987
Dec. 1988
Feb. 1991

15. Rinshaw, S. J., and Ketchen, E. E., "Curium Data Sheets", ORNL-4357, January 1969.

16. Cottrell, W. B., and Savolainen, A. W., Editors, "U. S. Reactor Containment Technology", ORNL-NSIC-5, August 1965.

Section IV

SECTION IV

COMPLIANCE WITH CFR, TITLE 10, CHAPTER 1, PART 71

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SECTION IV

Compliance With 10 CFR 71, Chapter 1

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22	Package Description	Shipping configuration with inner container.
71.22(a)(1)	Gross Weight	The maximum gross weight of the cask is 48,000 lbs.
71.22(a)(2)	Model Number	The model number of the cask is NLI-1-2
71.22(a)(3)	Specific materials, weights, dimensions, and fabrication methods	The weights of the cask components are given in Section VII, "Weight Calculations". The materials of construction are given in Section VI, "Material Specifications". Fabrication methods are described in Section XII ,"Manufacturing and Quality Control".
71.22(a)(3)(i)	Receptacles, identifying the one which is considered to be the containment vessel.	The cask structure consists of inner and outer stainless steel cylinders which are joined by stainless steel forgings at each end. The annules between the inner and outer cylinders contain a composite lead/uranium gamma shield. Neutron shielding is provided by a water jacket which surrounds the outer stainless steel cylinder and all of the region containing active fuel. The fuel is carried in an inner container whibh has its own closure head, and is fitted with an aluminum basket which supports the fuel. This inner container is considered the primary containment vessel while the cask cavity is considered as the secondary containment vessel.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22(a)(3)(ii)	Non-fissile neutron absorbers or moderators	There are no special materials used as non-fissile neutron absorbers or moderators. The fissile contents of the cask are so limited that the use of poison materials is not required to maintain the cask at subcritical condition. For further discussion see Section X "Criticality Analysis".
71.22(a)(3)(iii)	Internal and external structures supporting or protecting receptacles	The fuel is supported within the primary containment vessel by an aluminum basket. The aluminum basket is made up of four pieces of aluminum approximately 150 inches long. Each piece of aluminum is shaped to form a segment of a circle. The internal flat face of each segment forms a square which supports the fuel for its entire active length. The four aluminum pieces are held in position by circumferential aluminum straps which are welded to each aluminum segment. The aluminum basket and fuel are supported axially by stainless steel weldments. The primary containment vessel (Inner Container) flange is supported and bolted to a step which is machined into the head end forging of the cask body. The ends of the cask body are fitted with impact structures which are aluminum weldments filled with balsa wood.
71.22(a)(3)(iv)	Valves, sampling ports, lifting devices, and tie-down devices;	There are two (2) penetrations thru the cask body which exit in the closure head cavity region. The valves are located in the head end forging. There are two (2) penetrations thru the inner closure head. Both valves are the bellows seal type as manufactured by Hoke. The valve

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22 (a)(3)(iv) cont.		and bellows seal are made of type 316 stainless steel and have a operating temperature range of -320° to 1500° F. The valves are designed for liquids and gases of radioactive, reactive or toxic nature, liquid metals and cryogenic service. The water jacket is fitted with a 5100 series circle seal relief valve. The fill and drain valve is a Snap-Tite valved coupling, 300 series stainless steel. The integral expansion tank has an overflow pipe which is also fitted with a Snap-Tite valved coupling or may be fitted with a stainless steel 3000# pipe cap. Lifting and positioning of the cask is accomplished with the use of a lifting yoke which engages a set of trunnions welded to the top forging of the cask body. Each trunnion is machined from a solid bar of stainless steel. The top forging of the cask body provides a more than adequate foundation for the trunnion. Tie-down of the cask to the trailer is accomplished by a set of trunnions which engage sockets machined into bottom forging of cask and a saddle arrangement at the head end of the cask. The trunnion arrangement acts as a pivot to rotate the cask from a vertical to horizontal position on the trailer bed. The trunnions support the cask in the horizontal position and provide the necessary restraint for the vertical and transverse acceleration components of 2G and 5G respectively. The head end of the cask has two machined

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22 (a) (3) (iv) cont.		rings spaced some distance apart which engage a mating ring section in the front saddle. A bolting block which is welded between the two rings on the cask provide the tie-down points between the cask and the saddle. This arrangement is capable of withstanding the specified acceleration components of 2G vertical, 5G transverse, and 10G in the direction of travel without generating stresses in excess of the yield stress in any material of the package.
71.22 (a) (3) (v)	Structural and mechanical means for the transfer and dissipation of heat.	Decay heat is removed from the fuel to the cask first by thermal radiation and conduction through a helium filled inner container and then through the cask sides and ends by a combination of conduction, natural convection in the water filled neutron shield, and natural convection and radiation from the surfaces of the cask. Helium was selected because it is a chemically inert gas and does not become radioactive. Helium is only slightly soluble in water, and will neither burn nor explode. Being completely inert, there is no reaction with the materials used in the construction of the cask nor with the spent fuel elements being shipped. Thermal radiation augments the conduction heat transfer across well established air gaps within the cask. Being entirely passive, this means of heat dissipation is highly reliable.
71.22 (a) (4)	Identification and volumes of any coolant and of receptacles containing coolant.	Being a dry shipment with passive heat removal, there is no coolant associated with the package.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22(b)(1)	Identification and maximum radioactivity of radioactive constituents	See Section III, "Fuel Description and Source Data".
71.22(b)(2)	Identification and maximum quantities of fissile constituents	See Section III, "Fuel Description and Source Data".
71.22(b)(3)	Chemical and physical form	See Section III, "Fuel Description and Source Data".
71.22(b)(4)	Extent of reflection, the amount and identity of non-fissile neutron absorbers	See Section X, "Criticality Analysis".
71.22(b)(5)	Maximum weight of contents	The maximum weight of a fuel assembly(s) carried in the cask is 1600 pounds. The maximum weight of a consolidated fuel canister is 2934 pounds.
71.22(b)(6)	Maximum amount of decay heat	The maximum decay heat generated by a fuel assembly(s) in the cask will not exceed 10.63 kw.
71.23	Package evaluation	
71.23(a)	Demonstrate that the package satisfies the standards specified in Sub-Part C	The cask satisfies the standards in Sub-Part C. See Sub-Part "C" below.
71.23(b)	Fissile Class II	Not applicable
71.23(c)	Fissile Class III	The fissile contents of the cask are so limited that the use of poison materials is not required to maintain the cask at

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.23(c) Cont.	Fissile Class III	subcritical condition. Operating procedures and check-off lists will be used to control the loading, unloading and handling of the cask. Accident control and recovery plans will be established in accordance with local and federal regulations.
71.24	Procedural Controls	Procedural Control adequate to satisfy the requirements of 71.51(b) have been prepared. See 71.51 below.
SUBPART C		
71.31	General Standards for all Packaging	
71.31(a)	Packaging shall be of such materials and construction that there will be no significant chemical,galvanic,or other reaction among the packaging components.	There will be no significant chemical,galvanic, or other reaction among the packaging components, or between the packaging components and the package contents. The fuel is carried in an aluminim basket which is housed in the stainless steel inner container. The cask body is a stainless steel weldment. Reaction between the uranium shield and the stainless steel inner shell is prevented by a layer of flame-sprayed copper applied to those areas of the stainless steel shell where maximum temperatures are predicted. There is no reaction between the lead and uranium shield materials in the temperature ranges predicted during and after the fire accident conditions. Ref. Reactor Handbook, 2nd Edition, Volume I, Materials.
71.31(b)	Packaging shall be equipped with a positive closure which will prevent inadvertent opening.	The double containment system utilizes two separate closure heads. The inner head is held in place by 12 stud bolts, 1" in diameter. The outer closure head is held in place by 8 bolts, 1" in diameter. Removal of the closure head requires deliberate action and the use of tools.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.31 (c)	Lifting Devices	
71.31 (c) (1)		The cask lifting structure is capable of supporting 3 times the weight of the loaded cask without exceeding the yield strength of the materials involved. See Section XI, "Structural Analysis".
71.31 (c) (2)		The closure head lifting structure is capable of supporting 3 times the weight of the closure head without exceeding the yield strength of the materials involved. See Section XI, "Structural Analysis".
71.31 (c) (3)		The only structure available for lifting the entire cask is the structure intended for that purpose.
71.31 (c) (4)		The failure of any lifting device which is a part of the cask would not impair the containment or shielding properties of the cask.
71.31 (d)	Tie-Down Devices	
71.31 (d) (1)		When the acceleration defined by this section are applied to the cask the resulting stress in any material of the cask does not exceed the yield point of the material involved. See Section XI, "Structural Analysis".

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.31(d)(2)		There are no parts of the cask structure which can be used as tie-down devices, other than those specifically designed for that purpose.
71.31(d)(3)		The failure of any of the cask tie-down structures would not impair the ability of the cask to meet the other requirements of this subpart.
71.32	Structural Standards, Large Quantity Packaging	
71.32(a)	Load Resistance	Regarded as a simple beam, supported at its ends along the major axis, the cask can withstand a static load, normal to and uniformly distributed along its length, equal to 5 times its fully loaded weight without generating stress in any material of the cask in excess of its yield strength.
71.32(b)	External Pressure	The containment vessel can withstand an external pressure of 25 pounds per square inch without loss of contents. See Section XI, "Structural Analysis".
71.33	Criticality Standards	The cask remains sub-critical under all the conditions defined in this section. See Section X, "Criticality Analysis".
71.34	Evaluation of a Single Package	
71.34(a)(1)	Normal Transport	See 71.35 below.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.34(a)(2)	Hypothetical Accident	Model testing was not done. The mechanical properties of the materials of construction are well known. Analytical methods for predicting damage to a cask of this size have been developed and correlated to actual data. Considering this, and the fact that conservative assumptions have been used throughout the analysis, mathenatical analysis has been used to satisfy this subpart.
71.34(b)		For the purpose of the hypothetical accidents, the cask has been analyzed independently of the vehicle.
71.34(c)		The normal and accident conditions for which cask has been analyzed are the same as those defined in 71.35 and 71.36.
71.35	Standards for normal conditions of transport for a single package.	
71.35(a)(1)	There will be no release of radioactive material from the containment vessel;	Maximum integrity is achieved by double containment. Both the inner and outer closure heads maintain their integrity under the conditions specified in Appendix "A". See Section XI, "Structural Analysis".

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.35 (a) (2)	Packaging Effectiveness	The effectiveness of the cask is not reduced by the conditions specified in Appendix "A". See Section XI, "Structural Analysis".
71.35 (a) (3)	Explosive Mixtures	There is no mixture of gases or vapors in the package which could, through any credible increase in pressure of explosion, significantly reduce the effectiveness of the cask.
71.35 (a) (4)	Coolant Contamination	There is no coolant associated with the package. The dry double containment system isolates the low pressure cavity filler gas from the environment under normal conditions of transport and hypothetical accident conditions. The coolant activity limits of this section do not apply.
71.35 (a) (5)	Loss of Coolant	There will be no loss of coolant during a normal shipment. The dry double containment system provides maximum integrity at low operating pressure.
71.35 (b) (1)	Criticality	The cask is sub-critical under the normal conditions of transport. See Section X, "Criticality Analysis".
71.35 (b) (2)	Geometric Form	The geometric form of the cask contents are not altered under the normal conditions of transport.
71.35 (b) (3)	No leakage of water into the containment vessel.	There can be no leakage of water into the cask during normal shipment. The cask is equipped with two separately sealed closure heads.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.35(b)(4)(i)	Effective Volume	Under normal conditions of transport, there is no reduction in the volume of the cask or the containment vessel.
71.35(b)(4)(ii)	Effective Spacing	Under normal conditions of transport there is no reduction in the space between the center of the containment vessel and the outer surface of the cask.
71.35(b)(4)(iii)	Apertures	Under normal conditions of transport no apertures of any size can occur in the outer surface of the cask.
71.35(c)	Venting	The cask containment vessel does not vent to the atmosphere under the normal conditions of transport. See 71.35(a)(5) above.
71.36	Hypothetical Accident	
71.36(a)(1)	Radiation Dose Rate	Following the hypothetical accident condition the highest dose rate at point 3-feet from the external surface cask, would be 787 mrem/hr. See Section IX,"Shielding Analysis".
71.36(a)(2)	Radioactive Material Release	No radioactive material would be released from the package. The package is designed such that two individually sealed closure heads prevent loss of the low pressure gaseous mixture trapped in the dry system. The impact structures on each end of the cask effectively form a protective envelope around the cask. There are no valves in the external surface of the cask which provide a leakage path directly into the primary containment system.All values which penetrate the primary container are located on the inner head and are protected by a rugged outer stainless steel closure head.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.36(b)	Criticality	The cask would remain sub-critical following the hypothetical accident sequence specified in Appendix "B" of this part. See Section X, "Criticality Analysis".
71.37	Evaluation of Fissile Package Array	
71.37(a)	Model Testing	Model testing has not been done to evaluate the cask by the critieria specified in 71.39. Damage to the package, following the hypothetical accident described in Appendix "B" of this part, has been evaluated by analytical methods. See response to 71.34(a)(2) above.
71.37(b)	Criticality Assumpations	The assumptions made in determining compliance with 71.39 (a)(2) comply with this subpart. See Section X, "Criticality Analysis".
71.38	Standards for Fissile Class I	Not Applicable .
71.39	Standards for Fissile Class II	Not Applicable .
71.40	Standards for Fissile Class III	There will be only one cask per transport vehicle. The shipment remains sub-critical under the conditions of 71.40 (a) and (b). See Section X, "Criticality Analysis".
71.41	Previously Constructed Package	Not Applicable.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.51	Procedures	
71.51 (a)	Operating Procedures	See Section XV, "Operating Procedures".
71.51 (b)	Inspection Procedures	All loading, unloading and handling operations with the cask will be supervised by a qualified representative of the licensee who will ensure that the operating procedures are properly executed.
71.52	Unknown Properties	Conservative values have been assigned to variables;such as isotopic abundance, degree of irradiation, degree of moderation, etc., in all criticality calculations. The value of K_{eff} calculated are the maximum credible values. See Section X, "Criticality Analysis".
71.53	Preliminary Determinations	
71.53 (a)	Defects	All material of construction will be procured to established standards such as but not limited to ASTM, ASME, or AISI specifications. A thorough program of quality assurance including non-destructive testing will be conducted during fabrication to insure that there are no cracks, pinholes, uncontrolled voids, or other defects which could significantly reduce the effectiveness of the package.
71.53 (b)	Pressure Test	Prior to its first use the inner container and cask cavity will be given a helium leak test. See Section XIII, Functional Test Procedures."

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.53 (c)	Marking	The cask model number will be engraved in a stainless steel plate which will in turn be welded to the cask outer shell.
71.54	Routing Determination	
71.54 (a)	Damage	Prior to each use, a visual inspection will be made of all accessible surfaces of the cask. See Section XV, "Operating Procedures" and Section XVI, "Maintenance Program".
71.54 (b)	Neutron Absorbers	The cask will not contain any special moderators or neutron absorbers. Therefore, no inspection is required.
71.54 (c)	Closure	See 71.54 (a) above. In addition, a routine leak test will be performed by the gas bubble method. The formation of gas bubble streams in a liquid bath locates individual leaks. This will be accomplished by pressurizing the inner container to 10 psig with helium and flooding the closure head cavity area with water. This procedure is carried out prior to installation of the outer closure head. The outer closure head seal is checked by pressurizing the closure head and cask cavity utilizing the closure head cavity drain valve. The cask is to be pressurized to 10 psig and pressure held for 10 minutes. If there is no drop in pressure, the outer closure head seals are satisfactory.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.54 (d)	Valves	The valves which penetrate the primary system are located on the inner closure head. The inner closure is protected by an outer closure head which is designed to withstand the maximum internal pressure of the primary system as well as being structural adequate to survive the hypothetical impact condition. Unauthorized access to these valves would be extremely difficult if not impossible.
71.54 (e)	Internal pressure will not exceed normal operating pressure during anticipated period of transport.	After securing the inner closure head and preforming the routine pressure test on the inner container, the pool water remaining in the annulus between the inner container and the cask cavity shall be pumped out by attaching a suction pump to the cask cavity drain line fitting at top of inner closure head. This operation shall continue until there is no flow of water from the discharge side of the pump, at which time the pump is to be disconnected from the cask cavity drain line fitting. After initiating the above operation the evacuation of water from the inner container shall be accomplished concurrently as follows. The pool water remaining in the inner container will be blown out of the container by maintaining the gas pressure in the inner container and opening the drain line valve on the inner closure head. A line shall be attached to the valve so that the water being expelled can flow back to the fuel pool. The procedure shall continue until there is no flow of water from the drain line at which time the gas inlet valve and drain valve on the inner closure head shall be closed, and the gas supply line

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.54(e) Cont.		and the drain line disconnected. Then, a vacuum pump and guage is connected to the inner container inlet valve. After connecting a vacuum gauge to inner container outlet valve, the inner container is pumped down to 1.0 inch of mercury which assures the total removal of water from inner container. The vacuum pump, gauges and hoses are removed, after inner container is returned to atmospheric pressure. Upon completion of installation and torquing the outer closure head bolts, connect a vacuum pump to one closure head cavity drain valve. After a vacuum gauge is connected to the opposite closure head cavity drain valve, both cavity valves are opened, the closure head cavity and annulus is pumped to 1.0 inch of mercury which assures total removal of water from the cask cavity. The vacuum pump, gauges and hoses are removed, after cavity is brought to atmospheric pressure. Pressure testing of the outer closure head is also accomplished. This procedure assures that the pool water in the annulus between the inner container and cask cavity has been been completely removed. Internal pressure under normal shipping conditions are not critical in a dry system. The inner container and cask cavity will withstand an operating pressure eight times greater than the internal pressures associated with the normal conditions of transport.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.54 (f)	Coolant Contamination	The cask design precludes release of the radioactive contents including the gaseous coolant. The coolant is considered as being part of the package contents. Therefore, the restrictions on coolant activity levels are not applicable.
71.62	Records	A record of each spent fuel shipment shall be prepared and maintained as required by Paragraph 71.62.

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APPENDIX A

SECTION IV
Compliance With 10 CFR 71, Chapter 1

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22	Package Description	Shipping configuration without inner container. Only those parts which deviate from the previous assessment are addressed in this section.
71.22(a)(3)(i)	Receptacles, Identifying the one which is considered to be the containment vessel	The cask structure consists of inner and outer stainless steel cylinders which are joined by stainless steel forgings at each end. The annulus between the inner and outer cylinders contain a composite lead/uranium gamma shield. Neutron shielding is provided by a water jacket which surrounds the outer stainless steel cylinder and all of the region containing active fuel. The fuel is carried in the cavity formed by the inner shell, and is fitted with an aluminum basket which supports the fuel. The inner shell is considered the primary containment vessel while the outer shell is considered as the secondary containment vessel.
71.22(a)(3)(iii)	Internal and external structures supporting or protecting receptacles	The fuel is supported within the primary containment vessel by an aluminum basket. The aluminum basket is made up of four pieces of aluminum approximately 165 inches long. Each piece of aluminum is shaped to form a segment of a circle. The internal flat face of each segment forms a square which supports the fuel for its entire active length. The four aluminum pieces are bolted together. The aluminum basket and fuel are supported axially by stainless steel weldments. The basket used in Configuration C is described in Appendix F of Section IX. The baskets used in Configuration D are described in Appendices G and H of Section IX.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22(a)(3)(iii) (cont.)		The ends of the cask body are fitted with impact structures which are aluminum weldments filled with balsa wood.
71.22(a)(3)(iv)	Valves, sampling ports, lifting devices, and tie-down devices;	There are two (2) penetrations thru the cask body which exit in the closure head cavity region. The valves are located in the head end forging. There are (2) penetrations thru the inner closure head. Each penetration is fitted with a stainless steel block that is machined and welded to the top surface of the closure head. The block forms a closed passage from the head penetration to a tapped hole which receives a valved quick disconnect fitting. The block also provides a sealing surface to which is bolted a stainless steel cap having double "O" ring gaskets; one elastomer and one metal. The valves are designed to withstand all normal and accident conditions. Expansion tank is fitted with an overflow line which determines proper fluid level during filling operations This line is fitted with a valved quick disconnect fitting and pressure cap. As an alternate the line may be closed with a pipe cap in lieu of the valved quick disconnect fitting. Lifting and positioning of the cask is accomplished with the use of a lifting yoke which engages a series of trunnions welded to the top forging of the cask body. Each trunnion is machined from a solid bar of stainless steel. The top forging of the cask body provides a more than adequate foundation for the trunnion.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22(a)(3)(iv) (cont.)		Tie-down of the cask to the trailer is accomplished by a set of trunnions which engage sockets machined into bottom forging of cask and a saddle arrangement at the head end of the cask. The trunnion arrangement acts as a pivot to rotate the cask from a vertical to horizontal position on the trailer bed. The trunnions support the cask in a horizontal position and provide the necessary restraint for the vertical and transverse acceleration components of 2G and 5G respectively. The head end of the cask has two machined rings spaced some distance apart which engage a mating ring section in the front saddle. A bolting block which is welded between the two rings on the cask provide the tie-down points between the cask and the saddle. This arrangement is capable of withstanding the specified acceleration components of 2G vertical, 5G transverse, and 10G in the direction of travel without generating stresses in excess of the yield stress in any material of the package.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.22(a)(3)(v)	Structural and mechanical means for the transfer and dissipation of heat.	Decay heat is removed from the fuel to the cask first by thermal radiation and conduction through a helium filled cask cavity and then through the cask sides and ends by a combination of conduction, natural convection in the water filled neutron shield, and natural convection and radiation from the surfaces of the cask. Helium was selected because it is a chemically inert gas and does not become radioactive. Helium is only slightly soluble in water, and will neither burn nor explode. Being chemically inert, there is no reaction with the materials used in the construction of the cask nor with the spent fuel elements being shipped. Thermal radiation augments the conduction heat transfer across well established air gaps within the cask. Being entirely passive, this means of heat dissipation is highly reliable.
71.31(a)	Packaging shall be of such materials and construction that there will be no significant chemical, galvanic, or other reaction among the packaging components.	There will be no significant chemical, galvanic, or other reaction among the packaging components, or between the packaging components and the package contents. The fuel is carried in an aluminum basket which is housed in the cavity formed by the S.S. inner shell. The cask body is a stainless steel weldment. Reaction between the uranium shield and the stainless steel inner shell is prevented by a layer of flame-sprayed copper applied to those areas of the stainless steel shell where maximum temperatures are predicted. There is no reaction between the lead and uranium shield materials in the temperature ranges predicted during and after the fire accident conditions. Ref., Reactor Handbook, 2nd Edition, Volume 1, Materials.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.31(b)	Packaging shall be equipped with a positive closure which will prevent inadvertent opening.	The double containment system utilizes two separate closure heads. The inner head which weighs 743 lbs. is held in place by 12 stud bolts, 1 inch diameter. The outer closure head which weighs 341 lbs. is held in place by 8 bolts, 1 inch diameter. Removal of the closure head requires deliberate action and the use of tools.
71.53(b)	Pressure Test	Prior to its first use, the cask cavity and closure head cavity will be given a helium leak test. See Section XIII, Functional Test Procedures."
71.54(c)	Closure	See 71.54(a). In addition, a routine leak test will be performed by the gas bubble method. The formation of gas bubble streams in a liquid bath located individual leaks. This will be accomplished by pressurizing the cask cavity to 10 psig with helium and flooding the closure head cavity area with water. This procedure is carried out prior to installation of the outer closure head. The outer closure head seal is checked by pressurizing the closure head and cask cavity utilizing the closure head cavity drain valve. The cask is to be pressurized to 10 psig and pressure held for 10 minutes. If there is no drop in pressure, the outer closure head seals and closure head cavity drain valves are satisfactory.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.54(e)	Internal pressure will not exceed normal operating pressure during anticipated period of transport.	After securing the inner closure head and performing the routine pressure test on the inner head seal, the pool water remaining in the cask cavity shall be removed. The pool water remaining in the cask cavity will be blown out of the cavity by maintaining the gas pressure in the cask cavity and opening the drain line valve on the inner closure head. A line shall be attached to the valve so that the water being expelled can flow back to the fuel pool. The procedure shall continue until there is no flow of water from the drain line at which time the gas inlet valve and drain valve on the inner closure head shall be closed, and the gas supply line and the drain line disconnected. Then, a vacuum pump and gauge is connected to the cask cavity inlet valve. After connecting a vacuum gauge to cask cavity outlet valve, the cask cavity is pumped down to 1.0 inch of mercury which assures the total removal of water from cask cavity. The vacuum pump, gauges and hoses are removed, after cask cavity is returned to atmospheric pressure. Upon completion of installation and torquing the outer closure head bolts, connect a vacuum pump to one closure head cavity drain valve. After a vacuum gauge is connected to the opposite closure head cavity drain valve, both cavity valves are opened, the closure head cavity is pumped to 1.0 inch of mercury which assures total removal of water from the closure head cavity. The vacuum pump, gauges and hoses are removed, after cavity is brought to atmospheric pressure. Pressure testing of the outer closure head is also accomplished. This procedure assures that the pool water in the closure head cavity and cask cavity has been completely removed.

Section of Part 71	Requirement or Subject of Provision	Assessment of Compliance
71.54(e) (cont.)		Internal pressure under normal shipping conditions are not critical in a dry system. The cask cavity will withstand an operating pressure eight times greater than the internal pressures associated with the normal conditions of transport.

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Section V

SECTION V

COMPLIANCE WITH CFR, TITLE 49, CHAPTER 1, PART 170-189

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SECTION V

Compliance with CFR 49, Chapter 1

Section	Requirement or Subject of Provision	Assessment of Compliance
173.393	General Packaging Requirements	Compliance with this part, except as specifically noted below, is described in Section IV, "Compliance with CFR, Title 10, Chapter 1, Part 71".
173.393(b)	Evidence that Package has not been illicitly opened	Prior to each shipment, a tamper indicating seal shall be lock wired through the bolts that attach the top impact limiter to the cask.
173.393(e)(2)	Accessible Surface Temperature	Fully loaded, in shade, assuming still air at an anbient temperature of 130° F., the external surface of the cask body will be at a temperature of 375°F. However, the cask will be totally enclosed in an expanded metal personnel barrier. The personnel barrier is then the accessible surface of the package. The temperature of the personnel barrier will be the same as that of ambiant air. See Section VIII, "Thermal Analysis".
173.393(h)	Surface Contamination	See response to 173.397 below.
173.393(j)	Radiation Dose Rate	The cask will be transported by a sole use vehicle. The radiation dose rate 6-feet from external surface of the car or vehicle will not exceed 10 mrem/hr. See Section IX, "Shielding Analysis".

	Requirement or Subject of Provision	Assessment of Compliance
173.397	Surface Contamination	Prior to shipment, the exposed surfaces of the cask will be decontaminated to conform with the limits of this subpart. See Section XV, "Operating Procedures".
173.399)a)(3)	Labeling	The cask will be labeled Radioactive Yellow III.

Section VI

SECTION VI

MATERIAL SPECIFICATION

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SECTION VI

MATERIAL SPECIFICATION

The spent fuel shipping cask shall be constructed of the following materials per their respective specifications.

Plate-

1. Allegheny Ludlum Steel Corp.

   Type 216 Stainless Steel

2. ASME-SA-240, Type 304

Castings-

1. ASME-SA-351, CF8M

2. ASTM-A-451, Gr. CPF8M

Forgings-

1. ASME-SA-336, Grade F8

Bar-

1. ASTM-A-276, Type 304

2. 17-4Ph conditioned per drawing requirements

Lead-

1. ASTM-B-29, Pig Lead, Chemical Grade

Uranium-

1. ASTM-B-419

2. N L Industries, Inc. Specification No. 7605 dated 4/10/72, Issue No. 1

Aluminum-

1. 6061-T6

Material Specifications

Pipe-

1. ASTM-A-312, Type 304
2. ASTM-A-358, Class I, Type 304

Pipe Fittings-

1. ASTM-A-182, Type 304
2. ASTM-A-403, Type 304

Valves-

1. ASTM-A-276, Series 300

Tubing-

1. ASTM-A-269, Type 304
2. ASTM-A-213, Type 304

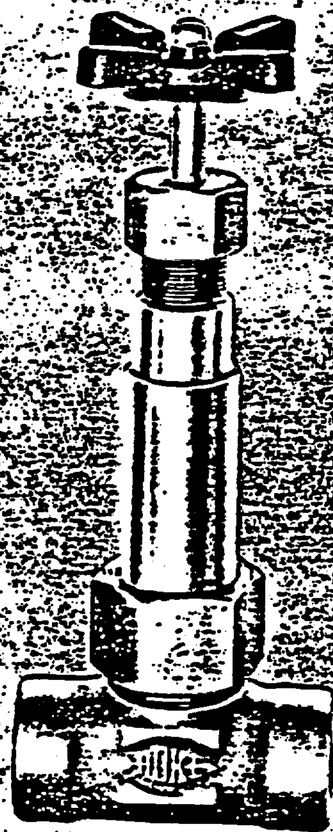
Fasteners-

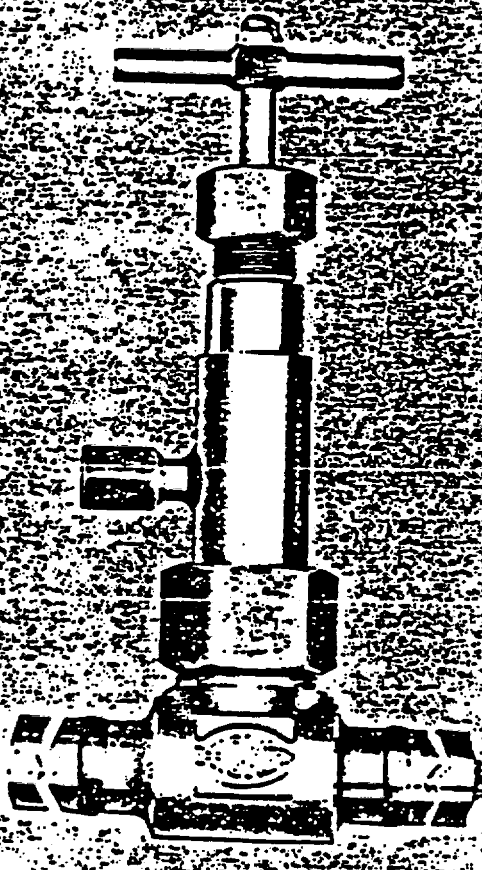
1. ASTM-A-320, Grade L7
2. ASTM-A-194, Grade 4 or Grade 7
3. ASTM-A-193, Grade B8
4. Commercial Grade Stainless Steel 18/8

Seals-

1. Metalic O-Rings Inconel X, Silver plated
2. Neoprene
3. Silicone Rubber Compound 1235-70

Substitution of appropriate ASME specification for the specified ASTM specification is acceptable.





HOKE 4300 SERIES 316 SS— bellows sealed valves (.312 orifice)

APPLICATIONS:

- *Heat treating furnaces*
- *Ultra-high vacuums**
- *Radioactive, Reactive or toxic fluids*
- *Liquid metals*
- *Cryogenic service*

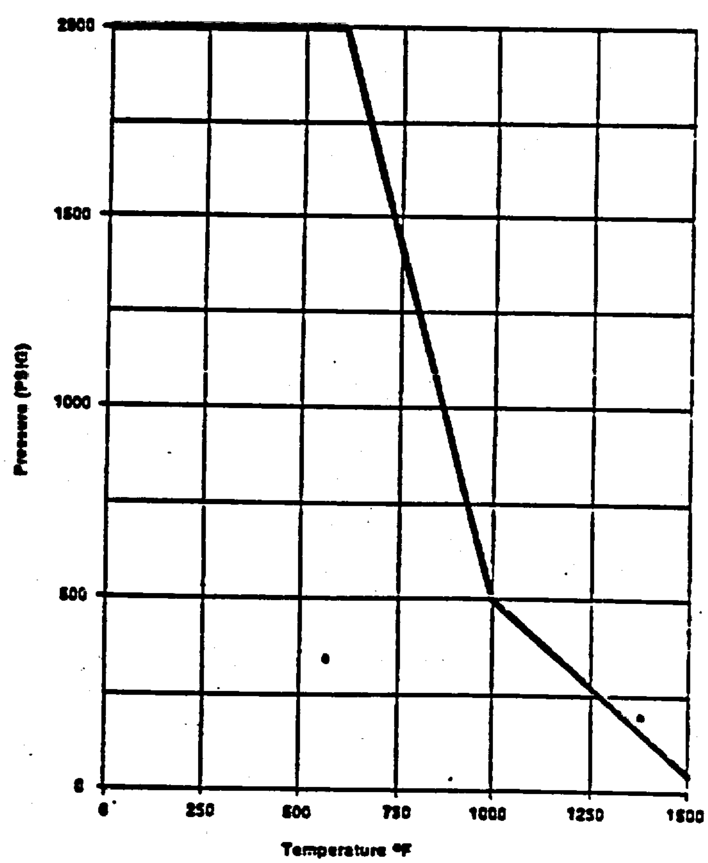
MAXIMUM OPERATING PRESSURE:	
(heavy wall 316SS bellows)	2000 PSI @ 600°F
(light wall 316SS bellows)	400 PSI @ 350°F
HIGH VACUUM*	to 10^{-5} TORR
TEMPERATURE RANGE	—320° to 1500°F
ORIFICE SIZE	.312
Cv FACTOR	1.3 (maximum)
INTERNAL VOLUME	.38 cu. in.

* See glossary on page 4 for explanation

FEATURES:

1. Positive plug return in all models
2. Back seating of valve stem in all models
3. Secondary packing prevents escape of process fluid in the event of bellows rupture
4. No torque transmitted to bellows
5. Easy to replace plugs and bellows in gasketed models
6. 316SS Forged body—union bonnet construction for long life
7. 316SS bellows is pressure formed from seamless tubing
8. Variety of custom modifications (see page 5)
9. All welded joints are fused using Tungsten arc argon shield (TIG method)
10. Choose from NPT, pipe, pipe extension, or Gyrolok tube fitting ends
11. Choice of globe or angle flow patterns
12. Air-to-open or air-to-close operators for remote actuation are available (see pages 19 and 22)

OPERATING PRESSURE VS. OPERATING TEMPERATURE
4300 SERIES VALVES



4300 SERIES 316 SS— bellows sealed valves (.312 orifice)

DIMENSIONS:

Number	D	E	F	H
.2F8Y	6⅞	2¾	2¾	21/32
4351F8Y	6⅞	2¾	1 13/16	21/32
4313R8Y	6⅞	7⅞	2¾	⅝
4333V8Y	6⅞	8¾	2¼	⅝
4393V8Y	6⅞	8¾	2¼	⅝
4351G8Y	6⅞	3 9/16	1 3/16	⅝
4322F3Y	6⅞	2 1/16	2¾	1⅛
4361F8Y	6⅞	2 1/16	1 13/16	1⅛

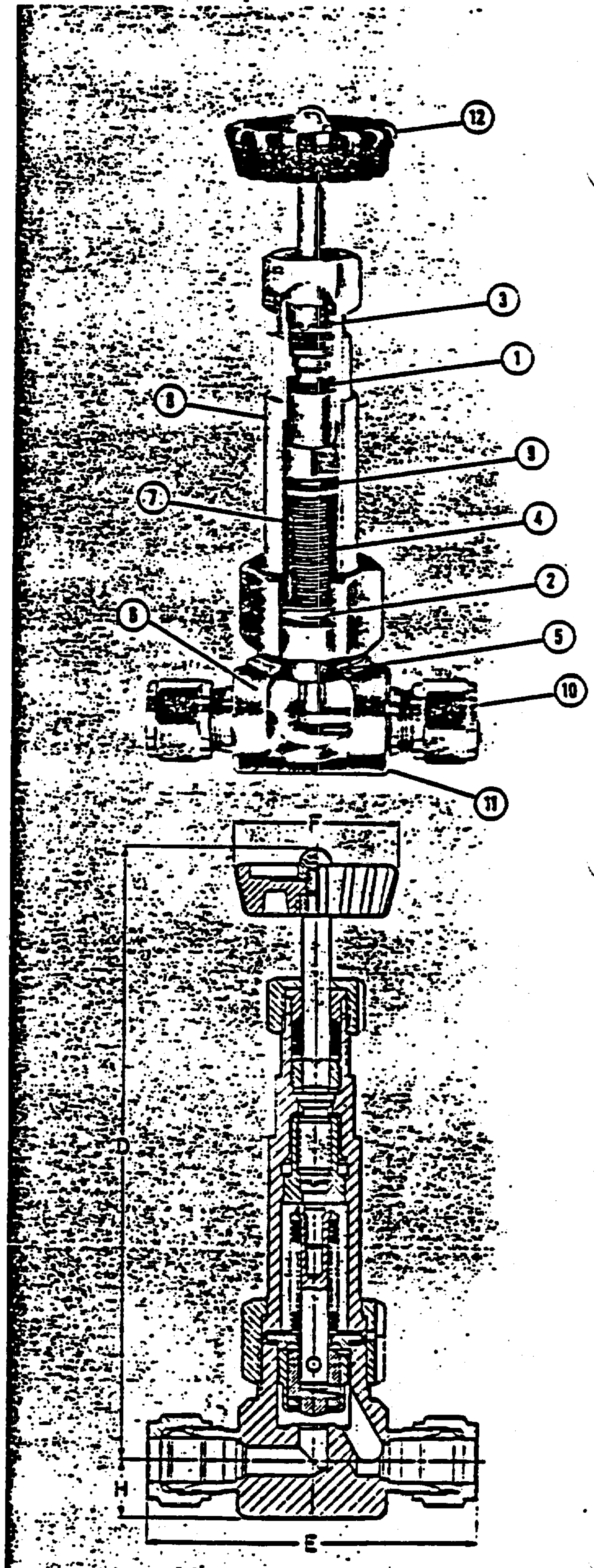
MODEL NUMBERS:

		Order By Catalog Number				
Flow Pattern	Inlet & Outlet A & B	Heavy Wall Bellows	Light Wall Bellows	Cv Factor	Maximum Operating Pressure (PSIG)	Temperature Range
Globe	½ NPT female	4312F8Y	—	1.0	2000 at 600°F	—320 to 600°F
		—	4351F8Y	1.3	400 at 350°F	—320 to 350°F
	½ Sch. 80 316SS pipe 3" extension	4313R8Y	—	1.0	2000 at 600°F 550 at 900°F	—320 to 900°F
	½ Sch. 40 316SS pipe 3" extension	4333V8Y	—	1.0	2000 at 600°F 250 at 1200°F	—320 to 1200°F
	½ Sch. 40 316SS pipe 3" extension	4393V8Y	—	1.0	2000 at 600°F 50 at 1500°F**	—320 to 1500°F**
	½ O.D. Tube Gyrolok	—	4351G8Y	1.3	400 at 350°F	—320 to 350°F
Angle	½ NPT female	4322F8Y	—	1.0	2000 at 600°F	—320 to 600°F
		—	4361F8Y	1.3	400 at 350°F	—320 to 350°F

***For use at 1500°F in liquid metal service such as Na or NaK or with other fluids with similar lubricating properties. Otherwise, Maximum temperature is 1,200°F. See page 5 for custom modifications.*

MATERIALS OF CONSTRUCTION:

Description	4312 F8Y 4322 F8Y	4313 R8Y	4333 V8Y	4393 V8Y	4351G8Y 4351F8Y 4361F8Y
Body Forging	316SS	316SS	316SS	316SS	316SS
Bellows assembly	316SS heavy wall	316SS heavy wall	316SS heavy wall	316SS heavy wall	316SS light wall
Seal, bellows-to-body	316SS gasket	316SS Seal welded	316SS Seal welded	316SS Seal welded	Teflon gasket
Method of plug return	Positive plug return 303SS	Positive plug return 303SS	Positive plug return 303SS	Positive plug return 303SS	Positive plug return 303SS
or Plug	17-4 PH SS	316SS	316SS Stellited	316SS Stellited	Teflon
Seat	316SS	316SS	316SS	Stellite	316SS
Packing, secondary	Garlock 903	Garlock 903	Garlock 908	Garlock 908	Teflon
Bonnet	303SS	303SS	303SS	303SS	Aluminum
Handle	Aluminum cross, die-cast	Carb. steel bar, black oxided	Carb. steel bar, black oxided	Carb. steel bar, black oxided	Nylon Wheel



4351G8Y

MIL-C-7413B
2 February 1970
SUPERSEDING
MIL-C-7413A(USAF)
5 October 1955

MILITARY SPECIFICATION

COUPLINGS, QUICK DISCONNECT, AUTOMATIC SHUTOFF, GENERAL SPECIFICATION FOR

This specification is mandatory for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers requirements for automatic shutoff, quick-disconnect couplings for fuel and oil lines.

1.2 Classification. Quick-disconnect couplings shall be of the following types and classes, as specified (see 6.2):

Type I - Fuel Line Coupling	Temperature Range
Class A	-65° to +135° F fuel and +160° F ambient
Class B	-65° to +200° F fuel and +350° F ambient
Class C	-65° to +300° F fuel and +600° F ambient

Type II - Oil Line Coupling	Temperature Range
Class A - Petroleum Oil (MIL-L-6082)	-65° to +250° F oil and +160° F ambient
Class B - Synthetic Oil (MIL-L-7808)	-65° to +350° F oil and +350° F ambient
Class C - Synthetic Oil (MIL-L-23699)	-40° to +400° F oil and +400° F ambient

Sizes: Types I and II couplings shall mate with hose and tubing of the following nominal sizes: 1/4, 3/8, 1/2, 5/8, 3/4, 1, 1-1/4, 1-1/2, and 2 inch.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

FSC 4730

4.6 Inspection methods

4.6.1 Examination of product. Each coupling half shall be carefully examined to determine conformance to the requirements of this specification with respect to design, workmanship, and identification.

4.6.2 Functional test. Each coupling half shall be manually connected and disconnected five times with a mating coupling half or adapter and with a pressure as specified in the detail specification. There shall be no binding, sticking or any other evidence of faulty operation.

4.6.3 Proof pressure. Each coupling, connected and disconnected, shall be subjected to the proof pressure listed in table II. There shall be no visible signs of leakage after 2 minutes minimum of pressurization.

4.6.4 Low pressure. Each coupling, connected or disconnected, shall be subjected to a pressure of 1 to 5 psi. There shall be no visible signs of leakage after 2 minutes minimum of pressurization.

4.6.5 Vacuum. A vacuum of -6 psi (12.2 inches mercury gage) shall be applied to the connected couplings and -3 psi (6.1 inches mercury gage) to the disconnected coupling halves. There shall be no visible signs of leakage as indicated by a loss of vacuum, shown by the vacuum gage used, in 5 minutes at these negative pressures. See figure 2 for a typical test setup.

4.6.6 Operation. The couplings shall be connected and disconnected 200 times consecutively by hand and without any special means to keep the coupling halves in perfect alignment with an internal pressure as specified in the detail specification. The coupling shall then be subjected to and pass the tests specified in 4.6.3 and 4.6.4.

4.6.7 Spillage. The average spillage (fluid loss) during five consecutive disconnect cycles at each of the pressures specified in 3.6.1.1 shall not exceed the amounts shown in table I. This test shall be performed immediately following the test specified in 4.6.6.

4.6.8 Temperature shock. Mating couplings shall be connected and tested in accordance with the temperature shock test specified in method 503 of MIL-STD-810. After this test the couplings shall respond freely to connecting and disconnecting operations and shall be subjected to and pass the tests specified in 4.6.3 and 4.6.4. There shall be no evidence of failure.

4.6.9 Pressure drop. The pressure drop through the connected couplings shall not exceed the values shown in table I when using water as the test fluid. The tests shall be conducted as recommended in ARP 868. Also, tests shall be conducted over a range of flows and temperatures completely covering the design capacity of the coupling using the fluid for which the coupling is intended as a test fluid. The data shall be presented in the form of curves. Pressure drops shall be conducted in both directions.

4.6.14.3 Endurance test procedure. The hose and coupling assemblies shall be subjected to a minimum of 200 hours of fluid circulation and vibration with a minimum of 10 cycles of temperature and pressure; each cycle shall consist of at least 20 hours duration. The total amplitude of the vibration shall be 0.060 inch, and the frequency of vibration shall be 55 ±2 hertz. The temperature and pressure readings shall be recorded at least once every hour.

4.6.14.4 Cyclic. The test shall be started with the fluid in the coupling at 1 to 5 psig static pressure, and the ambient temperature shall be the low temperature specified in 1.2 ±5° F. This temperature shall be maintained for a minimum of 4 hours (shutdown period). Fluid circulation and vibration shall be started and maintained for 20 hours. Fluid circulation shall be at a sufficient rate to maintain uniform pressures and temperatures. The operating pressure shall be maintained during the fluid circulation. The ambient temperature around the coupling shall be increased to the applicable ambient temperature ±5° F as specified in 1.2 within 1 hour after circulation is started. When circulation is started, the temperature of the internal fluid shall be increased to the applicable operating temperature ±5° F, as specified in 1.2, within 30 seconds of fluid circulation. This 24-hour test procedure shall be repeated until the 200 hours of fluid circulation and vibration on the coupling have been accomplished.

4.6.14.5 Disconnection. At least once during each shutdown period, the coupling shall be disconnected for 30 minutes and then reconnected.

4.6.14.6 Pressure tests after cyclic testing. After completion of cyclic testing, the couplings shall be subjected to and pass the proof and low pressure tests of 4.6.3 and 4.6.4, and the coupling shall not exhibit any undue looseness due to wear from the vibration.

4.6.15 Vibration

4.6.15.1 Vibration test installation. A complete hose assembly as used in 4.6.14.1 and coupling assembly shall be installed as shown on figure 4. The coupler half shall be connected to the hose assembly and pressure source. The other coupling half shall be connected to a rigid bulkhead mounted on the vibration table.

4.6.15.2 Vibration test fluid. The test fluid shall be the fluid for which the couplings were designed except that fuel couplings shall use solvent in accordance with P-D-680. The couplings shall be pressurized to the applicable operating pressure for the first vibration test and 10 psi for the second vibration test (see 4.6.15.3).

4.6.15.3 Vibration test procedure. Unless otherwise specified by the procuring activity, the assemblies shall be vibrated, in each of two mutually perpendicular axes according to method 514 of MIL-STD-810, procedure I, curves L and M. Two consecutive tests shall be run, one at operating pressure and one at low pressure, on each coupling (see 4.6.15.2).

4.6.15.4 Pressure tests after vibration. The couplings shall be subjected to and pass the test specified in 4.6.3 and 4.6.4 after completion of the vibration tests, and the coupling shall not exhibit any undue looseness due to wear from the vibration.

4.6.15.5 The burst pressure (see table II) shall be applied for 1 minute to the connected couplings. There shall be no leakage.

4.6.16 Compatibility

4.6.16.1 Fuel couplings

4.6.16.1.1 Fuel resistance and low temperature. The connected couplings shall satisfactorily complete the fuel resistance and low temperature tests of MIL-F-8615. The high temperatures shall be the operating temperatures specified in 1.2. The test fluid shall be as specified in MIL-F-8615.

4.6.16.1.2 Contaminated fluid endurance. Test fluid containing each type of contaminant and at the concentration specified in table III shall be circulated through connected couplings as follows:

a. With rated flow for 2-1/2 hours

b. With 10 percent rated flow for 2-1/2 hours.

The procedures shall be repeated one time. After this test, the couplings shall be flushed out with clear fluid and drained, and the functional and leakage tests specified in 4.6.2, 4.6.3, and 4.6.4 shall be conducted. The couplings shall perform satisfactorily.

4.6.16.2 Oil couplings

4.6.16.2.1 Oil resistance and low temperature. The connected couplings shall satisfactorily complete the oil resistance and low temperature tests shown in table IV. The high temperatures shall be the operating temperatures specified in 1.2.

4.6.17 Burst pressure. The burst pressure listed in table II shall be applied for 1 minute to the connected coupling at the maximum temperature conditions specified in 1.2. There shall be no leakage.

4.6.18 Electrical resistance. The electrical resistance across the interface of the two coupling halves shall be measured with the couplings in the dry condition. The resistance shall not exceed 1 ohm.

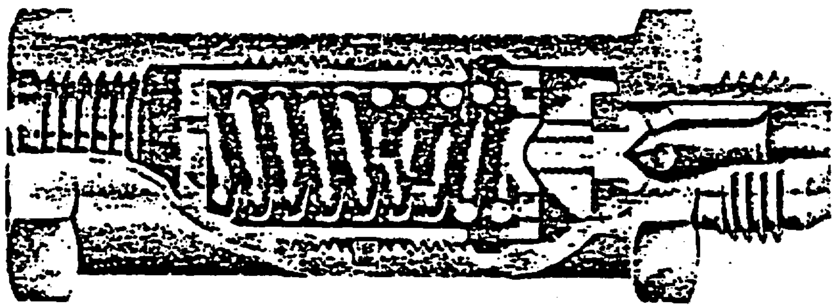
CIRCLE SEAL

precision valves

MANUFACTURED BY

James, Pond & Clark Incorporated

Wherever perfect sealing is required, the proven reliability of Circle Seal precision valves provides the one complete answer—a combination of absolute leakproof sealing when closed and virtually maintenance-free operation.

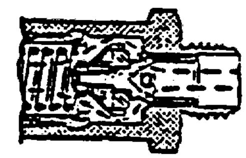


RELIEF VALVES

5100 Series

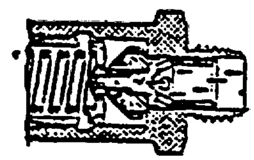
10-2400 PSI

HOW IT WORKS



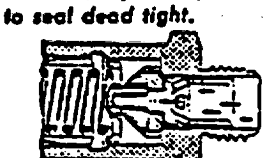
open

In-line construction and full flow ports permit maximum flow with minimum increase in system pressure.



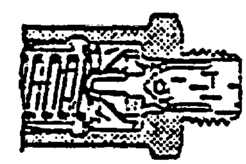
closing

Spring equalizer transmits to poppet only the axial component of spring force. Poppet slides smoothly inside bore. "O" Ring makes even contact with conical sealing surface. With "O" Ring seated, system pressure forces "O" Ring to seal dead tight.



closed

Spring load is carried by metal-to-metal seat which backs up the "O" Ring and prevents sticking. Sealing efficiency increases as pressure increases.



cracking

As valve opens, ports in poppet open fully and eliminate rapid increase in pressure. Flow is throttled between poppet shoulder and seat, providing regularly increasing flow area with increasing flow rates.

DESIGNED TO PROVIDE ACCURATE PERFORMANCE IN SERVICE WITH VIRTUALLY ALL GASES AND LIQUIDS

Exceptional performance characteristics of the Circle Seal relief valve provide the high degree of accuracy and reliability essential in modern circuit design concepts.

THE CIRCLE SEAL DESIGN OFFERS:

- ***Zero Leakage***

Valve will seal dead tight virtually to the cracking pressure.

- ***Dead Tight Reseat***

Valve reseats with virtually no hysteresis, reseals dead tight only slightly below cracking pressure.

- ***Minimum Pressure Rise During Opening***

Flow ports are fully exposed as soon as valve starts to open.

- ***Excellent Flow Characteristics***

Low rate springs and full porting insure minimum pressure buildup with increasing flow.

- ***Adjustability***

Tamper-proof internal adjustment allows setting cracking pressure to exact circuit requirements. Interchangeable springs allow changing cracking pressure ranges.

- ***No Chatter or Squeal***

Balanced design and smooth flow characteristics eliminate chatter and squeal.

- ***Long, Maintenance-Free Service Life***

Zero leak "O" Ring design prevents wire drawing across seat eliminating seat rework or replacement.

Distributors and Representatives in Principal U. S. Cities

James, Pond & Clark Incorporated

CIRCLE SEAL CENTER

FORM NO. 35-2118R

CONSTRUCTION DETAILS

Circle Seal 5100 Series relief valves are available in various materials to provide accurate, reliable performance with virtually all liquids or gases.

Careful in-line design provides ease of mounting, lightweight construction and exceptional flow characteristics without the complications arising from pilot operation.

Cracking pressures may be changed by a simple internal adjustment or by replacement of springs.

TECHNICAL DATA

Body and Internal Parts .... Bar Stock

Finish:

- Aluminum...2024 T4............ Anodized: MIL-A-8625A, Type I
- Aluminum...6064 T8............ Anodized: MIL-A-8625A, Type II
- Stainless Steel .... None

Spring 17-7PH

Seals .... Synthetic Rubber or Teflon

Crack and Reseat Pressure Accuracy .... See Chart on Facing Page

Operating Pressure .... 0-2500 PSI

Proof Pressure .... 3750 PSI

Burst Pressure .... over 5000 PSI

MATERIAL TABLE

material	letter
Aluminum 2024 T4	A
Aluminum 6064 T8	A1
Stainless Steel...303	T
316	T1
Carpenter 20	T3

END CONNECTIONS

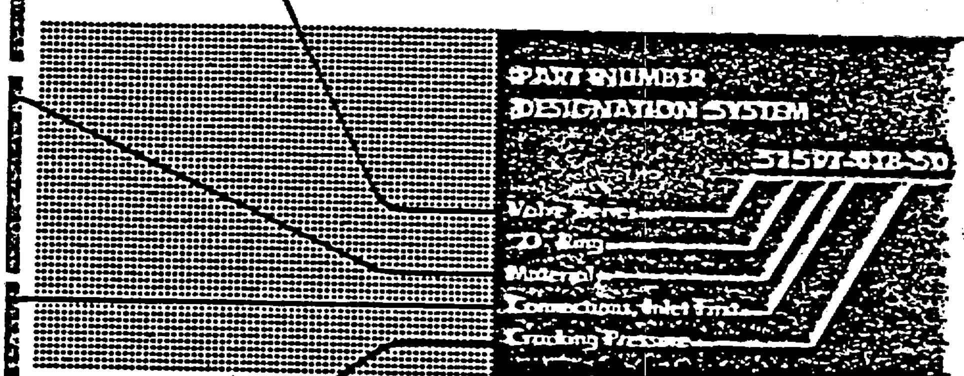
connections	letter*
Male Tube, MS33656 (AND10056)	T
Female Tube, AND10050	B
Male Tube, MS33514	E
Male Pipe	M
Female Pipe	P

*Tube sizes are in 1/16's; pipe sizes in 1/8's

MODEL NUMBER AND SERVICE RECOMMENDATIONS

model number	operating temperature	"o" ring material	service
5159	−40° to 275° F	Buna N	Air, Alcohol, Ammonia, Ammonium Hydroxide, Freon 12, Ethylene Glycol, Helium, Hydraulic Fluid (mineral base), Hydrogen, Lube Oil, MIL-H-5606, MIL-O-6083, Nitrogen, Water
5177	−65° to 275° F	MIL-P-25732	Same as 5159
5122	−60° to 300°F	Butyl	UDMH
5139	−40° to 250° F	Buna N	Aircraft Fuels, Aromatic Fuels, Gasoline
5133	−40° to 250° F	Neoprene	Air, Carbon Dioxide, Freon 12, Freon 22, Oxygen
5173	−40° to 300° F	Neoprene W	High temperature silicate ester base hydraulic fluids, Oronite 8515, OS-45-1
5132	−20° to 350°F	Viton A	IRFNA
5130	−20° to 450° F	Viton A	Aromatic Fuels, Carbon Tetrachloride, MIL-O-7808, Oronite 8515, OS-45-1, Steam (to 400° F), Toluene, Xylene
5120	−100° to 450° F	Teflon	Chemically inert. Suitable for virtually all fluids 50 to 1200 psi. For pressures below 50 or above 1200 consult factory.
K5120T	−320° to 450° F	Teflon	Cryogenic Service.

Note: "O" Rings rated for minimum service of −40°F are not adversely affected by exposure to −65°F.



After a prolonged period of storage with no system pressure, these relief valves will evidence an apparent high cracking pressure on first crack, therefore, in receiving inspection tests, true cracking pressure should be determined after the first crack.

ADJUSTMENT RANGE AND REPLACEMENT SPRING DATA

valves ordered in this range (psi)	will normally use this spring (nominal or dash no.)	which adjusts over this range.
10-15	13	10-16
16-25	20	15-25
26-41	32	24-41
42-57	50	40-60
58-81	70	58-84
82-117	100	80-120
118-162	140	112-168
163-230	200	160-240
231-285	250	200-300
286-345	300	240-360
346-450	400	320-480
451-575	500	400-600
576-710	625	500-750
711-999	850	680-1020
1000-1200	1000	680-1210
1201-1400	1250 (625)	1070-1410
1401-1900	1700 (850)	1250-1950
1901-2400	2000 (1000)	1530-2400

For replacement springs specify spring number from table below followed by cracking pressure number (middle column at left). EX: 515-50. Exception: in the 1201-2400 psi spring range, use spring number in brackets.

valve size (tube)	10-450 psi	451-1200 psi	1201-2400 psi
1/8	10515	10525	525
3/16, 1/4	515	525	525
5/16, 3/8	535	545	545
1	565	575	575

Springs in the 10-450 psi range are interchangeable

Springs in the 451-1200 psi range are interchangeable

Springs in the 1201-2400 psi range are interchangeable

5100 Series
10-2400 PSI

TYPICAL PART NUMBER INFORMATION

For Model Numbers or End Connections not shown, use Part Number Designation system on facing page to develop Part Number.

PART NUMBER TABLE

ALUMINUM 2024 T4

size	model 5159	model 5177	model 5133	model 5139	model 5120
MALE TUBE INLET AND FEMALE TUBE OUTLET					
¼	5159A-4TB-*	5177A-4TB-*	5133A-4TB-*	5139A-4TB-*	5120A-4TB-*
⅜	5159A-6TB-*	5177A-6TB-*	5133A-6TB-*	5139A-6TB-*	5120A-6TB-*
½	5159A-8TB-*	5177A-8TB-*	5133A-8TB-*	5139A-8TB-*	5120A-8TB-*
⅝	5159A-10TB-*	5177A-10TB-*	5133A-10TB-*	5139A-10TB-*	5120A-10TB-*
¾	5159A-12TB-*	5177A-12TB-*	5133A-12TB-*	5139A-12TB-*	5120A-12TB-*
1	5159A-16TB-*	5177A-16TB-*	5133A-16TB-*	5139A-16TB-*	5120A-16TB-*

For male tube both ends, connection designation is "TT". Ex: 5159A-8TT-150

For pop-off configuration, connection designation is "T". Ex: 5159A-8T-150

* Complete part number must include Cracking Pressure — denoted by * above.

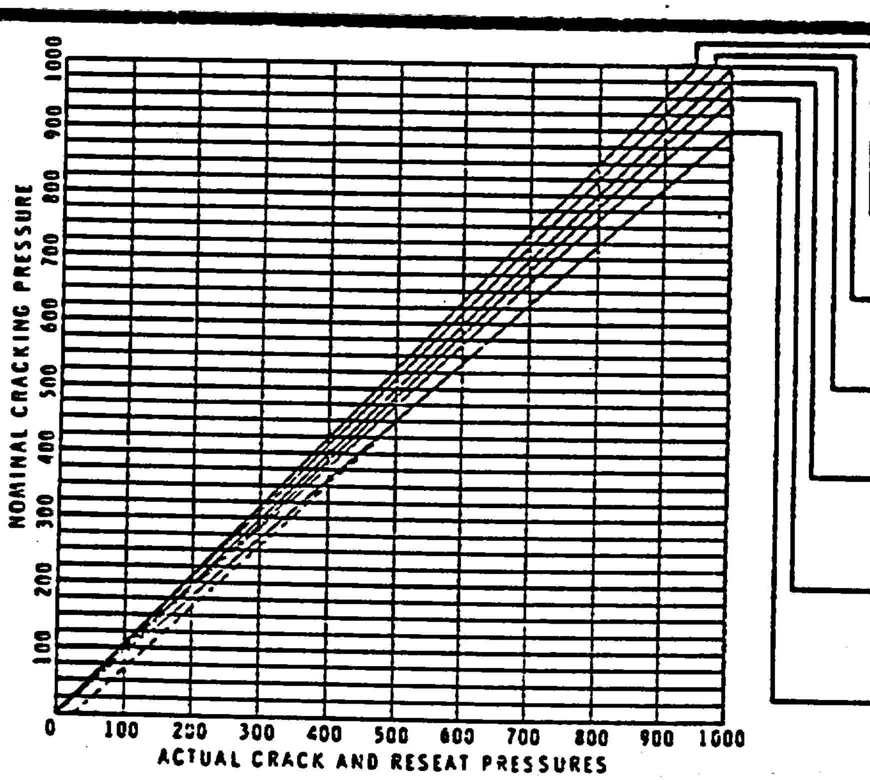
303 STAINLESS STEEL

size	model 5159	model 5177	model 5133	model 5139	model 5120
MALE TUBE INLET AND FEMALE TUBE OUTLET					
¼	5159T-4TB-*	5177T-4TB-*	5133T-4TB-*	5139T-4TB-*	5120T-4TB-*
⅜	5159T-6TB-*	5177T-6TB-*	5133T-6TB-*	5139T-6TB-*	5120T-6TB-*
½	5159T-8TB-*	5177T-8TB-*	5133T-8TB-*	5139T-8TB-*	5120T-8TB-*
⅝	5159T-10TB-*	5177T-10TB-*	5133T-10TB-*	5139T-10TB-*	5120T-10TB-*
¾	5159T-12TB-*	5177T-12TB-*	5133T-12TB-*	5139T-12TB-*	5120T-12TB-*
1	5159T-16TB-*	5177T-16TB-*	5133T-16TB-*	5139T-16TB-*	5120T-16TB-*

For male tube both ends, connection designation is "TT". Ex: 5159T-8TT-150

For pop-off configuration, connection designation is "T". Ex: 5159T-8T-150

* Complete part number must include Cracking Pressure — denoted by * above



Cracking pressure is defined as 5cc/min. with gas (0.02 scfm for Model 5120 or for C.P. over 450 psi).

Maximum pressure at which valve will crack in normal service (nominal cracking pressure plus 5%).

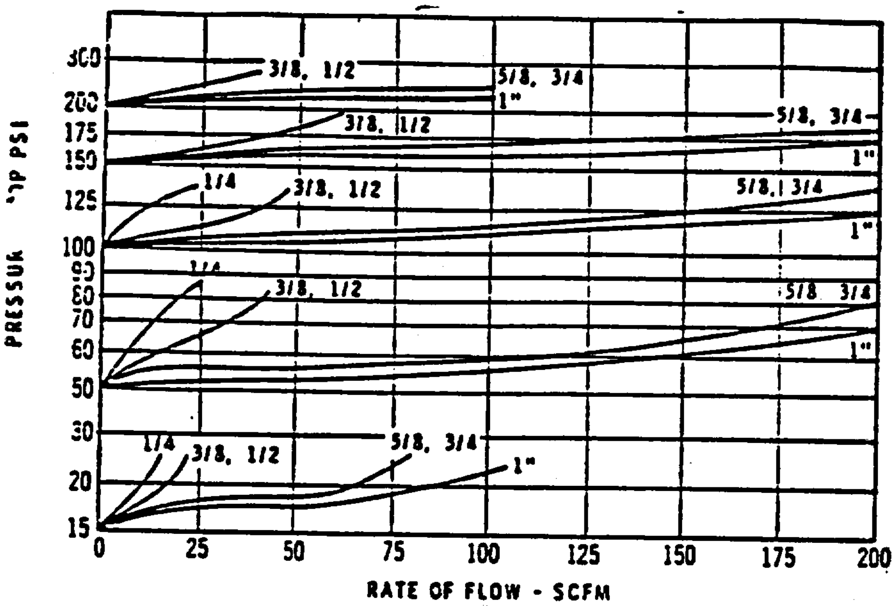
Maximum factory preset pressure (nominal cracking pressure plus 2%).

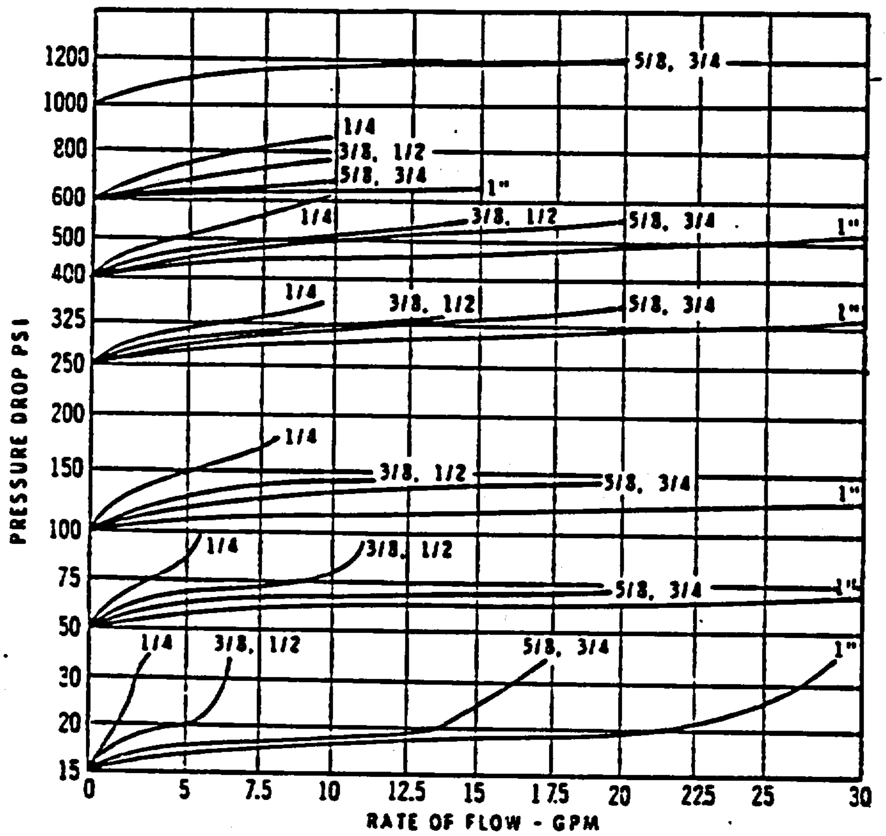
Nominal preset cracking pressure.

Minimum factory preset pressure (nominal cracking pressure less 2%).

Minimum pressure at which valve will crack in normal service (nominal cracking pressure less 5%). Nominal reseat.

Minimum pressure at which valve will reseat with zero leakage. (Dotted line is for Model 5120.)





MINIMUM ORIFICE AREAS

(approx., with valve open)

Tube Size		Orifice Area, sq. in. 10-1200 psi	1201-2000 psi
¼		.028	.028
⅜	½	.055	.028
⅝	¾	.130	.055
1		.200	.130

ADJUSTING INFORMATION

5100 Series valves are adjustable approximately ±15% of their nominal spring ratings (see p. 51.2).

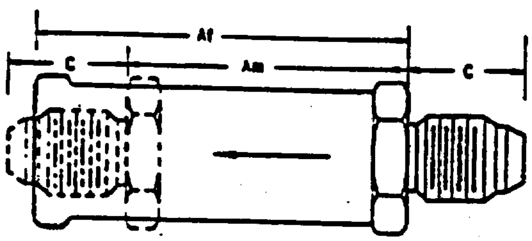
1. Remove discharge line, if any
2. "Break" body joint by wrenching hexes. Do not use pipe wrench.
3. Insert appropriate size "Allen" key into outlet end and adjust to desired cracking pressure.
4. Hold hex wrench stationary relative to inlet end and tighten body to lock in adjustment.

VALVE WEIGHTS

(lbs. approx.)

tube size	aluminum 10-449 psi	aluminum 450-999 psi	stainless 10-449 psi	stainless 500-999 psi
¼	.18	.19	.49	.66
⅜	.20	.23	.50	.87
½	.18	.19	.49	.66
⅝	.50*	.74	1.05	1.65
¾	.42	.60	1.00	1.14
1	.78	1.10	1.60	2.18

*With male outlet, 0.45



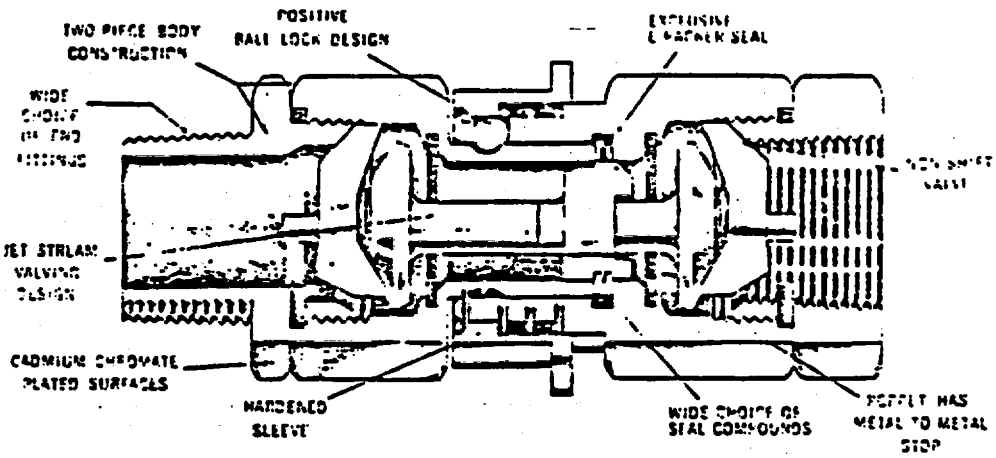
tube size	Am ±.030 male outlet 10-450	451-2400	Af ±.030 female outlet 10-450	451-2400	C ±.015	hex flats body dia. ref.
¼	2.45	3.05*	2.77	3.37**	.55	.81*
⅜	2.52	3.42	2.91	3.81	.58	1.00
½	2.25	3.15	2.80	3.70	.657	1.00
⅝	3.37	4.27	4.00	4.90	.758	1.25
¾	3.00	3.90	3.72	4.62	.864	1.375
1	4.33	5.83	5.17	6.67	.911	1.625

*For 1201 to 2400 psi, Am is 3.53; hex. flats and body dia. are 1.00.
**For 1201 to 2400 psi, Af is 3.80; hex. flats and body dia. are 1.00.

Distributors and Representatives in Principal U. S. Cities

☆Snap-tite

E SERIES QUICK-DISCONNECT COUPLINGS



DEPENDABLE WITH VACUUM AND PRESSURE SYSTEMS

Snap-Tite's E Series quick-disconnects are specifically designed for and have proved their performance in vacuum systems, gravity flow systems and pressure systems.

Because of their large inside diameter and streamlined valve design, E Series couplings work as efficiently with vacuum as with static pressures to 3000 psi (¼") size.

The unique E-Packer makes the series especially suitable for vacuum systems. Smaller size couplings hold vacuum in the *micron* range, in either the connected or disconnected position. Field reports show the ¼" size capable of pulling near absolute when coupled.

Features of E Series valved and valved quick-disconnects include:

LESS PRESSURE DROP. You benefit from greater flow with lower pressure drop than any other make of quick-disconnect with the same envelope size. The two-piece body construction permits larger orifices and a valve chamber 25% larger than the designated size of the coupling.

SMOOTHER FLOW. New "Jet-Stream" valve design maintains a clean linear flow. Use of positive valve stops—made possible by the two-piece body construction—combines maximum strength with minimum flow restrictions and eliminates the possibility of valve float. Smooth flow is further insured by recessing the valve washer in the body of the coupler and nipple. Positive positioning of valve maintains a steady, even flow under all conditions.

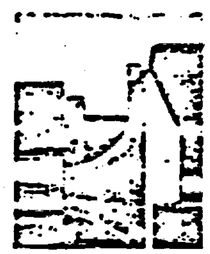
INSTANT FLOW ON CONNECT. Valves open automatically when halves are connected to permit full, free flow.

POSITIVE SHUT-OFF ON DISCONNECT. Valves automatically and completely shut-off at both ends when lines are disconnected.

FAST OPERATION. Connect or disconnect in seconds, without tools. To connect, pull back sleeve, push coupler onto nipple and release sleeve. To disconnect, pull back the sleeve . . . coupler and nipple halves separate.

DEPENDABLE OPERATION. The ball-lock mechanism is the simplest, most reliable type in use, providing positive connection under any operating condition. Ball bearing and sleeve engagement permits 360° swivel action, preventing build-up of hose torque. Hardened stainless steel balls give extra-long service. Ball race is radiused to provide line contact and spread the load.

TIGHT SEAL CONNECTED. Snap-Tite's exclusive E-Packer insures a positive seal under vacuum and pressure, enables the E Series to handle a wide range of the E-Packer partially compresses to provide a form fit between coupler and nipple. It maintains a reliable seal even after swelling as much as 25% — providing capability far beyond that of normal rubber seal designs while saving the expense of special seal materials. The unique E-Packer seal contact permits the use of high temperature seal materials without the danger of leakage due to seal shrinkage and tearing — a common occurrence with normal butt seals or peripheral seal configurations.



TIGHT SEAL DISCONNECTED. The poppet has a metal-to-metal stop to control compression on the valve O-ring seal. This seal is recessed and wedged in the coupler or nipple body to keep it in place. The metal-to-metal contact of the valve with coupler or nipple body is designed to control compression of the valve seal, eliminating wear and increasing seal life. To assure that vacuum is held, extra-strong springs are furnished in the coupler and nipple valves.

CORROSION RESISTANCE. The steel E Series coupling is plated with heavy cadmium chromate that resists corrosion while enhancing appearance.

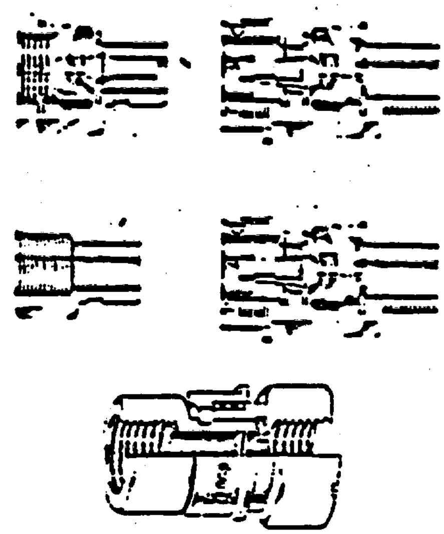
STRENGTH. Coupling bodies in sizes through 2" are machined from solid bar stock. The two-piece body construction with O-ring adapter seals provides built-in safety relief at ultimate pressure limits.

VERSATILITY. Wide choice of standard and special seal materials enables E Series to handle a great variety of fluids.

THREE COMBINATIONS

1. Double shut-off coupling: Valved nipple and valved coupler.
2. Single shut-off coupling: Plain nipple and valved coupler.
3. No shut-off coupling: Plain nipple and plain coupler.

All combin... the same size are



Plain couplers are NOT used with valved nipples — valve in nipple cannot be actuated.

TWELVE SIZES. ¼", ⅜", ½", ¾", 1", 1¼", 1½", 2", 2½", 3", 4", 6". Other sizes on request.

TEN END FITTINGS. Female NPT, Male NPT, Hose Shank, AND 10050 (female), SAE Female, MS33656 (male), SAE (JIC) 37° Male Flare, MS33514 (male), MS33657 (bulkhead), MS33515 (bulkhead). Other fittings on request.

FIVE METALS. Heat-treated alloy steel, brass, aluminum, 303 stainless, 316 stainless. Other metals on request.

EIGHT SEAL COMPOUNDS. Choice of eight basic E-Packer and O-Ring seal compounds, plus a variety of specials. See Packer Usage Guide for details.

FINISHES. Cadmium chromate steel, anodized aluminum and passivated stainless steels. Electroless nickel, chrome, nickel and other finishes on request.

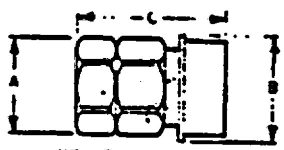
CAPS AND PLUGS. Dust caps, pressure caps or dust plugs protect disconnected couplers or nipples from damage, dirt and other contaminants. See back page.

SLEEVE LOCK. Prevents accidental disconnection of coupling. Sleeve cannot be

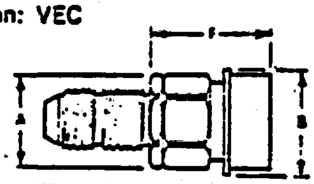
E SERIES VALVED COUPLINGS WITH END FITTINGS

Valved Couplers

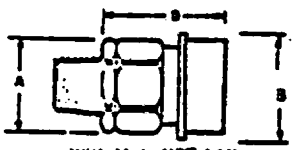
Basic Coupler Designation: VEC



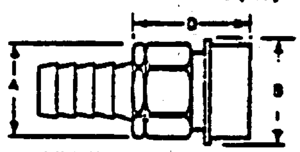
With Female NPT (-F)



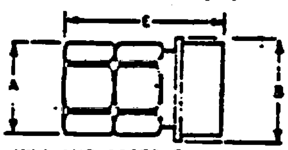
With MS33657, Bulkhead (-57)



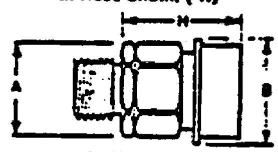
With Male NPT (-M)



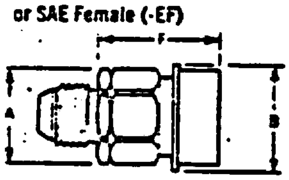
With Hose Shank (-H)



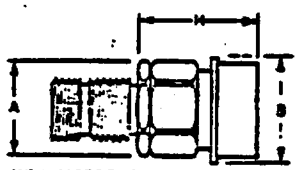
With AND 10050, Female (-50)
or SAE Female (-EF)



With MS33514, Male (-14)



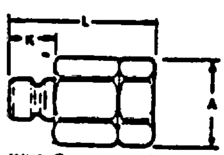
With MS33656, Male (-56)
or SAE (JIC) Male (-EM)



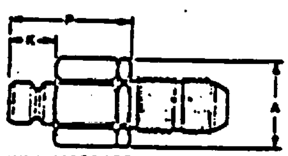
With MS33515, Bulkhead (-15)

Valved Nipples

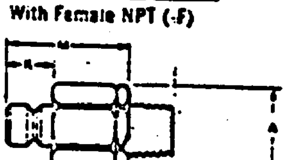
Basic Nipple Designation: VEN



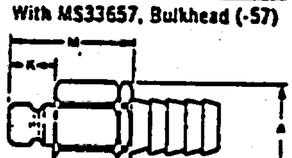
With Female NPT (-F)



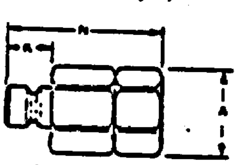
With MS33657, Bulkhead (-57)



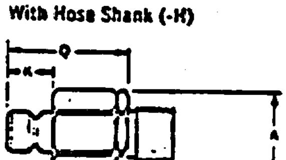
With Male NPT (-M)



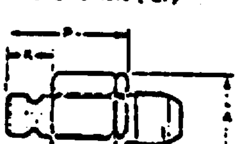
With Hose Shank (-H)



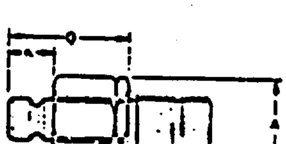
h AND 10050, Female (-50)
SAE Female (-EF)



With MS33514, Male (-14)



With MS33656, Male (-56)
or SAE (JIC) Male (-EM)



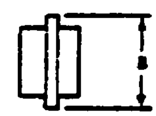
With MS33515, Bulkhead (-15)

Dimensions (Inches)

	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
A (Hex)	⅞	1	1⁵⁄₁₆	1⅛	1⅜	2	2¼	3⅜	4⁵⁄₁₆	4¼	5¹⁵⁄₁₆	8
B	1⅛	1⁵⁄₁₆	1⁷⁄₁₆	1⅞	2⁵⁄₁₆	2½	2⅞	3⅜	5¼*	5¾*	6⅝*	10⁵⁄₁₆*
C	1.65	1.90	2.09	2.42	2.67	3.54	3.27	3.92	4.53	4.77	5.71	9.31
D	1.53	1.63	1.83	2.11	2.28	2.59	2.94	3.52	4.20	4.38	5.71	9.31
E	1.80	1.98	2.19	2.58	2.74	3.39	3.42	4.15				
F	1.53	1.69	1.80	2.16	2.32	2.59	2.94	3.50				
H	1.53	1.69	1.80	2.16	2.32							
K	0.55	0.68	0.69	0.24	0.85	0.79	0.94	1.12	1.22	1.38	1.73	2.39
L	1.54	1.81	1.94	2.24	2.49	3.29	2.95	3.50	4.10	4.48	5.47	8.41
M	1.42	1.53	1.67	1.95	2.09	2.34	2.62	3.08	3.78	4.08	5.37	8.41
N	1.70	1.89	2.04	2.41	2.56	3.13	3.10	3.73				
P	1.42	1.60	1.66	1.99	2.14	2.34	2.62	3.09				
Q	1.42	1.63	1.68	1.99	2.14							

NOTES:

Hex dimensions are taken from flat of hex and not across corners.
Decimal dimensions are ±.015.
Dimensions are subject to change without notice.



**Sleeve configurations for these sizes as shown.*

Weights With End Fittings (Pounds) in Steel and Stainless Steels

COUPLERS	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
VEC-F	0.22	0.25	0.44	0.75	1.22	1.60	2.50	4.20	8.50	10.50	20.50	42.00
VEC-M, VEC-56, VEC-14, VEC-EM	0.22	0.25	0.44	0.72	1.06	1.50	2.30	4.50	8.50	10.95	22.00	43.00
VEC-H	0.21	0.25	0.44	0.78	1.30	1.58	2.25	4.82	9.00	11.14	22.00	43.00
VEC-50, VEC-EF	0.25	0.28	0.47	0.78	1.22	1.53	2.72	4.80				
VEC-57, VEC-15	0.25	0.28	0.47	0.91	1.44	1.70	2.75	5.20				
NIPPLES	**¼"**	**⅜"**	**½"**	**¾"**	**1"**	**1¼"**	**1½"**	**2"**	**2½"**	**3"**	**4"**	**6"**
VEN F	0.16	0.19	0.32	0.56	0.85	1.19	1.66	2.91	5.45	8.00	15.50	30.00
VEN-M, VEN-56, VEN-14, VEN EM	0.16	0.19	0.32	0.50	0.82	1.18	1.88	3.38	5.95	8.44	16.00	31.00
VEN H	0.14	0.19	0.31	0.52	0.91	1.22	1.82	3.69	6.45	8.65	16.00	31.00
VEN-50, VEN-EF	0.19	0.22	0.35	0.56	0.85	1.19	1.91	3.53				
VEN-57, VEN-15	0.19	0.22	0.35	0.69	1.06	1.38	2.35	4.07				

OTHER METALS:

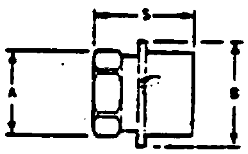
Multiply weights given in table by the following conversion factors: ALUMINUM: 0.379. BRASS: 1.08

Snap-tite

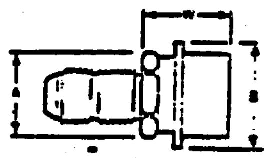
E SERIES PLAIN COUPLINGS WITH END FITTINGS

Plain Couplers

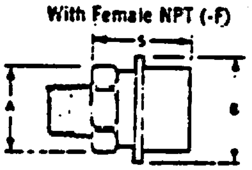
Basic Coupler Designation: PEC



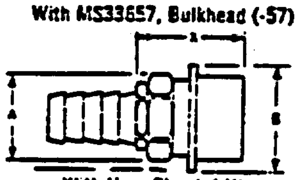
With Female NPT (-F)



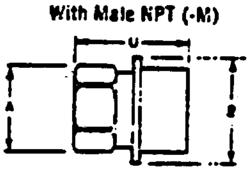
With MS33657, Bulkhead (-57)



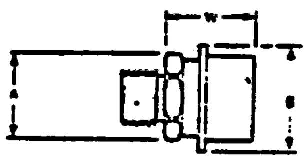
With Male NPT (-M)



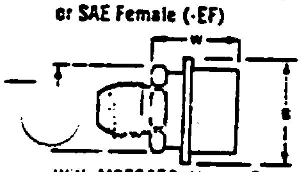
With Hose Shank (-H)



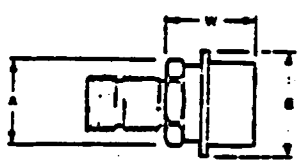
With AND 10050, Female (-50) or SAE Female (-EF)



With MS33514, Male (-14)



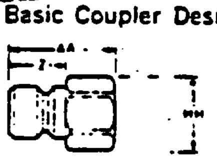
With MS33656, Male (-56) or SAE (JIC) Male (-EM)



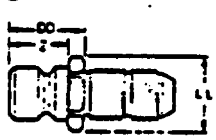
With MS33515, Bulkhead (-15)

Plain Nipples

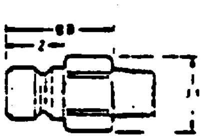
Basic Coupler Designation: PEN



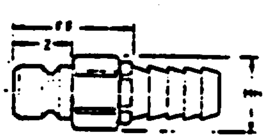
With Female NPT (-F)



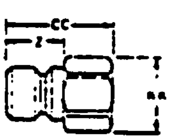
With MS33657, Bulkhead (-57)



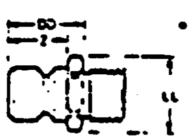
With Male NPT (-M)



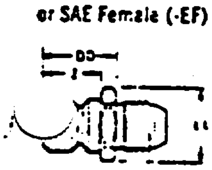
With Hose Shank (-H)



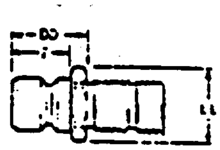
With AND 10050, Female (-50) or SAE Female (-EF)



With MS33514, Male (-14)



With MS33656, Male (-56) or SAE (JIC) Male (-EM)



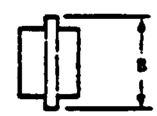
With MS33515, Bulkhead (-15)

Dimensions (inches)

	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	4"	6"
A (Hex)	11/16	1	1 5/16	1 3/8	1 7/8	2	2 1/4	3	3 3/4	4 3/4	5	8
B	1 3/8	1 5/16	1 5/16	1 5/8	2 5/16	2 1/2	2 7/8	3 3/8	5 1/16*	5 3/4*	6 3/4*	10 3/16*
S	1.31	1.53	1.72	1.94	2.03	2.25	2.41	2.67	3.21	3.35	3.82	4.88
U	1.22	1.43	1.56	1.94	1.96							
W	0.82	0.83	0.93	1.04	1.17							
X	1.43	1.65	1.90	2.13	2.24							
Z	0.55	0.68	0.63	0.84	0.85	0.79	0.94	1.12	1.22	1.28	1.73	2.39
AA	1.27	1.54	1.48	1.69	1.88	2.12	2.23	2.35	2.88	3.19	3.50	4.60
BB	0.67	0.87	0.88	1.04	1.88	2.12	2.23	2.35	2.88	3.19	3.50	4.60
CC	1.19	1.38	1.51	1.88	1.91							
DD	0.73	0.87	0.87	1.04	1.10							
FF	1.39	1.66	1.67	1.88	2.04							
HH (Hex)	5/8	13/16	1	1 5/16	1 1/2	1 7/8	2 1/2	2 3/4	3 3/4	4	5	8
JJ (Hex)	9/16	11/16	7/8	1 1/16	1 1/2	1 7/8	2 1/2	2 3/4	3 3/4	4	5	8
KK (Hex)	5/8	13/16	1	1 1/8	1 3/8							
LL (Hex)	11/16	15/16	1	1 3/8	1 5/8							

NOTES:

Hex dimensions are taken from flat of hex and not across corners.
Decimal dimensions are ± .015.
Dimensions are subject to change without notice.



**Sleeve configurations for these sizes as shown.*

Weights With End Fittings (Pounds) in Steel and Stainless Steels

COUPLERS	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	4"	6"
PEC-F	0.16	0.22	0.35	0.50	0.81	0.85	1.72	3.00	6.00	7.50	10.50	26.00
PEC-M, PEC 56, PEC 14, PEC EM	0.20	0.22	0.32	0.59	0.95	1.04	2.04	3.50	6.00	8.50	12.20	27.50
PEC-H	0.18	0.22	0.44	0.68	1.13							
PEC 50, PEC-EF	0.19	0.25	0.38	0.54	0.63							
PEC 57, PEC-15	0.23	0.25	0.41	0.78	0.69							

NIPPLES	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	4"	6"
PEN-F	0.07	0.07	0.13	0.22	0.35	0.56	0.82	1.47	2.00	3.50	5.50	19.50
PEN-M, PEN 56, PEN 14, PEN-EM	0.07	0.09	0.13	0.22	0.47	0.75	1.13	1.94	3.00	4.60	7.20	21.00
PEN-H	0.09	0.13	0.17	0.35	0.69							
PEN 50, PEN EF	0.10	0.10	0.16	0.25	0.50							
PEN 57, PEN 15	0.10	0.13	0.16	0.41	0.52							

OTHER METALS:

Multiply weights given in table by the following conversion factors
ALUMINUM: 0.379, BRASS 1.08

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E SERIES COUPLINGS: TECHNICAL DATA

Pressure Data

T : following data were determined by actual test under si ic conditions with no flow or surge and are conserva- ti . Conditions such as shock, cycles per given time, and o er factors will affect coupling life.

F ssure ratings of standard units can be increased in some a lications by slight design modifications or if specific operating conditions are met. On applications requiring higher ratings than those listed, please consult with Snap-Tite, Inc.

Burst pressures listed were taken at the point at which failure that rendered the couplings inoperative occurred—not at complete bursting of the units.

Working Pressures (psig)

lved & Valved and Valved & Plain Couplings

C PLING SIZE	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
S L	3000	3000	3000	2000	1500	1250	1000	750	750	750	500	500
B S	1500	1500	1500	1500	500	300	300	300	300	200	150	150
A INUM	1500	1500	1500	1500	500	300	300	300	300	200	150	150
S NLESS STEELS	3000	3000	3000	2000	1000	1000	750	500	400	300	200	200

ain & Plain Couplings

C PLING SIZE	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
S L	4500	4000	4000	3750	3000	2000	1500	1000	750	750	500	300
B S	3000	2000	2000	1750	1000	750	500	500	300	200	150	150
A INUM	3000	2000	2000	1750	1000	750	500	500	300	200	150	150
S NLESS STEELS	4000	3500	3500	3500	2000	1500	1000	750	400	300	200	200

OOF PRESSURES (psig): 1½ times working pressures.

RST PRESSURES (psig): 2 times working pressures.

Vacuum Test: Valved Nipple and Valved Coupler

(Connected and Disconnected)

PLING SIZE	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
PLED UNIT VACUUM "Hg Absolute	.20"	.20"	1.40"	1.90"	1.90"	1.90"	2.90"	2.90"	29.90"	29.90"	29.90"	29.90"
PLER AND NIPPLE (Separated) CUUM "Hg Absolute	.20"	19.90"	19.90"	19.90"	25.90"	29.90"	29.90"	29.90"	29.90"	29.90"	29.90"	29.90"

Force to Connect: Valved Nipple and Valved Coupler

JPLING SIZE	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
LING INTERNAL PRESSURE (psig)	200	200	200	100	100	100	50	50	50	50	2	2
CE TO CONNECT (Pounds)	50	60	95	95	145	195	155	245	425	560	45	35

Spillage on Disconnect: Valved Nipple and Valved Coupler

e following data were determined by actual test using hydraulic oil MIL-H-5606, specific gravity 0.83 in circulating w with pressure applied on coupler side only.

JPLING SIZE	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
psig INTERNAL LIQUID PRESSURE	1.2 cc	1.4 cc	4.2 cc	10.5 cc	19.6 cc	30.8 cc	55.2 cc	85.3 cc	172.0 cc	262.0 cc	[illegible]	[illegible]
psig INTERNAL LIQUID PRESSURE	1.5 cc	2.5 cc	4.6 cc	11.6 cc	21.4 cc							

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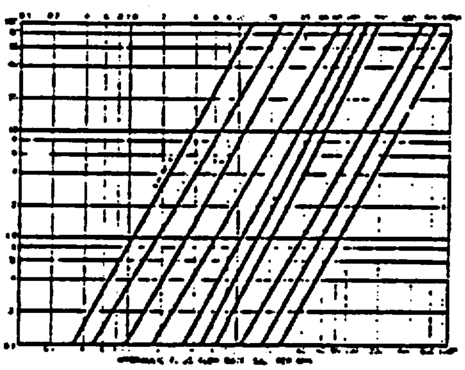
E SERIES COUPLINGS: TECHNICAL DATA

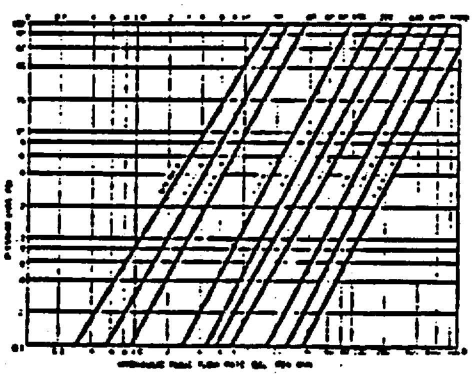
Flow and Pressure Drop

HYDRAULIC FLUIDS

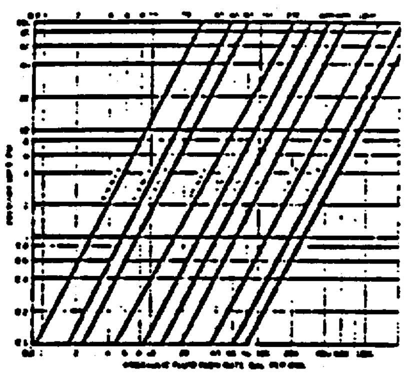
VALVED AND VALVED COUPLINGS:
Pressure loss vs. flow rate
(MIL-H-5606 hydraulic fluid).



VALVED AND PLAIN COUPLINGS:
Pressure loss vs. flow rate
(MIL-H-5606 hydraulic fluid).

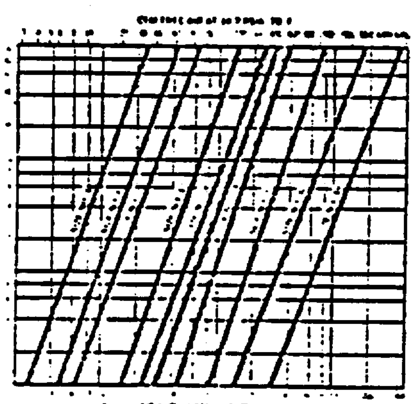


PLAIN AND PLAIN COUPLINGS:
Pressure loss vs. flow rate
(MIL-H-5606 hydraulic fluid).

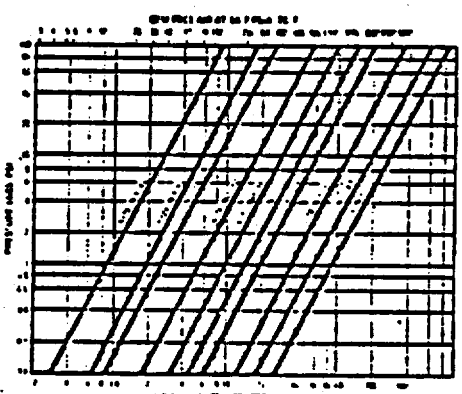


AIR

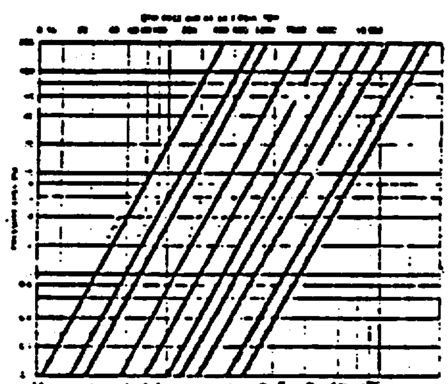
...D AND VALVED COUPLINGS:
...ressure loss vs. air flow rate.



VALVED AND PLAIN COUPLINGS:
Pressure loss vs. air flow rate.



PLAIN AND PLAIN COUPLINGS:
Pressure loss vs. air flow rate.



If inlet pressure is 85 psig. pressure drop at any specified rate of flow in either cubic feet per minute or pounds per minute can be taken directly from graphs. If inlet pressure is higher or lower than 85 psig. multiply the pressure drop by the pressure correction factor given in table below.

Air Flow Pressure and Temperature Correction Factors

AIR PRESSURE BEFORE COUPLING (PSI GAUGE)	3000	2000	1000	500	250	200	150	100	90	80	70	60	50	40
PRESSURE CORRECTION FACTOR	0.032	0.051	0.097	0.193	0.38	0.47	0.61	0.87	0.95	1.00	1.18	1.34	1.54	1.67

AIR TEMPERATURE (F°)	200	180	160	140	120	100	90	80	70	60	50	40
TEMPERATURE CORRECTION FACTOR	1.25	1.21	1.17	1.13	1.09	1.06	1.04	1.03	1.00	0.98	0.96	0.95

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E SERIES COUPLINGS: ORDERING INFORMATION

Select the proper coupling — consisting of coupler half with end fitting and nipple half with end fitting — from the table.

Coupler and Nipple Part Numbers in table are given in CADMIUM-CHROMATED STEEL.

If other material is desired, specify as follows:

ALUMINUM: Prefix the part number with the letter A. Example: AVEC6-6F.

BRASS: Prefix the part number with the letter B. Example: BVEC6-6F.

303 STAINLESS STEEL: Use prefix letter S and suffix designation (303). Example: SVEC6-6F (303).

316 STAINLESS STEEL: Use prefix letter S and suffix designation (316). Example: SVEC6-6F (316).

SLEEVE LOCK: To order, add W/SL to part number selected. Example: SVEC-6F (316) W/SL.

Steel Couplings with End Fittings

VALVED COUPLERS

End Fitting	¼"x⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
Female NPT	VEC4-2F	VEC4-4F	VEC6-6F	VEC8-8F	VEC12-12F	VEC16-16F	VEC20-20F	VEC24-24F	VEC32-32F	VEC40-40F	VEC48-48F	VEC64-64F	VEC96-96F
Male NPT	VEC4-2M	VEC4-4M	VEC6-6M	VEC8-8M	VEC12-12M	VEC16-16M	VEC20-20M	VEC24-24M	VEC32-32M	VEC40-40M	VEC48-48M	VEC64-64M	VEC96-96M
Hose Shank	VEC4-2H	VEC4-4H	VEC6-6H	VEC8-8H	VEC12-12H	VEC16-16H	VEC20-20H	VEC24-24H	VEC32-32H	VEC40-40H	VEC48-48H	VEC64-64H	VEC96-96H
AND 10050	VEC4-2-50	VEC4-4-50	VEC6-6-50	VEC8-8-50	VEC12-12-50	VEC16-16-50	VEC20-20-50	VEC24-24-50	VEC32-32-50				
MS33656	VEC4-2-56	VEC4-4-56	VEC6-6-56	VEC8-8-56	VEC12-12-56	VEC16-16-56	VEC20-20-56	VEC24-24-56	VEC32-32-56				
MS33657	VEC4-2-57	VEC4-4-57	VEC6-6-57	VEC8-8-57	VEC12-12-57	VEC16-16-57	VEC20-20-57	VEC24-24-57	VEC32-32-57				
MS33514	VEC4-2-14	VEC4-4-14	VEC6-6-14	VEC8-8-14	VEC12-12-14	VEC16-16-14							
MS33515	VEC4-2-15	VEC4-4-15	VEC6-6-15	VEC8-8-15	VEC12-12-15	VEC16-16-15							
SAE Female	VEC4-2-EF	VEC4-4-EF	VEC6-6-EF	VEC8-8-EF	VEC12-12-EF	VEC16-16-EF	VEC20-20-EF	VEC24-24-EF	VEC32-32-EF				
SAE Male	VEC4-2-EM	VEC4-4-EM	VEC6-6-EM	VEC8-8-EM	VEC12-12-EM	VEC16-16-EM	VEC20-20-EM	VEC24-24-EM	VEC32-32-EM				

VALVED NIPPLES

End Fitting	¼"x⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
Female NPT	VEN4-2F	VEN4-4F	VEN6-6F	VEN8-8F	VEN12-12F	VEN16-16F	VEN20-20F	VEN24-24F	VEN32-32F	VEN40-40F	VEN48-48F	VEN64-64F	VEN96-96F
Male NPT	VEN4-2M	VEN4-4M	VEN6-6M	VEN8-8M	VEN12-12M	VEN16-16M	VEN20-20M	VEN24-24M	VEN32-32M	VEN40-40M	VEN48-48M	VEN64-64M	VEN96-96M
Hose Shank	VEN4-2H	VEN4-4H	VEN6-6H	VEN8-8H	VEN12-12H	VEN16-16H	VEN20-20H	VEN24-24H	VEN32-32H	VEN40-40H	VEN48-48H	VEN64-64H	VEN96-96H
AND10050	VEN4-2-50	VEN4-4-50	VEN6-6-50	VEN8-8-50	VEN12-12-50	VEN16-16-50	VEN20-20-50	VEN24-24-50	VEN32-32-50				
MS33656	VEN4-2-56	VEN4-4-56	VEN6-6-56	VEN8-8-56	VEN12-12-56	VEN16-16-56	VEN20-20-56	VEN24-24-56	VEN32-32-56				
MS33657	VEN4-2-57	VEN4-4-57	VEN6-6-57	VEN8-8-57	VEN12-12-57	VEN16-16-57	VEN20-20-57	VEN24-24-57	VEN32-32-57				
MS33514	VEN4-2-14	VEN4-4-14	VEN6-6-14	VEN8-8-14	VEN12-12-14	VEN16-16-14							
MS33515	VEN4-2-15	VEN4-4-15	VEN6-6-15	VEN8-8-15	VEN12-12-15	VEN16-16-15							
SAE Female	VEN4-2-EF	VEN4-4-EF	VEN6-6-EF	VEN8-8-EF	VEN12-12-EF	VEN16-16-EF	VEN20-20-EF	VEN24-24-EF	VEN32-32-EF				
SAE Male	VEN4-2-EM	VEN4-4-EM	VEN6-6-EM	VEN8-8-EM	VEN12-12-EM	VEN16-16-EM	VEN20-20-EM	VEN24-24-EM	VEN32-32-EM				

PLAIN COUPLERS

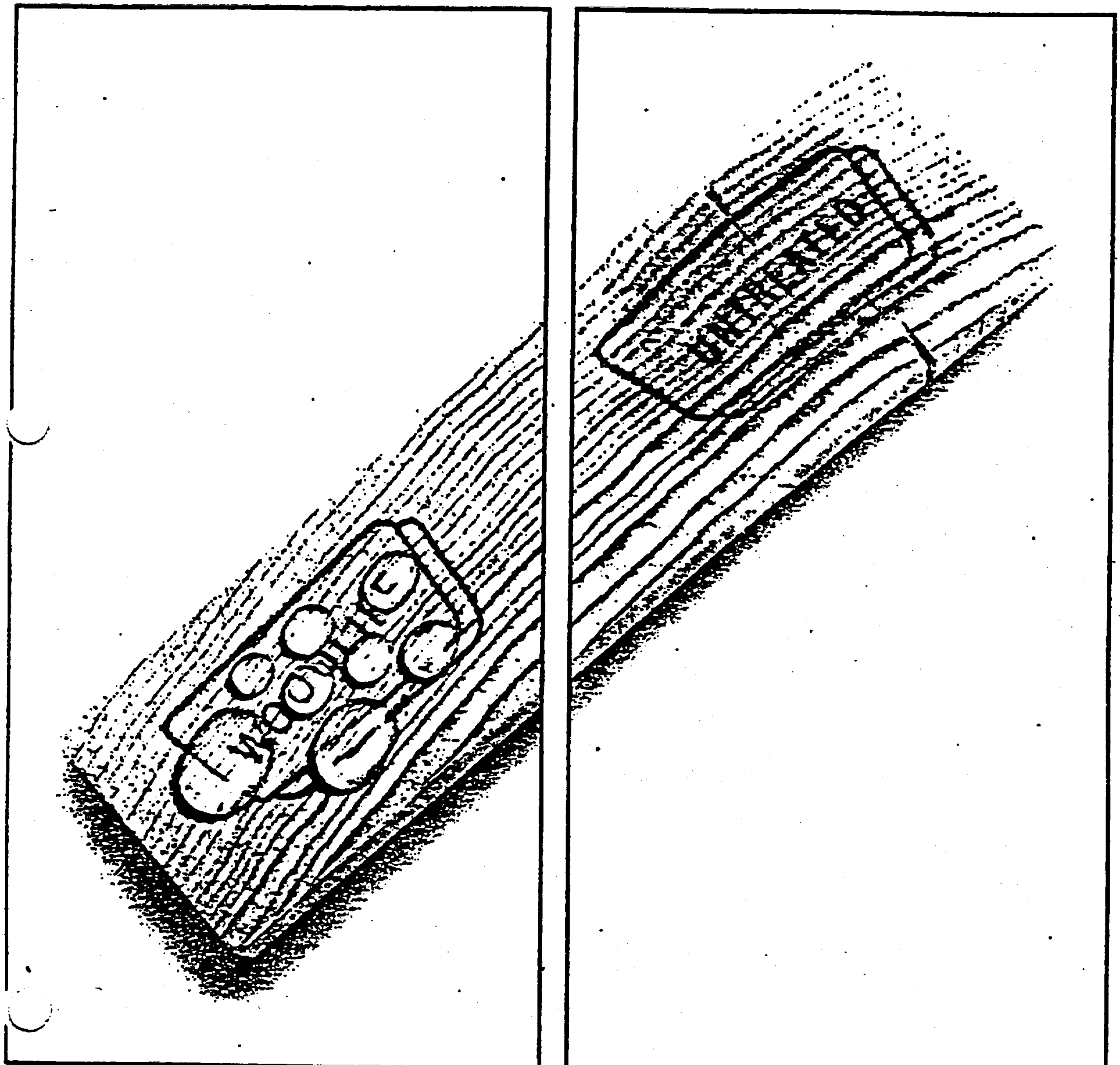
End Fitting	¼"x⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
Female NPT	PEC4-2F	PEC4-4F	PEC6-6F	PEC8-8F	PEC12-12F	PEC16-16F	PEC20-20F	PEC24-24F	PEC32-32F	PEC40-40F	PEC48-48F	PEC64-64F	PEC96-96F
Male NPT	PEC4-2M	PEC4-4M	PEC6-6M	PEC8-8M	PEC12-12M	PEC16-16M	PEC20-20M	PEC24-24M	PEC32-32M	PEC40-40M	PEC48-48M	PEC64-64M	PEC96-96M
Hose Shank	PEC4-2H	PEC4-4H	PEC6-6H	PEC8-8H	PEC12-12H	PEC16-16H							
AND10050	PEC4-2-50	PEC4-4-50	PEC6-6-50	PEC8-8-50	PEC12-12-50	PEC16-16-50							
MS33656	PEC4-2-56	PEC4-4-56	PEC6-6-56	PEC8-8-56	PEC12-12-56	PEC16-16-56							
MS33657	PEC4-2-57	PEC4-4-57	PEC6-6-57	PEC8-8-57	PEC12-12-57	PEC16-16-57							
MS33514	PEC4-2-14	PEC4-4-14	PEC6-6-14	PEC8-8-14	PEC12-12-14	PEC16-16-14							
MS33515	PEC4-2-15	PEC4-4-15	PEC6-6-15	PEC8-8-15	PEC12-12-15	PEC16-16-15							
SAE Female	PEC4-2-EF	PEC4-4-EF	PEC6-6-EF	PEC8-8-EF	PEC12-12-EF	PEC16-16-EF							
SAE Male	PEC4-2-EM	PEC4-4-EM	PEC6-6-EM	PEC8-8-EM	PEC12-12-EM	PEC16-16-EM							

PLAIN NIPPLES

End Fitting	¼"x⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"
Female NPT	PEN4-2F	PEN4-4F	PEN6-6F	PEN8-8F	PEN12-12F	PEN16-16F	PEN20-20F	PEN24-24F	PEN32-32F	PEN40-40F	PEN48-48F	PEN64-64F	PEN96-96F
Male NPT	PEN4-2M	PEN4-4M	PEN6-6M	PEN8-8M	PEN12-12M	PEN16-16M	PEN20-20M	PEN24-24M	PEN32-32M	PEN40-40M	PEN48-48M	PEN64-64M	PEN96-96M
Hose Shank	PEN4-2H	PEN4-4H	PEN6-[illegible]	PEN8-8H	PEN12-12H	PEN16-16H							
AND10050	PEN4-2-50	PEN4-4-50	PEN6-6-50	PEN8-8-50	PEN12-12-50	PEN16-16-50							
MS33656	PEN4-2-56	PEN4-4-56	PEN6-6-56	PEN8-8-56	PEN12-12-56	PEN16-16-56							
MS33657	PEN4-2-57	PEN4-4-57	PEN6-6-57	PEN8-8-57	PEN12-12-57	PEN16-16-57							
MS33514	PEN4-2-14	PEN4-4-14	PEN6-6-14	PEN8-8-14	PEN12-12-14	PEN16-16-14							
MS33515	PEN4-2-15	PEN4-4-15	PEN6-6-15	PEN8-8-15	PEN12-12-15	PEN16-16-15							
SAE Female	PEN4-2-EF	PEN4-4-EF	PEN6-6-EF	PEN8-8-EF	PEN12-12-EF	PEN16-[illegible]							

Woodlife®

The Original Water Repellent Preservative



Woodlife

W'¬ter-repellent preservative for all wood

.‧oodlife is the original, and it remains the most widely used, water-repellent wood preservative throughout the lumber and wood product industries. It is a light-bodied, penetrating solution which leaves no perceptible surface coating. It does not discolor the wood. It is odorless when dry. It does not interfere with subsequent painting or varnishing, and it does not affect the flammability of the wood.

Woodlife is suitable for the preservation of the finest cabinet work, and lumber items, alike.

In addition to its high water repellent effectiveness, Woodlife has a unique and outstanding ability to retard the surface wetting of wood. This quality, "anti-wicking action," is especially important for the protection of wood siding, millwork, and any other wood products where the entrance of water by capillary attraction is undesirable.

Woodlife Clear Colorless—best base for paint finishes. Use sealer before lacquers.

Marine Woodlife Green Also offers superior protection against salt water borers. Green tint. Contains Copper Naphthenate.

Woodlife conforms to the definition of a "non-swelling, paintable, water-repellent wood preservative" and meets or exceeds all requirements of the Preservative Minimum Standards of the National Woodwork Manufacturers Association. Conforms to the U.S. Department of Commerce National Bureau of Standards recommended commercial standard for Water Repellent Preservative Treatment of Millwork (CS-262).

Conforms to Federal Spec. TT-W-572 and TT-W-00572. Contains Pentachlorophenol (Federal Spec. TT-W-570).

Application Wood may be treated with Woodlife by immersion, DRI-VAC vacuum, roller-coater, brush, or low-pressure spray, allowing 24-48 hours before applying finishes. May be force-dried for production requirements.

Retention (Meets NWMA Standards for 3-minute immersion.)

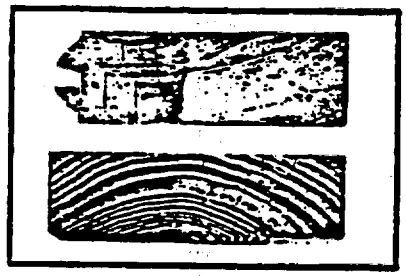
Immersion (3-minute) — 5-10 gal. per MBM*
Brush Application — 150 sq. ft. per gal.

**Absorption varies according to wood species and its condition.*

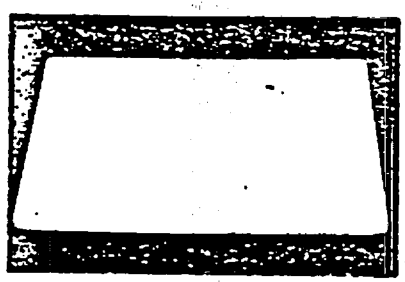
P‧intability Excellent compatibility with finishes. Clear ɔdlife—Use sealer coat before lacquers. Marine Woodlife Green—Possible staining of light colored prime ɔat; acceptable after second coat. Where requirements are critical, seal wood prior to painting.

Danger — Woodlife contains petroleum distillates and may be harmful or fatal if swallowed. If swallowed, do not induce vomiting but call a physician. Keep out of the reach of children.

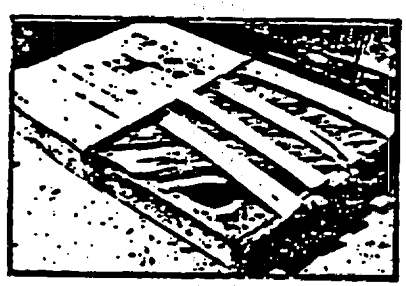
1. Reduces warping Hardwood truck body panels after 18 months of weathering. All were cut from the same board and the pai¬n the left was immersed in V life for 3 minutes. All were finished with O.D. enamel in accordance with Ordinance Specifications.



2. Guards against checking and splitting These laboratory test blocks of Southern Yellow Pine and Ponderosa Pine, partially treated in Woodlife, vividly show its ability to reduce end checking. They are alternately soaked and dried to accelerate checking.

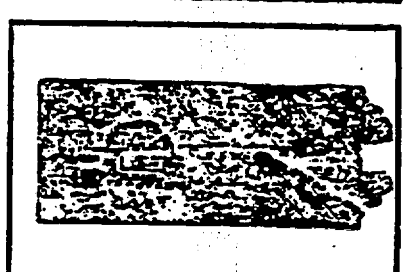


3. Minimizes grain raising and surface checking Half of this piece of Douglas Fir Plywood was dipped in Woodlife for 30 seconds. The entire piece was then given the same enamel finish and exposed to high humidity—a severe test for any wood.

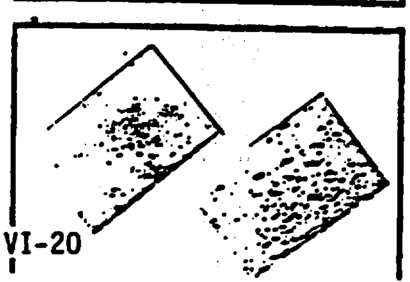


4. Prevents decay Woodlife-treated flooring section, at the left in photo, is sound and from decay after 7½ years e sure.

5. Controls fungus stain These Woodlife-treated and untreated windows in the south wall of a humidity chamber show that in actual service of the most severe kind, Woodlife gives the same control of stain-fungi as in laboratory tests.

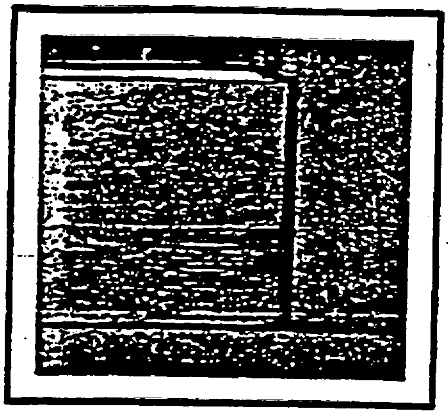


6. Stops termite and insect attack After one end was treated with Woodlife, this block was placed in laboratory termite bed. Termites tunneled across the treated area, but bored a hole clear through the untreated portion. During a 6-month test, the untreated end checked badly and developed decay.

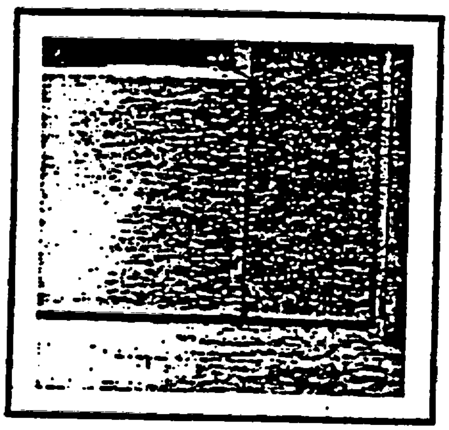


7. Improves paintability and paint holding quality These blocks from the same board identically finished with white enamel but the one on the left had previously been immersed in Woodlife. One winter's outdoor exposure demonstrated the value of Woodlife in keeping the wood

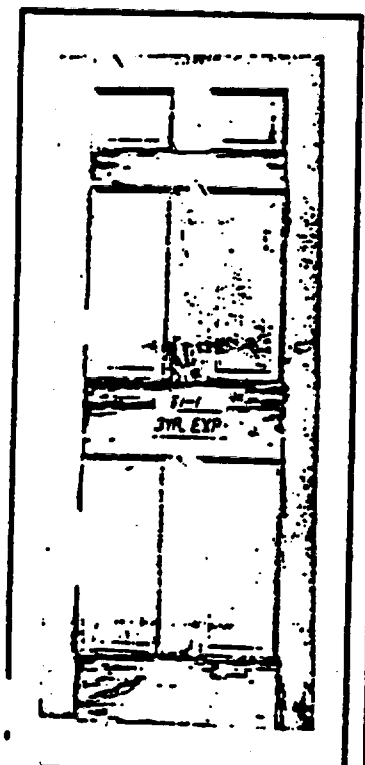
This shows what moisture can do even to quality millwork, in spite of a paint finish, after four years of exposure to the elements.



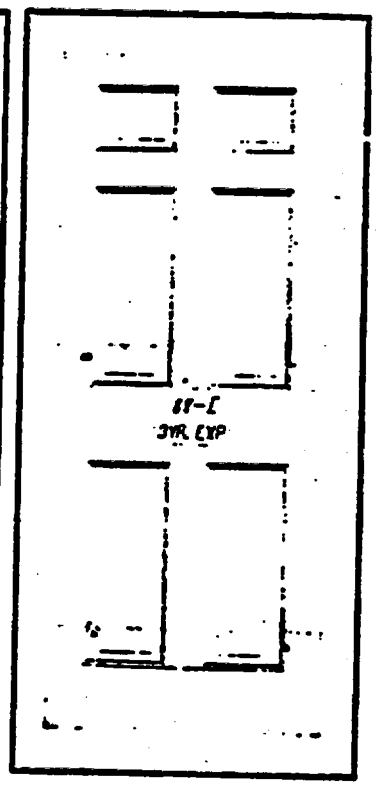
This sash joint was not treated before painting. Observe the open joint, glazing compound failure, staining, and poor condition in general.



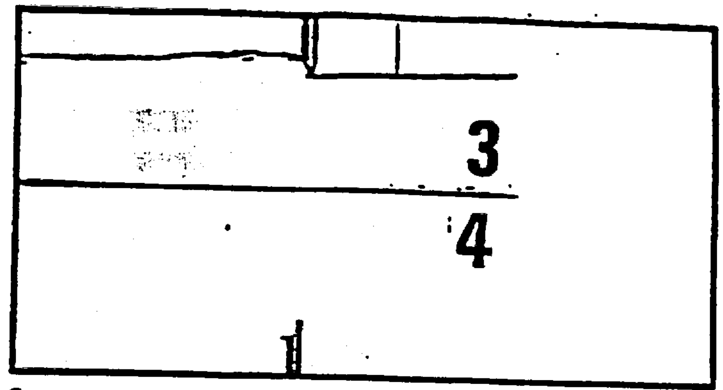
This sash joint was Woodlife treated before painting. Notice the excellent condition of the paint, glazing compound and joint.



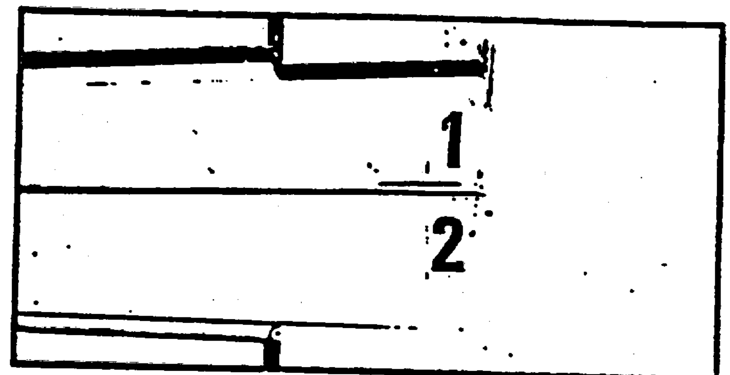
Note the paint failure and general deterioration of the untreated door.



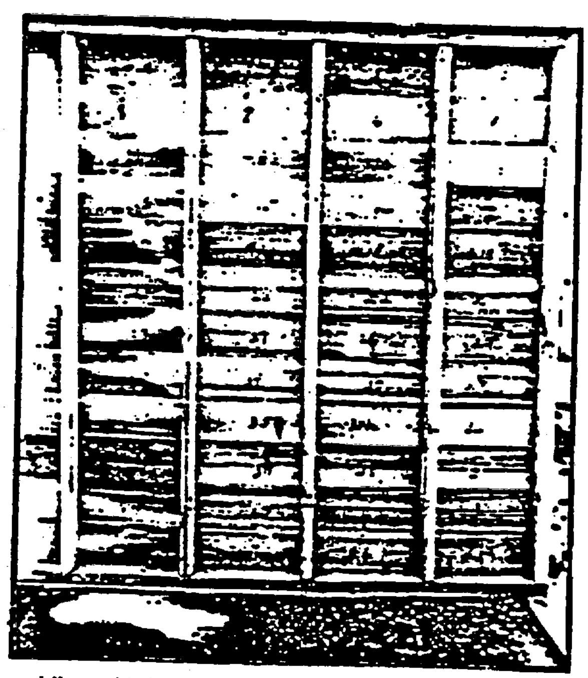
After 3 years exposure to year-around weathering, the Woodlife treated door is in excellent condition.



Garage door sections constructed by a large, well-known manufacturer. Stiles and rails are finger jointed hemlock with Douglas fir plywood panels. No. 3 was left untreated, No. 4 WOODLIFE treated by 3 minute immersion. Both units then primed with a well-known brand of industrial primer finished with one coat exterior house paint. Both panels exposed to the elements for 12 months.



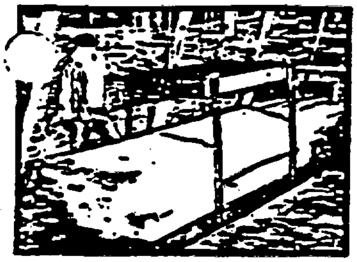
Close-up of painted garage door sections with hardboard panels. The untreated panel (#1) shows checking of the stile, paint failure where panel joins the rail; the glue line and corner joint have failed. The Woodlife treated panel (#2) is in excellent condition. Both have been exposed to the weather for 10 months.



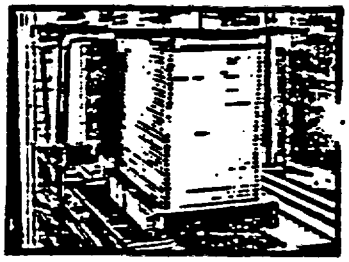
Treating siding with Woodlife preserves wood's natural good qualities and offers the added benefits shown in this photograph. Note how the water has darkened the back of the untreated (left side of photo) portion of the siding test panel after one year's exposure to the weather. Water worked in between the lap joints and wetted the back side. Treated siding (right side of photo) loses its affinity for water, so remains dry.

How to apply Woodlife

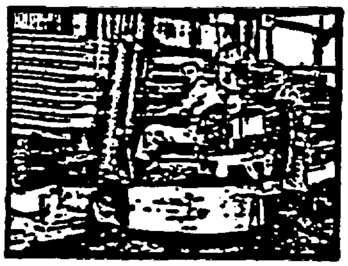
Immersion (Open Tank Method)



Woodlife-treating tank in the shed of a prominent lumber dealer. The carriage and overhead hoist enable one man to handle full lumber-buggy loads.



An elevator-type Woodlife tank in the plant of a leading millwork manufacturer. Roller conveyors on the elevator, and connecting rollers on the floor, permit one-man handling of full pallet loads.

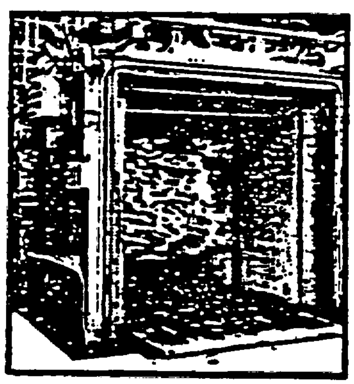


Another Woodlife tank in a frame plant. Here a standard fork truck provides a very flexible and economical means of handling large pallet loads.

As shown here, a Woodlife-treating tank need not be elaborate or expensive. Many plants and yards find a hand operation serves for small jobs.

Dri-Vac® Process (Controlled Vacuum)

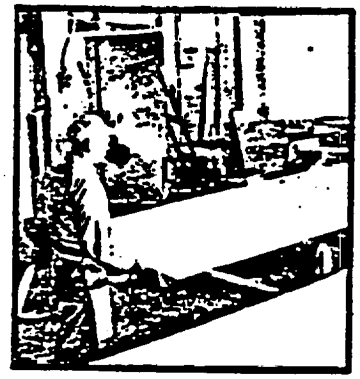
The Dri-Vac Process was developed and perfected in the U.S. Plywood laboratory for applying clear, paintable, water-repellent preservatives. It gives deeper penetration and higher retentions than are obtainable in open-tank immersion of some species. It is also used to control and speed up the treatment of millwork.



The Dri-Vac tank of a large lumber firm where Woodlife treatment of everything from timbers to millwork is done quickly and economically. Note the cleanli- ›s of the floor—evidence of the ..eated lumber's being virtually surface dry upon removal from the tank. Side-views of elevator-type Dri-Vac unit in a large millwork plant. Full pallet loads of sash and frames are Woodlife-treated in accordance with NWMA standards or commercial standards. The entire operation is automatic.

Flooding, Roller Coating, Brushing

Where immersion is not practical, Woodlife may be applied by flooding or roller-coating. These processes should be designed to s‥ify your individual plant requirements. Consult our Technical S‥ Department for assistance, on any Woodlife application.



Roller-coating is a fast, economical and effective method of treating plywood. The flow of Woodlife is easily controlled, and the results are comparable to those obtained in a standard 30-second immersion. Brushing is the least effective method of continuous application. It is only worth doing if care is exercised to soak all joints and end-grain with several applications.

CHEMWARE

CHAMPION INTERNATIONAL
INDUSTRIAL ‥ PRODUCTS
2305 Superior Ave ‥o, Michigan 49003

6132 / Printed in U.S.A./Sept. 1973

Section VII

SECTION VII

WEIGHT CALCULATIONS

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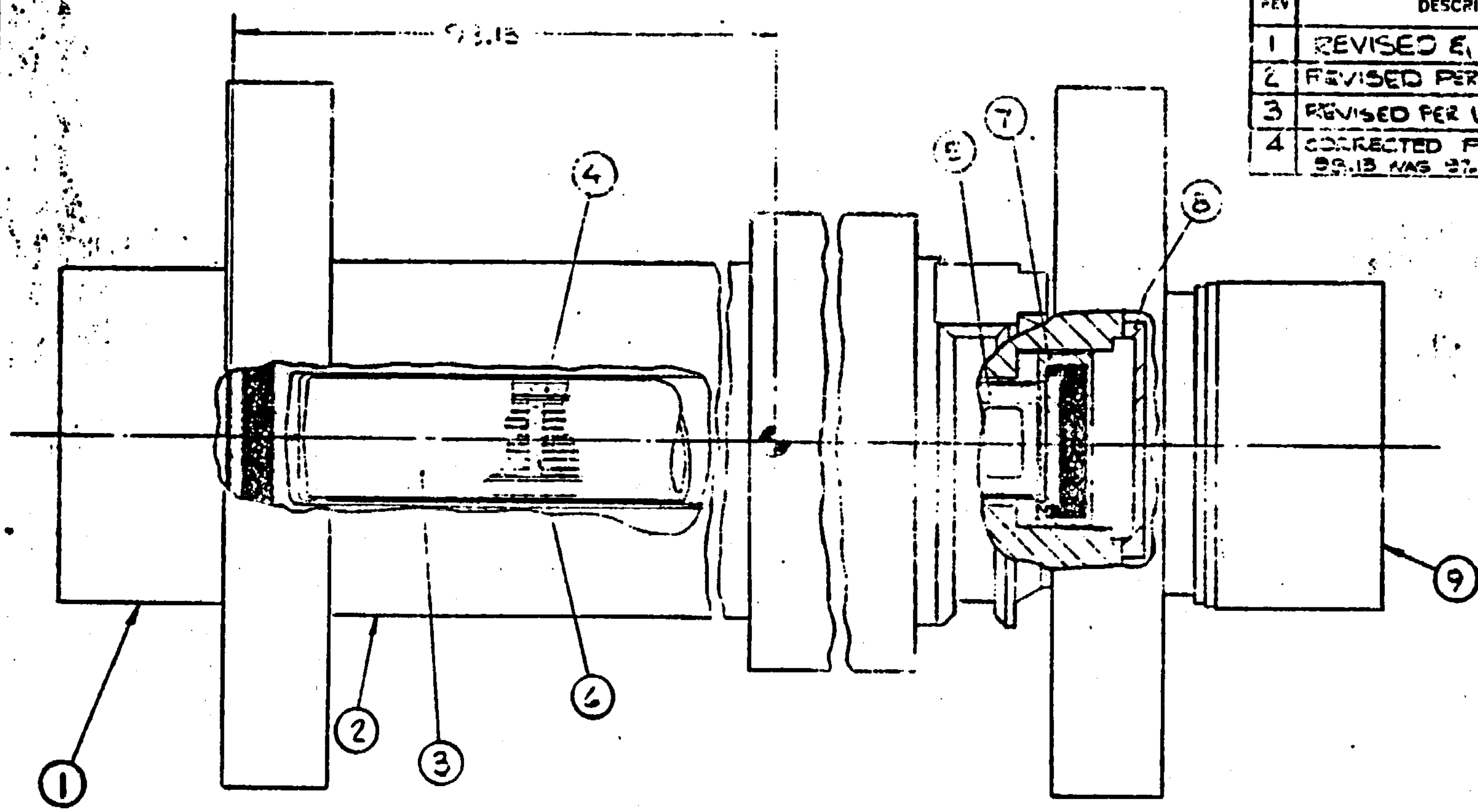
REV	DESCRIPTION	DATE	
1	REVISED & REDRAWN	11/29/72 WGS	
2	REVISED PER LATEST DESIGN	-/13/73 TAT	
3	REVISED PER LATEST DESIGN	7/19/73 TAT	
4	CORRECTED PICTURE 99.13 WAS 97.14	2/29/80	[illegible]



NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

	DATE
DRAWN WGS	11/29/72
CHKD.	
ENG	
Q.C.	
PROD	

1/2 SPENT FUEL CASK
WEIGHT & C.G.
CONFIGURATION "A"

CODE IDENT	PROD №	SIZE	DRAWING №	REV
29932	A-5325	B	20026B	4

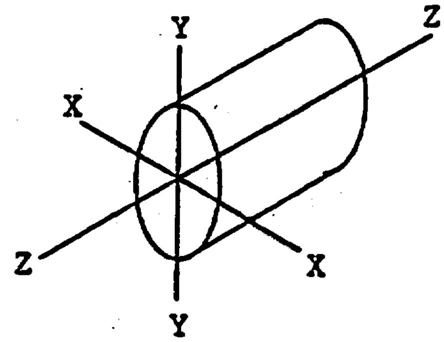
WT 47[illegible] LBS | SCALE —— | SHEET 1 OF 1

NL INDUSTRIES, INC. NUCLEAR DIVISION WILMINGTON, DELAWARE	WEIGHTS & BALANCES

COMPONENT CASK FINAL ASSEMBLY

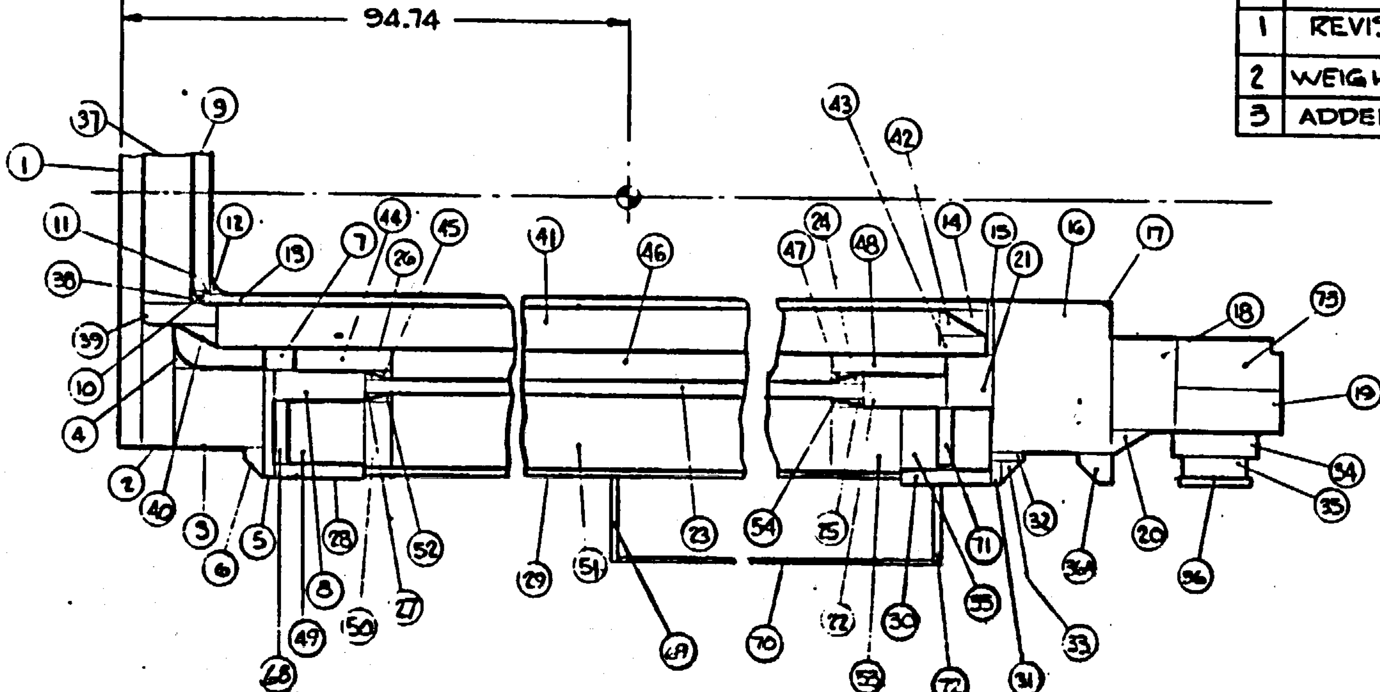
DRAWING NO. 20026 B

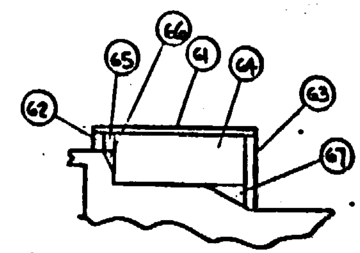
CONFIGURATION "A"



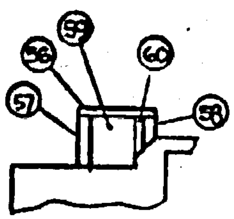
IT. NO.	1 WEIGHT LBS.	2 X In.	3 Y In.	4 Z In.	5 W_x In. Lb.	6 W_y In. Lb.	7 W_z In. Lb.
1	454.37			1.2			545.24
2	42505.11			94.74			4026728.32
3	692.84			98.83			68473.37
4	690.09			91.14			628[illegible]
5	20.55			183.25			3765.[illegible]
6	1600			105.02			168032
7	665.69			188.44			125442.62
8	341.04			195.66			66727.8
9	865.09			198.09			171365.67
Σ	47834.78						4693975.61
		Σ_5/Σ_1	Σ_6/Σ_1	Σ_7/Σ_1			
				98.13			

REV	DESCRIPTION	DATE	APPD
1	REVISED & REDRAWN	11/29/72 HGS	
2	WEIGHT & C.G. CHANGE	TNT 7/19/73	
3	ADDED (73), CORRECTED C.G.	2/29/80	[illegible]





CAVITY VALVE BOX
2 REQ'D



LOWER
WATER JACKET VALVE BOX

	DATE
DRAWN HGS	11/29/72
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

1/2 SPENT FUEL CASK
WEIGHTS & C.G - CASK BODY

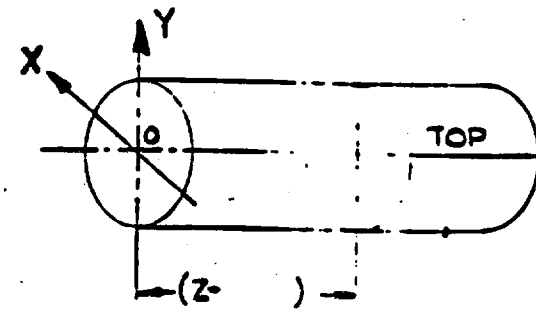
CODE IDENT	PROD №	SIZE	DRAWING №	REV
29932	A-5325	B	20034B	3

WT 41912.94 LBS. SCALE — SHEET 1 OF 1

NL INDUSTRIES, INC. NUCLEAR DIVISION
WILMINGTON, DELAWARE

WEIGHTS & BALANCES

Drawing No. 20034B REV 1



ORIGIN (O) AT

CASK BODY (WET)

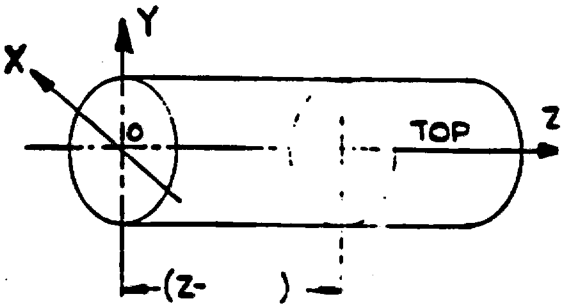
Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z - In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In.
1	S/S	297.14			0.61			181.26
2	↑	379.90			2.28			866.17
3		752.10			6.35			4775.84
4		17.10			3.80			64.98
5		111.68			9.68			1081.06
6		66.9			9.00			602.10
7		67.71			10.38			702.83
8		236.21			13.00			3070.73
9		52.01			5.27			274.09
10		6.67			5.25			35.02
11		5.27			5.64			29.72
12		5.49			6.32			34.70
13		1043.5			89.95			93866.47
14		45.62			172.70			7895.8
15	↓	12.37			174.01			2152.5
16	S/S	1600.31			178.07			284967.
	Σ							
CENTER OF GRAVITY			Σ5/Σ1	Σ6/Σ1	Σ7/Σ1			

VII-4

DATE ________ PAGE ________

NL INDUSTRIES, INC. NUCLEAR DIVISION WILMINGTON, DELAWARE	WEIGHTS & BALANCES

Drawing No. 20034B REV 1



ORIGIN (O) AT

CASK BODY (WET)

Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z - In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
17	S/S	-0.34			183.12			-62.2[illegible]
18	↑	507.61			185.23			94024.6[illegible]
19		480.08			190.375			91397.63
20		40.44			184.31			7453.50
21		216.41			172.75			37384.83
22		216.52			168.50			36483.62
23		2947.66			90.875			267868.60
24		9.44			165.08			1558.36
25		10.36			165.08			1710.23
26		9.44			16.67			157.36
27		10.36			16.67			172.70
28		97.37			13.00			1265.81
29		1243.50			92.63			115185.4[illegible]
30		97.37			171.25			16674.6[illegible]
31	↓	44.70			174.81			7814.[illegible]
32	S/S	44.99			175.25			7884.[illegible]
	Σ							

CENTER OF GRAVITY	Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1	
				VII-5

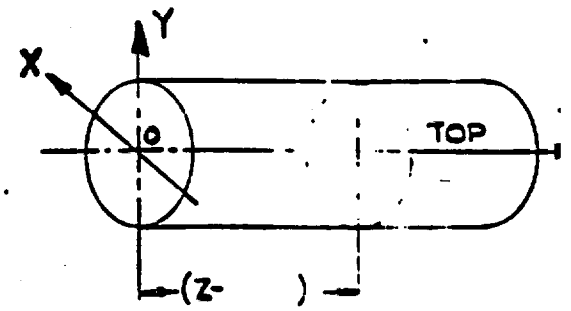
DATE________ PAGE____ OF____

NL INDUSTRIES, INC. NUCLEAR DIVISION

WILMINGTON, DELAWARE

WEIGHTS & BALANCES

Drawing No. 20034B REV I



ORIGIN (O) AT

CASK BODY (WET)

Item	Dwg. No.	1	2	3	4	5	6	7
		W	X	Y	Z -	Wx	Wy	Wz
		Lb.	In.	In.	In.	In. Lb.	In. Lb.	In.
33	S/S	24.05			175.82			4228.47
34		44.01			188.75			8306.89
35		26.28			188.75			4960.35
36		9.07			188.75			1711.96
36A	S/S	79.62			181.33			14437.49
37	U	344.88			2.78			958.77
38		3.62			4.62			16.72
39		271.85			3.63			968.82
40		79.84			5.14			410.38
41		16961.74			88.18			1495686.2
42		117.16			171.55			20098.8
43	U	161.19			172.18			27753.6
44	Pb	282.84			14.38			4067.24
45		13.44			17.33			232.9
46		8826.44			90.88			802146.8
47	Pb	13.44			164.32			2208.4
	Σ							

CENTER OF GRAVITY	$\Sigma 5 / \Sigma 1$	$\Sigma 6 / \Sigma 1$	$\Sigma 7 / \Sigma 1$

VII-6

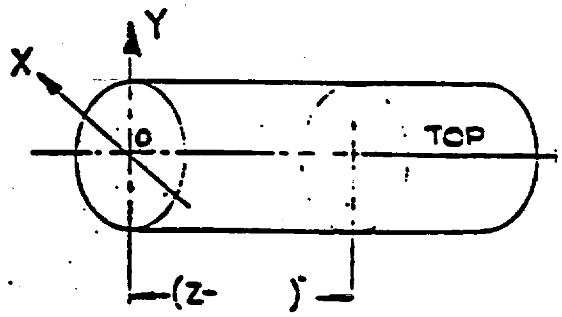
DATE________ PAGE____ OF____

NL INDUSTRIES, INC. NUCLEAR DIVISION

WILMINGTON, DELAWARE

WEIGHTS & BALANCES

Drawing No. 20034B REV 2



ORIGIN (O) AT

CASK BODY (WET)

Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z - In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
48	Pb	353.55			166.50			58866.0
49	H_2O	82.51			13.375			1103.57
50	↑	32.44			17.00			551.48
51	│	2555.02			90.88			232200.2
52	│	1.32			17.33			22.88
53	│	32.44			166.50			5401.26
54	↓	1.32			164.32			216.90
55	H_2O	78.58			171.25			13456.8:
56	S/S	1.78			7.00			12.46
57		2.62			4.88			12.79
58		1.12			8.88			9.95
59		5.24			6.13			32.12
60		0.80			8.63			6.90
61		18.28			179.59			3282.91
62		6.41			174.63			1119.35
63		25.65			184.56			4733.9(
	Σ	3199.08						321029.6.

CENTER OF GRAVITY	Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1

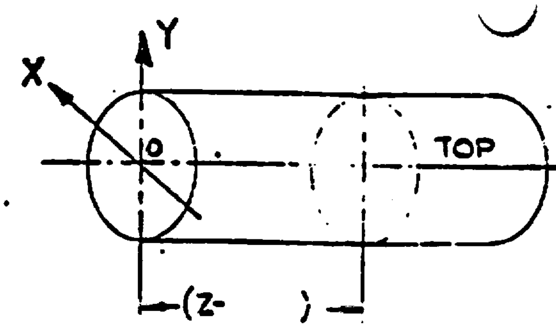
VII-7

DATE______ PAGE____ OF____

NL INDUSTRIES, INC. NUCLEAR DIVISION
WILMINGTON, DELAWARE

WEIGHTS & BALANCES

Drawing No. [illegible]



ORIGIN (O) AT

[illegible] (WET

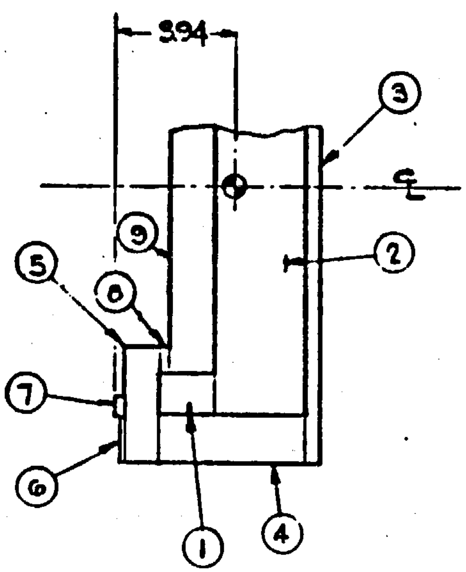
Item	Dwg. No.	1	2	3	4	5	6	7
		W	X	Y	Z -	Wx	Wy	Wz
		Lb.	In.	In.	In.	In. Lb.	In. Lb.	In. Lb.
[illegible]	[illegible]	[illegible]			180.24			[illegible]
[illegible]	↓	[illegible]			175.63			[illegible]
[illegible]		[illegible]			175.75			[illegible]
[illegible]		[illegible]			183.56			[illegible]
[illegible]		[illegible]			[illegible]			[illegible]
		124.30			156.937			17507.26
[illegible]		321.78			167.50			53898.1[illegible]
[illegible]	↓	12[illegible].40			171.75			21365.70
[illegible]	S/S	121.74			178.062			21677.2[illegible]
73	S/S	592.17			182.4			108011.8
	Σ	42505.11						4026[illegible]

CENTER OF GRAVITY	Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1
			94.74

VII-8

DATE ________ PAGE ________ OF ________

REVISIONS			
REV.	DESCRIPTION	DATE	APPD
1	DESIGN CHANGE HGS	11-28-72	
2	OUTER CLOS. HD.	TAT 6/7/73	
3	WEIGHT & C.G CHANGE	TAT 6/14/73	
4	REVISED PER LATEST DESIGN	TAT 7/19/73	
5	DELETED OUTER CL.HD.	3/29/80	CEK



INNER CLOSURE HEAD

WT. = 665.69 LBS

	DATE
DRAWN HGS	11/29/72
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

INNER CLOSURE HEAD
WEIGHT & C.G.
CONFIGURATION "A"

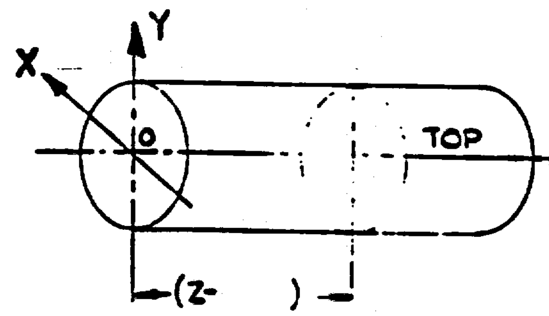
CODE IDENT	PROD Nº	SIZE	DRAWING Nº	REV
29932	A-5325	B	20033B	5

WT ———— SCALE ———— SHEET 1 OF 1

NL INDUSTRIES, INC. NUCLEAR DIVISION
WILMINGTON, DELAWARE

WEIGHTS & BALANCES

Drawing No. 20033B



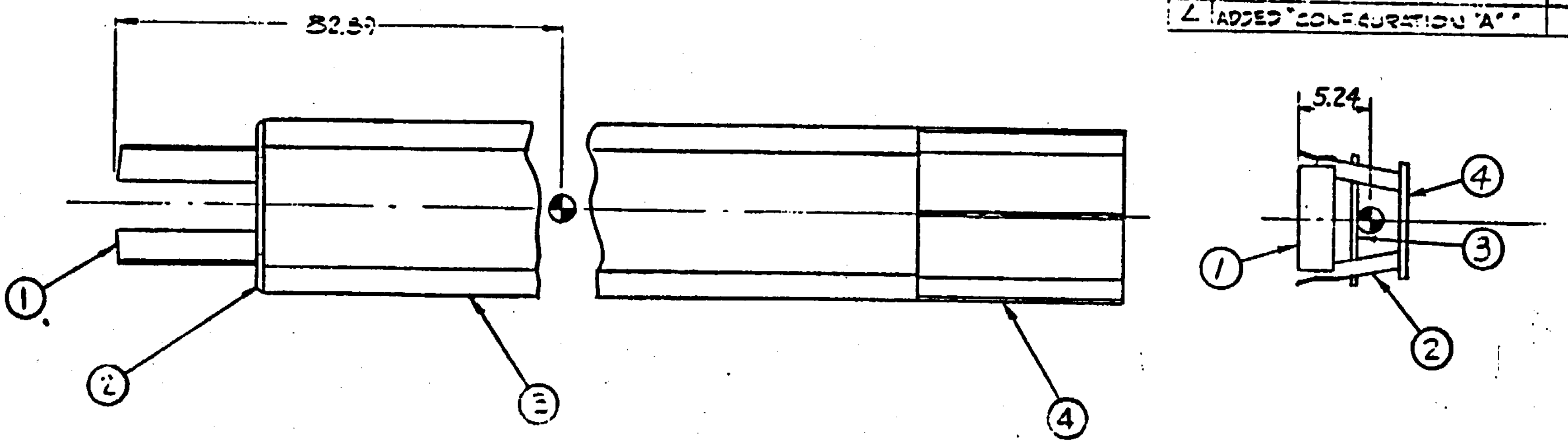
INNER CLOSURE HEAD

Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z- in.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
1	U	47.97			2.38			114.17
2	U	342.70			4.75			1627.83
3	S/S	36.26			6.50			235.69
4	↓	117.07			3.88			454.23
5		59.81			0.81			48.45
6		2.87			0.18			0.52
7		1.50			0.09			0.14
8	↓	2.93			1.63			4.78
9	S/S	54.58			2.50			136.45
	Σ	665.69						262
CENTER OF GRAVITY			Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1			
					3.94			

VII-10

DATE ______ PAGE ______

REVISIONS			
REV	DESCRIPTION	DATE	APPD
1	REVISED & REDRAWN	TAT	
2	REVISED PER LATEST DESIGN	TAT 6/5/73	
3	REVISED PER LATEST DESIGN	F.L. 6/11/74	
4	ADDED "CONFIGURATION 'A'"	[illegible]	[illegible]



PWR FUEL BASKET
[illegible] #

PWR SPACER
20.55 #

CONFIGURATION "A"

	DATE
DRAWN TAT	6/5/73
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

PWR FUEL BASKET & SPACER
WEIGHTS & C.G.'S.
1/2 SPENT FUEL CASK

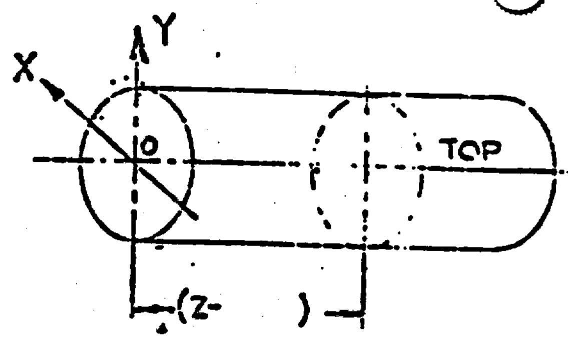
CODE IDENT	PROD Nº	SIZE	DRAWING Nº	REV
29932	4-3325	B	200368	4

WT — SCALE — SHEET 1 OF [illegible]

NL INDUSTRIES, INC. NUCLEAR DIVISION
WILMINGTON, DELAWARE

WEIGHTS & BALANCES

Drawing No. 20036B



ORIGIN (O) AT

PWR FUEL BASKET

Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z - In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
1		14.42			5.250			75.70
2		12.14			10.125			122.91
3		661.21			85.625			56616.10
4		2.32			168.062			389.90
	Σ	690.09						57204.61

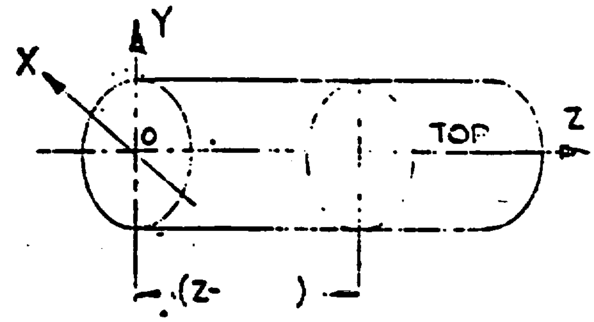
CENTER OF GRAVITY	Σ5/Σ1	Σ6/Σ1	Σ7/Σ1
			82.89

NL INDUSTRIES, INC. NUCLEAR DIVISION

WILMINGTON, DELAWARE

WEIGHTS & BALANCES

Drawing No. 200363



ORIGIN (O) AT

PWR SPACER

Item	Dwg. No.	1	2	3	4	5	6	7
		W	X	Y	Z -	Wx	Wy	Wz
		Lb.	In.	In.	In.	In. Lb.	In. Lb.	In. Lb.
1		1.66			1.25			2.075
2		9.72			4.86			47.239
3		4.28			4.33			19.549
4		4.89			7.92			38.748
Σ		20.55						107.611

CENTER OF GRAVITY	Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1
			5.24

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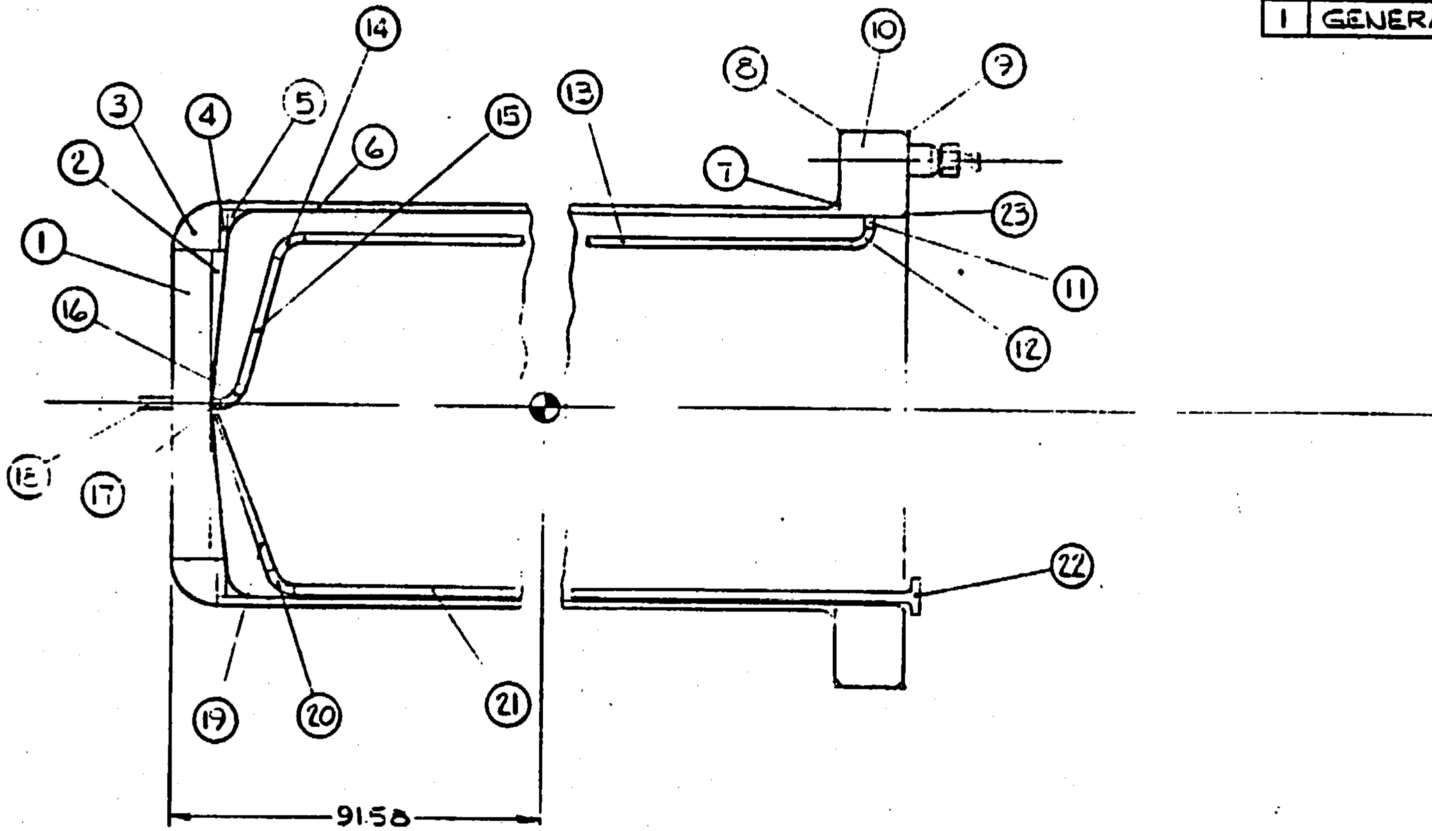
DATE ________ PAGE ________ OF ____

REVISIONS			
REV	DESCRIPTION	DATE	APPD
1	GENERAL REVISION	4/8/73	



	DATE
DRAWN HGS	11/29/72
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

INNER CONTAINER
WEIGHT & C.G.
CONFIGURATION "A"

CODE IDENT	PROD NO	SIZE	DRAWING NO	REV
29932	A-5325	B	20037 B	1

WT 692.31 LBS SCALE — SHEET 1 OF 1

NATIONAL LEAD CO. NUCLEAR DIVISION
WILMINGTON PLANT

WEIGHTS BALANCES

Drawing No. 20037B REV 1

Coordinate Designation

INNER CONTAINER

Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
1		28.96		.625			18.10	
2		4.21		1.5			6.31	
3		18.11		.972			17.60	
4		2.60		1.625			4.22	
5		2.41		1.726			4.15	
6		555.45		88.937			49400.05	
7		.02		176.17			3.52	
8		-.45		175.50			78.97	
9		-.14		177.437			24.84	
10		78.29		176.438			13813.33	
11		.003		176.781			.530	
12		.01		176.531			1.765	
13		1.59		90.230			143.465	
14		.003		3.50			.010	
15		.04		3.00			.120	
16		.006		2.437			.014	
	Σ							

Center Of Gravity	Σ5/Σ1	Σ6/Σ1	Σ7/Σ1

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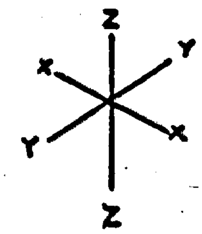
DATE______ PAGE______ OF______

NATIONAL LEAD CO. NUCLEAR DIVISION
WILMINGTON PLANT

WEIGHTS BALANCES

Drawing No. 200313 REV 1



Coordinate Designation

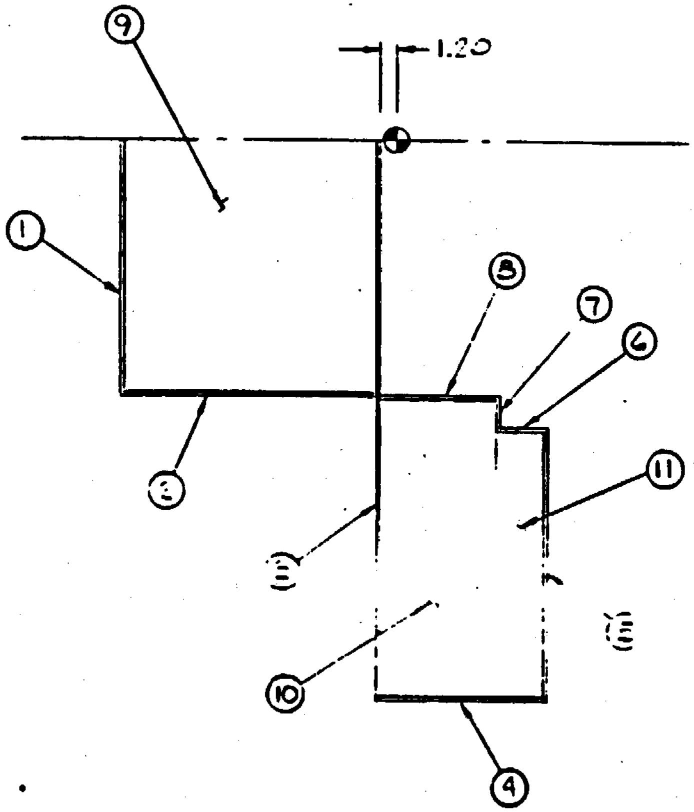
INNER CONTAINER

Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
17		.004		1.50			.006	
18		.03		-.531			-.015	
19		.054		1.718			.092	
20		.014		2.375			.033	
21		1.61		88.965			143.23	
22		.07		177.812			12.44	
23		-.05		177.437			-8.87	
	Σ	692.844					63456.29	

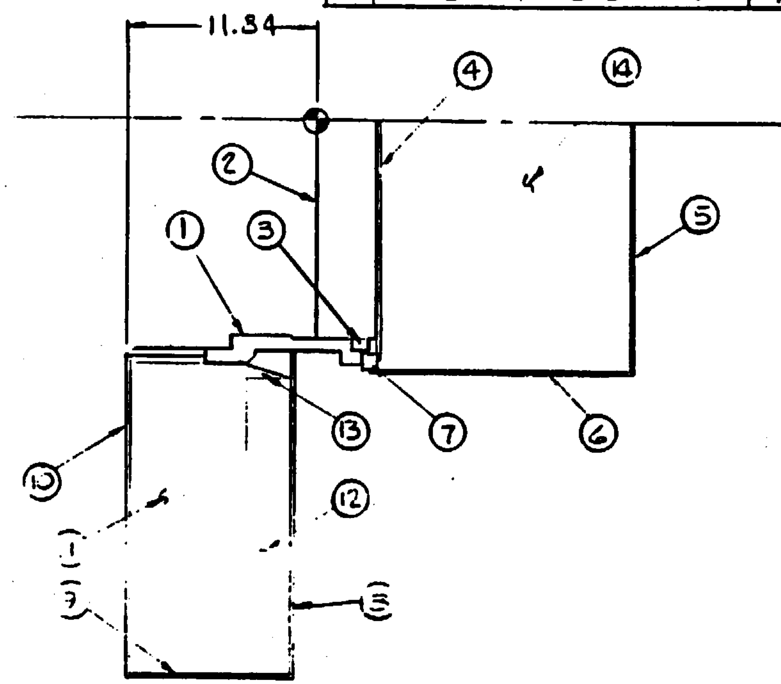
Center Of Gravity	Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1	
		91.58		VII-16

DATE______ PAGE______ OF______

REV	DESCRIPTION	DATE	APPD
1	REVISED & REDRAWN	4/4/73 TAT	
2	WEIGHT & C.G CHANGE	9/17/73 TAT	



BOTTOM IMPACT STRUCTURE
WT = 454.37#



TOP IMPACT STRUCTURE
WT = 865.09#

	DATE
DRAWN TAT	4/14/73
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

TOP & BOTTOM IMPACT STRUCTURES
WEIGHTS & C.G'S
1/2 SPENT FUEL CASK

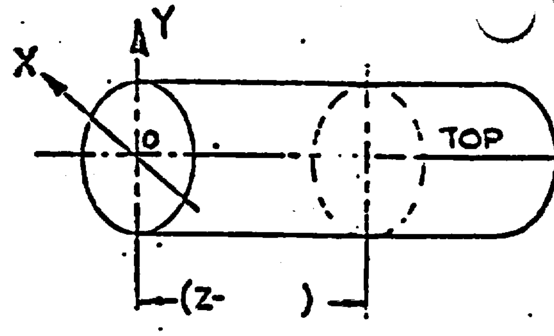
CODE IDENT	PROD Nº	SIZE	DRAWING Nº	REV
29932	A-5325	B	200353	2

WT ~ SCALE ~ SHEET 1 OF 1

NL INDUSTRIES, INC. NUCLEAR DIVISION — WEIGHTS & BALANCES

WILMINGTON, DELAWARE

Drawing No. 200353 REV 2



ORIGIN (O) AT

TOP IMPACT STRUCTURE

Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z - In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
1		134.99			8.85			119[illegible]
2		248.79			14.687			3653.9[illegible]
3		9.84			15.125			148.8[illegible]
4		9.19			16.750			153.9[illegible]
5		10.42			33.687			351.0[illegible]
6		21.87			24.812			542.6[illegible]
7		15.19			16.062			243.9[illegible]
8		45.80			10.64			487.3[illegible]
9		30.18			5.35			161.4[illegible]
10		45.28			.062			2.8[illegible]
11		150.09			4.125			619.1[illegible]
12		45.49			9.35			425.3[illegible]
13		9.07			8.50			27.[illegible]
14		88.89			25.187			2235.[illegible]
	Σ	865.09						10[illegible]
CENTER OF GRAVITY			Σ5/Σ1	Σ6/Σ1	Σ7/Σ1 11.84			

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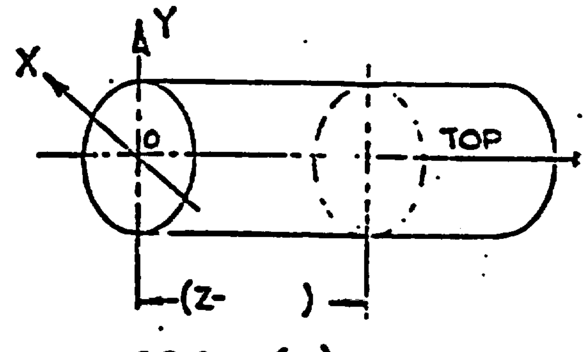
DATE________ PAGE________

NL INDUSTRIES, INC. NUCLEAR DIVISION
WILMINGTON, DELAWARE

WEIGHTS & BALANCES

Drawing No. 20035B REV 2



ORIGIN (O) AT ______

BOTTOM IMPACT STRUCTURE

Item	Dwg. No.	1 W Lb.	2 X In.	3 Y In.	4 Z - In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
1		10.74			-16.937			-181.9
2		21.72			-8.50			-184.6
3		54.56			-.062			-3.38
4		29.46			5.23			154.07
5		41.10			10.58			434.83
6		4.44			9.312			41.34
7		2.69			7.687			20.67
8		9.90			5.437			53.82
9		90.25			-8.50			-767.12
10		140.49			3.812			535.54
11		49.02			9.03			442.6
	Σ	454.37						545.8

CENTER OF GRAVITY	Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1
			1.20

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APPENDIX A

CASK CONFIGURATION "B"

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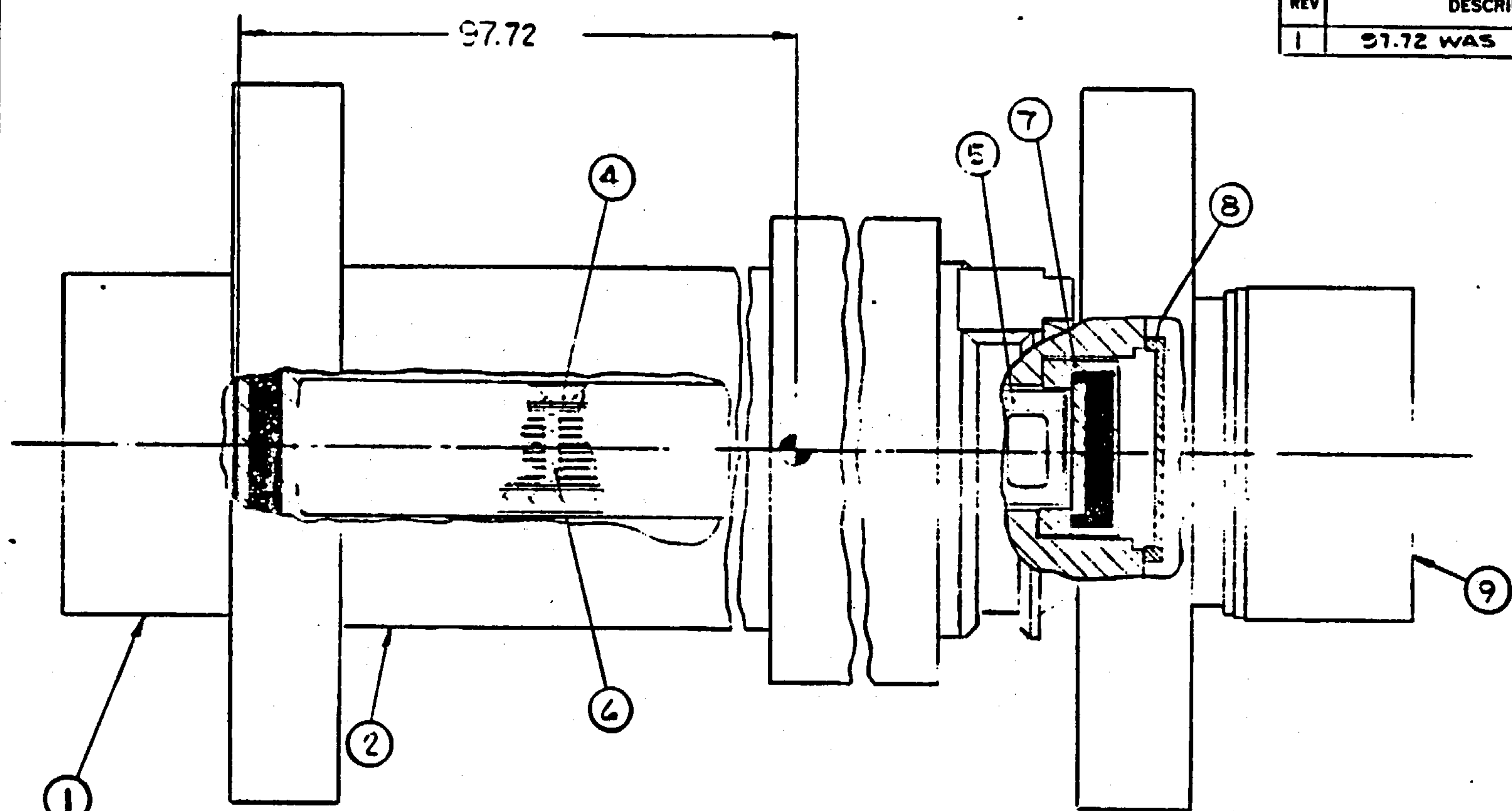
REV	DESCRIPTION	DATE	APPD
1	97.72 WAS 97.95	2-29-80	[illegible]



CASK CONFIGURATION "B"

	DATE
DRAWN J W	12/31/74
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

1/2 SPENT FUEL CASK
WEIGHT & C.G.

CODE IDENT	PROD №	SIZE	DRAWING №	REV
29932	A-5325	B	20252B	1

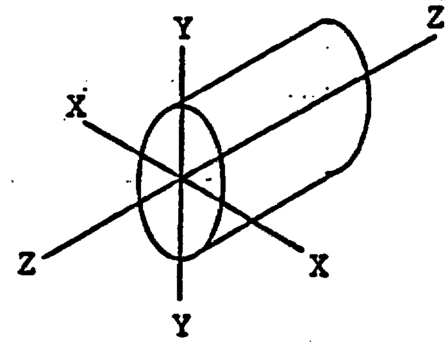
WT 47542.34 LBS | SCALE ——— | SHEET 1 OF 1

NL INDUSTRIES, INC. NUCLEAR DIVISION WILMINGTON, DELAWARE	WEIGHTS & BALANCES

COMPONENT CASK FINAL ASSEMBLY

DRAWING NO. 20252 B

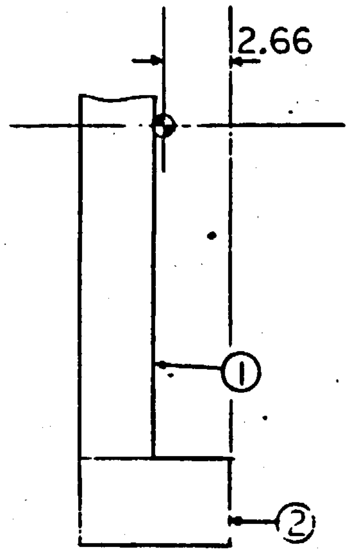
CONFIGURATION "B"



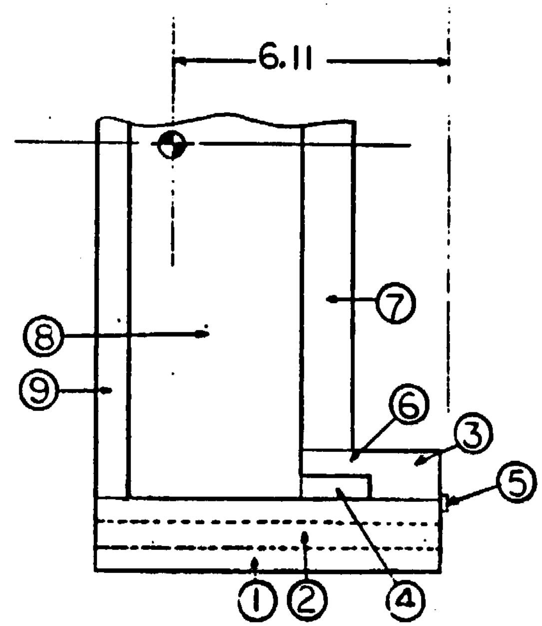
IT. NO.	1	2	3	4	5	6	7
	WEIGHT	X	Y	Z	W_x	W_y	W_z
	LBS.	In.	In.	In.	In. Lb.	In. Lb.	In. Lb.
1	454.37			1.2			545.2
2	42505.11			94.74			4026728.3
3	865.09			198.09			171365
4	1039.95			89.40			9297
5	40.20			179.915			7232.58
6	1600			91.23			145968
7	743.27			187.36			139259
8	341.04			195.66			66727.8
Σ	47589.03						4650797.4

Σ_5/Σ_1	Σ_6/Σ_1	Σ_7/Σ_1
		97.72

REVISIONS			
REV	DESCRIPTION	DATE	APPD



OUTER CLOSURE HEAD
WT. =341.04#



INNER CLOSURE HEAD
WT. =743.27#

CASK CONFIGURATION "B"

	DATE
DRAWN JW	12/31/74
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

WEIGHTS & C.G.'s
INNER & OUTER CLOSURE HEADS
1/2 SPENT FUEL CASK

CODE IDENT	PROD №	SIZE	DRAWING №	REV
29932	A-5325	B	20251B	0

WT SCALE SHEET OF

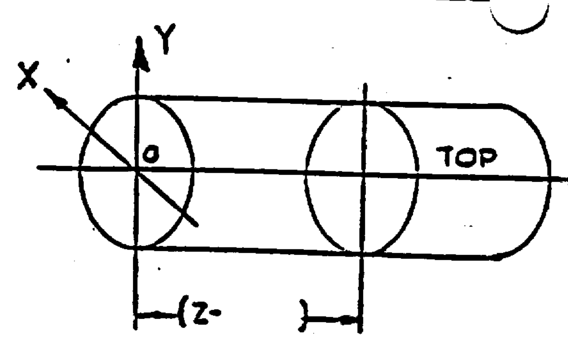
VII-A3

NL INDUSTRIES, INC. NUCLEAR DIVISION — WEIGHTS & BALANCES

WILMINGTON DELAWARE

Drawing No. 202518

OUTER CLOSURE HEAD



Item	Dwg. No.	1 W Lb.	2 X In	3 Y In.	4 Z- In.	5 Wx In. Lb	6 Wy In. Lb.	7 Wz In. Lb.
1		112.17			3.63			407.17
2		238.91			2.19			523.21
3		-10.04			2.19			-21.98
	Σ	341.04						908.
CENTER OF GRAVITY			Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1			
					2.66			

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DATE ______ PAGE ______ OF ______

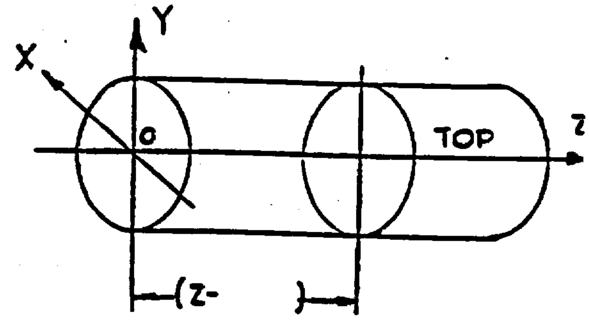
NL INDUSTRIES, INC. NUCLEAR DIVISION

WILMINGTON DELAWARE

WEIGHTS & BALANCES

Drawing No. 202518

INNER CLOSURE HEAD



ORIGIN (O) AT

Item	Dwg. No.	1 W Lb	2 X In	3 Y In.	4 Z - In.	5 Wx In. Lb	6 Wy In. Lb.	7 Wz In. Lb.
1		273.73			4.563			1249.03
2		-40.74			4.563			-185.89
3		48.60			1.048			50.93
4		61.51			3.355			206.36
5		1.27			.075			.0953
6		24.89			3.355			83.50
7		33.67			3.63			122.22
8		410.74			6.38			2620.52
9		21.22			8.64:			183.34
10		19.76			10.70			211.43
	Σ	743.27						4541.54

CENTER OF GRAVITY	Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1
			6.11

REVISIONS			
REV	DESCRIPTION	DATE	APPD
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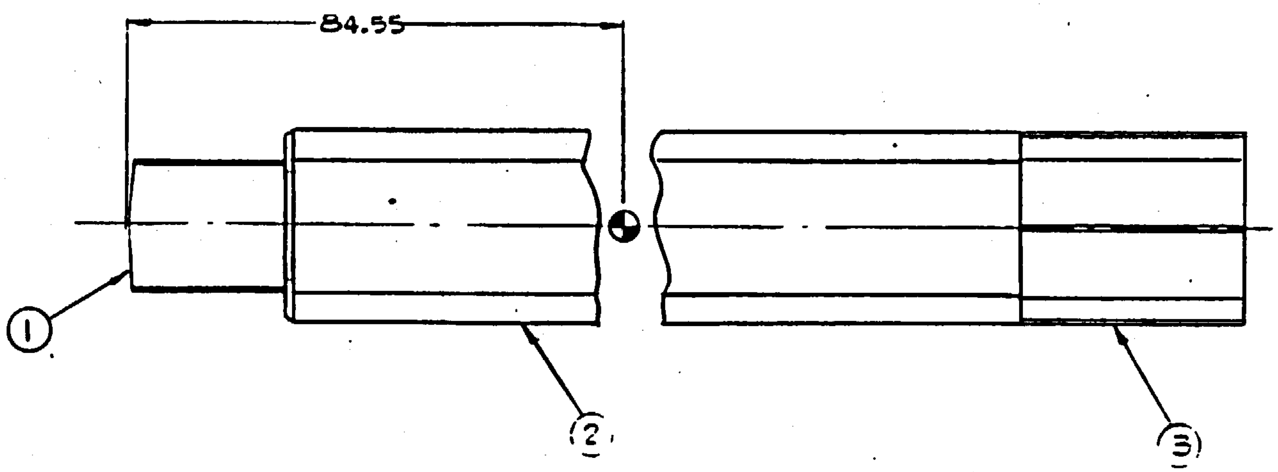
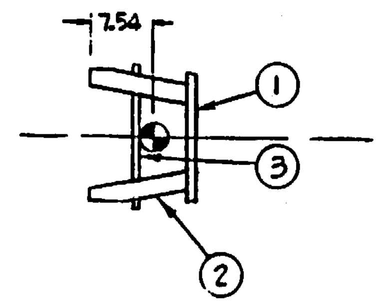


PWR FUEL BASKET
1039.95#



PWR SPACER
40.20#

CASK CONFIGURATION "B"

	DATE
DRAWN JW	[illegible]
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

PWR FUEL BASKET & SPACER
WEIGHTS & C.G.'S.
1/2 SPENT FUEL CASK

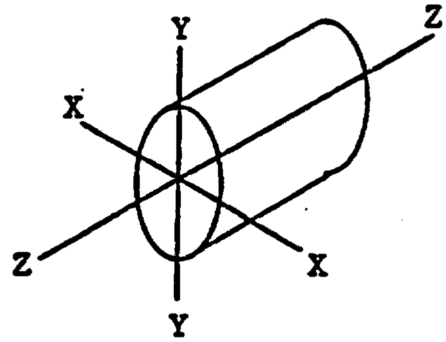
CODE IDENT	PROD Nº	SIZE	DRAWING Nº	REV
29932	A-5325	B	20249B	1
WT ~	SCALE ~		SHEET 1 OF 1	

NL INDUSTRIES, INC. NUCLEAR DIVISION
WILMINGTON, DELAWARE

WEIGHTS & BALANCES

COMPONENT PWR BASKET

DRAWING NO. 20249 B



IT. NO.	1 WEIGHT LBS.	2 X In.	3 Y In.	4 Z In.	5 W_x In. Lb.	6 W_y In. Lb.	7 W_z In. Lb.
1	48.61			5.39			262.06
2	977.09			87.25			85251.1
3	14.25			169.15			2410.42
Σ	1039.95						87923.58

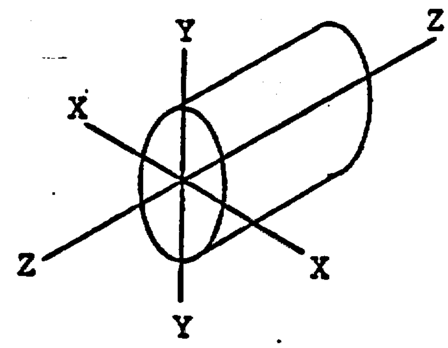
Σ_5/Σ_1	Σ_6/Σ_1	Σ_7/Σ_1
		84.55

NL INDUSTRIES, INC. NUCLEAR DIVISION
WILMINGTON, DELAWARE

WEIGHTS & BALANCES

COMPONENT PWR SPACER

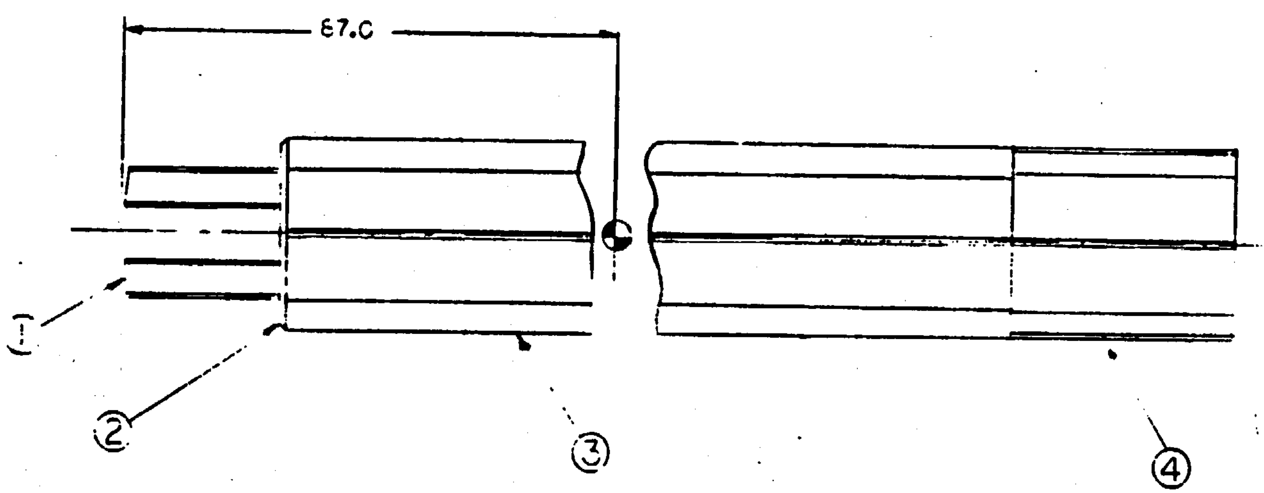
DRAWING NO. 20249 B



IT. NO.	1 WEIGHT LBS.	2 X In.	3 Y In.	4 Z In.	5 W_x In. Lb.	6 W_y In. Lb.	7 W_z In. Lb.
1	6.50			11.78			76.57
2	20.58			5.78			118.95
3	13.12			8.185			107.39
Σ	40.20						302.91

Σ_5/Σ_1	Σ_6/Σ_1	Σ_7/Σ_1
		7.54

REVISIONS			
REV	DESCRIPTION	DATE	APPD
1	DELETED BWR SPACER		



BWR FUEL BASKET
1259.04 #

CASK CONFIGURATION "B"

	DATE
DRAWN JW	[illegible]
CHKD.	
ENG	
Q.C.	
PROD	

NATIONAL LEAD COMPANY
NUCLEAR DIVISION
WILMINGTON PLANT

BWR FUEL BASKET
WEIGHTS & C.G.'s
1/2 SPENT FUEL CASK

CODE IDENT	PROD Nº	SIZE	DRAWING Nº	REV
29932	A 5325	B	202438	1

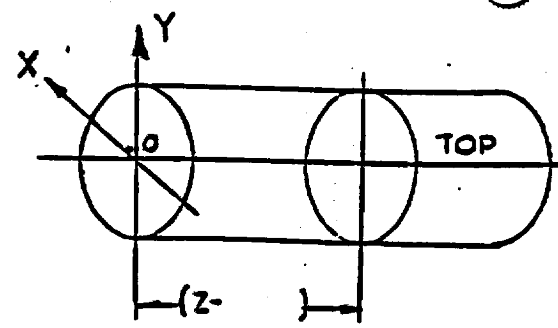
WT — SCALE — SHEET 1 OF 1

NL INDUSTRIES, INC. NUCLEAR DIVISION
WILMINGTON DELAWARE

WEIGHTS & BALANCES

Drawing No. 20248 B

BWR BASKET



ORIGIN (O) AT

Item	Dwg. No.	1 W Lb.	2 X in	3 Y In.	4 Z – In.	5 Wx In. Lb.	6 Wy In. Lb.	7 Wz In. Lb.
1		11.84			173.19			2050.57
2		10.42			170.75			1779.22
3		1197.54			87.0			104185.98
4		16.34			89.4			1460.8
5		16.92			3.25			54.99
6		5.4			1.5			8.1
7		.58			1.5			.87
Σ		1259.04						109540.53

	Σ5 / Σ1	Σ6 / Σ1	Σ7 / Σ1
CENTER OF GRAVITY			87.00

V11-A10

DATE________ PAGE______ OF______

Section VIII

SECTION VIII

THERMAL ANALYSIS

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SECTION VIII

THERMAL ANALYSIS

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Revised
Feb. 1987
May 1987
Dec. 1988
Feb. 1990
Oct. 1990

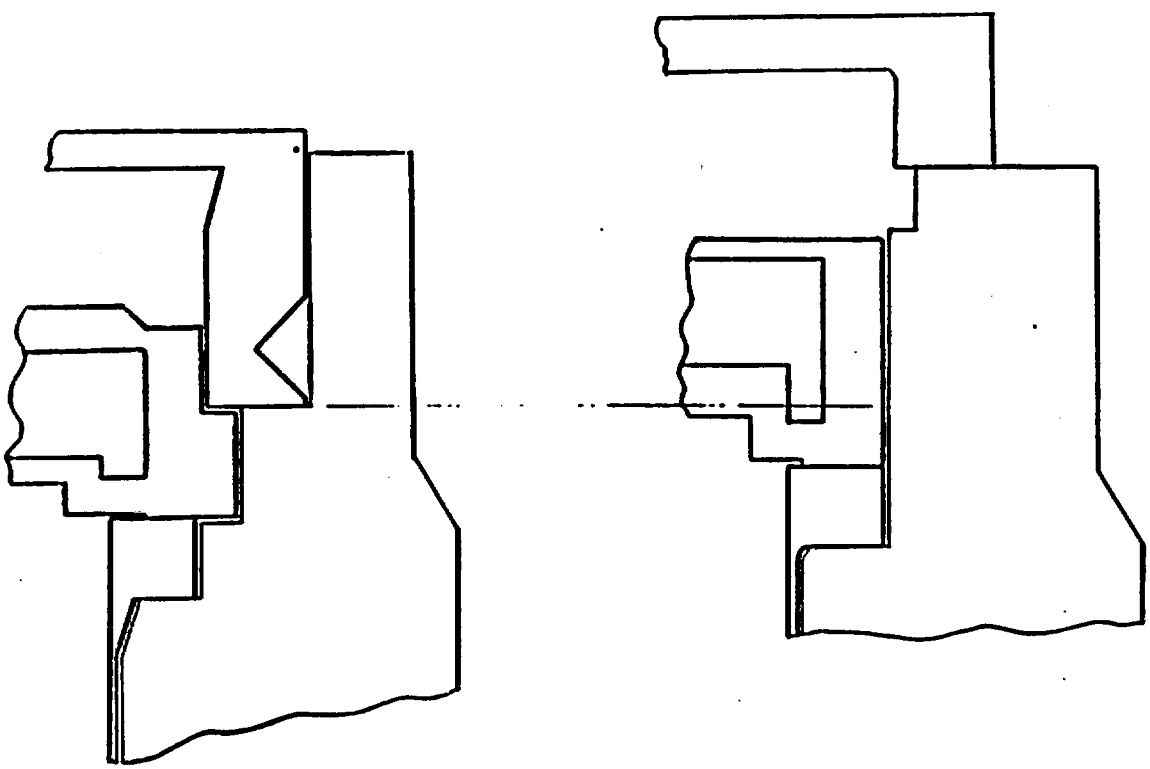
List of Tables

Revised
Feb. 1987
Dec. 1988
Feb. 1990

List of Figures

INTRODUCTION

The thermal model used in the two-dimensional analysis is not an exact representation of the actual closure head arrangement. Minor design modifications were made in the closure head area subsequent to the thermal analysis. The following sketch shows the differences between the two configurations. It can be seen that the differences between the two configurations are minor, however it is recognized that the temperatures reported for the various modes in this region could change by as much as 20 to 30%. Such a temperature change has not significance relative to the structural design of the head joints since metallic seals are being used which function satisfactorly at temperatures 85% higher than those reported.



Thermal Analysis Model
Based on this Configuration

Final Design
Configuration

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Section VIII

THERMAL ANALYSIS

1.0 SUMMARY

This section summarizes the thermal analyses which were performed to demonstrate fulfillment of the thermal capability requirements established by AEC regulations, Title 10 CFR Part 71.

The shipping cask is designed to safely contain irradiated fuel under a variety of normal conditions (71.35 and Appendix A of 10 CFR 71) and accident conditions (71.36 and Appendix B of 10 CFR 71). In order to verify the adequacy of the design, detailed analyses of a reference design PWR shipment were performed considering extreme normal operating conditions and hypothetical fire conditions in conjunction with appropriate postulated cask interactions. Both BWR and PWR type fuels are adequately considered by analyzing only the PWR reference fuel element since it represents the highest decay heat generated. Geometric differences between BWR and PWR types of loading are conservatively covered by the PWR analysis.

Transport of consolidated PWR fuel rods is acceptable for fuel cooled 4,380 days. At 4,380 days, the maximum thermal output of the consolidated fuel is 6% of the thermal output of the design basis PWR assembly.

Transport of up to 24 PWR or 24 BWR rods is acceptable for fuel cooled 150 days. At 150 days, the maximum thermal output is 16% of the thermal output of the design basis assemblies.

1.1 Normal Conditions of Transport

The ambient temperature around all parts of the cask is 130°F during hot operation. The air is still and direct solar heating has an effective intensity of 92 Btu/hr-ft^2 on all exposed surfaces of the cask with the exception of the balsa crash barriers which act as thermal insulators. The cask average design decay heat load is 36,300 Btu/hr. An axial power peaking factor of 1.2 is applied to this heat load to establish the design maximum local heating rate in the cask. Decay heat is removed from the fuel to the cask first by thermal radiation and conduction through a helium filled

Revised
May, 1987

can and then through the cask sides and ends by a combination of conduction, natural convection in the water filled neutron shield, and natural convection and radiation from the surfaces of the cask. Thermal radiation augments the conduction heat transfer across well established air gaps within the cask.

Under cold operation the ambient temperature is $-40^{\circ}F$ in still air and shade (no solar heat load). No thermal analysis of the cask under these conditions was not performed since a uniform cask temperature of $-40^{\circ}F$ may be conservatively assumed.

1.2 Hypothetical Accident Conditions

The following hypothetical accident conditions were applied sequentially as specified in Appendix B of 10 CFR 71 (In some areas additional conservative assumptions were involved):

Beginning with an assumed ambient temperature of $100^{\circ}F$, the cask experiences a 30-foot drop onto a flat surface followed by a puncture. This is assumed to result in the complete and instantaneous loss of neutron shield water even though the neutron shield jacket is essentially intact because of the balsa crash barrier effectiveness. All of the insulating crash barriers are conservatively assumed to have been stripped from the cask after the drop and just prior to the fire. Concurrent with the instantaneous loss of neutron shield water, the cask is exposed to a thermal radiation environment of $1475^{\circ}F$ for 30 minutes with an emissivity coefficient of 0.9 and a cask surface absorption coefficient of 0.8. (Convection heat transfer at the outer surface has been conservatively considered even though the above regulations do not specify convection heat transfer during the fire.)

After the fire the cask is cooled naturally until equilibrium conditions are reached in ambient air at 130°F. With the insulating crash barriers removed, all surfaces of the cask are subjected to a full solar heat load. The cask surface emissivities after the fire are conservatively assumed to be the same as before the fire. Heat transfer within the cask occurs by a combination of conduction, radiation, and gaseous natural convection.

The decay heat load throughout the entire accident is as specified under normal conditions. The solar heat before and after the fire is as specified under normal conditions. No solar heat load is applied during the fire.

1.3 Results

Steady-state and transient analyses were performed on thermal models of the central portion of the cask assuming negligible end effects and on the lid end of the cask considering one-half the cask length. The bottom end of the cask was not analyzed explicitly because it presented no unique thermal problems associated with cask integrity and performance. The pin-to-pin temperature distributions of interest within the fuel element were analyzed separately from those of the cask. A steady-state analysis was performed because of the relatively slow response of the fuel under peak temperature transients.

The temperatures applicable to the central portion of the cask and the fuel element per se are based on a maximum local heat load which includes an axial peaking factor of 1.2. This peaking factor is based on the 300 day burnup distribution curve of Figure III-1. This is a conservative representation of the axial specific power distribution applicable to decay heat calculations. The temperatures applicable to the top half of the cask are based on a reference design heat load without representation of axial power gradients because such a gradient has negligible effect on cask end temperature distributions, is not uniquely defined, and its omission is conservative with respect to the end temperature calculations.

A summary of the results of the cask thermal analyses is provided in Table VIII-1. The thermal responses of selected points in the cask during and after the fire accident are shown in Figure VIII-1. In Figure VIII-2 are shown the maximum temperature distributions within a quadrant of the reference fuel element under design steady state and transient conditions.

The results of thermal analyses may be summarized as follows:

a. Under normal conditions the hottest fuel pin temperature is 1013°F from the conservative one dimensional analysis. The actual maximum temperature will more likely be closer to 860°F (from the 2D analysis).

b. Under normal conditions the neutron shield bulk water temperature is 296°F. The neutron shield local maximum water temperature is 352°F.

c. Under normal conditions the outer head closure seal temperature is 309°F. The internal closure seal temperature is 375°F.

d. The maximum cask surface temperature during normal operation is 340°F.

e. Following the fire transient the hottest fuel pin temperature is 1102°F. (A temperature of 1072°F will eventually be reached if all the neutron shield water is lost in a less severe accident.)

f. Maximum outer head closure seal temperature at the end of the fire is 648°F. The maximum internal closure seal temperature is 564°F.

TABLE VIII-1

SUMMARY OF RESULTS

Cask Location	T_{MAX}, °F Normal Steady-State	T_{MAX}, °F Post Fire Steady-State	T_{max}, °F During Fire Accident, Time (hrs)	
Fuel Surface	1013	1072	1102	5.0
Cavity Surface Aluminum (Cask Middle)	674	767	813	4.0
Can	659	753	799	4.0
Uranium Shield (Cask Middle)	373	514	627	1.5
Lead OD (Cask Middle)	356	497	652	0.53
Cask OD (Cask Middle)	352	493	702	0.5
Neutron Shield Jacket	340	341	1280	0.5
Neutron Shield Bulk Fluid	296	302	981	0.5
Cavity Surface (Center of Inner Head)	388	391	567	3.0
Gaskets (outer head)	309	304	648	0.75
(inner seal)	375	379	564	2.5
Ambient	130	130	1475	

FIGURE VIII-1

THERMAL RESPONSE TO HYPOTHETICAL FIRE

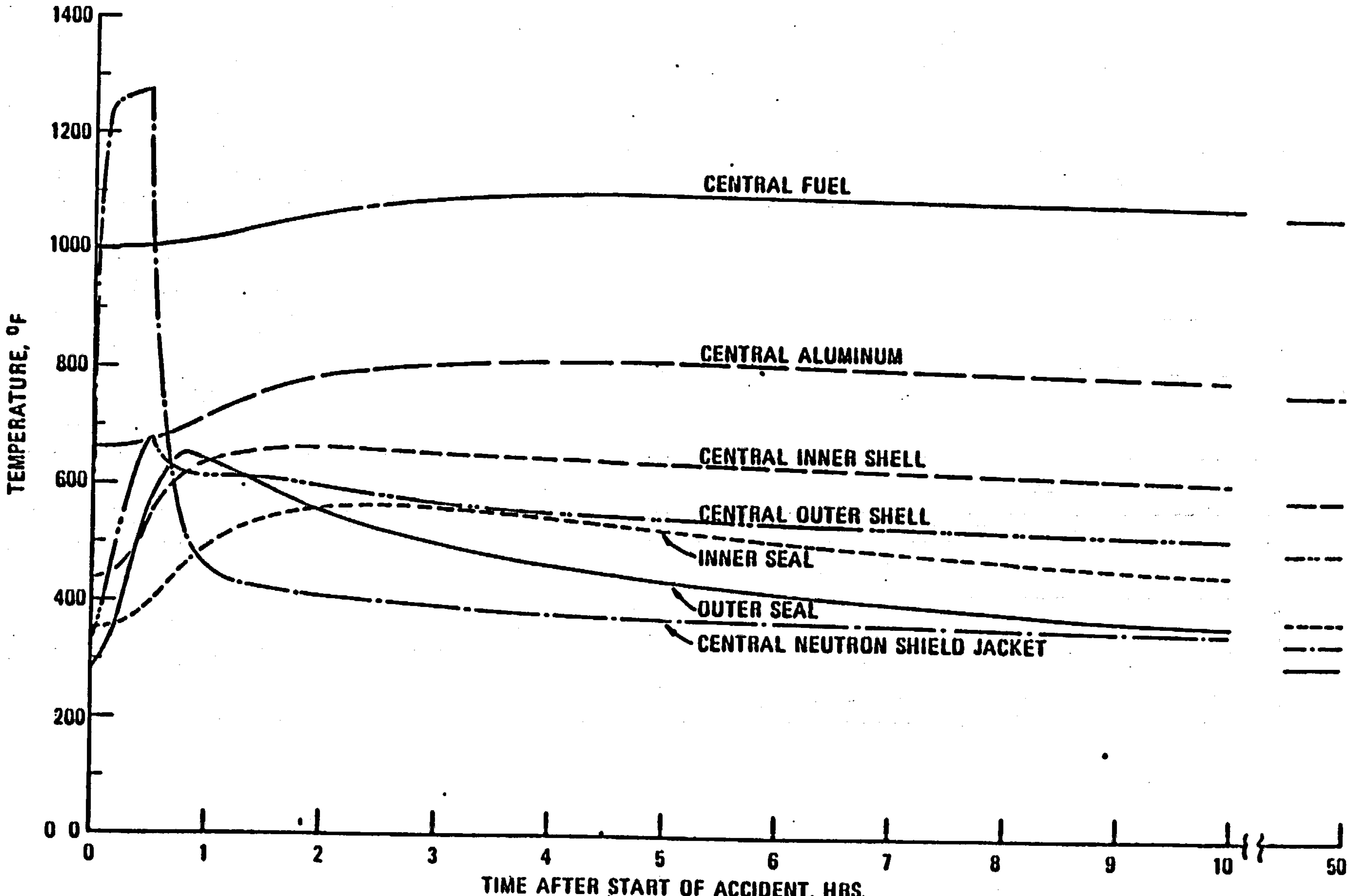

FIGURE VIII-2

MAXIMUM TEMPERATURE DISTRIBUTION IN FUEL ELEMENT QUADRANT

Steady State Wall Temperature = 674°F

Maximum Wall Temperature = 812°F

℄	845 957	894 998	935 1033	(960) (1055)	988 1080	1004 1094	1013 1102	(1011) (1099)
	843 956	892 997	932 1031	962 1057	986 1077	1001 1091	1010 1099	1013 1101
	839 952	886 992	(920) (1021)	955 1051	977 1070	992 1083	1001 1091	1004 1094
	832 946	878 984	915 1016	942 1039	(957) (1053)	977 1070	986 1077	988 1080
Wall	821 937	864 972	898 1002	924 1024	942 1039	955 1051	962 1057	(960) (1055)
	807 925	844 956	(870) (977)	898 1002	915 1016	(920) (1021)	932 1031	935 1033
	787 908	818 934	844 956	864 972	878 984	886 992	892 997	894 998
	760 886	787 908	807 925	821 937	832 946	839 952	843 956	845 957
				Wall				℄

NOTE: Each pair of numbers represents a fuel pin location

( ) indicates no fuel in these locations.

Top number applies to normal steady state

Bottom number applies to transient maximum fuel temperature condition

g. Practically all of the lead melts in the mid-section of the cask during the fire accident on the basis of a maximum local heat load. Little or no lead melting will occur at the ends of the cask. All lead will have solidified 1.25 hours after the end of the fire.

h. Under extreme cold, freezing in the neutron shield is avoided by addition of antifreeze. The remaining parts of the cask are not adversely affected by $-40^{\circ}F$.